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Technical Evidence Report

Brisbane River Strategic Floodplain Management Plan

Prepared for the State of Queensland

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Technical Evidence Report (Amended Final)

The *Brisbane River Strategic Floodplain Management Plan* project is a joint initiative of the Australian Government, Queensland Government, Brisbane City Council, Ipswich City Council, Lockyer Valley Regional Council, Somerset Regional Council and Seqwater.

Document Control Sheet

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Synopsis: This report provides the technical evidence to support the directions, outcomes and recommendations of the Brisbane River Strategic Floodplain Management Plan. It has been compiled from a series of integrated Milestone Reports that have documented different work packages under the project.

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Executive Summary

Context

In December 2010 and January 2011, a strong La Niña weather pattern caused extensive and prolonged rainfall across Queensland. More than 78% of Queensland was declared a disaster zone, affecting more than 2.5 million people, and inundating approximately 29,000 homes and businesses *(Queensland Floods Commission of Inquiry Final Report [QFCoI], 2012).* More than 14,000 properties were inundated in Brisbane, Ipswich and the Brisbane River Valley.

The QFCoI was established in response to the scale of the disaster and recommended several changes to how state and local governments manage flooding. In particular, recommendation 2.12 states "*Councils in floodplain areas should, resources allowing, develop comprehensive floodplain management plans that accord as closely as practicable with best practice principles*". Following the QFCoI, the Queensland Government and local governments in the Brisbane River Catchment committed to developing a long-term plan to manage the impact of future floods and enhance community safety and resilience in the floodplain.

The floodplain management process adopted within the Brisbane River Catchment comprises four key phases. The first two phases, Data Collection and the Flood Study, were completed in 2013 and 2017 respectively. The purpose of Phase 3 is to provide an overarching strategy for managing flood risk across the lower Brisbane River floodplain, providing a consistent basis for the subsequent Local Floodplain Management Plans (LFMPs) to be prepared in Phase 4 by the Somerset and Lockyer Valley Regional Councils, and Ipswich and Brisbane City Councils.

Phase 3, comprises a Technical Evidence Report (this Report) and the accompanying Strategic Floodplain Management Plan (the Strategic Plan), together with a number of parallel projects exploring property-scale mitigation and a regional flood intelligence system. This Report provides an assessment of flood risk and considers a broad range of flood risk mitigation measures, as a foundation for making informed decisions about the future management of the floodplain. The Strategic Plan outlines the stakeholders' shared understanding of flood risk, and lists a suite of actions that the Queensland Government and local governments will work towards to improve community safety and reduce the impact of future floods.

Brisbane River Catchment

The Brisbane River Catchment includes the Brisbane River and several major tributaries, including Cooyar, Emu and Cressbrook Creeks in the Upper Brisbane River catchment, the Stanley River which flows from the Conondale and D'Aguilar Ranges, Lockyer Creek which converges with the Brisbane River downstream of Wivenhoe Dam and the Bremer River which flows to the Brisbane River downstream of Ipswich. Within the catchment are the two major cities of Brisbane and Ipswich, as well as numerous townships interspersed by extensive rural and agricultural land. Approximately half of the catchment's surface water is regulated through the management of the Somerset and Wivenhoe Dams. The study area is focussed on the lower Brisbane River floodplain below Wivenhoe Dam, including the major tributaries of Lockyer Creek and the Bremer River.

The Brisbane River has an extensive history of floods. The largest recorded floods occurred in the 19th century, notably in 1841 and two significant events in 1893. However, the local Jagera and Turrbal people have an extensive oral history and indicate that a larger flood occurred sometime from the 1700s to the 1800s. This oral history is consistent with the *Big Flood Project's* (Queensland Government, 2017) investigation into the paleoflood record of the Lockyer Valley, which noted a significant event occurring in the 1700s. A flood in 1974 caused major flooding throughout the Brisbane River Catchment. Partly in response to this flood, and also due to increasing water demand from the growing urban population, Wivenhoe Dam was constructed to provide a dual role of water supply and flood mitigation.

Following the construction of Wivenhoe Dam, minor to major floods have occurred on the Brisbane River with the most notable being in 1996, 1999, 2011 and 2013. Wivenhoe Dam played a significant role in reducing the flood peak and modifying the flood behaviour downstream in all these events. The 2011 flood was the largest of these. Within the lower Brisbane River, it was equivalent to a 1 in 100 (1%) Annual Exceedance Probability (AEP) flood; within the Bremer River it was equivalent to about a 1 in 50 (2%) AEP; and within the lower reaches of Lockyer Creek it was equivalent to about a (0.7%) 1 in 150 AEP.

Figure 1 Estimated magnitude (return period) of the 2011 flood

The confined nature of the lower floodplain means that it is very sensitive to changes in flow, with flood levels increasing significantly from one AEP to the next. In the lower Bremer River and mid Brisbane River, a 1 in 100 AEP flood is some three to four metres higher than a 1 in 50 AEP flood, while a 1 in 500 AEP flood is four to five metres higher again.

Whilst floods can cause extensive damage and pose a safety risk to people, they also play an important role in maintaining ecosystem functions and biodiversity. The flow of water onto floodplains is essential for sustaining wetlands, connecting aquatic habitats, exchanging nutrients, and recharging aquifers. Within the context of flood risk management it is important to consider these environmental benefits, particularly with respect to mitigation works that have the potential to alter flood behaviour.

Approach to Flood Risk Management

Effective flood risk management requires an integrated, multi-disciplinary approach using a suite of implementation tools. In Australia, *Handbook 7, Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017) is regarded as the national guidance for floodplain management. It identifies three distinct approaches to managing existing flood risk.

- **Reducing flood risk at the community scale with structural works.** Structural mitigation alters flood behaviour to reduce risk. However it is often expensive and must be hydraulically assessed to ensure works do not cause unacceptable impacts elsewhere in the floodplain. Examples of these works include dams, levees, floodgates, temporary barriers, detention basins etc. At a broad scale, landscape management activities such as revegetation, re-engaging floodplains and naturalisation of waterways also have potential to reduce flood risk through modification of flood behaviour.
- **Reducing flood risk at property scale with mitigation works.** Property-scale measures have not been included in this study, though they have been considered as part of a parallel project and are noted for future consideration in the Phase 4 (Local Floodplain Management Plans). These include residential property buyback / voluntary purchase schemes, house raising, flood proofing of buildings, and built design.
- **Treating residual risk at the community scale.** Measures to treat residual risk are typically the simplest and most cost-effective to implement. These primarily focus on disaster management and community awareness and resilience. Examples of these risk treatments include flood warning systems, emergency response plans and community education programs.

In terms of future flood risk to new development, this can best be managed by avoiding or minimising the consequences of flooding. This is most effectively achieved through a risk-based approach to land use planning, which takes into consideration both current and future climate conditions and future urban growth plans.

Managing flooding within a catchment should be cognisant of both the broader environmental outcomes that are sought to achieve sustainability, including the environmental benefits that come from periodic flooding and the recharge of floodplain wetlands and groundwater reserves. The focus of this Report is flooding, however it is underpinned by an integrated catchment planning approach, which identifies where options can offer multiple benefits in addition to flood risk management. In a similar vein, many approaches which make a community more resilient to flooding can also have benefits across all hazards, as well as broader community shocks and stressors. Many of the recommendations from this Report can effectively deliver the flood component of an all-hazards approach, or be ‘all-hazards’ in nature.

Regional Approach

It is recognised that Brisbane River flooding can occur at a catchment scale, extending across multiple administrative boundaries. Whilst it is important that flood planning and response is tailored to local conditions and communities, a regional approach to floodplain management can add significant value to local planning. This regional strategy aims to achieve:

- an integrated catchment planning approach to floodplain management
- consistency in the assessment and understanding of current and future Brisbane River flood risk
- consistency in the approach to estimation of flood damages and economic assessment of floodplain management options across the region
- assessment of a suite of regionally significant structural mitigation options in the Brisbane River floodplain
- a catchment-wide approach to landscape management activities
- a consistent risk-based approach to land use planning and development in the Brisbane River floodplain, to be tailored to local conditions
- a co-ordinated and consistent approach to disaster management planning, tailored to local conditions
- knowledge and information sharing across the region, supporting efficient planning and execution of community awareness and resilience activities
- consistency of language, messaging, data and tools for understanding and communicating Brisbane River flood risk between stakeholder groups and the community
- effective coordination between local, State and Federal government agencies and stakeholders.

These regional considerations informed the development of flood risk management measures in this Report.

Current Flood Risk

The lower Brisbane River floodplain includes a wide range of land uses; from the large urban areas of Ipswich and Brisbane, to smaller towns such as Fernvale, urban fringe areas, and rural uses. Similarly, the flood behaviour varies significantly across the floodplain; with different patterns of constrained flows, broad floodplains, and high flow breakout flowpaths. Communities also vary significantly across the catchment; with long-term and newer residents, people from non-English speaking backgrounds, large and small families, etc. It is important to understand all of these factors when assessing the current flood risk within the study area.

This Report was developed through a best-practice approach to the quantification and assessment of flood risk in the lower Brisbane River floodplain. In accordance with leading practice risk standards, including the *Queensland Emergency Risk Management Framework*, risk is defined as the combination of the likelihood of the hazard occurring, together with the consequence of the hazard occurring. Likelihoods can range from very frequent to very rare, while consequences can range from insignificant to catastrophic. The approach adopted in this Report considered and prioritised 42 distinct combinations of flood likelihood and hazard. These combinations were grouped into five bands of potential hydraulic risk (HR1 to HR5, with HR1 representing the highest level of risk), and mapped for the entire floodplain. The potential hydraulic risk mapping provides a consistent frame of reference for all four local government areas to help define flood risk in the same way, and is one of the key deliverables of this Report.

Flood risk is only present where people, properties and assets are impacted by the flooding. True flood risk (beyond potential hydraulic risk) therefore considers flood exposure, population vulnerability to flooding and other flood risk factors such as isolation and time of flood onset.

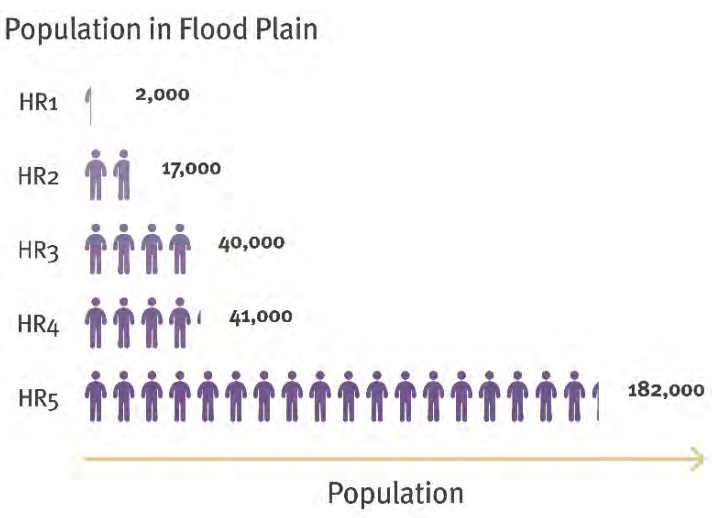
To support the flood exposure assessment, a property dataset was developed. The dataset required a field survey of more than 80,000 properties, which captured the property location, type, building ground and floor level, and a street view photo. The field survey was supplemented with data derived remotely from an aerial survey to form a comprehensive data set of more than 215,000 properties in the study area. This dataset was utilised for the risk assessment, flood damage assessment, and to quantify the impact of potential structural works.

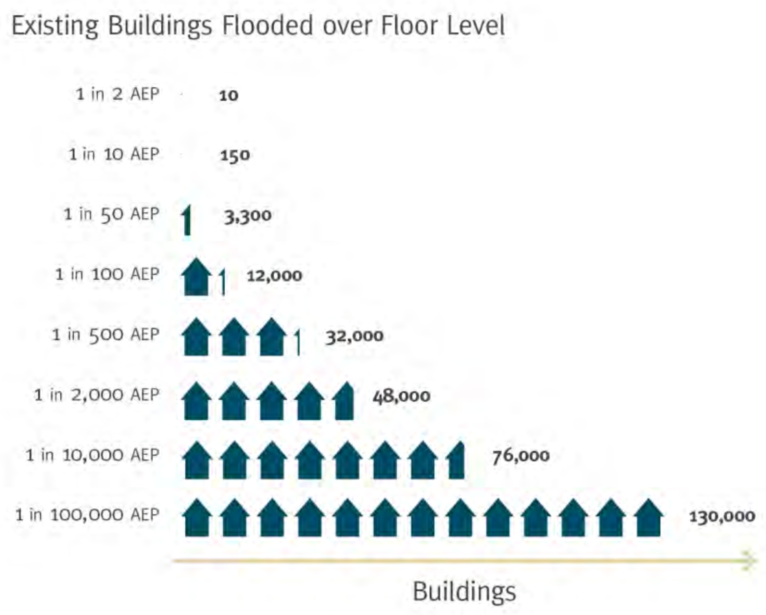
Flood Exposure

The flood exposure assessment estimated there are upwards of **130,000 buildings** and **280,000 people** living in the floodplain, with approximately **10,000 buildings** and **19,000 people** living within the two highest hydraulic risk areas (HR1 and HR2).

Some existing development is considered to be particularly sensitive to the potential impacts of flooding due to the nature of residents who use the facilities. It is estimated there are **1,900 sensitive developments** in the floodplain, including hospitals, child care centres and education facilities. If flooding impacts these developments, additional resources and time will be required to help evacuate the more vulnerable occupants and visitors.

Critical infrastructure assets are also exposed to flooding, with a minimum of **730 known assets** identified in the floodplain. Of these, it is estimated that at least 100 assets relating to water / wastewater, electricity and telecommunications are within the higher hydraulic risk areas. Impact to critical infrastructure assets has significant compounding effects for the broader community and in some cases the broader infrastructure network. In addition to the loss of amenity during a flood, delay in restoring essential services can impede recovery of the entire community.





Isolation

In addition to flood inundation impacts, people, properties and assets can also be subject to isolation risk. Some locations may initially become isolated and then subsequently inundated (referred to as 'low islands'). Other locations may become isolated, but the risk of inundation may be very unlikely (referred to as 'high islands'). During periods of isolation, people may become stressed or anxious, may be unable to access important services such as medical attention, and may take unnecessary risks, such as driving or wading through floodwaters, significantly increasing their risk to life. Understanding the risk of isolation is critical for emergency response organisations, so that appropriate resources can be provided to areas deemed most at risk, and to assist with evacuation as necessary.

As part of the assessment of overall flood risk, this study analysed the State controlled road network to determine the susceptibility of roads to inundation; the locations where these roads first close; the length of time it takes for the road to close; and the duration that the road is closed. The most notable location at risk of losing access via the primary road network is Fernvale, where an estimated 680 residents would be isolated by a 1 in 100 (1%) AEP flood event. Exacerbating this risk is the limited warning time these residents would receive of an imminent flood event (noting that Fernvale has a flood warning system in place).

Community Vulnerability

While all people are vulnerable to the impacts of flooding, some residents are considered more vulnerable due to inherent demographic characteristics. If residents are more vulnerable than the average population, they may require additional support to prepare for, respond to, and recover from flooding, and may take longer to recover. The Report incorporates a region-wide vulnerability assessment to identify parts of the community that are more vulnerable than average due to physical, socio-economic, mobility, and awareness factors.

In total, more than 130,000 residents in the floodplain (almost 50% of all residents) were classified as 'highly vulnerable' due to one or more of these factors, with almost half of these residents classified as highly vulnerable across two or more factors. Within the HR1 potential hydraulic risk area (the highest risk level), approximately three quarters of the population is highly vulnerable. Nearly 10,000 residents were identified to be highly vulnerable and living in regions of the floodplain classified as higher hydraulic risk (HR1 and HR2 areas); meaning these residents have some of the highest flood risk in the area. Regions which have many residents classified as highly vulnerable to flooding include the Brisbane suburbs of West End, St Lucia, Rocklea and Oxley (primarily due to high proportions of renters, people without cars, new residents and / or limited English). Within the Ipswich area, the residents considered most vulnerable to the impacts of flooding are in Brassall, Goodna, One Mile, East Ipswich, North Boovall and North Ipswich.

Overall Current Flood Risk

A brief summary is provided below of the areas located within the Brisbane River floodplain that are identified to have a high level of flood risk. It is important to note that not all properties and residents within the locations specified are at risk, as flooding is controlled by topography. Properties of higher relative elevation will have less flood risk and not all residents within a location have the same demographics and vulnerabilities.

- The village of Lowood is at higher flood risk due to the presence of sensitive developments and highly vulnerable communities in the floodplain. Rural properties located along the perched banks of Lockyer Creek are also at-risk due to a combination of proximity to the creek, short warning time and isolation risk.
- The village of Fernvale is at higher flood risk due to its potential for isolation during medium to large events and faster onset of flooding.
- The Ipswich suburbs of Karalee and Barellan Point are at higher flood risk due to a combination of isolation and high potential hydraulic risk.
- Most areas along the Bremer River and the Brisbane River within the Ipswich local government area are at a higher risk. Areas that experience high potential hydraulic risk and contain concentrations of sensitive development and vulnerable communities include Goodna, Brassall, Moores Pocket, North Booval, East Ipswich, One Mile, North Ipswich, Bundamba and Basin Pocket.
- The western suburbs of Brisbane, Sherwood, Graceville and Oxley experience high potential hydraulic risk and contain sensitive development and vulnerable communities. There are also critical infrastructure assets in the floodplain at Rocklea.
- Areas with a notable number of vulnerable people located in the western suburbs of Brisbane include Fairfield, Sherwood, Rocklea, Yeronga, Moorooka, Archerfield, Graceville and Oxley.
- West End is the highest risk area in the Brisbane inner city area with high potential hydraulic risk and a vulnerable community.
- Other areas around inner-city Brisbane that contain vulnerable communities include Toowong, Taringa, St Lucia, Coorparoo, and Auchenflower.
- Critical infrastructure is also located in the floodplain in the Brisbane CBD and Newstead.

It is noted that areas upstream of the study area, and therefore not described above, may also be inundated and isolated during the same weather events that cause flooding along the lower Brisbane River.

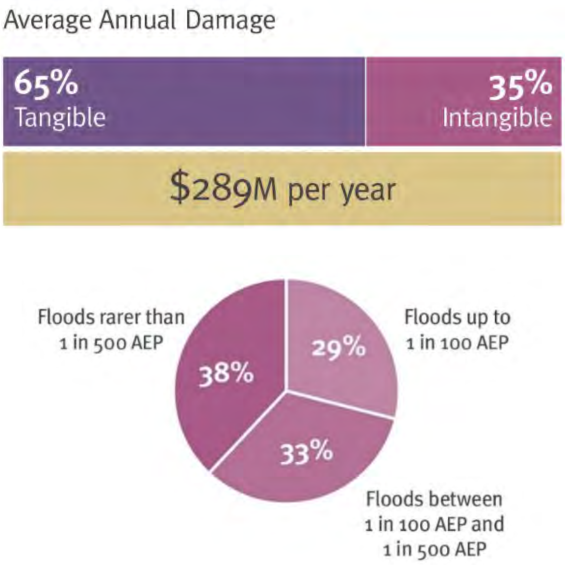
Flood Damage Assessment

This Technical Evidence Report includes a regional economic framework for the estimation of flood damages in the lower Brisbane River floodplain, for both current and future catchment conditions. This is based on an extensive literature review, which established current best practice in flood damage estimation, together with a detailed survey of 96 representative properties. It also includes representative relationships between flood depth and damage (i.e. stage-damage curves), and the regional building database, which contains an extensive floor level survey. The new stage-damage curves provide the most significant update to residential and commercial damage estimation in Australia since the 1980s.

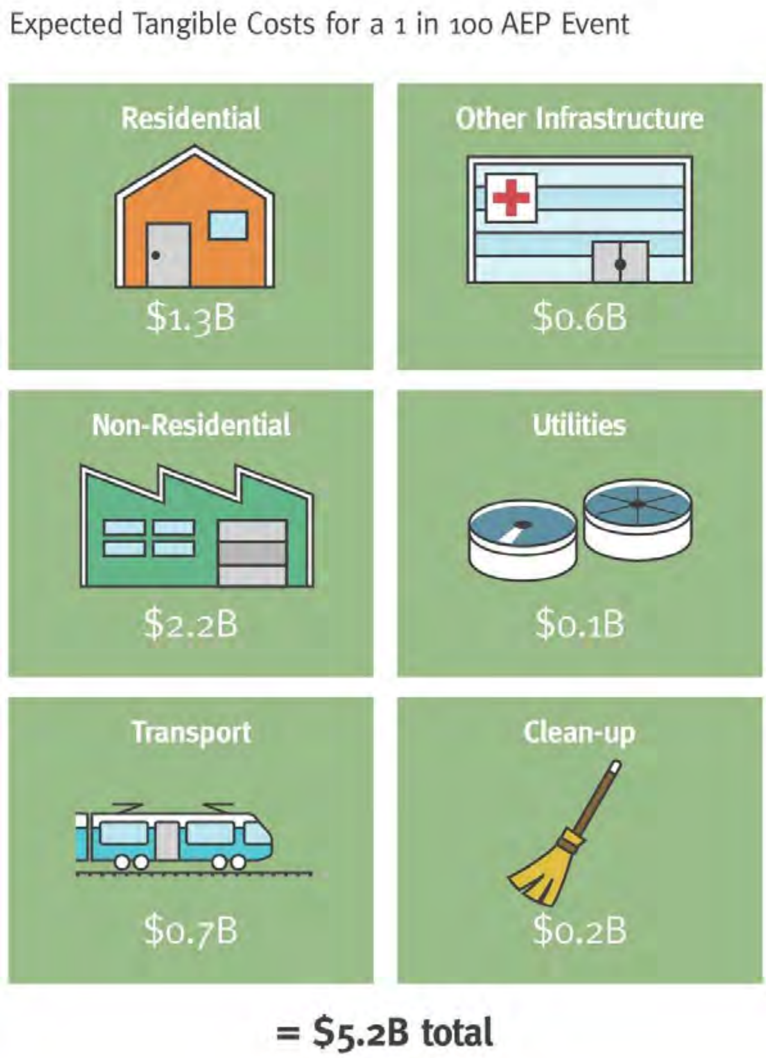
This framework has been used to estimate tangible damages, both direct and indirect, to residential, commercial and industrial properties and public infrastructure. It also establishes intangible damages such as social, environmental, cultural and heritage impacts, for a range of floods ranging from the 1 in 2 (50%) AEP to the 1 in 100,000 (0.001%) AEP. As well as providing a regionally-consistent framework for damages associated with Brisbane River flooding, it can also be applied to other sources of flooding in the region (e.g. creek or stormwater) as part of future Phase 4 (Local Floodplain Management Plans).

Based on the comprehensive building survey, approximately **130,000 buildings** are located within the floodplain (up to the 1 in 100,000 AEP extent). Of these, the majority (80%) are residential, 10% commercial / industrial, with the rest rural / agricultural, public, community, mining and outbuildings. In a 1 in 100 (1%) AEP flood, approximately **17,000 buildings** are flood prone, of which approximately 70% (12,000) are inundated above floor level. Based on previous studies, it is estimated that there has been a 70% increase in the number of buildings within the current 1 in 100 (1%) AEP extent in Brisbane and Ipswich since 1974.

This Technical Evidence Report estimates average annual flood damage (i.e. per year) to be **$289 million** (in 2017 dollars), of which approximately two-thirds comprises tangible damage, and one-third intangible damage. In terms of the relationship to hydraulic risk, the majority (approximately 90%) of damages occur in the highest three risk categories (HR1 to HR3). Floods up to and including the 1 in 100 (1%) AEP contribute approximately 30% to average annual damage, with the remainder attributed to larger and rarer events. The damage estimate, should a 1 in 100 (1%) AEP flood occur, is **$6.8 billion.**




Property Damages
Residential
$m/year
6.8
21.4
17.6
4.1
1.8
HR1 HR2 HR3 HR4 HR5
Non-Residential
$m/year
12.9
37.2
19.4
4.4
1.6
HR1 HR2 HR3 HR4 HR5


Expected Tangible Costs for a 1 in 100 AEP Event
Residential
$1.3B
Other Infrastructure
$0.6B
Non-Residential
$2.2B
Utilities
$0.1B
Transport
$0.7B
Clean-up
$0.2B
= $5.2B total

Flood damages impact all sectors of the community including government, businesses and residents. Understanding the shared economic benefits and impacts of flooding highlights the importance of an integrated approach to floodplain management.

As well as quantifying flood damages in the study area, the framework and estimates have been used as a basis for the economic assessment of structural mitigation works. Whilst there are inherent limitations and uncertainties in any assessment of this type, the flood damage assessment presents the most robust and comprehensive study of this type and scale ever undertaken in Australia for flood damage estimation. The data collected for this study is of national significance, and will be of considerable value for future flood management studies in South East Queensland, and nationally.

Future Flood Risk

Current flood risk describes the potential for flood impacts to occur, based on current conditions such as catchment topography and climate. However, the flood risk may change in the future due to climatic conditions such as increased rainfall and sea level rise, as well as changes in the topography, primarily caused by development. This Technical Evidence Report includes sensitivity analyses to better understand how sensitive the Brisbane River catchment is to future changes.

Future Development

The Brisbane River floodplain population has increased significantly over the past few decades. *Shaping SEQ,* the regional plan for South East Queensland, indicates that population is expected to grow by an additional 1.8 million people over the next 25 years. While some of this includes expansion of urban areas (including within the floodplain), much of it will come from consolidation of existing areas. Any increase in density of existing development within the floodplain will increase population exposure and hence the consequences for future flood risk.

Further urban development within the floodplain will potentially increase the number of people exposed to flooding due to population growth, or by altering the flood behaviour as a result of development. New development can reduce the available floodplain storage, block flood flowpaths and reduce rainfall infiltration causing increased runoff. These changes can cause impacts on existing communities upstream and/or downstream of the development.

Future development areas were identified within the floodplain across all four local government areas, based on the unrealised potential of urban zones within current planning schemes, and other urban investigation areas nominated within planning schemes. These future urban areas were included in the flood model of the lower Brisbane River and were tested to assess the sensitivity of the catchment to increased fill areas and changes in surface roughness. Results of the flood modelling found that the majority of the floodplain is very sensitive to filling, particularly within the 1 in 100 (1%) AEP flood extent. This means that if new development is filled to above the 1 in 100 (1%) AEP level, the fill required on land parcels to reach those levels will affect flood behaviour and worsen flooding for existing development elsewhere in the catchment. Estimates of flood damage will also increase with any new or intensification of development within the floodplain, even if built above the 1 in 100 (1%) AEP level, as larger and rarer events can and do occur (noting that 70% of current annual averaged flood damages already relate to properties higher than the 1 in 100 (1%) AEP flood extent).

For the fill scenario assessed, it was found that 1 in 100 (1%) AEP flood levels may increase by up to 0.9m in the Ipswich CBD area and approximately 0.4m at Jindalee. These results highlight that the more constricted areas of the floodplain are likely to be more sensitive to filling in the floodplain. In addition, the scenario highlighted that large-scale filling in one local government area can result in adverse impacts in other areas, reinforcing the importance of assessing and managing development cumulatively and at a regional scale.

Climate Change Sensitivity

Changes to climatic patterns in the future are likely to worsen flooding in the Brisbane River Catchment. However the magnitude of the impact is difficult to estimate due to uncertainty in how climate change parameters influence flooding, combined with the complex existing flood behaviour in Brisbane River. Three separate climate sensitivity scenarios were tested in the flood model to better understand the sensitivity of the catchment to increased rainfall and sea level rise. The selected scenarios were derived from international climate change projection guidance, interpreted by Australia's national hydrology guideline, Australian Rainfall and Runoff[1]. The tested scenarios ranged from the lower-end of climate projections (rainfall increase of 10% and sea level rise of 0.3m) to higher-end climate projections (rainfall increase of 20% and sea level rise of 0.8m). Based on the Intergovernmental Panel on Climate Change (2013) scenarios, these climate change projections are expected to be realised within the Brisbane River Catchment in the next 30 to 80 years.

Results of the climate change scenario simulations indicate that the Brisbane River Catchment is very sensitive to changes in climate variables, particularly increased rainfall (and resulting catchment flows). Under climate change conditions, flood levels at Fernvale may increase by 2.8 to 4.5m; levels around Ipswich CBD may increase by 0.9 to 2.4m; and levels around Brisbane CBD may increase by 1.2 to 2.5m, for a 1 in 100 (1%) AEP flood. Generally across the floodplain, the present day 1 in 100 (1%) AEP flood would occur with a frequency of 1 in 50 (2%) AEP for the higher-end climate projection. The number of flood prone properties and damage estimates would also rise significantly, with average annual damages increasing by between **50%** and **130%**, depending on climate projections. Even at the lower end of the projections, the increase in flood levels and damage is substantial across the floodplain if unmitigated. Flood risk will be heightened, with increasingly deep and fast flowing floods affecting a greater area and more people and properties.

Landscape Management

Landscape management from a flood management perspective involves changing the behaviour of the catchment so that it alters the hydrology of the rainfall runoff, reducing peak flows and levels downstream. Actions such as broad scale revegetation, restoration of floodplain connections and naturalisation of waterways, aim to achieve this attenuation of flow. Landscape management is an important consideration of integrated catchment planning, wherein the value of environmental actions within the catchment are assessed and planned considering the multitude of benefits they can bring to the community and the environment.

Two options for landscape management were considered:

- targeted revegetation within selected parts of the catchment, reflecting current and planned future initiatives for environmental actions across the Brisbane River catchment, as identified through stakeholder consultation
- full catchment revegetation restoring pre-European conditions for hypothetical, comparative purposes only.

It is difficult to quantify the flood mitigation benefits of catchment revegetation without further research in the local catchment and climate, as well as re-evaluating the detailed and complex hydrology of the catchment.

[1] Refer IPCC, 2013 and Ball et al., 2016 for details

As an indicator of the potential benefit of landscape management works to catchment flooding, the hydraulic model was used to assess a reduction in peak inflows by 5% and 10% (whilst maintaining total inflow volume) from catchments downstream of Wivenhoe Dam (i.e. Lockyer Creek and Bremer River). The results of the modelling reiterated previous findings that flood levels in the lower catchment are very responsive to changes in inflow due to the nature of the floodplain (i.e. limited floodplain storage areas), and indicates that broad-scale landscape management activities have the potential to lower downstream flood levels if reductions in peak flows can be achieved, though changes must be considered cumulatively to ensure there is no adverse impact due to changes in timing of flow.

Landscape management is expected to be more effective at reducing peak flows for smaller AEP floods than for larger and rarer floods, with further research required to quantify benefits in extreme flood events. Notwithstanding, and in alignment with the principles of integrated catchment management, landscape management activities would also be expected to create significant environmental and social benefit, which is largely intangible and difficult to quantify.

To progress these measures, further research is required to better quantify the relationship between broad scale catchment vegetation and hydrologic / hydraulic parameters in the Brisbane River Catchment, as well as local geomorphological studies to prioritise sites. Based on the outcomes of this research, the hydrologic and hydraulic models can be used to assess the proposed landscape management strategy for the upper catchment.

Structural Options

Structural works such as dams, levees, floodgates, temporary barriers, detention basins have significant potential to mitigate risk by modifying the behaviour of floodwater to be less dangerous, or to reduce the frequency of flooding. However, structural mitigation has the potential to increase flood risk elsewhere in the floodplain and cause other (non-flood) impacts (e.g. environmental, social etc.), as well as carry significant residual risk. Given the changes to flood behaviour associated with structural works, and the known sensitivity of the floodplain to hydraulic changes, potential options need to be considered cumulatively, at a regional level.

Various options to mitigate flooding in the lower Brisbane River have been posited, notably since the river experienced significant and devastating flooding in early 2011, with a number of ideas presented as part of the QFCoI. An initial ‘long list’ of ideas was collated from a number of sources, including previous investigations, stakeholder suggestions, and the study team. This was then refined to a ‘short list’ of 24 options that were considered regionally significant. It is noted that a number of options were identified which have the potential to improve flood risk at a local-scale, but are not of regional significance. These local-scale options may be investigated as part of subsequent Phase 4 (Local Floodplain Management Plans).

Levees and Flood Gates

Levees and flood gates provide a physical barrier between flood waters and areas that are being protected, removing sections of the floodplain that otherwise would have been used for flood storage or flow conveyance. As noted above, the Brisbane River floodplain is very sensitive to changes in the floodplain as there is a relatively little overbank storage available. Loss of floodplain storage increases flood levels in the river and can have a detrimental impact on other areas.

Levees and floodgates were considered for small, isolated sections of the floodplain, where these locations were considered to have regional or significant local importance to the community, as well as for large backwater sections of the floodplain that contain a large number or properties and items of critical infrastructure. The options included levees and / or floodgates at Fernvale, Amberley air base, Ipswich CBD, Goodna CBD, Woogaroo Creek, Oxley Creek, Norman Creek, and Breakfast Creek.

Generally, the small areas had inconsequential impacts on flood behaviour and therefore no adverse impacts on flood behaviour. However, benefits were also proportionally minor, resulting in marginal economic benefits (dependant on the costs of the works). The larger areas considered such as Oxley Creek, had a larger impact on flood behaviour, but also exacerbated flooding for other properties. These large-scale works are typically unfeasible due to the very high costs (associated with very large pumps which would be required to drain local catchment flows from behind the structures) and relatively low benefit cost ratios in most cases.

Temporary Levees and Barriers

Temporary levees and barriers are designed to be deployed for short periods of time only, to provide a physical barrier between flood waters and areas that are being protected. They target isolated sections of the floodplain that have a high value to the community, but that are not particularly suitable for permanent levees due to issues such as space or amenity constraints. Generally, these works do not have an impact on flooding elsewhere if they are very localised, while the high value of property and infrastructure being protected makes them an economical solution. They are, however, only likely to be deployed on an infrequent basis. Temporary barriers have been investigated at two locations on the Brisbane River to reduce flood inundation of the Brisbane CBD and at South Brisbane.

Flood Mitigation Dams

Dams within the upper floodplain and catchment area can have a very significant impact on flood behaviour as they capture runoff from the catchment, and release it more slowly to the downstream river system. This has the benefit of reducing peak flood flows downstream, and lowering peak flood levels. Dams, however, are very expensive and often have negative environmental consequences, as they permanently modify the natural hydrological regime of the waterway and catchment.

This Technical Evidence Report identifies the potential option of a new dry flood mitigation dam on Warrill Creek at Willowbank as having significant potential to reduce flood damages, but at a large construction cost. Options for reducing costs or sharing costs across multiple stakeholders such as via integration with Southern Freight Railway are recommended for further consideration. This Report also discusses the potential option of a new on-line dry flood mitigation dam at Kholo, and found this option would be more costly, and would have significant community consequences compared to other more feasible options being considered by the Department of Natural Resources, Mines and Energy (DNRME) and Seqwater, so was not progressed for detailed assessment.

In 2014, the former Department of Energy and Water Supply (now DNRME) and Seqwater reviewed a range of flood mitigation storage options for the Brisbane River in the *Prefeasibility Investigation into Flood Mitigation Storage Infrastructure*, including the option to raise the Wivenhoe Dam wall to increase storage capacity. Upgrades to Wivenhoe Dam have not been included within the scope of this Study, as Seqwater and the Queensland Government are currently progressing further feasibility level planning of options for upgrading Wivenhoe Dam as a parallel study. The findings of that investigation are due to be finalised in 2019 and will build upon these outcomes and the preceding Phase 2 (Flood Study).

Options Assessment

The shortlisted options were evaluated based on hydraulic modelling, an assessment of reduction in damages, conceptual design and costing, cost-benefit analysis, and a multi-criteria assessment. Options with a high benefit cost ratio have a more tangible economic justification for proceeding. Options with a low ratio may still be considered to have merit on other grounds, as captured by the multi-criteria assessment. The multi-criteria assessment framework was based on *Handbook 7* (AIDR, 2017), and refined for application in the lower Brisbane River floodplain in consultation with stakeholders. It considers a range of factors including safety, social, economic, feasibility, governance, community, infrastructure and environmental, many of which are intangible.

The options below all showed a net positive multi-criteria score (in brackets), relative to 'no change' (a score of 0). These options were also found to have a net positive score in combination, and are recommended to progress to further investigations and / or feasibility studies. A levee to improve the immunity of the Amberley air base has also been included, despite a neutral score, due to the significant intangible benefits associated with maintaining functionality of critical infrastructure. The upgrade of Wivenhoe and Somerset Dams was not assessed as part of this study, but is included in the summary for completeness.

Recommended structural options	Key findings	Multi criteria assessment score
Wivenhoe and Somerset dam upgrades	Seqwater and the Queensland Government are currently progressing further feasibility level planning of options for upgrading Wivenhoe Dam as a parallel study, therefore this is not included in the multi criteria assessment for this study. Findings due 2019.	NA
Warrill Creek dry flood mitigation dam	Widespread benefits to downstream properties across a range of flood events, particularly in the Bremer River Catchment with areas of higher vulnerability. Improved immunity of the Cunningham Highway downstream. Moderate benefit cost ratio (0.69) however there is potential to integrate with the planned Southern Freight Railway crossing. **Recommendation:** The Queensland Government to consult with Australian Rail Track Corporation to progress feasibility investigations as a matter of urgency, given the Southern Freight Railway project is further progressed. The Queensland Government to also investigate any other infrastructure crossings where it may be opportunity to incorporate flood mitigation works.	+1.10
Brisbane CBD temporary barrier	Benefits Brisbane CBD, however only for a narrow range of floods (around the 1 in 200 (0.5%) AEP). Moderate benefit cost ratio (0.71). **Recommendation:** Feasibility investigations to be progressed as part of the Brisbane Phase 4 (Local Floodplain Management Plan), in concert with the South Brisbane temporary barrier option.	+0.71
South Brisbane temporary barrier	Benefits a significant area in South Brisbane (behind South Bank), however only for a narrow range of floods (around the 1 in 100 (1%) AEP). It does not protect the riverside commercial and tourism precinct due to feasibility constraints. Low benefit cost	+0.63

Recommended structural options	Key findings	Multi criteria assessment score
	ratio (0.28) affected by significant requirements for backflow prevention (which may have broader benefits). **Recommendation:** Feasibility investigations be progressed as part of the Brisbane Phase 4 (Local Floodplain Management Plan), in concert with Brisbane CBD temporary barrier option.	
Ipswich CBD flood gate	Benefits flood prone commercial properties in the Ipswich CBD, which supports a community that is more vulnerable than average. Highest benefit cost ratio of the structural options (0.92). **Recommendation**: Feasibility investigations be progressed as part of the Ipswich Phase 4 (Local Floodplain Management Plan).	+0.34
Fernvale levee	Benefits a small number of properties within a narrow range of floods (around the 1 in 100 (1%) AEP). Very low benefit cost ratio (0.12), however the community is more vulnerable than average, has limited warning time, and the township is locally significant. **Recommendation:** Further assessment to be undertaken as part of the Somerset Phase 4 (Local Floodplain Management Plan) to investigate whether there are other more effective alternatives.	+0.16
Goodna CBD levee	Benefits approximately 30 businesses in the Goodna CBD, which supports a community that is more vulnerable than average. Significant capital cost and very low benefit cost ratio (0.08). **Recommendation:** Further assessment is undertaken as part of the Ipswich Phase 4 (Local Floodplain Management Plan) to investigate other more effective alternatives.	+0.01
Amberley air base levee	Benefits the Amberley RAAF air base for a range of floods up to the 1 in 100 (1%) AEP. Neutral multi criteria assessment score, however significant intangible benefits associated with maintaining functionality of critical infrastructure. **Recommendation:** Progress this option in consultation with the Department of Defence, and preferably in combination with Warrill Creek dry flood mitigation dam (to capitalise on improve immunity of access via Cunningham Highway, and offset downstream impacts).	-0.01

A number of other shortlisted options were abandoned that either had a net negative score (e.g. the dry flood mitigation dam at Kholo, flood gate on Oxley Creek in isolation, and combined with flood gates on Norman Creek and Breakfast Creek) or had one or more significant or widespread impacts, which would be difficult to offset or accommodate (i.e. the flood gate at Woogaroo Creek, the realignment of the Oxley Creek mouth, and dredging of the tidal reach).

Land Use Planning

Land use planning is recognised as one of the suite of floodplain management responses, particularly in respect of the management of future risk associated with new development within the floodplain.

Strategic analysis undertaken to inform this report has identified that future flood risk in the Brisbane River floodplain is sensitive to further urban development in the floodplain, particularly development relying on landform changes, such as filling, to achieve an acceptable level of risk, and to the anticipated impacts of climate change.

Land use planning in the Brisbane River floodplain therefore has a particular role to play in advancing the key flood risk management outcomes of:

- resilience of the region's settlement pattern to current and future flood risk; and
- 'no worsening' of flood risk arising from new development.

To achieve these outcomes through land use planning, regional consistency in the way in which flood risk is identified, evaluated and treated will be required for a number of key issues.

The need for regional consistency arises in response to four local governments with four discrete planning instruments regulating development within the floodplain. In addition there are a range of other planning instruments regulating development in areas outside of planning scheme jurisdictions in the floodplain, such as Priority Development Area - Development Schemes.

Regional consistency is defined as the achievement of consistent floodplain management outcomes across administrative boundaries in the floodplain. The key issues considered to require a regionally consistent response include:

- A shared understanding of flood behaviour across a range of flood likelihoods and flood hazard conditions for the full extent of the Brisbane River floodplain. Application of the Phase 3 (SFMP) Potential Hydraulic Risk definition provides a consistent and robust understanding of flood behaviour and is one of the key flood risk factors to inform integrated local flood risk assessments, Phase 4 (local floodplain management plans) (LFMPs) and land use planning responses;
- The assessment of land use planning and development proposals involving land form change (such as filling) informed by a regional cumulative impact assessment across the Brisbane River Floodplain. A regional assessment of cumulative impacts to achieve development assumptions across the Brisbane River floodplain will provide a holistic examination and understanding of the implications of land form change and filling on flood risk. It will provide a more complete understanding of flood risk and is a key technical input to inform Phase 4 (LFMPs), local flood risk assessments and land use planning responses and development requirements;
- The incorporation of climate change impacts into hazard and local flood risk assessments, Phase 4 (LFMPs) and land use planning responses informed by a regionally coordinated climate change adaptation response;
- The incorporation of evacuation capability risk factors into local flood risk assessments, Phase 4 (LFMPs) and land use planning responses, informed by a regional evacuation capability assessment;
- Consideration of the tolerability and acceptability of vulnerable land uses involving vulnerable persons in areas of higher flood risk.

Risk-based land use planning is discussed in detail within this report as the primary approach to treating flood risk through land use planning. Risk-based land use planning has been recognised through best practice and, most significantly, through the Queensland Floods Commission of Inquiry (QFCoI) and the Queensland State Government land use planning system as the means by which land use within areas affected by flooding can best be planned and regulated. This report and associated attachments provide detailed guidance to assist planning authorities in the floodplain to consider and respond to flood risk through risk-based planning approaches.

Phase 4 (Local Floodplain Management Plans) are identified as a pathway through which local flood risk assessments informing risk-based planning response can occur. Phase 4 (LFMP) or a natural hazard (flood) risk assessment (as required by the State Planning Policy) will integrate multiple considerations in establishing the preferred land use planning response, including integrated catchment planning principles, the role of other floodplain management measures in treating flood risk and state statutory requirements related to land use planning and flood risk.

The process of preparing amendments to planning instruments following Phase 4 (LFMP) or the natural hazard (flood) risk assessment will provide the opportunity for the state interest for Natural Hazard, Risk and Resilience (flood), as described in the State Planning Policy (SPP), to be balanced with the other 16 state interests to determine planning responses which respond to flood risk in the context of other local and regional considerations. This will be undertaken through a local government-led process in collaboration with state agencies.

It is acknowledged that the process of preparation of the Phase 4 (LFMP), and the subsequent amendment of planning instruments, will take a number of years to complete. A number of issues, particularly related to the uniform regulation of filling and land form change in the floodplain, may potentially need planning implementation arrangement/s in the interim, ahead of the completion of amendments to existing planning instruments. A detailed review of the effectiveness of existing approaches, the statutory policy context and evaluation of various options has not been undertaken as part of Phase 3 (SFMP). It is recommended that investigation of whether there is a need for planning implementation arrangement/s to proceed in the interim, is determined through collaboration between the Department of State Development, Manufacturing, Infrastructure and Planning (DSDMIP) and local planning authorities to address priority land use matters across the floodplain. The ongoing governance arrangements for the implementation of the Brisbane River Phase 3 (SFMP) provides an opportunity for collaboration between DSDMIP and planning authorities to occur.

Review of land use planning arrangements across the floodplain – particularly allocation of land to accommodate future growth and development in the context of flood risk – may identify the need to revisit local and regional land use planning assumptions. Should this be required, it is recommended that state and local planning authorities collaborate on any future review of the ShapingSEQ Regional Plan and investigate potential implications for regional land use, land supply and outcomes. This will enable consistent regional planning assumptions to be identified and incorporated into the future review of the SEQ Regional Plan to improve the resilience of the region’s settlement pattern to flood risk.

This report, although strongly supportive of risk-based planning as a methodology to address flood risk through planning instruments, does not make recommendations for its implementation by planning authorities within the Phase 3 SFMP Study Area. The reason for this is that the existing State statutory instruments directing the preparation of planning instruments in Queensland under the *Planning Act 2016* already adopt this risk-based planning approach for responding to natural hazards in land use planning. This report, however, strongly advocates for the application of this approach in a manner that achieves consistent floodplain management outcomes across the Brisbane River floodplain.

Disaster Management

The roles and responsibilities of the state’s disaster management entities are outlined in the Disaster Management Act 2003 and DM regulation 2014. The primacy of disaster management rests with local government and based within the respective local government boundaries. Notwithstanding this, local government frequently collaborate across boundaries to share resources, undertake planning and develop public-facing communications where necessary. Queensland Government agencies also actively support local governments in managing flood response and recovery phases, and provide resources for local governments to better plan for flood impacts. Collaboration and consistency were therefore identified as key drivers for regional disaster management planning. This Report leverages the regional flood model to develop a range of data and information to support all stakeholders involved with disaster management throughout the catchment. This Technical Evidence Report also provides processes and guidance, to promote continued consistency at all scales as part of the development of Phase 4 (Local Floodplain Management Plans).

This Report provides information to help disaster managers better understand what different floods might look like, and how flooding might impact people, properties and infrastructure. This information builds upon the understanding of existing flood risk to also consider relative flood timing, isolation and evacuation constraints, which will inform pre-flood planning, and response. Tools referenced herein will assist local governments to understand how flood maps relate to stream gauge heights, and whether the available flood maps sufficiently represented the full range of possible flood heights.

The community is a key stakeholder in effective disaster management. This Report and associated data provides information that can be used to help the community understand their personal flood risk, including how to relate flood warning information to risk at their property. By providing this information to the public, local governments will empower the community to better respond to flooding, ensuring disaster management resources can be directed to people who need the most support.

Comprehensive disaster management is underpinned by a continual cycle of improvement and requires a combination of short-term actions and long-term planning to achieve this goal. This Report supports immediate improvement through the provision of data and information and provides recommendations that can be implemented in the short-term as well as paving the way for future studies and projects requiring long-term investment.

The data and information developed is available for disaster managers to immediately implement in their planning processes and inform the development of flood intelligence. As local governments undertake new analysis in the future, this Report provides guidance to inform local-scale studies, including road inundation assessments (using a purpose-built analysis tool), review of stream gauge classifications and evacuation capability assessments. Due to the large number of people at risk of flooding in the catchment, it is essential to understand if all parts of the catchment have enough warning time to evacuate, whether there are sufficient roads to facilitate evacuation, and if local governments have identified enough evacuation centres for residents to shelter in. Although evacuation planning information was not available for assessment, a range of data has been developed to support assessments of this nature. In addition, a high-level assessment of the regional-scale evacuation processes in recommended in the short-term, with more detailed assessments to follow. Other recommendations can be implemented in the short-term including the development of new emergency alert polygons, and improvements to flood forecasting systems through adoption of new products and services from the Bureau of Meteorology.

Additional studies and consultation are also recommended, including a review process of the reporting templates used by local governments to share key information with Queensland Government agencies, consideration of evacuation route immunity as a road design criterion and a scoping study for a new real-time regional flood modelling system. This modelling system would seek to develop a world-class, region-wide system capable of simulating hydraulic models during flood events, and producing event-specific flood mapping and flood intelligence on demand. A fully integrated and coordinated system would greatly reduce the burden of time-critical decision making, ensure that all stakeholders refer to a single data source, and ultimately improve disaster management outcomes for the entire community. Supporting studies are also underway, including one to upgrade, customise and unify flood data within the waterRIDE™ software systems currently used by the 4 local government authorities. New functionality is also being built to use BoM issued forecast data in the execution of the hydraulic model, along with expanded functionality and reporting capabilities to provide more extensive flood intelligence.

Community Awareness and Resilience

Community awareness and resilience is one of the most crucial considerations for floodplain management, as well as one of the most challenging. Awareness and resilience needs to strike a balance between consistency of messaging to avoid confusion or conflict, and tailoring information to meet the varied needs of different communities. In addition, evaluation of the effectiveness of awareness and resilience activities is extremely difficult, resulting in uncertainty about the most effective approaches. The Technical Evidence Report seeks to overcome these challenges by building on current activities and processes, better understanding the needs of the community, and establishing a framework that articulates the agreed community awareness and resilience aspirations for the region. This work was informed and underpinned by a sound evidence and literature basis to provide greater confidence in findings and recommendations.

Using best-practice guidance and stakeholder input, this Report establishes a set of fundamental aspirations that describes key attributes of a flood resilient community in the Brisbane River Catchment: risk-informed, appropriately prepared, and adaptable. These aspirations were expanded to demonstrate what those attributes look like as community characteristics, and how stakeholder organisations can support the community in developing those attributes. Development of these aspirations is a key deliverable, making the concept of resilience tangible and relevant to flooding in the Brisbane River Catchment.

This Report aims to characterise the community's flood resilience, based on the region-wide vulnerability mapping, and the findings from market research and community survey, to better understand awareness and resilience behaviours, attitudes and issues. A significant market research exercise was undertaken, involving more than 800 residents within the catchment to better understand the community's level of flood awareness and resilience. This market research was followed up by a community survey, which received almost 200 responses. The new data highlights the importance of personalised information, the community's tendency to 'triangulate' information by cross-checking multiple information sources, and the strong bonds that exist within the community. These and other findings, helped to shape the recommendations relating to both community awareness and resilience, and disaster management.

Community awareness and resilience recommendations were identified using a multi-stage and multi-input process, including development of the flood resilience aspirations, improved understanding of the community and its needs, identification of principles for resilience activities (informed by a literature review and case study analysis), and review of current awareness and resilience activities against the resilience aspirations to identify gaps and opportunities for improvement.

The recommendations provided herein seek to facilitate efficiency and collaboration at the regional level as well as to optimise resources and learnings. A key recommendation is to develop regional reference material including the compendium of current activities and learnings in this Report, coupled with a toolkit of guidance to support new activities, and guidelines for communication and engagement reinforcing consistent messaging and terminology throughout the region. This set of documents can support the region specifically, or can be broadened in scope to cover state-wide application, with implementation in the Brisbane River Catchment in the first instance. Evaluation of resilience activities, including the sharing of those learnings and processes to establish a cycle of continual improvement, is recognised to be key to improving community flood resilience. A research activity is also recommended to help local governments and other stakeholders to realise the benefits of evaluating their own activities and learn from others.

This Report also provides a range of new data and information that can be used immediately to support community awareness and resilience activities including online flood mapping, provision of property-scale flood information, and the establishment of place-based installations of flood data and information.

Summary

The Brisbane River Strategic Floodplain Management Plan (Strategic Plan) sets out an overarching strategy for managing flood risk in the lower Brisbane River floodplain. This Technical Evidence Report follows best practice principles to provide an assessment of current and future flood risk and considers a holistic suite of multi-disciplinary measures including structural mitigation works, land use planning, disaster management and community awareness and resilience activities. The resultant recommendations have been developed in response to the identified risks shaped by qualitative and quantitative analysis, together with additional recommendations identified during stakeholder consultation, and form the foundation for the Strategic Plan to make informed decisions about the future management of the floodplain and provide a consistent basis for the subsequent Phase 4 (Local Floodplain Management Plans).

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Glossary

1D	One dimensional
2D	Two dimensional
3D	Three dimensional
AEP	Annual Exceedance Probability
AEP ensemble	A collection of Monte Carlo events that together comprise an ensemble for a given Annual Exceedance Probability (AEP) in relation to peak flood levels.
B15	**B**ase Case circa 20**15**
BCC	Brisbane City Council
BoM	Bureau of Meteorology (Bureau)
BRCFS	Brisbane River Catchment Flood Studies
CC1	Climate Change Sensitivity Scenario 1
CC2	Climate Change Sensitivity Scenario 2
CC4	Climate Change Sensitivity Scenario 4
CBD	Central Business District
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEM	Digital Elevation Model – a fixed grid of elevations
Design Flood	Hypothetical floods used for planning and floodplain management investigations. They may be comprised of a single design event or multiple events grouped into an ensemble. A design flood is defined by its probability of occurrence, for example the 1 in 100 Annual Exceedance Probability (AEP).
Detailed hydraulic model	2D hydraulic model developed as part of the Flood Study
DxV	Hydraulic flood hazard equal to **D**epth x **V**elocity. DxV is tracked separately at every 2D cell at every computational timestep during a model simulation to produce maps of peak DxV.
Fast hydraulic model	1D hydraulic model developed as part of the Flood Study
Flood Study	Phase 2 Brisbane River Catchment Flood Study (BMT WBM, 2017) which also comprises the BRCFS Data Collection Study (Aurecon *et al*., 2013), the BRCFS Hydrologic Assessment Technical Reports (Aurecon *et al*., 2015) and BRCFS Hydraulic Assessment Technical Reports (BMT WBM, 2016)
GIS	Geographic Information System
Hydraulic Assessment	Brisbane River Catchment Flood Study Comprehensive Hydraulic Assessment (BMT WBM, 2017)
Hydrologic Assessment	Brisbane River Catchment Flood Study Comprehensive Hydrologic Assessment (Aurecon *et al*., 2015)
ICP	Integrated Catchment Planning
LFMP	Local Floodplain Management Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging, an aerial ground survey technique
QFCoI	Queensland Floods Commission of Inquiry (QFCoI, 2012)

QRA	Queensland Reconstruction Authority
SFMP	Brisbane River **S**trategic **F**loodplain **M**anagement **P**lan
SPP	State Planning Policy
TER	Brisbane River Strategic Floodplain Management Plan **T**echnical **E**vidence **R**eport
URBS	Unified River Basin Simulator. A rainfall runoff routing hydrologic model (Carroll, 2012a)

1 Introduction

1.1 Context

In December 2010 and January 2011, a strong La Niña weather pattern caused extensive and prolonged rainfall in 100 locations across Queensland. More than 78% of Queensland was declared a disaster zone, affecting more than 2.5 million people, and inundating approximately 29,000 homes and businesses (Queensland Floods Commission of Inquiry, QFCoI). More than 14,000 properties were inundated in Brisbane, Ipswich and the Brisbane River Valley (McAneney and van den Honert, 2011).

The QFCoI was subsequently established and recommended several changes to how state and local governments manage flooding. Recommendations were related to flood control, dam release and procedures, planning, emergency procedures and management of future development in the Brisbane River floodplain.

Recommendations from the QFCoI which are particularly relevant to the Brisbane River catchment, are as follows:

"Recommendation 2.2

Brisbane City Council, Ipswich City Council and Somerset Regional Council and the Queensland Government should ensure that, as soon as practicable, a flood study of the Brisbane River catchment is completed in accordance with the process determined by them under recommendation 2.5 and 2.6.

Recommendation 2.12

Councils in floodplain areas should, resources allowing, develop comprehensive floodplain management plans that accord as closely as practicable with best practice principles.

Recommendation 2.13

For urban areas or areas where development is expected to occur:

- *councils with the requisite resources should develop a flood map which shows 'zones of risk' (at least three) derived from information about the likelihood and behaviour of flooding*
- *councils without the requisite resources to produce a flood behaviour map should develop a flood map which shows the extent of floods of a range of likelihoods (at least three)."*

In addition to these recommendations, QFCoI states in Section 2.6.1 – "*Floodplain Management in Australia recommends that a floodplain management plan should be reviewed within 10 years of the last and after severe flood events"*, referring to the then best practice guideline on floodplain management (SCARM, 2000), which has subsequently been replaced by AIDR (2013).

Following the QFCoI, the Queensland Government and local councils have committed to developing a long-term plan to manage the impact of future floods and enhance community safety and resilience in the Brisbane River floodplain. This work includes reviewing the floodplain management process within the Brisbane River catchment to ensure alignment with current best practice including

Managing the floodplain: a guide to best practice in risk management in Australia (Handbook 7) (AIDR, 2013).

Flooding occurs on a catchment scale and does not respect local government boundaries. As such, a regional scale strategy is required to manage flood risk across the full floodplain. The Brisbane River Strategic Floodplain Management Plan will deliver on QFCoI recommendation 2.12 by using current best practice to provide an overarching regional strategy and delivery framework for the stakeholders within the catchment.

1.2 Brisbane River Catchment Flood Studies

The floodplain management process adopted within the Brisbane River catchment includes 4 components and is presented in Figure 1-1. In response to Recommendation 2.2 of the QFCoI, Phase 1 and 2 have been completed through the completion of the Data Collection Report (Aurecon, 2013), and the Brisbane River Catchment Flood Study (BMT WBM, 2017) comprising comprehensive hydrologic and hydraulic assessments, which align with best practice as recommended within Australian Rainfall and Runoff (Ball *et al*., 2016).

The Phase 2 (Flood Study) covered the Brisbane River downstream of Wivenhoe Dam, as well as the lower reaches of the major tributaries of Lockyer Creek and the Bremer River (Figure 2-1). The area is sufficient in extent to capture the full floodplain for floods up to and including the 1 in 100,000 AEP flood. Note that the Brisbane River Catchment Flood Studies only consider riverine flooding of the Brisbane River and its major tributaries (i.e. Lockyer Creek and the Bremer River). It has not assessed other sources, such as creek flooding or stormwater inundation.

The Brisbane River Strategic Floodplain Management Plan (SFMP) is the third phase in the delivery of the Brisbane River Catchment Flood Studies. The Phase 3 (SFMP) will provide an overarching strategy for managing flood risk across the Brisbane River floodplain, including regional scale strategies and frameworks that stakeholders can incorporate into the fourth phase, undertaking Local Floodplain Management Plans (LFMPs).

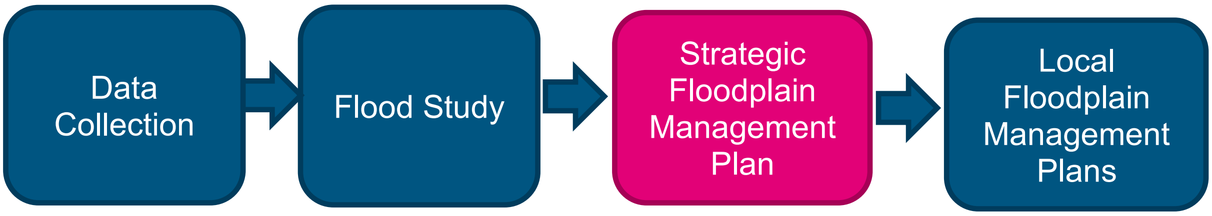


Figure 1-1 Brisbane River floodplain management process

Phase 4 (LFMPs) will provide more granularity on proposed direction and actions at a local government level. These local plans will capture the requirements of regional consistency, established as part of the Phase 3 (SFMP), but with local application. Phase 4 (LFMPs) will also include floodplain management measures to address local issues of concern, and take into consideration local community awareness and flood resilience.

1.3 Scope

The State of Queensland, in conjunction with key stakeholders, has prepared this Phase 3 (SFMP) for the lower Brisbane River. It takes a regional approach to floodplain management for the river reaches below Wivenhoe Dam. Importantly, it forms a consistent basis for Phase 4 (LFMPs) prepared by stakeholder organisations across the catchment, including Somerset and Lockyer Valley Regional Councils, Ipswich and Brisbane City Councils, and others as relevant.

The Phase 3 (SFMP) directly responds to recommendations of the *Queensland Floods Commission of Inquiry* (QFCoI, 2012). Furthermore, the flood risk assessment (Sections 4 and 5) and land use planning recommendations (Section 9) have been prepared in accordance with the *Queensland State Planning Policy* (SPP) (DILGP, 2017).

The Phase 3 (SFMP) uses the outputs of the Phase 2 (Flood Study) to describes the flood behaviour of the lower Brisbane River, to assess and characterise the nature of flood risk across the floodplain, and how to best manage the risk. Within the context of floodplain management, the community affected by flooding can extend beyond just the residents of the floodplain. The Phase 3 (SFMP) study area has been nominally defined as the area contained within a 5 km buffer of the 1 in 100,000 AEP flood extents, as presented in Figure 1-2.

The primary objective of the Brisbane River Phase 3 (SFMP) is to build on the comprehensive modelling outputs from the Phase 2 (Flood Study) to develop an overarching regional approach to floodplain management. The QFCoI noted that *"government agencies need to engage in a process of floodplain management involving a combination of land planning and building controls, emergency management procedures, and structural mitigation measures".* This regional-scale study includes the following components:

- Assessment of current and future flood risks (Sections 4 and 5)
- Flood damages assessment (Section 6)
- Identification of potential landscape management activities (Section 7)
- Identification and assessment of structural mitigation options (Section 8)
- Establishing a regionally consistent framework for land use planning (Section 9)
- A regional disaster management strategy and supporting information (Section 10)
- Activities for improving community awareness and resilience at the regional scale (Section 11).

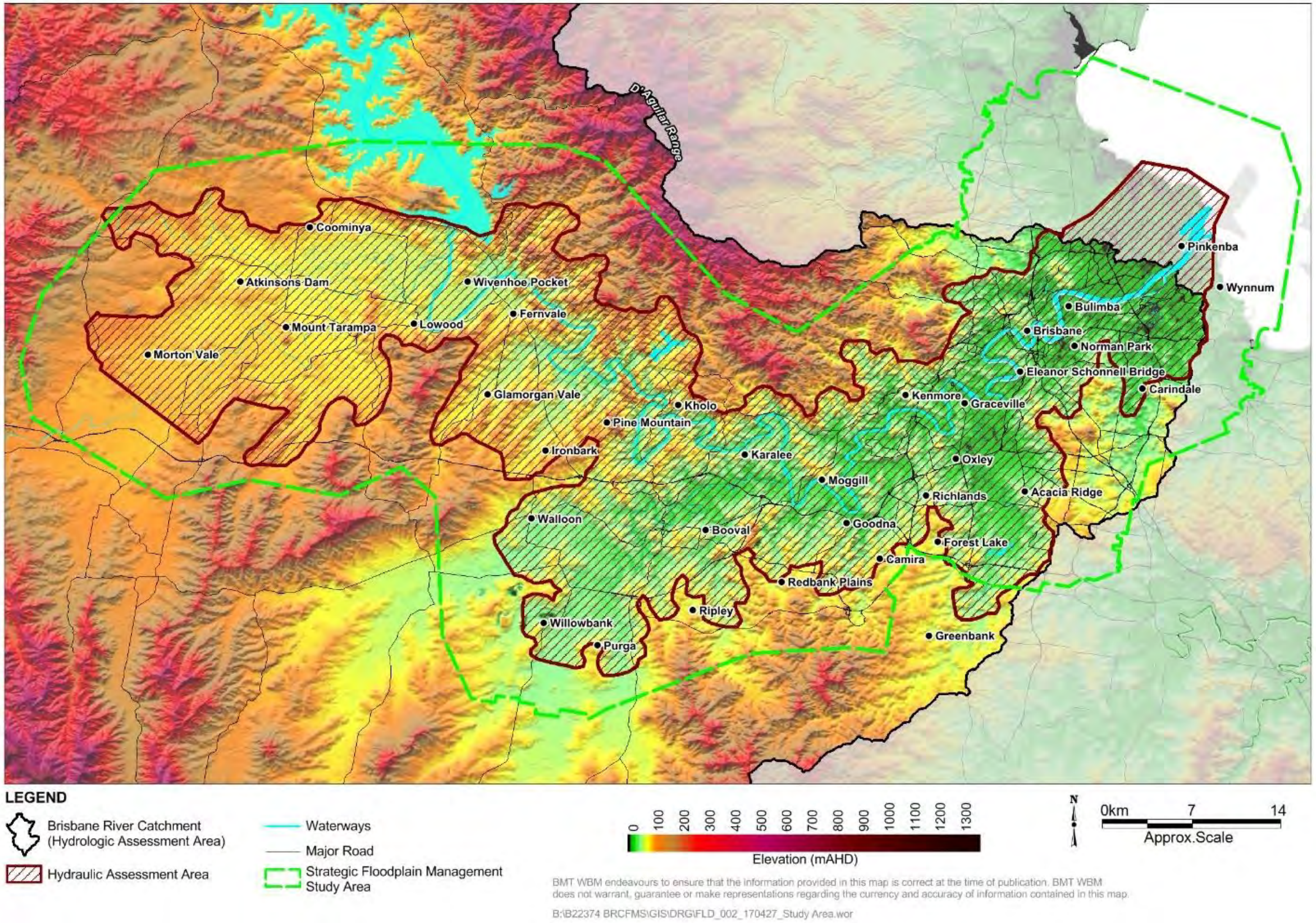


Figure 1-2 Brisbane River Strategic Floodplain Management Plan study area

1.4 Project Structure

The Brisbane River SFMP (Phase 3) has been delivered through the completion of various work packages covering different aspects of floodplain management. The outcomes of these work packages were documented in a series of 6 interim reports. This Technical Evidence Report (TER) combines the materials contained in the interim reports into a single reference document, which informs a separate, overarching Strategic Floodplain Management Plan (SFMP) document which forms the agreed policy response from the key stakeholders.

A summary of the work packages and TER are provided in Table 1-1. The interaction between the various study inputs are shown in Figure 1-3. Fundamental to the outcomes of this Phase 3 (SFMP) has been engagement with the extensive list of stakeholders for this study. This engagement has been undertaken via working groups for each work package, overseen by the QRA and the Brisbane River Catchment Flood Studies (BRCFS) Steering Committee.

Table 1-1 Brisbane River Phase 3 (SFMP) work packages and milestone reports

Work Package	Technical Evidence Report (TER)
FMS1: Current Flood Risk Describes the flood risk of the lower Brisbane River under existing development conditions. Flood risk is defined through consideration of hydraulic behaviour, existing development extents and types, the vulnerability of the community, the potential isolation of areas and populations across the floodplain, and the loss of access for evacuation. Flood risk is determined over the full spectrum of potential flood conditions, from small but frequent events (1 in 2 AEP) up to a very extensive, but extremely rare event (1 in 100,000 AEP).	Section 4
FMS2: Future Flood Risk Describes changes to current flood risk (as determined through FMS1) as a result of i) potential future climate change, including both sea level rise and increases to rainfall across the catchment; and ii) increasing levels of urban development within the floodplain as defined by existing plans and strategies for future land use planning.	Section 5
FMS3: Damages Assessment Describes and quantifies the tangible and intangible damages that result from flooding of the lower Brisbane River under both current and future conditions (as defined in FMS1 and FMS2). Damages are informed by the type of development within the floodplain, and the extent of flooding that would be experienced by each property. Economic damages are presented as Average Annual Damages (AAD).	Section 6
FMS4: Options Identification Identifies and describes a range of structural options that could be implemented to potentially modify flood behaviour, thus reducing risk and damage. These options are evaluated to establish a short list for more detailed assessment. Options are primarily ‘regional scale’ rather than addressing flooding in localised areas. Excludes potential modifications to existing dams, as this is scoped within other studies being undertaken by Seqwater.	Sections 6 and 8
FMS5: Options Assessment	Sections 6 and 8

Work Package	Technical Evidence Report (TER)
Further assessment of short listed options (as determined through FMS4), including concept design, preliminary cost estimates, impacts on hydraulic behaviour, impacts on flood damages, and a cost benefit assessment. Multi-criteria assessment to progress or abandon selected options.	
FMS6: Disaster Management Describes how a regional disaster management strategy can be implemented, based on improved understanding of flood behaviour to better inform emergency management authorities, and to help address flood risk before, during and after flood events of varying magnitude.	Section 10
FMS7: Land Use Planning Describes how a consistent, regional and risk-based approach to land-use planning can be implemented to minimise impacts of future development within the floodplain, as well as helping to mitigate existing flood risk to current development through land use planning responses.	Section 9
FMS8: Community Awareness and Resilience Supported by an appreciation of existing community awareness, describes actions and initiatives that can be applied consistently across the floodplain to increase the community's appreciation of flood risk and appropriate responses during flooding events. Informed by market research and community surveys.	Section 11
FMS9: Integrated Catchment Planning The Phase 3 (SFMP) takes an Integrated Catchment Planning approach to floodplain management. This includes adopting a multi-disciplinary approach and implementing a suite of measures that offer regional and multi-objective benefits. Elements of this work package are therefore integrated within all other work packages.	All sections
FMS10: Project Management The operational processes required to deliver the project and milestone reports.	-
FMS11: Strategic Floodplain Management Plan Integrates all of the work packages with the preparation of 2 documents to be used by a range of stakeholders. The Technical Evidence Report (TER) is a collation of the milestone reports wrapped into a single standalone document. The Strategic Floodplain Management Plan (SFMP) is a separate, higher level strategic document targeted at a multi-disciplined technical audience.	-

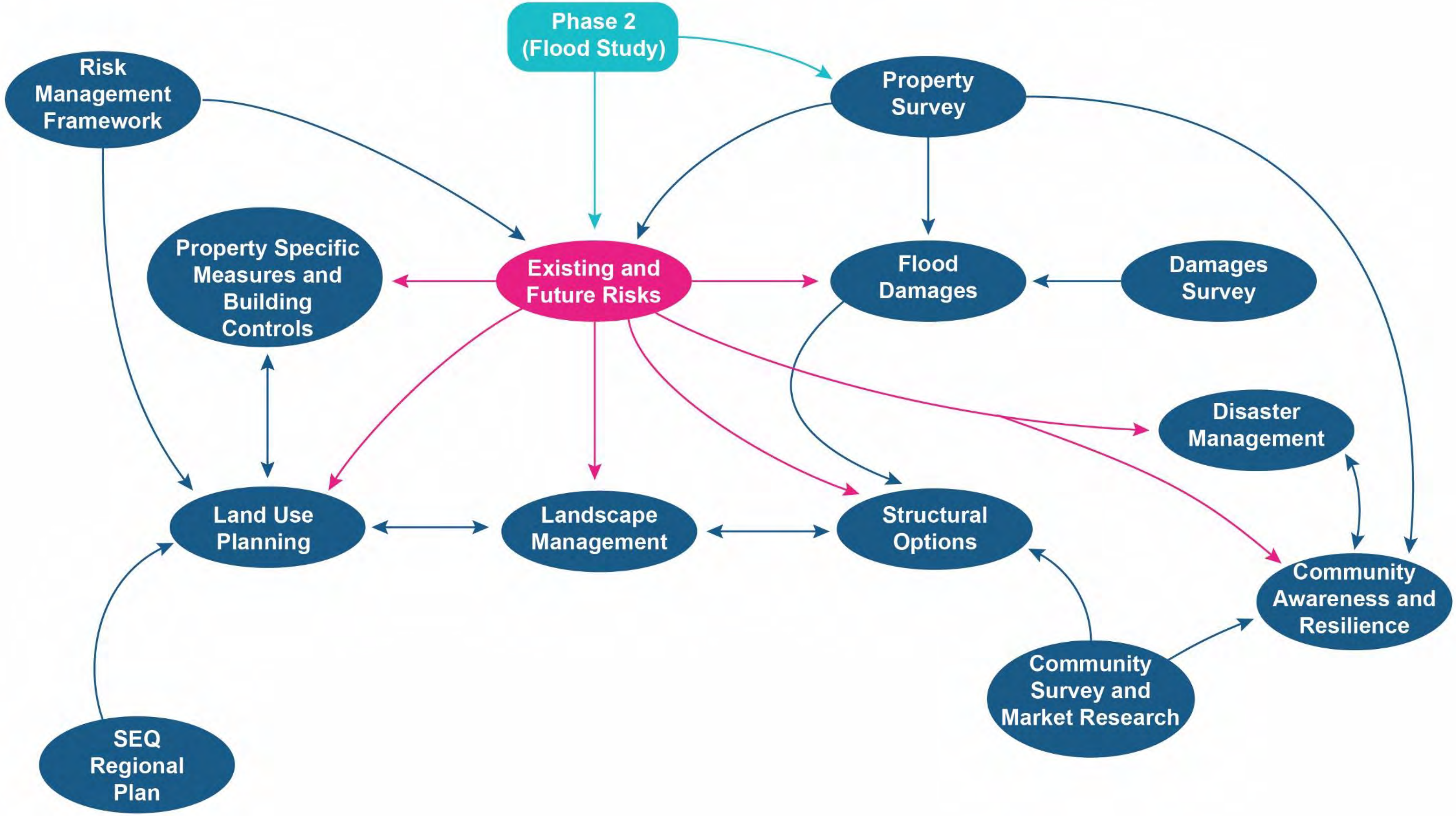


Figure 1-3 Interaction between study inputs and components

2 Brisbane River Catchment

2.1 Catchment Description

The Brisbane River catchment covers approximately 13,570 km^2, and includes:

- Brisbane River and several major tributaries, including Cooyar, Emu and Cressbrook Creeks in the Upper Brisbane River catchment
- Stanley River which flows from the Conondale and D'Aguilar Ranges
- Lockyer Creek, which converges with the Brisbane River downstream of Wivenhoe Dam
- Bremer River which flows to the Brisbane River downstream of Ipswich.

The catchment is bounded by the Great Dividing Range to the west, and a number of smaller coastal ranges including the Brisbane, Jimna, D'Aguilar and Conondale Ranges to the north and east. Most of the Brisbane River catchment lies to the west of the coastal ranges. Within the catchment are the two major cities of Brisbane and Ipswich, as well as numerous townships interspersed by extensive rural and agricultural land.

The catchment comprises a combination of natural forest, rural, industrial, commercial and residential lands. The upper reaches of the catchment are largely comprised of natural forest and rural land, with a small component made up of residential land. Downstream within the Ipswich and Brisbane local government areas, the catchment becomes dominated by residential land, with the remainder consisting of predominantly industrial and commercial land.

The Brisbane River has two major dams located in its upper reaches, both of which were built to supplement Brisbane's water supply and to provide flood mitigation. Wivenhoe Dam was completed in 1985 and has a catchment area of approximately 7,000 km^2. Somerset Dam is located upstream of Lake Wivenhoe on the Stanley River near Kilcoy, and has a catchment area of approximately 1,300 km^2. These dams regulate flows from approximately half the overall Brisbane River catchment.

Flows from Lockyer Creek and the Bremer River (and their tributaries) are unregulated, as are other tributaries downstream of Wivenhoe Dam, including numerous creeks in the Brisbane City local government area, such as Oxley Creek, Norman Creek, Breakfast Creek and Bulimba Creek. In the lower reaches, flooding is affected by tidal influences. The Brisbane River is tidal up to Mt Crosby Weir, which is located some 90 km from the mouth of the river. The Bremer River is also tidal in its lower reaches to Hancocks Bridge.

The Brisbane River is governed by its topography, which consists of a steep gradient, hilly terrain, and limited floodplains. These features contribute to high flood velocities. Flooding within the catchment is extremely complex, as detailed in the Phase 2 (Flood Study) and summarised in Section 2.2.3.

The Brisbane River catchment and study area are shown in Figure 2-1.

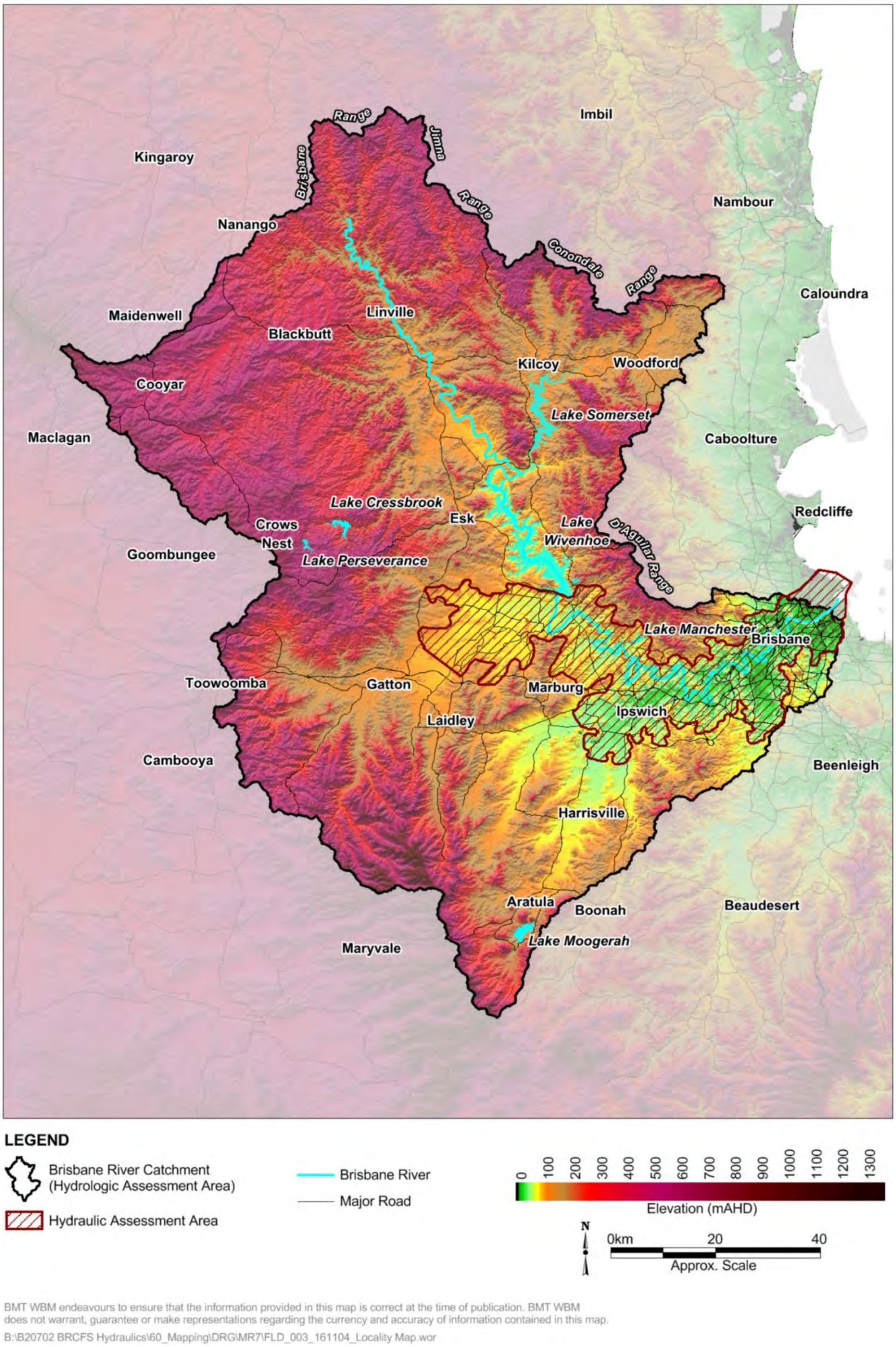


Figure 2-1 Brisbane River catchment and study area

2.2 Flooding in the Brisbane River Catchment

2.2.1 The Role of Brisbane River Dams in Flood Mitigation

From as early as 1893 there were requests to reduce downstream flooding in the Brisbane River by building major dams in upstream areas of the catchment. Construction of Somerset Dam began in the 1930s. Wivenhoe Dam investigations and planning were initiated in the early 1970s, before the 1974 flood. Following the devastating 1974 floods, there was sufficient assessment of benefits to proceed with construction, which was completed in the mid 1980s. Somerset Dam and Wivenhoe Dam were always envisaged, and subsequently operated, as dual purpose dams with a permanent reservoir compartment for water supply storage and further temporary storage reserved for flood mitigation operations.

Since completion, the flood mitigation benefits of the dams have been realised during many events including April 1989 (2 floods), May 1996, February 1999, May 2009, February 2010, October 2010, December 2010, January 2011, January 2013, February 2013, and May 2015 (Seqwater 2013, 2015).

The floods in 1999 and 2013 were mitigated to the extent that potentially 'Major' flooding at Moggill (had the dams not existed) was reduced to below 'Minor' flood level (a difference in flood level of more than 5.5 metres). In the 2011 flood, downstream flood levels exceeded the Major flood level at Moggill only after the operations at Wivenhoe Dam required the essential implementation of operating procedures to protect the safety of the dam due to the very large inflow rate and volume. Detailed analysis by Seqwater (2013) has shown that the 2011 flood inflow volume was approximately 2.7 million ML, some 1.1 million ML more than the 1974 flood volume that passed the site of Wivenhoe Dam. For contrast, the flood storage capacity of Wivenhoe Dam is only 911,000 ML (being the volume between full supply level at 67 m AHD and the trigger level for the dam safety procedures at 74 m AHD, as applicable in 2011).

Detailed modelling and analysis conducted in the Phase 2 (Flood Study) estimated that the effect of the major dams in the Brisbane River catchment in the 2011 flood event reduced flood levels by 2.8m at Ipswich, 2.3m at Fernvale, 3.2m at Moggill, and 2.0m at Brisbane City (relative to an equivalent 'no dams' scenario).

Despite the benefits that major dams can play in reducing downstream flooding, the experience drawn from the 2011 Brisbane River flood emphasised the fact that dams cannot prevent or eliminate flooding as extreme events can and do occur.

2.2.2 Flood History

The Brisbane River has an extensive history of floods, with records dating back to the early exploration of the river by John Oxley in 1824. It is subject to both high intensity storms producing flash flooding and prolonged rainfall resulting in riverine flooding. The largest floods on record occurred in the 19th century, notably in 1841 and two significant events in 1893, however, the local Jagera and Turrbal people have an extensive oral history and indicate that sometime from the 1700s to 1800s saw a larger flood than that formally on record. This oral history is consistent with results from the *Big Flood Project's* (Queensland Government, 2017) investigation into the paleoflood record of the Lockyer Valley, which noted a significant event occurring in the 1700s. Recorded data up until the mid-1950s is limited due to a scarcity of rainfall and water level observations.

The 1974 flood caused major flooding throughout the Brisbane River catchment. Following the construction of Wivenhoe Dam, minor to major floods have occurred on the Brisbane River with the most notable being in 1996, 1999, 2011 and 2013. The 2011 flood was the largest of these. Within the lower Brisbane River, it was equivalent to about a 1 in 100 AEP event; within the Bremer River it was equivalent to about a 1 in 50 AEP event; and within the lower reaches of Lockyer Creek is was equivalent to about a 1 in 150 AEP event. This difference in response during the 2011 event highlights the complexity of flooding within the Brisbane River, driven by spatial variability of rainfall across the catchment, combined with the management regime of Wivenhoe Dam (and Somerset Dam to a lesser degree).

While the 2011 flood event was not the largest, it was the most significant in terms of community impact (across virtually the whole of Queensland). In some areas of the catchment, floodwaters were so powerful they washed cars away and shifted houses. The event affected an area larger than the Brisbane River catchment and saw 78% of the state impacted. Within the Brisbane River catchment, flash flooding occurred in a number of areas including Withcott, Murphy's Creek, Helidon, Grantham and Gatton, whilst riverine flooding also impacted townships and cities including Fernvale, Lowood, Brisbane and Ipswich. Recorded stream flow and stream level data indicate that upstream of the Somerset and Wivenhoe Dams, the 2011 flood was the largest on record with inflows into the dams reaching nearly double the flow in 1974.

2.2.3 Flood Behaviour

The lower Brisbane River valley (i.e. downstream of Wivenhoe Dam) has a wide range of hydraulic complexities that make it very interesting and challenging to manage. The lower catchment area is large, roughly half of the overall catchment area, and includes the major tributaries of Lockyer Creek and the Bremer River. These tributaries add to the complexity in terms of the timing and shape of the flood hydrograph. Rainfall across the catchment can be highly variable from the wetter coastal hinterland ranges, to the drier areas in the west of the catchment. Wivenhoe Dam, and to a significantly lesser extent Somerset Dam, offer substantial flood storage capture and can significantly affect the shape and attenuation of the flood, and therefore the severity of flooding downstream.

Hydraulically, the lower Brisbane River valley is a mixture of conveyance and storage dominated reaches. Lockyer Creek, due to its flat wide topography is, in a large flood event, dominated by flood storage areas, with substantial slow moving volumes of floodwaters 'stored' on the floodplain from its local catchment or backwater from the Brisbane River. The Brisbane River from Pine Mountain to Mt Crosby is predominantly conveyance dominated, with relatively minor overbank floodplains, and floodwaters largely confined to an incised paleovalley. The river experiences high velocities and steep gradients through these reaches.

The Bremer River and the Brisbane River downstream of Mt Crosby have significant floodplains that store flood water, however most of the flow is conveyed in the main river. The lower Brisbane River, unlike most large east coast Australian rivers, has few natural meanders, with many of the river's reaches controlled by the surrounding hilly terrain. The hydraulic consequence is that substantially higher velocities, driven by a steep gradient, develop along the lower Brisbane River during a flood.

Consequently, the Brisbane River banks are often bedrock controlled; bends can literally be as sharp as 180º (e.g. Kangaroo Point), and the entire flood flow is often solely confined between the river banks with relatively little or no overbank flow. There are also several river meanders that are bypassed during large flood events.

The travel time of a flood peak from Wivenhoe Dam to Brisbane City is highly dependent on the degree to which the flows in the Brisbane River coincide with respective flows from Lockyer Creek and the Bremer River. It is also dependent on the magnitude of the flood as the attenuating effect of floodplain storage, and the degree of bypassing of river meanders, varies with flood magnitude. Because of the influence of the tributaries, the travel time of floodwater does not necessarily correspond to the relative timings of a flood peak. Ignoring the influence of these tributaries, the travel time of a flood hydrograph, such as releases from Wivenhoe Dam to Brisbane City, is similar to the timing of the flood peak that occurred in the 2011 event, typically around 30 hours. In the 1974 event however, the flood peaked in Brisbane just 24 hours after the peak at Wivenhoe Dam. This shorter time was most likely due to the greater flow and timing of the Lockyer Creek and Bremer River tributaries.

2.2.4 The Environmental Benefits of Flooding in the Brisbane River Catchment

The Queensland Government has recognised the broad benefits of flooding in the following extract from the report *Understanding Floods: Questions and Answers* (Queensland Government, 2011):

"In many natural systems, floods play an important role in maintaining key ecosystem functions and biodiversity. They link the river with the land surrounding it, recharge groundwater systems, fill wetlands, increase the connectivity between aquatic habitats, and move both sediment and nutrients around the landscape, and into the marine environment. For many species, floods trigger breeding events, migration, and dispersal. These natural systems are resilient to the effects of all but the largest floods.

The environmental benefits of flooding can also help the economy through things such as increased fish production, recharge of groundwater resources, and maintenance of recreational environments."

It is now widely accepted that the natural variation in the flow regime, including flood events, whereby water flows out onto floodplains, or down distributary systems to wetlands, is required to sustain freshwater ecosystems (Bunn and Arthington, 2002). The characteristics of these flood events determine the amount and quality of habitat created for different organisms to complete their life cycles, as well as providing opportunity for exchange of carbon and nutrients between the river and floodplains (Bunn *et al.*, 2014). The Queensland Government has also recognised the importance of flooding in the recharge of groundwater aquifers (DEHP, 2012).

The mechanisms which link flows and aquatic biodiversity have been summarised by Bunn and Arthington (2002) as four general principles. These principles, along with some examples are, as follows:

(1) Large flow events shape and scour stream and river channels and are a major determinant of physical habitat, which affects biotic composition.

(2) Many aquatic species have evolved life history strategies in response to the natural pattern of flow and rely on these cues to trigger movement or breeding. For example, a variable flow regime can affect seedling survival and plant growth rates (Blanch *et al*., 1999).

(3) Flow is important to maintain the natural patterns of longitudinal and lateral connectivity, essential to the viability of populations of many riverine species. Loss of longitudinal and lateral connectivity through altered flows or construction of dams and other barriers can fragment habitats, isolate populations, and cause recruitment failure and local extinctions. For example, it is thought that many species of fish in Australian rivers use the inundated floodplain wetlands of lowland rivers for breeding and juvenile habitat (Geddes and Puckridge, 1989). In addition, large colonies of waterbirds are triggered to breed when high flows inundate floodplain wetlands (Bunn *et al.*, 2014).

(4) Invasions by introduced or exotic species are less likely to succeed at the expense of native biota if the natural flow regime has not been modified. For example, inundation of floodplain wetlands provides a habitat that favours native aquatic macrophytes as opposed to species such as *Typha spp* and water hyacinth (Kingsford, 2000). This is similar to fish species whereby exotic fish species such as carp and mosquitofish are more successful in streams with a disturbed flow regime (Pusey *et al.*, 1989).

3 Approach to Flood Risk Management

3.1 Integrated Catchment Planning Approach

Environmental sustainability can be achieved by integrating the management of land, water, and related biological resources at a catchment-scale. Within this report, Integrated Catchment Planning (ICP) is used to describe the more holistic planning and strategic development of catchment-wide objectives, acknowledging the intrinsic values of our environment, and that healthy catchments underpin regional economies and provide social and recreational benefits for the community (Council of Mayors, 2015; DELWP, 2016). Management of flood risk within a catchment should be cognisant of the broader environmental outcomes that are sought to achieve sustainability, including the benefits that come from flooding and the recharge of floodplain wetlands and groundwater reserves.

The Brisbane River Phase 3 (SFMP) has been developed using an ICP approach founded on the principles outlined in the Queensland Audit Office (QAO) report, *Flood Resilience of River Catchments* (QAO, 2016):

- Recognising and balancing the relationships between cause and effect impacting on ecosystems within a catchment
- Coordinated approach from all levels of government
- Community and private enterprise engagement.

Floodplain management captures some of the ICP principles outlined by QAO (2016) through the consideration of land use planning, disaster management, building controls, infrastructure options, and community awareness and resilience. These ICP principles have been embedded within each component of the Brisbane River Phase 3 (SFMP). To capture the linkages between each element, they are not considered individually, but as part of a suite of floodplain management responses. Figure 3-1 illustrates where relationships between the key elements exist, and how these have been integrated in this Phase 3 (SFMP). Whilst the study only considers options that potentially mitigate flood risk, it also captures where these options can offer multiple benefits in addition to flood mitigation.

The Brisbane River Phase 3 (SFMP) focuses on managing flood risk within the Brisbane River catchment downstream of Wivenhoe Dam. One element of the study has been to assess potential structural options within the Brisbane River floodplain. This also includes assessment of landscape management activities within the wider Brisbane River catchment. A multi-objective approach has been taken to evaluate each option through the consideration of social, economic and environmental factors. Some key environmental objectives include the protection of water supply and quality, the ecosystem health including species and vegetation impacts, and the soil erosive capacity.

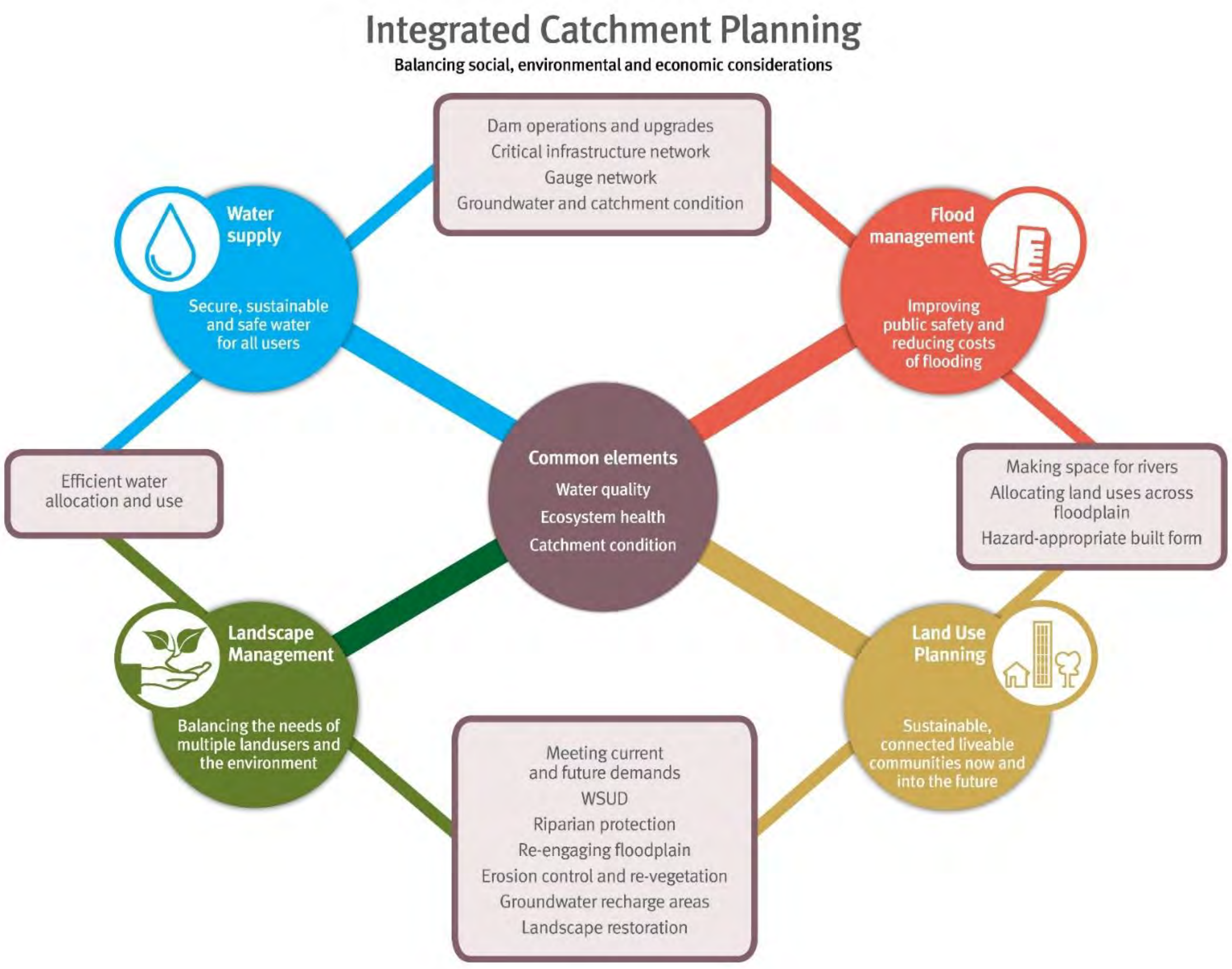


Figure 3-1 Key linkages of the Integrated Catchment Planning approach

(Source: Queensland Reconstruction Authority)

Each component of the Brisbane River Phase 3 (SFMP) has been developed in partnership with all levels of government and relevant organisations. This approach ensures the Phase 3 (SFMP) is delivered using an integrated and coordinated approach, and will aid in the capture of other planning processes currently in place. This project will be followed up by undertaking community consultation to both inform the community and capture feedback on project direction and deliverables. The Brisbane River Phase 3 (SFMP) has produced a number of coordinated strategic responses that incorporate the ICP principles defined by the QAO.

3.2 All Hazards Approach

The *Queensland Prevention, Preparedness, Response and Recovery Disaster Management Guideline* (QFES, 2018) outlines five main principles of disaster management which form the basis of the *Queensland Disaster Management Act 2003*:

(1) The comprehensive approach

(2) The all hazards approach

(3) The all agencies approach

(4) Local disaster management capability

(5) A prepared resilient community.

Most disaster management organisations operate across all hazards (such as flooding, fire, land slide etc.) and utilise many of the same approaches to disaster management for each hazard. In particular, approaches which focus on making the community more resilient, as opposed to standard awareness activities, are likely to have benefits across all hazards, as well as broader community 'shocks and stressors'. While this study focuses solely on flooding, it should be noted that it is important to continue this all hazards approach, and to recognise that many of the recommendations from this study can effectively deliver the flood component of an all-hazards approach or be all-hazards in nature. This notion is captured in the Queensland Disaster Management Participants Guide (QFES 2018) which notes that:

> *The all hazards approach assumes that the functions and activities applicable to one hazard are most likely applicable to a range of hazards and consequences, a disaster management plan captures the functions and activities applicable to all hazards. For example, health services and emergency supply are functions common to most disasters. This approach allows for a general, non-specific approach to delivery of services. It does not, however, effect the need for specific plans and arrangements for identified hazards and risks that require specific technical capability or authority to effect or direct a response.*

3.3 Flood Risk Management in Australia

3.3.1 Overview

Although all flood problems are different, the general principles of strategic flood management remain the same for all catchments and communities. An international team of water scientists (Galloway et. al 2014) published the below ten 'golden rules' for managing floods, which provide a helpful framework for considering issues when identifying flood management options:

(1) Accept that absolute protection is not possible

(2) Promote some flooding as desirable

(3) Base decisions on an understanding of risk and uncertainty

(4) Recognise that the future will be different from the past

(5) Do not rely on a single measure, but implement a portfolio of responses

(6) Utilise limited resources efficiently and fairly to reduce risk

(7) Be clear on responsibilities for governance and action

(8) Communicate risk and uncertainty effectively and widely

(9) Promote stakeholder participation in the decision-making process

(10) Reflect local context and integrate with other planning processes.

In Australia, the *Australian Disaster Resilience Handbook Collection* (referred to as the Handbooks) captures nationally agreed principles, policies and practices to support the development of disaster resilience. Of most relevance to the management of flood risk is *Handbook 7, Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017). This handbook is regarded as the national guidance for floodplain management.

Handbook 7 outlines 8 key principles for a best-practice approach to flood risk management:

- A cooperative approach to manage flood risk
- A risk management approach
- A proactive approach
- A consultative approach
- An informed approach
- Supporting informed decisions
- Recognition that all flood risk cannot be eliminated
- Recognition of individual responsibility.

The process followed in preparing the Phase 3 (SFMP) has been informed by current best practice for floodplain management in Australia, and current risk-based assessment methods. The following documents in particular, *inter alia*, have informed the approach:

- *Handbook 7, Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017)
- *National Land Use Planning Guidelines for Disaster Resilient Communities* (PIA, 2015)
- *Handbook 10, National Emergency Risk Assessment Guidelines* (AIDR, 2015)
- *Recommendations of the Queensland Floods Commission of Inquiry Final Report* (QFCoI, 2012)
- *Planning for Stronger More Resilient Floodplains* (QRA, 2011).

3.3.2 Managing Existing Risks

Handbook 7 identifies three distinct approaches to managing existing flood risk:

- **Reduce flood risk at the community scale with structural works.** Structural mitigation alters flood behaviour to reduce risk, however it is often expensive and must be hydraulically assessed to ensure works do not cause unacceptable impacts elsewhere in the floodplain. Examples of these works include dams, levees, floodgates, temporary barriers, detention basins etc (Section 8). At a broad scale, landscape management activities such as revegetation, re-engaging floodplains, and naturalisation of waterways (Section 6), also have potential to reduce flood risk.
- **Reduce flood risk at property scale with mitigation works.** Property-scale measures have not been included in this regional study, though are noted for future consideration in the Phase 4 (LFMPs) (Section 12). These include residential property buyback / voluntary purchase schemes, house raising, flood proofing of buildings etc.
- **Treat residual risk at the community scale.** Measures to treat residual risk are typically the simplest and most cost-effective to implement. These primarily focus on disaster management (Section 10), and community awareness and resilience (Section 11). Examples of these risk treatments include flood warning systems, emergency response plans, community education programs, etc.

Measures to treat residual risk are typically the simplest and most cost-effective to implement. Conversely structural works are often expensive, and can potentially have an adverse impact on properties elsewhere in the floodplain. The selection of measures is not solely based on risk, but follows a multi-criteria framework comprising a range of factors (safety of people, social, economic, feasibility, environment, etc.) as described further in Section 8 Structural Options Assessment.

3.3.3 Managing Future Risks

The best way to manage future flood risk to new development is to avoid and / or minimise consequences which is most effectively achieved through risk-based land use planning, as outlined in Handbook 7. This needs to take into consideration both existing and future climate conditions. In this Phase 3 (SFMP), this is covered in Section 9 Land Use Planning, with the exception of building controls which are being considered in a separate project by the QRA, as summarised in Section 12.3.

3.4 Regional Approach

Supporting the ICP approach, it is recognised that flooding can occur at a catchment scale, extending across multiple administrative boundaries. Fundamental to effectively managing this risk is having a common understanding of flood behaviour at a whole of floodplain scale. This means having a regionally consistent approach in how flood risk is defined, characterised, mapped and prioritised. Underpinned by this, effective flood risk management also requires an integrated approach, using a suite of implementation tools.

The Brisbane River floodplain extends through the four local government areas of Brisbane, Ipswich, Somerset and Lockyer Valley. Current flood risk management responses and approaches vary across the Brisbane River floodplain with differing methodologies for defining, describing and assessing the extent and degree of flood risk to people and property. A regional approach is fundamental to improving coordination and efficiency of floodplain management throughout the catchment. Whilst it is important that flood planning and response are tailored to local conditions and communities, this will be underpinned by a regionally-coordinated strategy as set out by this Phase 3 (SFMP).

In general, a regional approach to floodplain management can add significant value to local planning. This regional strategy for the lower Brisbane River aims to achieve:

- An integrated catchment planning approach to floodplain management
- Consistency in the assessment and understanding of current and future Brisbane River flood risk
- Consistency in the approach to estimation of flood damages and economic assessment of floodplain management options across the region
- Assessment of a suite of regionally significant structural mitigation options located throughout the Brisbane River floodplain
- A catchment-wide approach to landscape management activities
- A consistent risk-based approach to land use planning and development in the Brisbane River floodplain, to be tailored to local conditions
- A co-ordinated and consistent approach to disaster management planning, tailored to local conditions
- Knowledge and information sharing across the region, supporting efficient planning and execution of community awareness and resilience activities
- Consistency of language, messaging, data and tools for understanding and communicating Brisbane River flood risk between stakeholder groups, and to the community
- Effective coordination between local, State and Federal government agencies and stakeholders.

These regional considerations informed the development of flood risk management recommendations included in the Phase 3 (SFMP).

It should be noted that while this study focuses on the Brisbane River floodplain and the nature of the hazard (riverine flooding) applies to a catchment-scale, it is recognised that disaster management is implemented at local and district scales (see Sections 10.1.2 and 10.1.4 for further discussion).

4 Current Flood Risk

4.1 Risk Assessment Framework

4.1.1 Overview

The Phase 3 (SFMP) aims to establish a strategic framework for flood risk management across the lower Brisbane River floodplain. While flooding cannot be prevented, the Phase 3 (SFMP) can help to guide stakeholders to reduce the impacts to the community when flooding does occur.

Consideration of total flood risk rather than just the hazards associated with specific flood events has become embedded into best practice, as described in key flood management guidelines for Australia (Ball *et al.*, 2016, AIDR, 2013). A risk-based approach is useful when dealing with high degrees of uncertainty in processes and information. Rather than providing a single answer, the risk assessment approach allows managers to consider a range of events, their likelihood, consequence and thus the overall level of risk.

Where flood hazard defines the nature of a flood for a specific event, flood risk is the interaction of flood hazards with the community (through occupation and use of the floodplain) across the full spectrum of potential flood conditions.

A risk-based approach to floodplain management differs from historic approaches which have been based primarily on consideration of specific events only, such as a single 'defined flood event' (DFE), for example the 1 in 100 AEP. The weakness of the single DFE approach is that it does not reflect the spectrum of possible flood conditions, and tends to simplify flood risk to either inside the line (flood liable), or outside the line (flood free). Current best practice recommends synthesising mapping of flood hazard for multiple flood sizes, with community vulnerability and tolerability, as part of a holistic flood risk assessment.

The Queensland State Planning Policy (SPP) (DILGP, 2017) now advocates the use of risk-based management for natural hazard management, including flood management. The SPP recommends the International Risk Standard ISO 31000:2009 framework as a methodology to undertake risk assessments.

4.1.2 Application of Risk Management Standard

The International Standard *Risk management – Principles and guidelines* (AS/NZS ISO 31000:2009) is a recognised and reliable methodology for systematic application of procedures and practices to establish the context, and identify, analyse, evaluate and treat risks.

ISO 31000:2009 establishes a four step process to risk assessment. These steps can be summarised as:

(1) Risk identification

(2) Risk analysis

(3) Risk evaluation

(4) Risk treatment

The flood risk management approach adopted for this study follows the process outlined in Figure 4-1.

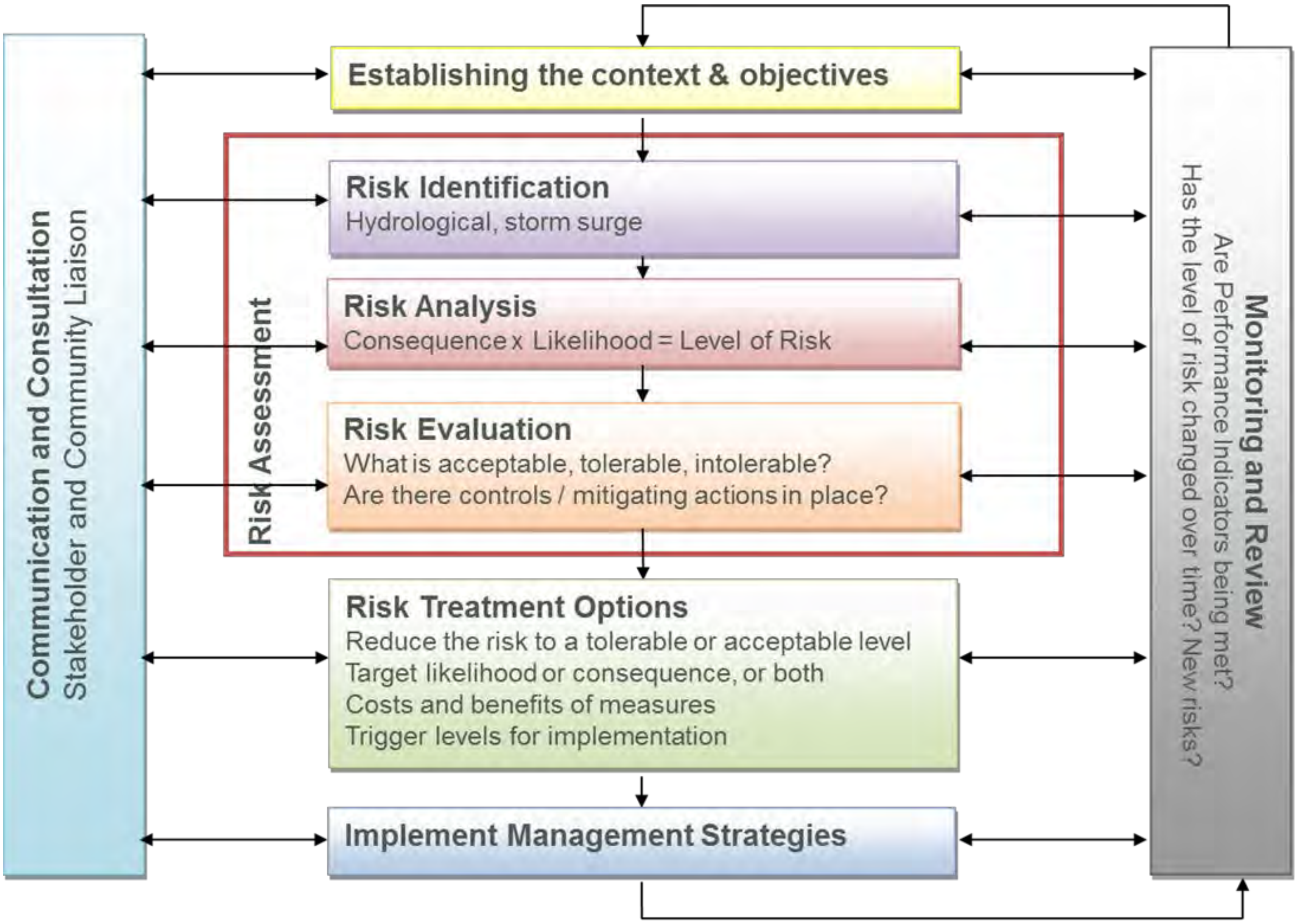


Figure 4-1 Risk Management Process applied to Floodplain Management, adapted from ISO 31000:2009

4.1.2.1 Establishing the Context

The context for the Phase 3 (SFMP) is to manage flood risk within the lower Brisbane River floodplain, downstream of Wivenhoe Dam. Risk occurs where the flooding potentially impacts on existing or future use of the floodplain. The floodplain contains a wide range of rural, rural-urban transition zone and urban land uses, which would potentially be detrimentally impacted by flooding. The objective of the Phase 3 (SFMP) is therefore to manage the full spectrum of flood risks associated with existing and future development within the floodplain.

4.1.2.2 Risk Identification

Risks considered involve riverine flooding as a result of rainfall and catchment runoff (i.e. hydrological flooding), combined with storm surge conditions within Moreton Bay (as a result of low atmospheric pressure conditions). Operational releases of water from Wivenhoe Dam are considered, as this forms a major contributor to flooding along the lower Brisbane River. However, inundation as a result of catastrophic dam failure is not included. Inundation due to tsunami backwater effects are also not included as part of the Phase 3 (SFMP).

Flood risks to the community extend beyond the floodplain. As well as direct inundation of land, flooding has the potential to affect communities through:

- Isolation creating flood islands (that is, flood waters surround lands preventing movement);
- Loss of transportation access (especially where access is needed for evacuation purposes); and
- Loss of services and amenity (where critical infrastructure is crucial to the on-going function of the community during and after a flood event, including water treatment, power supplies, communications and health/emergency services).

4.1.2.3 Risk Analysis

The ISO 31000:2009 approach recognises that risk is dependent on both likelihood and consequence to determine the overall level of risk (i.e. ***Risk = Likelihood x Consequence***).

Likelihood is simply the chance of a flood occurring at a particular locality. To prevent misinterpretation of flood likelihood, and in accordance with industry standard methodology, the approach used in this study is to describe flood probabilities in terms of an 'annual exceedance probability' (AEP). Using this language, what was previously known as a "Q100 flood" is now referred to as a "1 in 100 (1%) AEP flood", meaning there is a 1 in 100 (1%) chance that a flood of this size or larger will occur at that location in any given year (see Table 4-1).

The 1 in 100 (1%) AEP is commonly used to identify areas at risk of large-scale flooding. However, it is important to understand the risks and potential consequences of the full range of floods, from the small and frequent, to the very large and rare. The Phase 2 (Flood Study) provided estimates for 11 different floods ranging from a frequent 1 in 2 (50%) AEP, to an extremely unlikely flood with a 1 in 100,000 (0.001%) chance of occurring or being exceeded in any given year. The 1 in 100,000 AEP flood is considered the notional extreme event and, in the context of the Flood Studies, has been used to define the full extent of the Brisbane River floodplain.

Table 4-1 Average Likelihood of AEP Floods Occurring in an 80 Year Lifetime

AEP	At least once in 80 years	At least twice in 80 years	Brisbane (City Gauge) flood level	Ipswich (CBD) flood level
1 in 10 (10%)	100%	100%	1.8 mAHD	14.8 mAHD
1 in 20 (5%)	98%	91%	2.2 mAHD	16.1 mAHD
1 in 50 (2%)	80%	48%	3.2 mAHD	18.7 mAHD
1 in 100 (1%)	55%	19%	4.5 mAHD	20.1 mAHD
1 in 500 (0.2%)	15%	1%	7.3 mAHD	23.4 mAHD
1 in 2,000 (0.05%)	4%	0.1%	9.9 mAHD	25.7 mAHD
1 in 100,000 (0.001%)	0.1%	< 0.1%	23.7 mAHD	36.1 mAHD

Consequence for flood risk is dependent on several factors as follows:

- Hazard: where will the flood go and what is its hydraulic behaviour (depths, velocities etc.)?
- Exposure: what development/landuse is in the path of the flood?
- Vulnerability: Is the development/landuse particularly susceptible or sensitive to flooding?
- Tolerability: Is there a higher degree of acceptance of flooding for this development/landuse?

Flood tolerability relates to the attitudes and level of resilience within a community, which can reduce the impacts of flood exposure when an event occurs. This can include both subjective and quantifiable metrics, including personal attitudes to and awareness of flood events, levels of insurance, prevalence of use of flood emergency plans, and the extent to which people assist each other in times of flood. In the context of the regional Phase 3 (SFMP), risk consequence has not specifically considered 'tolerability', as this can vary unpredictably through time as the population changes, so cannot be relied on for the long term management of flood risk. However, the need to better understand tolerability at the local level remains and should be considered further when preparing local floodplain risk management plans.

Integrating likelihood and consequence is achieved through the use of a two-dimensional matrix. The specific combination of likelihood and consequence defines the level of risk. An example matrix is shown in Figure 4-2, using qualitative descriptors for both likelihood and consequence. The resulting risk level ranges from low to high, where low risk is characteristic of low/rare likelihood combined with low/minor consequence, while high risk is characteristic of high/frequent likelihood combined with high/major consequence. In between areas represent medium level risk.

EXAMPLE ONLY		Consequence		
		Minor	Moderate	Major
Likelihood	Frequent	Medium	High	High
	Possible	Low	Medium	High
	Rare	Low	Low	Medium

Figure 4-2 Simple example risk matrix (adapted from ISO 31000:2009)

4.1.2.4 Risk Evaluation

It is impractical to mitigate all risk. Priority should be given, however, to treating risks that are considered to be the most important. Determining which risks to address is a critical part of strategic risk management. In most cases, it would be expected that low risks can simply be monitored, while high risks would require further investigation and potentially more immediate management attention.

Risk tolerance defines which risks/locations/assets should be addressed as a priority. Risk tolerance should also take into account the timeframe for impact. This becomes significant if the risk profile is likely to change in the future as a result of potential climate change or on-going development and population change/turnover within the floodplain.

4.1.2.5 Risk Treatment

Risk management typically advocates the following risk treatment options:

(1) Avoid the risk;

(2) Reduce the risk (through reducing the likelihood or reducing the consequence);

(3) Share the risk (typically through insurance or similar); and

(4) Retain/accept the risk.

These options are generally considered with a continuum of treatment approaches wherein avoiding the risk is the most ideal (but often not the most practical) approach, while retaining the risk, or at least some component of the risk is usually necessary in some form.

Risks associated with existing development/landuse are typically much harder to manage as works and infrastructure are already in place that limit the opportunity for avoiding the risk, than for building developments that are better able to accommodate the risk.

Managing the Floodplain: A guide to Best Practice in Flood Risk Management in Australia (AIDR, 2013) identifies three distinct approaches to managing the flood risk to existing development:

- **Reduce flood risk at the community scale with structural works.** These works might include levees, floodgates, detention basins etc.
- **Reduce flood risk at property scale with mitigation works.** These works might include house raising, flood proofing of buildings etc.
- **Treat residual risk at the community scale.** These treatments might include flood warning, emergency response plans, community education etc.

The treatment of residual risk is often the most effective use of money and simplest to implement, whereas reduction of flood risk at the community scale can be very expensive and may cause adverse flood impacts elsewhere in the catchment. Reduction of flood risk at the property scale is not within the scope of this report, though it has been considered, refer to Flood Resilient Building Guidance for Queensland Homes (2018) Brisbane River Catchment Flood Studies for flood resilient building considerations when preparing detailed floodplain risk management plans. Flood risk management options are discussed in more detail as part of Section 8 Structural Options Assessment.

4.1.3 Use of Flood Risk Assessment in the Phase 3 (SFMP)

Risk assessment in accordance with ISO 31000:2009 and informed by *ADR National Emergency Risk Assessment Guidelines (NERAG) Handbook 10* (AIDR, 2015) has been used in the Phase 3 (SFMP) as a tool for helping to characterise flood risk across the floodplain, and for prioritising areas of greatest concern for both current and future conditions. The products of the flood risk assessment, including mapping of flood risk zones, are not complete outcomes in their own. Rather, they define conditions that are considered, along with other important criteria, when formulating a strategy for regional floodplain management across the lower Brisbane River floodplain and surrounding areas.

4.2 Potential Hydraulic Risk

4.2.1 Description of Potential Hydraulic Risk

Potential Hydraulic Risk represents the potential flood risk independent of the actual use or development of the land within the floodplain. Potential Hydraulic Risk is defined purely on the basis of the hydraulic conditions and behaviour of the flood events. It is determined by analysing the likelihood of floods and the hydraulic hazard that occurs during floods of different size and likelihood.

Thus, ***Potential Hydraulic Risk = Likelihood x Hydraulic Hazard***.

4.2.2 Flood Likelihood

Eleven (11) different flood likelihood conditions were assessed as part of the Phase 2 (Flood Study), ranging from a 1 in 2 AEP event up to a 1 in 100,000 AEP event. Stakeholders have agreed that seven (7) flood likelihoods should initially be considered when determining potential hydraulic risk across the floodplain. These likelihoods are:

- 1 in 10 AEP
- 1 in 20 AEP
- 1 in 50 AEP
- 1 in 100 AEP
- 1 in 500 AEP
- 1 in 2,000 AEP
- 1 in 100,000 AEP.

These likelihoods were chosen to provide a good mix of more frequent and rarer events, and also correspond to likelihoods that are already used by the stakeholders to some degree for strategic assessment and planning purposes.

4.2.3 Hydraulic Hazard

Hydraulic hazard is the term generally used to describe the potentially dangerous aspects of flood behaviour; based on the depth and velocity of the water. Stakeholders have agreed that hydraulic hazards across the floodplain are to be defined in accordance with the AIDR *Guideline 7-3, Flood Hazard - Supporting document for the implementation of Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017). The hazard curves, which recognise key thresholds in flood depths, velocities and combined depth-velocity values, are provided in Figure 4-3.

Each hazard category has been determined based on recognised limits of safety for people, buildings and vehicles, as shown in Table 4-2. Thresholds for safety of people, buildings and vehicles have been established through research and physical testing over many decades in Australia and overseas. Hydraulic hazard across the study area for each of the above likelihoods was an output of the Phase 2 (Flood Study).

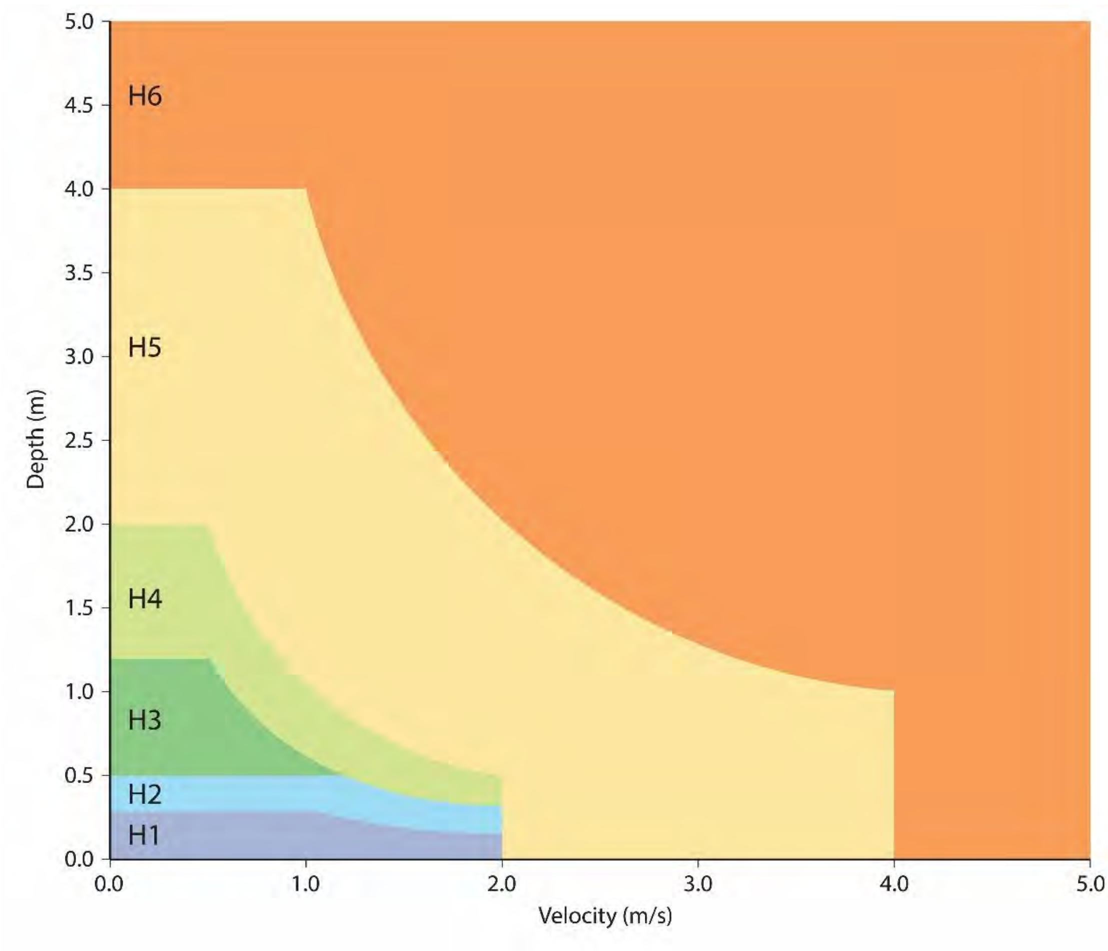


Figure 4-3 Hydraulic Hazard Definition (AIDR, 2017[2])

Table 4-2 Hazard Classification and Impacts on People, Vehicles and Buildings (AIDR, 2017)

Flood Hazard Category	Description
H1	Generally safe for vehicles, people and buildings
H2	Unsafe for small vehicles
H3	Unsafe for vehicles, children and the elderly
H4	Unsafe for vehicles and people
H5	Unsafe for vehicles and people All building types vulnerable to structural damage
H6	Unsafe for vehicles and people All building types considered vulnerable to failure

[2] Reproduced from (Smith et al. 2014)

4.2.4 Potential Hydraulic Risk Matrix

In accordance with the risk assessment framework prescribed in ISO 31000:2009 and described in Section 4.1, the overall level of risk is defined by specific combinations of likelihood and consequence. The easiest way to represent this is using a two-dimensional matrix, where one axis describes the likelihood and the other axis describes the consequence (or in the case of 'potential hydraulic risk', consequence is defined by hydraulic hazard). With seven AEP likelihoods (see Section 4.2.2), and six hydraulic hazard categories (see Section 4.2.3), a 7x6 matrix yields 42 possible combinations defining potential hydraulic risk. Practicality governs the number of risk bands that are applied for risk management. Generally between three and five bands of risk have been adopted for other flood risk assessments elsewhere (e.g. Moreton Bay, Toowoomba), and three to five bands of risk are common in most Enterprise Risk Frameworks for Industry and Government, including Queensland Treasury's *A guide to Risk Management* (2011), and DSITI's *Risk Management Framework* (2013).

The stakeholders have agreed that five bands of potential hydraulic risk are suitable for the Brisbane River. Defining the appropriate potential hydraulic risk level for each of the 42 matrix cells is an inherently subjective process, which requires a detailed appreciation of the hazards involved and the objectives of the risk assessment outcomes. Having five levels of risk (compared to three, say) provides a good opportunity for capturing greater granularity within the risk definitions.

The development of the matrix has been informed by best practice risk assessment guidelines, including *ADR Managing the Floodplain: A guide To Best Practice in Flood Risk Management in Australia, Handbook 7,* (AIDR, 2013) and *ADR National Emergency Risk Assessment Guidelines (NERAG) Handbook 10* (AIDR, 2015). Development of the matrix has taken a pragmatic approach that considered the potential consequences of hazards for specific AEP, within the overarching objectives of floodplain management and expectations of stakeholders and the community.

Five potential hydraulic risk categories have been defined, from HR1 (highest risk and priority) to HR5 (lowest risk and priority). Each of the 42 combinations of likelihood and hydraulic hazard were assigned to one of these risk categories based on consideration of consequences.

Experience tells us that when floods threaten lives (which can happen notably in Hazard categories H3 to H6), the level of risk should be commensurate. As the 1 in 100 AEP likelihood is broadly accepted as a default standard by the community, combinations of H3-H6 hazards with floods at, or more frequent than, 1 in 100 AEP should be regarded as a 'higher' overall risk (e.g. the higher risk categories HR1 and HR2).

Fundamental to the principle of the risk matrix, the risk level should vary in the horizontal direction of the matrix (to reflect the variation in consequence, or hazard level). That is, for the same likelihood (or specific flood event, e.g. a 1 in 100 AEP event), the overall risk level will be higher for an area that has a high hazard level compared to an area that has a lower risk level (e.g. higher potential risk category HR2 for the higher hazard areas H5 and H6, compared to lower potential risk category HR4 for the lower hazard areas H1 and H2). Similarly, the risk level should vary in the vertical direction of the matrix (to reflect the variation in likelihood of the risk). That is, for the same hazard band (say H3), the overall level of risk will be higher for a flood that occurs more frequently than one that occurs very infrequently (e.g. higher potential risk category HR1 for the more frequent 1 in 10 AEP event, compared to lower potential risk category HR5 for the very rare 1 in 100,000 AEP event).

Figure 4-4 presents the potential hydraulic risk matrix adopted for the Phase 3 (SFMP). The matrix has been derived in consultation with the stakeholders taking these considerations into account, together with practical experience in developing and using risk matrices for a range of flood risk assessments elsewhere.

AEP	H1	H2	H3	H4	H5	H6
1 in 100k	HR5	HR5	HR5	HR5	HR5	HR5
1 in 2000	HR5	HR5	HR4	HR4	HR4	HR4
1 in 500	HR5	HR4	HR4	HR3	HR3	HR3
1 in 100	HR4	HR4	HR3	HR2	HR2	HR2
1 in 50	HR4	HR3	HR2	HR2	HR1	HR1
1 in 20	HR3	HR2	HR2	HR1	HR1	HR1
1 in 10	HR2	HR1	HR1	HR1	HR1	HR1

Figure 4-4 Potential Hydraulic Risk Matrix for the Phase 3 (SFMP)

Key features of the Phase 3 (SFMP) matrix include:

- Use of six hazard categories, seven likelihoods, and five “levels” of potential hydraulic risk (as prescribed by the stakeholders);
- Potential hydraulic risk is used to prioritise areas of the full floodplain for further investigation and management based on their hydraulic characteristics. HR1 is the highest level of priority; HR5 is the lowest level;
- The five risk bands are roughly evenly represented within the matrix;
- At the 1 in 100 AEP likelihood, priority ranges from HR2 to HR4. Other likelihoods have at least two risk bands, except the 1 in 100,000 AEP likelihood;
- There are distinct gradations in risk level between likelihoods, at each hazard level. All hazards except H1 contain a full range of HR1 to HR5 priorities, with the highest priorities occurring at the more frequent events;
- The 1 in 100,000 AEP likelihood is sufficiently rare that it represents equally low potential hydraulic risk across all hazard levels;
- Potential hydraulic risk levels are the same for both H5 and H6 hazard areas. This is because there is little difference in the hydraulic hazard – the main distinction is whether buildings are just structurally damaged, or whether they are considered vulnerable to failure;

- For the 1 in 10 AEP event, all hazard areas are prescribed as HR1 potential hydraulic risk, except for H1 hazard areas. As H1 hazards do not generally cause significant risk to the community, these areas are prescribed as HR2 potential hydraulic risk.

4.2.5 Limitations of the Potential Hydraulic Risk Maps

Potential hydraulic risk mapping of the lower Brisbane River floodplain has the following limitations:

- It represents flooding from the major rivers and tributaries only based on the Phase 2 (Flood Study) design scenarios. It therefore does not reflect flooding from local sub-catchments, creeks and overland flowpaths, or other scenarios such as erosion or changes in geomorphology; and
- It does not take into consideration non-hydraulic risk factors, such as the landuse or development exposure to flooding, the vulnerability of the community at risk, specific challenges associated with evacuation or isolation during flooding, or risks associated with loss of essential services during a flood.

For these reasons, application of the potential hydraulic risk should be limited. In the context of the Phase 3 (SFMP), potential hydraulic risk mapping is used as one of the inputs to determine overall flood risk. It does not represent the total flood risk and should not be interpreted as such.

4.2.6 Comparison with Floodplain Function Mapping

The traditional way of describing different sections of floodplains is based on their ‘floodplain function’. This includes flow conveyance areas, flood storage areas, and flood fringe areas, as defined below based on Handbook 7 (AIDR, 2013):

- Flow conveyance areas are the sections of the floodplain that convey the bulk of the flood flow. They are generally continuous from the upper reaches to the lower reaches. They are often, but are not necessarily, areas where flow is deeper or velocities are greater. Obstructions within flow conveyance areas due to existing or proposed land uses can have a significant impact on flood behaviour upstream and downstream;
- Flood storage areas are sections of the floodplain where floodwaters are temporarily stored and detained during the passage of the flood. The presence of flood storage areas means that downstream flows and impacts are generally reduced and abated. Significant infilling within flood storage areas due to existing or proposed development may have an impact on the routing of floodwaters through the catchment;
- Flood fringe areas are the remaining sections of the floodplain, generally on the edges adjacent to higher land. These sections of the floodplain do not have a major influence on the hydraulic behaviour of the flood, and therefore infilling of these areas is not expected to change flood levels upstream or downstream.

The characterisation of the floodplain into these different areas has been useful for floodplain management, and in particular, for managing future development that may potentially alter the flood behaviour (e.g. filling of land, construction of levee banks, obstruction of flowpaths etc.).

Characterisation of floodplains according to floodplain function can be a very complex task, requiring considerable professional judgement. Additionally, floodplain function characterisation has traditionally only been done for discrete flood conditions (i.e. single AEP events).

Defining flood function is generally done giving consideration to the depths and velocities of flood flows. Thus, there are strong parallels between flood function and hydraulic hazard, which has also been recognised by others when defining potential hydraulic risk (e.g. Moreton Bay Regional Council flood risk mapping; see MBRC, 2015).

Preliminary flood function mapping was carried out for this study for the 1 in 100 AEP event only, with these categories defined as below (no additional hydraulic modelling was undertaken to develop this mapping)[3]:

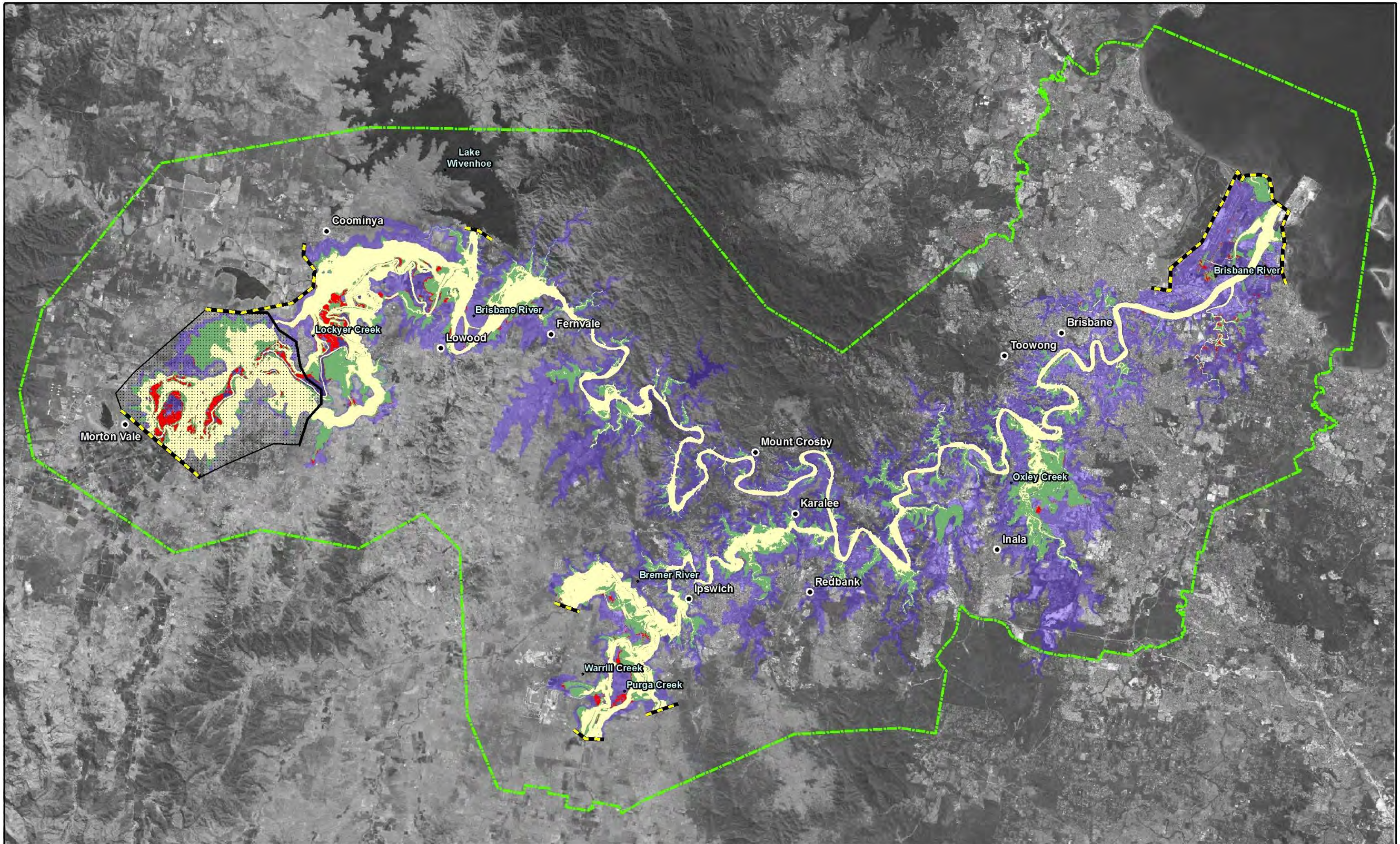
- Floodway: Velocity x depth > 0.25 m^2/s AND velocity >0.25m/s; or simply velocity > 1m/s
- Flood storage: Land outside the floodway where depth > 0.2m
- Flood fringe: Land outside the floodway where depth < 0.2m.

An overview map of the flood function across the lower Brisbane River floodplain is presented in Figure 4-5 with detailed maps provided in the Drawing Addendum (Drawings 6 to 10 in the Drawing Addendum).

The flood function mapping was compared to the potential hydraulic risk mapping prepared for this study. In summary, this comparison identified that:

- 1 in 100 AEP flow conveyance areas are almost exclusively characterised as HR1 or HR2 potential hydraulic risk areas.
- 1 in 100 AEP flood storages areas are mostly HR3 potential hydraulic risk areas, although in backwater tributaries it also includes some HR2 potential hydraulic risk areas. Some deep floodplain basins, such as in the lower Lockyer Creek floodplain, also include HR1 potential hydraulic risk areas, given the high frequency of inundation of these locations (i.e. become inundated during 1 in 10 AEP or 1 in 20 AEP event).
- 1 in 100 AEP flood fringe areas are relatively rare for the Brisbane River floodplain given the nature of the floodplain, however, there is a high degree of coincidence with HR4 potential hydraulic risk areas.
- Areas beyond the 1 in 100 AEP inundation extents are largely HR4 or HR5 potential hydraulic risk areas.

[3] Note the flood function mapping is preliminary only, based on one event (the 1 in 100 AEP) for riverine flooding (i.e. not local flooding). See also Section 4.7.2 for limitations associated with the design flood mapping approach undertaken in the Phase 2 (Flood Study).



LEGEND

- Limit of Detailed Modelling
- Study Area Boundary
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

1 in 100 AEP Flood Class

- **Flood Fringe**
- **Flood Storage**
- **Floodway**
- **1 in 100,000 AEP Flood Extent**

Brisbane River Catchment Flood Study

Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Preliminary Flood Function Mapping of the Study Area

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

Filepath : B:\B22374 BRCFMS\GIS\MXD\MXD_OUTPUT\Risk Mapping\FLD_010_Preliminary Flood Function.mxd

Fig 4-5 | A

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Based on these observations, it is considered that the use of potential hydraulic risk mapping is a suitable alternative to traditional flood function mapping, as it can be interpreted to guide future management and landuse decisions on the floodplain in a similar way to that previously done by flood function mapping. For example, in this lower Brisbane River application, development with HR1 to HR3 areas that would alter the landform or the flood flow regime would likely have measurable detrimental impacts on hydraulic behaviour in areas upstream or downstream, and therefore would need to be assessed with considerable rigour. Development within HR4 areas may also need to give some attention to local flood impacts. Development within HR5 areas would normally be beyond the area considered necessary for specific flood assessment, unless it involves critical or particularly sensitive services or infrastructure.

These considerations are documented in Section 9 Land Use Planning.

4.2.7 Summary of Potential Hydraulic Risk

An overview map of the potential hydraulic risk across the lower Brisbane River floodplain is presented in Figure 4-6 with detailed maps provided in the Drawing Addendum. The different levels of potential hydraulic risk provide an indication of the hydraulic behaviour of the floods when consolidated over the full spectrum of flood likelihood, ranging from a 1 in 10 AEP up to a 1 in 100,000 AEP. Maps in the Drawing Addendum have been produced covering five regions within the lower Brisbane River, consistent with mapping developed for the Phase 2 (Flood Study). Descriptions of potential hydraulic risk associated with riverine flooding across these five regions are provided below.

4.2.7.1 Region A – Lower Lockyer Creek

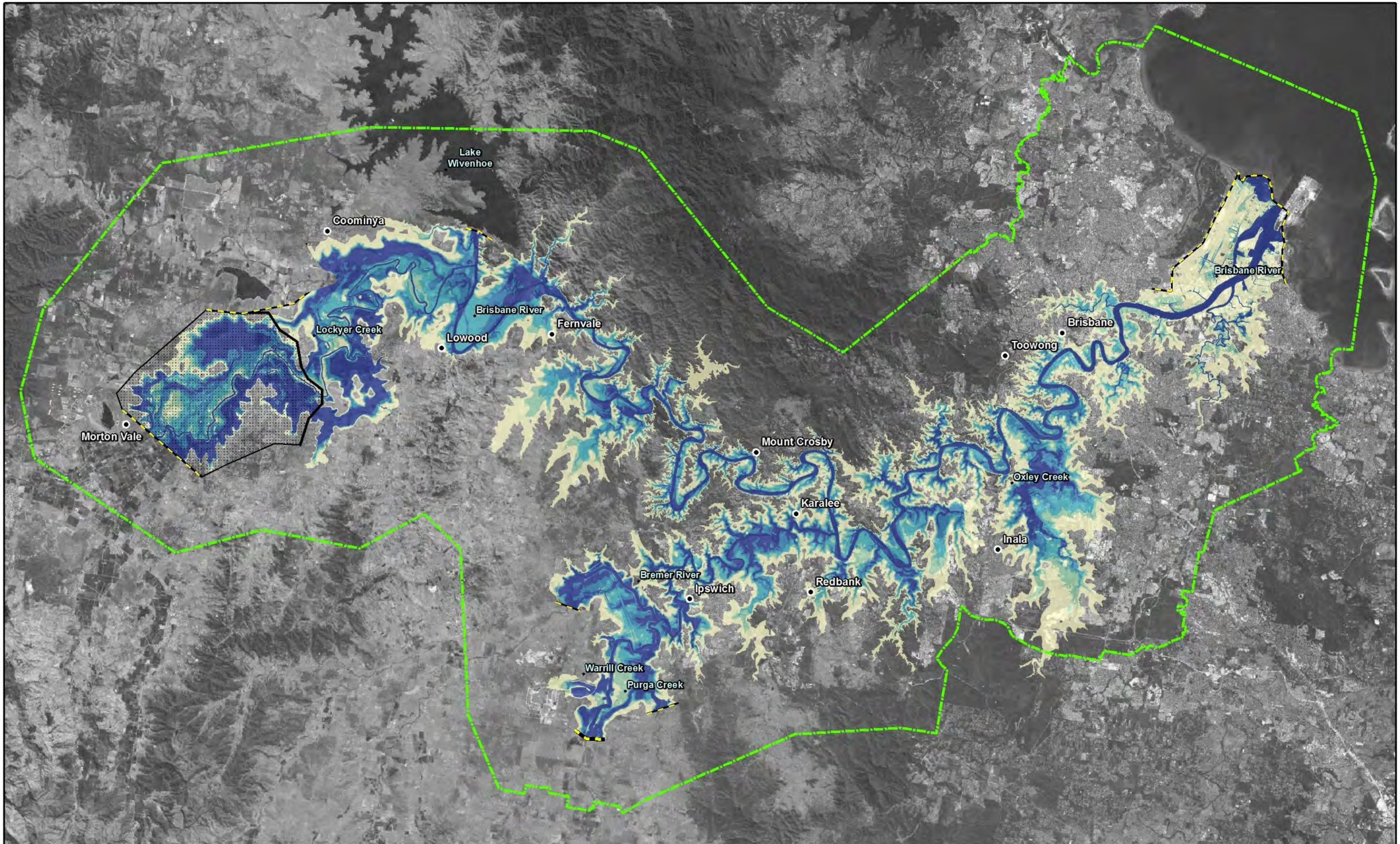
The lower Lockyer Creek between Morton Vale and Brisbane River junction (downstream of Wivenhoe Dam) is characterised by broad ‘basin’ floodplains with relatively low relief (see Drawing 1 in the Drawing Addendum). Natural levee banks border the river channel, with lower-lying land adjacent to surrounding hills and ranges which both convey and storage water during times of flood.

Floodways and deep floodwaters within the low-lying floodplain areas mean that much of the floodplain along the lower Lockyer Creek is characterised as HR1 or HR2 potential hydraulic risk. Slightly higher areas of the floodplain including the embankments along the perched creek are characterised as generally HR3 or HR4 potential hydraulic risk. There is relatively little HR5 potential hydraulic risk area in the lower Lockyer Creek given the broad ‘basin’ nature of the floodplain.

4.2.7.2 Region B – Wivenhoe Dam to the Bremer River Junction

Between Fernvale and the Bremer River junction, the lower Brisbane River flows through a narrow incised paleovalley (see Drawing 2 in the Drawing Addendum). Floodwaters are largely confined to the river channel only, and there is very little overbank floodplain. Backwater inundation occurs in small lateral tributary valleys.

Hydraulic risk within this reach of the lower Brisbane River is primarily HR1 and HR2, given the large depths and velocities of flow through the central flowpath. Some area of backwater inundation occur, with a gradation of potential hydraulic risk from HR2 to HR5 determined largely by depth of flooding.



LEGEND

- Limit of Detailed Modelling
- Study Area Boundary
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

Hydraulic risk mapping

- HR1
- HR2
- HR3
- HR4
- HR5

Brisbane River Catchment Flood Study
Study Partners

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Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Hydraulic Risk Mapping of Study Area

0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

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Fig 4-6 **A**

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4.2.7.3 Region C – Lower Bremer River

The lower Bremer River has a mixed floodplain characteristic (see Drawing 3 in the Drawing Addendum). There is relatively little floodplain area on the northern side of the river as the topography is similar to the steep valley formation in Region B. The southern side of the river, however, and the upper parts of the river in the vicinity of Warrill Creek and Purga Creek confluences, display more extensive overbank floodplains. Floodplains contain a mix of potential hydraulic risk, with HR1 and HR2 located extensively along the river and immediate overbank areas. Areas of HR4 and HR5 are generally confined to backwater inundation areas within lateral tributary valleys.

The area around Amberley RAAF base is the confluence between the Bremer River, Warrill Creek and Purga Creek. Overbank floodplains in this area are extensive. HR1 and HR2 areas generally cover primary flowpaths in this vicinity, while HR3 and HR4 areas represent broad flood storage areas.

4.2.7.4 Region D – Bremer River Junction to St Lucia

The Brisbane River downstream of Bremer River is again represented by an incised valley formation, however, the valley is not as narrow and gorge-like as it is upstream of the Bremer River. Potential hydraulic risks between the Bremer River and St Lucia are generally highest in the river channel, as well as selected tributary valleys where flood depths are likely to be significant (see Drawing 4 in the Drawing Addendum). This is particularly the case for Oxley Creek, where backwater inundation from the Brisbane River is extensive.

The lowest level of potential hydraulic risk (HR5) primarily comprises areas inundated by the 1 in 100,000 AEP event (and some lower hazard areas in the 1 in 2,000 and 1 in 500 AEP events). The 1 in 100,000 AEP extent is extensive along the river, capturing large areas of developed land within the Brisbane metropolitan region. For this event, flood depths are still expected to be significant, however, the likelihood of this event is so rare that it is prescribed the lowest level of potential hydraulic risk.

4.2.7.5 Region E – St Lucia to Port of Brisbane

The Brisbane River downstream of St Lucia is still essentially represented by an incised valley formation. Significant potential hydraulic risk is limited to the main river channel and only the waterway sections of lateral tributaries where water depths are greatest (see Drawing 5 in the Drawing Addendum). Beyond the river channel, potential hydraulic risk is generally low, as overbank flood depths are not significant, except in the 1 in 100,000 AEP event.

Small pockets of slightly higher potential hydraulic risk are present in some areas adjacent to the river due to backwater inundation in more frequent events. Modelling used to define potential hydraulic risk has assumed that backflow prevention devices on stormwater drains in the Brisbane City Council area are not present (refer Section 4.7.3). Therefore, the potential hydraulic risk mapping reflects the potential risk associated with backwater inundation rather than actual risk for floods up to the design level of protection.

4.3 Exposure

4.3.1 Assessment of Exposure

Flood exposure recognises that flood hazard does not in itself pose a risk unless it intersects with people or valued property. Exposure therefore is taken to relate to existing buildings / properties for assessment of current risk, as well as land zoned for certain purposes for assessment of risk to development potential.

4.3.1.1 Existing Development

The flood exposure under current conditions has been assessed as the exposure of existing development to flood conditions. It has been assessed as the risk priority at the location of the building, assessed at ground level. Buildings were identified through the creation of a detailed building database using survey and existing databases as described in Section 6 Flood Damages Assessment, discussed further in Section 4.3.2, below.

4.3.1.2 Development Potential

Exposure of undeveloped land to flooding can limit the development potential of that land. Assessment of the exposure to development potential was undertaken using land use zonings to understand the impact to development potential that may occur due to increased development in the floodplain (Section 5.1), and with changed climatic conditions (Section 5.2).

4.3.2 Building Database

4.3.2.1 Building Database

An extensive building database was developed for this study using site survey of all properties up to the 1 in 2,000 year AEP, and a combination of LiDAR and building footprints for remaining properties in the floodplain.

There are 215,710 entries in the building database created for this study, which encompasses all identified buildings in the Extreme flood extent, plus a small buffer area. Of these, there are 69,800 entries which represent upper levels of multi-storey buildings. There are a total of 145,910 ground (bottom) floor entries in the database (hereafter referred to as the number of buildings). Of the 145,910 buildings captured within the study area, 119,800 (82.1%) are residential, 17,230 (11.8%) are commercial/industrial, 2,290 (1.6%) are rural/agricultural and 6,040 (4.1%) are buildings that are classified under public & community, public authority, mining, vacant land, outbuildings and other/miscellaneous land uses. The remaining 530 (0.4%) buildings have no land use specified. Due to the buffer area in the survey capture, not all of the entries are within the floodplain.

Note that the term ‘building’ is used preferentially to ‘property’ in this chapter to clarify that exposure counts relate to individual buildings. This means that if a cadastral parcel includes multiple buildings (e.g. five townhouses), these are counted as individual buildings.

4.3.2.2 *Urban Footprint*

The urban footprint (as defined by urban land use mapping in the Phase 2 (Flood Study) hydraulic model development) was used to filter the building database for some reporting purposes (see Figure 4-7). This filtering process ensured that focus was not unduly placed on scattered properties, but instead focussed on clusters of properties, as is appropriate for a regional-scale study. Reporting of total numbers of exposed buildings is not limited to the urban footprint, but includes the entire study area.

4.3.2.3 *Community Database*

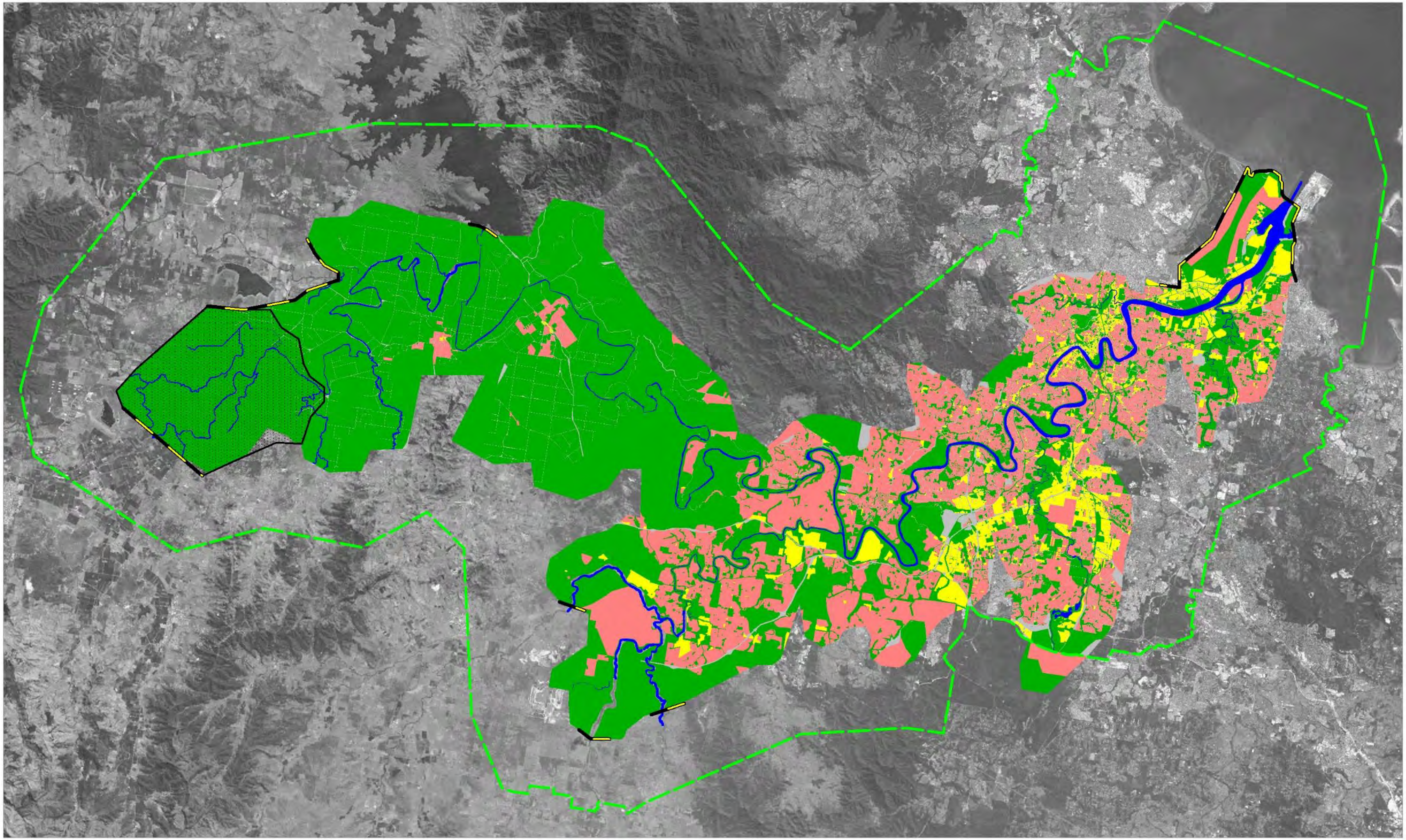
Information about the population within the floodplain was derived from the Australian Bureau of Statistics 2016 census data. For the exposure assessment, the primary metrics used were total population and residential properties. These values were intersected to define a “person to dwelling” ratio for each Statistical Area 1 (SA1) census collection area. This ratio was then applied to the residential properties in the building database (i.e. point-based data) to estimate the spatial distribution and density of the population within the floodplain.

4.3.3 Building Exposure

Floodplain exposure has been assessed by identifying those buildings in the building database which are within the floodplain area. The buildings have been grouped by building type (as defined in Section 4.3.2.1), and by the potential hydraulic risk category. It has been assumed that a building is ‘exposed’ if the estimated building location is within the flood extent at ground level. This assumption means that flood exposure calculations report on the number of buildings exposed, not the number of dwellings. This is an important distinction, particularly in locations with numerous multi-storey buildings. In those locations, exposure calculations may underestimate flood exposure, because a multi-storey building will only be reported as a single entry.

There are an estimated 22,200 residential buildings in the highest three potential hydraulic risk categories of HR1 to HR3, with more than 880 residential buildings in the highest potential hydraulic risk category of HR1.

A summary of estimated building numbers in the floodplain is provided in Table 4-3. Note that sensitive institutions (reported separately in Section 4.3.5) are a subset of total building numbers and are reported in the below table under ‘Commercial’ (for child care facilities) and ‘Community and Public Facilities’ (for all other reported sensitive uses). Entries in the building database which relate to ‘Public Utilities’ have been removed from these totals and are reported separately in Section 4.3.6.



LEGEND

Study Area Boundary

Limit of Detailed Modelling

Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for ocal flooding beyond limit

Land Use Mapping

Agriculture and Vegetation

Urban Blocks

Commercial and Industrial

Roads and Car Parks

Waterways

Brisbane River Catchment Flood Study
Study Partners

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Queensland Government

Title:
Current Land Use: Study Area

Figure: 4-7

Rev: A

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0 7 14
Kilometers

Map Grid of Australia 1994, Zone 56

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Table 4-3 Estimated Buildings in the Floodplain

Building Type	HR1	HR2	HR3	HR4	HR5	TOTAL
Residential	725	5,423	12,295	13,020	61,149	92,612
Residential Multi-Dwelling	157	922	2,692	3,095	10,268	17,134
Commercial	92	581	1,295	1,589	3,398	6,955
Industrial	181	1,285	2,119	1,824	4,028	9,437
Community and Public Facilities	22	201	378	380	1,613	2,594
Agriculture	83	217	358	351	892	1,901
Other	82	387	529	513	1,775	3,286
Total	**1,342**	**9,016**	**19,666**	**20,772**	**83,123**	**133,919**

4.3.4 Population Exposure

There are approximately 281,500 people living within the lower Brisbane River floodplain. There are an estimated 58,200 residents in the highest three potential hydraulic risk categories of HR1 to HR3, with 2,100 residents in the highest potential hydraulic risk category of HR1. The spatial distribution of at-risk residents is similar to the distribution of residential properties.

A summary of estimated population numbers in the floodplain is provided in Table 4-4.

Table 4-4 Estimated Population in the Floodplain

	HR1	HR2	HR3	HR4	HR5	TOTAL
Residents	2,170	16,510	39,530	41,050	182,200	281,460

Within the community, some residents may be more vulnerable to the impacts of flooding, due to socio-economic and demographic characteristics. Residents with these increased vulnerabilities are identified in Section 4.5.

4.3.5 Sensitive Institutions Exposure

Floodplain exposure of certain building types are considered more sensitive than others due to an increase in perceived vulnerability and significant community value. These property types are identified as ‘sensitive institutions’ and generally house more vulnerable residents and / or require assistance or emergency resources to support evacuation.

The building database identified the following sensitive institution types: hospitals, child care facilities, educational (including kindergartens, primary and high schools, and universities and tertiary institutions), and community protection facilities (gaols and similar). Other sensitive development types which were not identified within the building database includes aged care and other health facilities. It is recommended that local knowledge be used to supplement the building database with this information.

Table 4-5 provides a summary of the estimated numbers of sensitive institutions in the lower Brisbane floodplain. Note that as for all exposure summaries, these values relate to the number of buildings (rather than entities), therefore a single school with multiple buildings may appear to be overrepresented in the summary. There are an estimated 444 sensitive institutions situated within the highest three potential hydraulic risk categories of HR1 to HR3, with 20 institutions estimated to be within the highest potential hydraulic risk category of HR1. Of the 444 sensitive institutions located within the HR1 to HR3 flood extents, there are an estimated 27 child care facilities, 394 educational facilities, 7 hospitals and 12 community protection facilities.

Table 4-5 Estimated Sensitive Institutions in the Floodplain

Sensitive Use Type	HR1	HR2	HR3	HR4	HR5	TOTAL
Hospital	-	-	7	17	88	**112**
Child care	2	12	13	22	76	**125**
Educational	18	134	242	165	846	**1,405**
Community protection	-	4	12	83	146	**245**
Total	**20**	**150**	**274**	**287**	**1,156**	**1,887**

4.3.6 Critical Infrastructure Exposure

Critical infrastructure is infrastructure that assists people in a natural disaster or provides essential life supporting services. The flood exposure of these assets is considered separately due to the crucial support and resources they provide the community during a flood event. Information used to develop the critical infrastructure database was derived from land use classifications, and various primary data sources provided for this study. Note however that not all critical infrastructure datasets were made available for this study (some due to confidentiality issues), and hence the dataset does not provide a complete listing of all critical assets in the floodplain[4].

There are an estimated 204 critical infrastructure assets situated within the highest three potential hydraulic risk categories of HR1 to HR3, 30 of which are estimated to be within the highest potential hydraulic risk category of HR1. Of the 204 critical infrastructure assets located within the HR1 to HR3 flood extents, there is 1 airfield, 9 emergency management facilities, 130 water infrastructure sites and 64 electrical and telecommunications sites.

A summary of estimated critical infrastructure numbers in the floodplain is provided in Table 4-6.

Table 4-6 Estimated Critical Infrastructure in Floodplain

Critical Infrastructure Type	HR1	HR2	HR3	HR4	HR5	TOTAL
Airports and associated infrastructure	0	0	1	1	12	14
Emergency management facilities	0	2	7	8	53	70
Water infrastructure	29	63	38	37	159	326
Electricity and telecommunications	1	7	56	71	185	320
Total	**30**	**72**	**102**	**117**	**409**	**730**

[4] A summary of input data sets is provided in Appendix C.

4.3.7 Summary of Exposure Risk

4.3.7.1 Region A – Lower Lockyer Creek

There are no properties in the building database in the HR1 or HR2 risk category, within Region A. There are a number of rural buildings located along the banks of Lockyer Creek in the lower HR3 and HR4 risk categories, however this risk is increased by proximity to the creek and potential for bank erosion during overtopping in flood events. Note that there are limitations relating to design flood mapping upstream of Lyons Bridge, see Section 4.7.2.

4.3.7.2 Region B – Wivenhoe Dam to the Bremer River Junction

The majority of buildings (of all types) in the HR1 risk category and within the urban footprint (per Section 4.3.2.2) are located in the following suburbs:

- Karalee
- Barellan Point

The majority of residential buildings in the HR2 risk category are located in the following suburbs:

- Fernvale
- Karana Downs
- Lowood
- Karalee
- Barellan Point

4.3.7.3 Region C – Lower Bremer River

The majority of the buildings (of all types) in the HR1 risk category and within the urban footprint (per Section 4.3.2.2) are located in the following suburbs:

- Brassall
- North Ipswich
- Tivoli
- East Ipswich
- Moores Pocket
- North Booval
- Bundamba
- Ipswich CBD
- Churchill
- West Ipswich
- One Mile

The majority of residential buildings in the HR2 risk category are located in the following suburbs:

- Brassall
- North Booval
- One Mile
- East Ipswich
- Bundamba
- Basin Pocket

4.3.7.4 Region D – Bremer Junction to St Lucia

The majority of the buildings (of all types) in the HR1 risk category and within the urban footprint (per Section 4.3.2.2) are located in the following suburbs:

- Oxley
- Rockley
- Goodna
- Sherwood
- Graceville

The majority of residential buildings in the HR2 risk category are located in the following suburbs:

- Riverview
- Bellbowrie
- Riverhills
- West Lake
- Sumner
- Jindalee
- Kenmore
- Figtree Pocket
- Corinda
- Oxley
- Rocklea
- Archerfield
- Coopers Plains
- Chelmer
- Sherwood
- Graceville
- Tennyson
- Yeronga
- Fairfield
- Goodna

4.3.7.5 Region E – St Lucia to Port of Brisbane

The majority of the buildings (of all types) in the HR1 risk category and within the urban footprint (per Section 4.3.2.2) are located in the following suburbs:

- Hemmant
- Teneriffe
- New Farm

The majority of residential buildings in the HR2 risk category are located in the following suburbs:

- Indooroopilly
- Taringa
- St Lucia
- West End
- Toowong
- Auchenflower
- Milton
- Paddington
- South Brisbane
- Brisbane City
- New Farm
- Norman Park
- Newstead
- Teneriffe
- Hamilton

4.4 Isolation

4.4.1 Assessment of Isolation

Isolation can be a major risk, particularly when the isolation persists for more than a few hours, or when essential services (such as electricity and water) are cut-off, or where isolated residents require medical attention.

During periods of isolation, residents can become stressed or anxious, there may be food and water shortages, and medical emergencies may become more serious due to delayed treatment. Identification of isolation risk can inform future planning decisions, either through evacuation plans which ensure residents are evacuated prior to isolation, or as a backup, services are provided on islands within the floodplain.

An understanding of isolation risk within the study area has been developed through:

- Identifying road immunity (i.e. the most frequent flood event which is likely to close that segment of road)
- Identifying low points on roads where flooding is likely to occur first
- Identifying the time from the start of the event when the road first becomes impassable, to know whether there will be sufficient time to warn and evacuate residents
- Identifying the duration that the road remains impassable, to inform decisions about evacuation, shelter-in-place, resupply etc.
- Identifying those areas which become isolated (islands).

Guidance is provided in Section 10 Disaster Management to support emergency managers use this information for flood planning and response.

4.4.2 Road Flood Immunity

State controlled roads (and some local roads identified by Somerset Regional Council) were used as a proxy for evacuation routes for this regional-scale assessment, recognising that further assessment will be required within the detailed studies to understand the flood immunity of feeder roads connecting to the state controlled roads.

The flood immunity of road segments (i.e. between intersections) was identified for the following flood events / categories:

- Less than and including 1 in 10 AEP
- 1 in 20 AEP
- 1 in 50 AEP
- 1 in 100 AEP
- 1 in 500 AEP
- 1 in 2,000 AEP and greater

The specific immunity of bridges on these roads has not been assessed due to a lack of specific infrastructure detail.

An overview map of the road flood immunity across the lower Brisbane River floodplain is presented in Figure 4-8 with detailed maps provided as Drawings 11 to 15 in the Drawing Addendum.

The immunity assessment provides general trends and highlights locations in the study area which might be constrained by poor flood immunity. It is noted that areas upstream of the study area may also be inundated and isolated during the same weather events that cause flooding along the lower Brisbane River. These areas will also need to be considered as part of network continuity and disaster management planning.

4.4.3 Road Inundation Locations

The following process was used to identify locations where road segments on the state controlled roads are likely to first become inundated by flooding from the Brisbane River:

(1) Road segments were identified between intersections of state controlled roads.

(2) Segments were assessed using the detailed model for the 1 in 100,000 AEP event ensemble (comprising four 1 in 100,000 AEP events) using the TUFLOW evacuation route feature to ‘monitor’ those road segments for the location where the road is first inundated. This was based on a nominal trigger depth of 10cm of water.

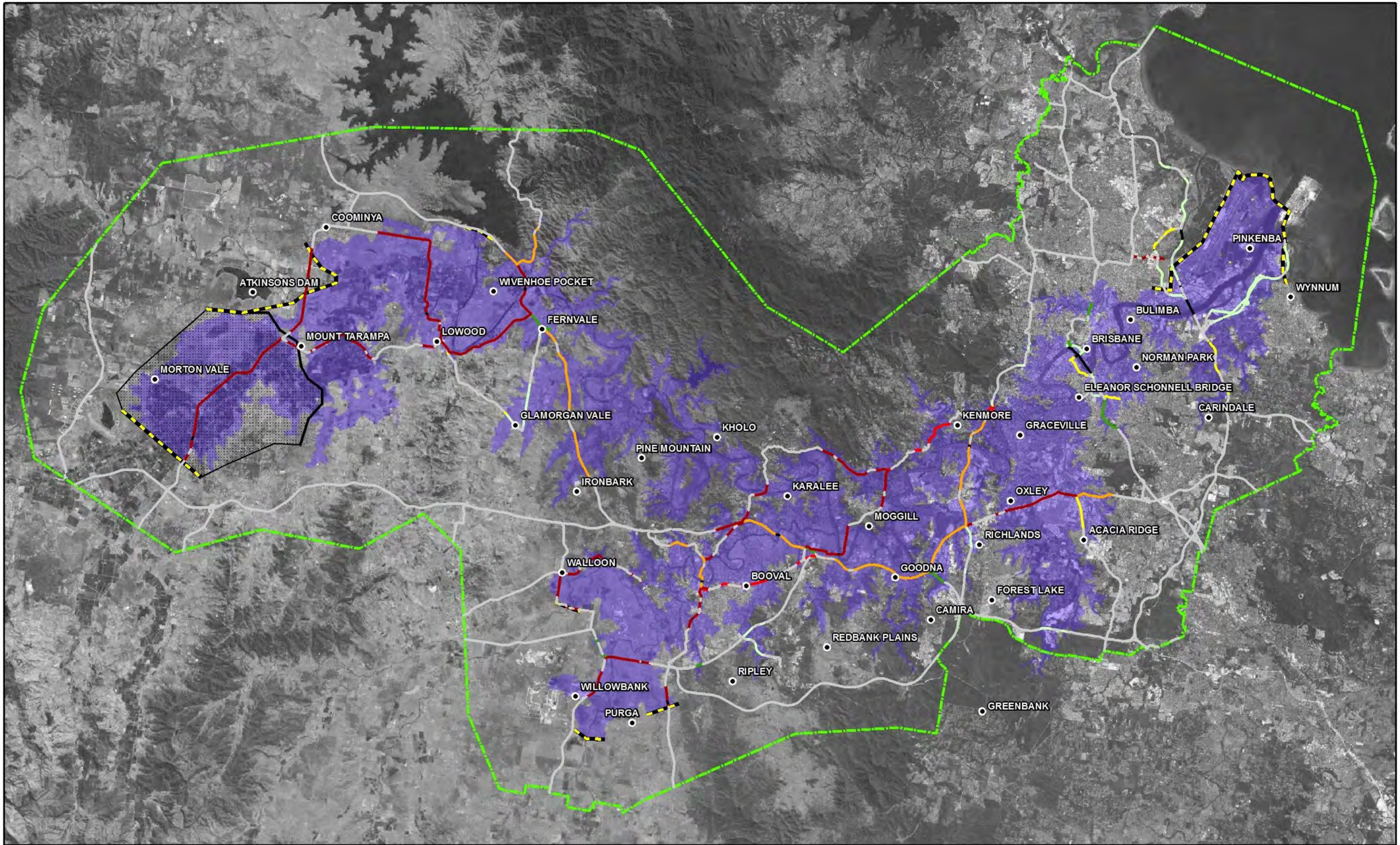
(3) Locations where the road closes for each of the four 1 in 100,000 AEP events were compared and rationalised to identify a single road closed location for each segment. In general, the four events identified the same location. Where there was some variation, the location where the road segment closed earliest was selected.

(4) The ground / topographic level of the road at the closed location was identified for use in subsequent assessments.

(5) The nearest node in the one-dimensional Phase 2 (Flood Study) fast model was identified for each of the locations for use in subsequent assessments.

4.4.4 Classification of Flood Event Sizes

Standard flood models are extremely limited in their ability to provide useful information about flood timing due to the reliance on a single design flood event. The Phase 2 (Flood Study) sought to improve on this limitation through the simulation of 11,340 separate design flood events in the fast hydraulic model. Therefore, although the detailed hydraulic model was used to identify road inundation locations, the fast hydraulic model was relied upon for subsequent statistical information about road inundation time and duration. This allowed the assessment to fully exploit the wealth of information captured in the fast model runs and best understand the inherent uncertainty which exists with design flood timing.



LEGEND

- Study Area Boundary
- 1 in 100,000 AEP Flood Extent
- Limit of Detailed Modelling
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

Evacuation Routes

- <1 in 10 AEP
- 1 in 20 AEP
- 1 in 50 AEP
- 1 in 100 AEP
- Outside Modelled Extent
- 1 in 500 AEP
- >1 in 2000 AEP
- Not Inundated
- Bridge

Brisbane River Catchment Flood Study

Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Evacuation Route Immunity

0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

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Fig 4-8

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To provide emergency managers an indication of the event size, each flood from the 11,340 Phase 2 (Flood Study) Monte Carlo events were classified into five categories based on available rainfall depth data falling on the sub-catchment[5] upstream. Classifications were primarily based on those provided in AR&R (Ball *et al*., 2016) with minor modifications to better suit the range of Phase 2 (Flood Study) events and to provide slightly more differentiation (i.e. inclusion of an additional category). The temporal pattern ranges provided in AR&R are demonstrated in Figure 4-9, with their application in this study in Table 4-7.

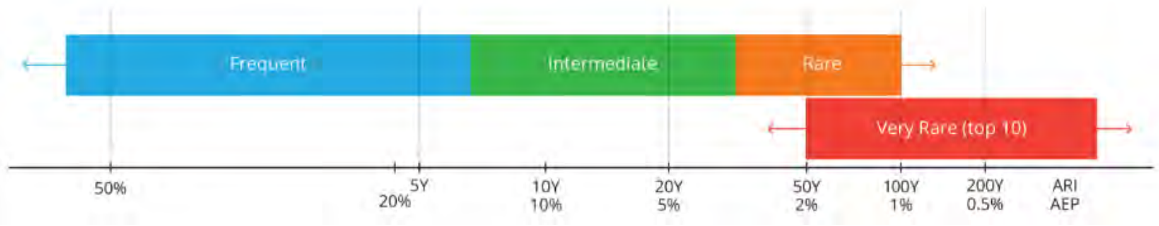


Figure 4-9 Temporal Pattern Ranges (from Figure 2.5.12, AR&R, Ball *et al.*, 2016)

Table 4-7 Application of AR&R Temporal Pattern Ranges to Study (from Ball *et al.*, 2016)

AR&R Category	Brisbane River Rainfall AEP
Frequent	More frequent than 14.4%
Intermediate	Between 14.4% and 3.2%
Rare	Between 3.2% and 1%
Very Rare	Between 1% and 0.05%
Extremely Rare*	Less frequent than 0.05%

*Not an AR&R category; added to provide additional differentiation within this study

4.4.5 Time of Earliest Road Inundation

The time of earliest road inundation was identified by calculating the time from the start of the rainfall until the time when water level in the fast model reaches the same level as the ground level of the adjacent road inundation location. This assessment was undertaken for each of the 11,340 fast model simulations and for each of the road segments. Results of the assessment were grouped according to rainfall AEP categorisation (per Section 4.4.4), with the results presented in 'box and whisker' plots, which are provided in the Plot Addendum.

A box and whisker plot displays groups of numerical data through their quartiles (Q), where the top of the 'box' is the third quartile Q3 (i.e. 75% of data is below this value) and the bottom of the box is the first quartile Q1 (i.e. 25% of data is below this value). The 'whiskers' extend to the farthest points that are not outliers (defined here as points that are within 1.5 times the interquartile range of Q1 to

[5] Contributing upstream catchments rainfall depth AEPs from the Phase 2 (Flood Study) metadata sites: Wivenhoe Dam, Glenore Grove, Savages Crossing, Mount Crosby, Walloon, Amberley, Loamside, Ipswich, Moggill, Centenary and Brisbane City. Each evacuation route was paired with the most representative aforementioned metadata location.

Q3). Values beyond the whiskers are displayed as outlier points. Figure 4-10 demonstrates the various components of the box and whisker plots.

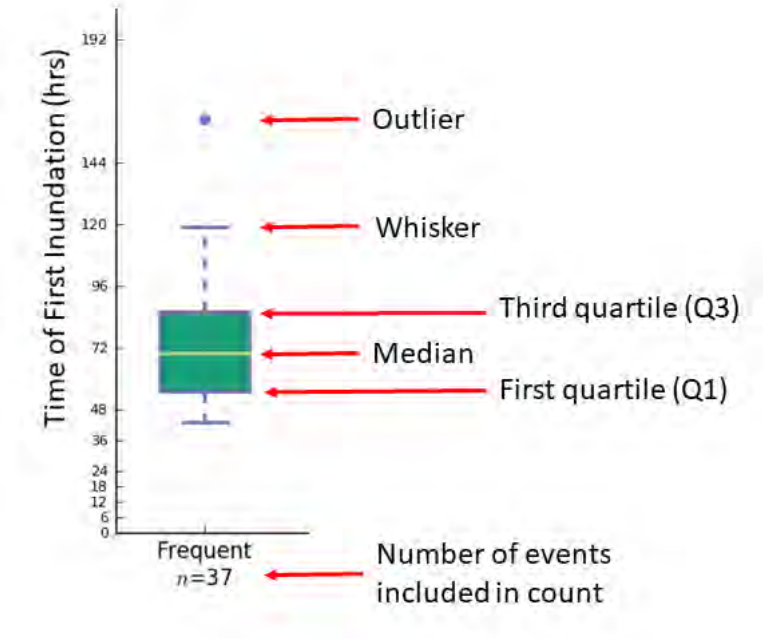


Figure 4-10 Box and Whisker Plot Explainer

The plots demonstrate the diversity in potential road inundation times for each of the locations and event size combinations. For some locations, the spread in results is small, indicating there is greater certainty of when in an event a road may first become closed. For other locations, the spread may be large, indicating there is less certainty, and highlighting the need for greater contingency planning in this location. An example plot has been provided in Figure 4-11 with the full set of plots provided in the Plot Addendum.

4.4.6 Duration of Road Inundations

The duration of road inundation was identified by calculating the time at which the water level in the fast model exceeds the same level as the ground level of the adjacent road inundation location. This assessment was undertaken for each of the 11,340 fast model simulations and for each of the road segments. Results of the assessment were grouped according to rainfall AEP categorisation (per Section 4.4.4), with the results again presented in a 'box and whisker' style plot.

The plots demonstrate the diversity in potential road inundation durations for each of the locations and event size combinations. For some locations, the spread in results is small, indicating there is greater certainty for how long a road may remain inundated. For other locations, the spread may be large, indicating there is less certainty, and highlighting the need for greater contingency planning in this location. An example plot has been provided in Figure 4-12, below with the full set of plots provided in the Plot Addendum.

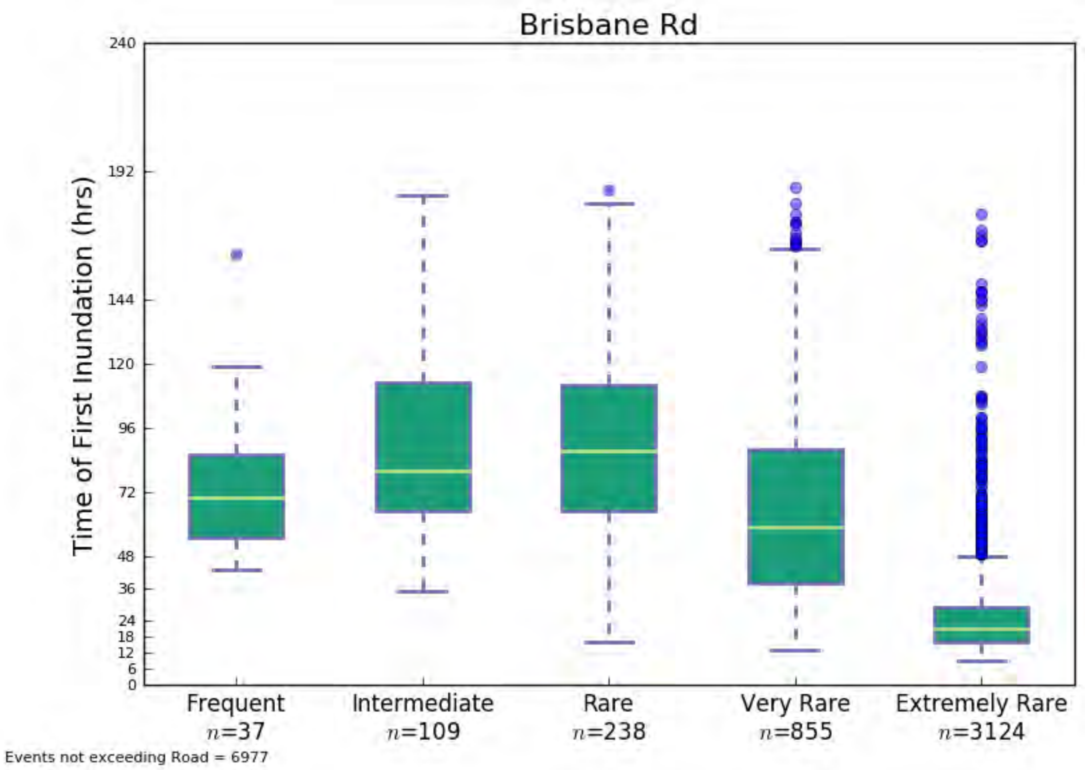


Figure 4-11 Example Time of Earliest Road inundation Plot

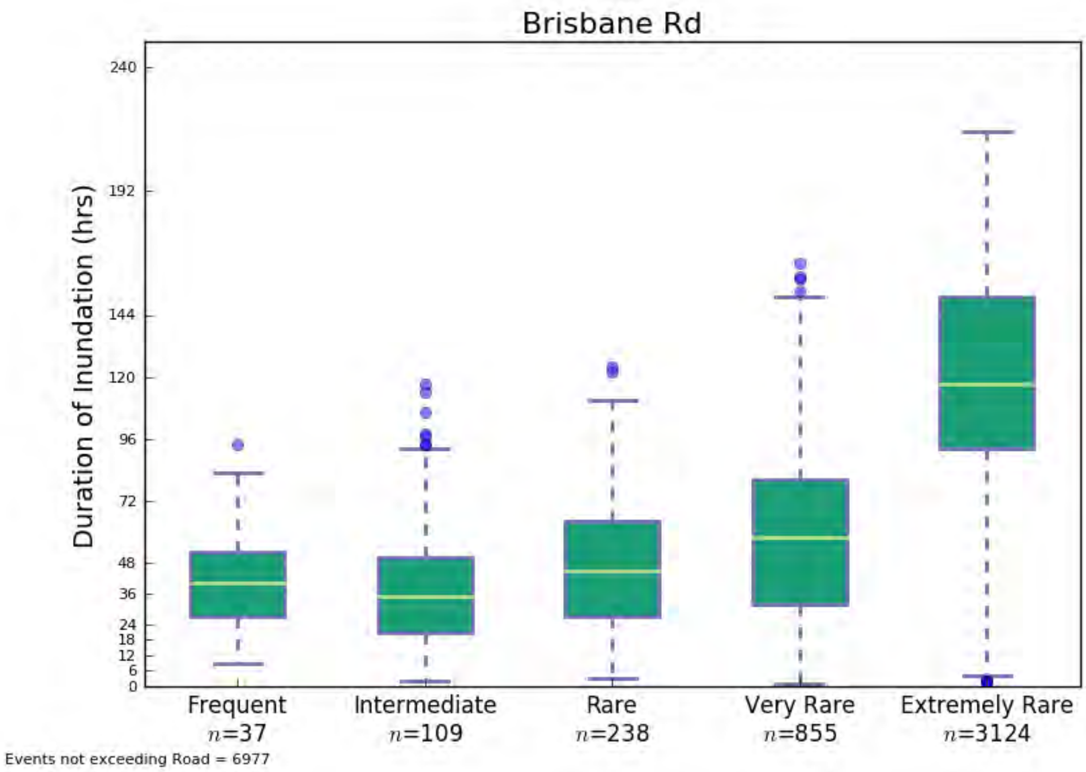


Figure 4-12 Example Duration of Road Inundation Plot

4.4.7 Flood Islands

Flood islands, or locations of isolation, are defined as either low or high islands. High islands are those areas which remain flood free, even in extreme events. Properties within high islands need to be considered when planning for isolation risk. In particular, consideration must be given to the amount of time that properties are expected to be isolated and the types of facilities which exist on the high island.

Isolated properties which subsequently become inundated by flood waters as the waters rise (up to an extreme event) are referred to as low islands. These locations are particularly hazardous to life, and they may require early warning and evacuation. A schematic representation of low and high islands is provided in Figure 4-13.

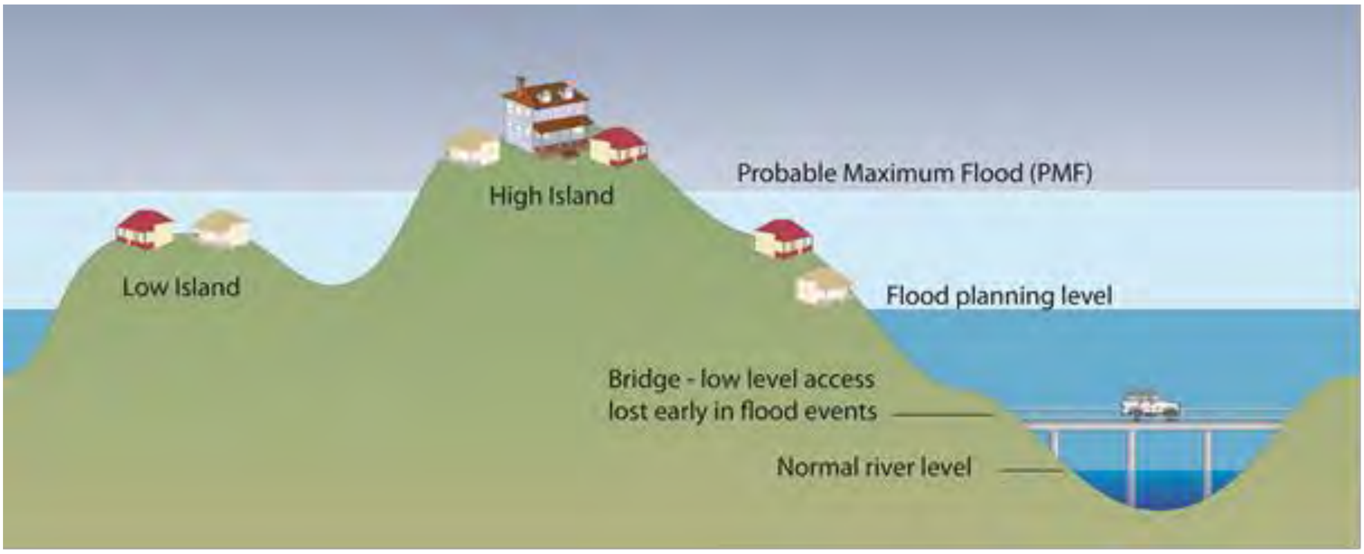
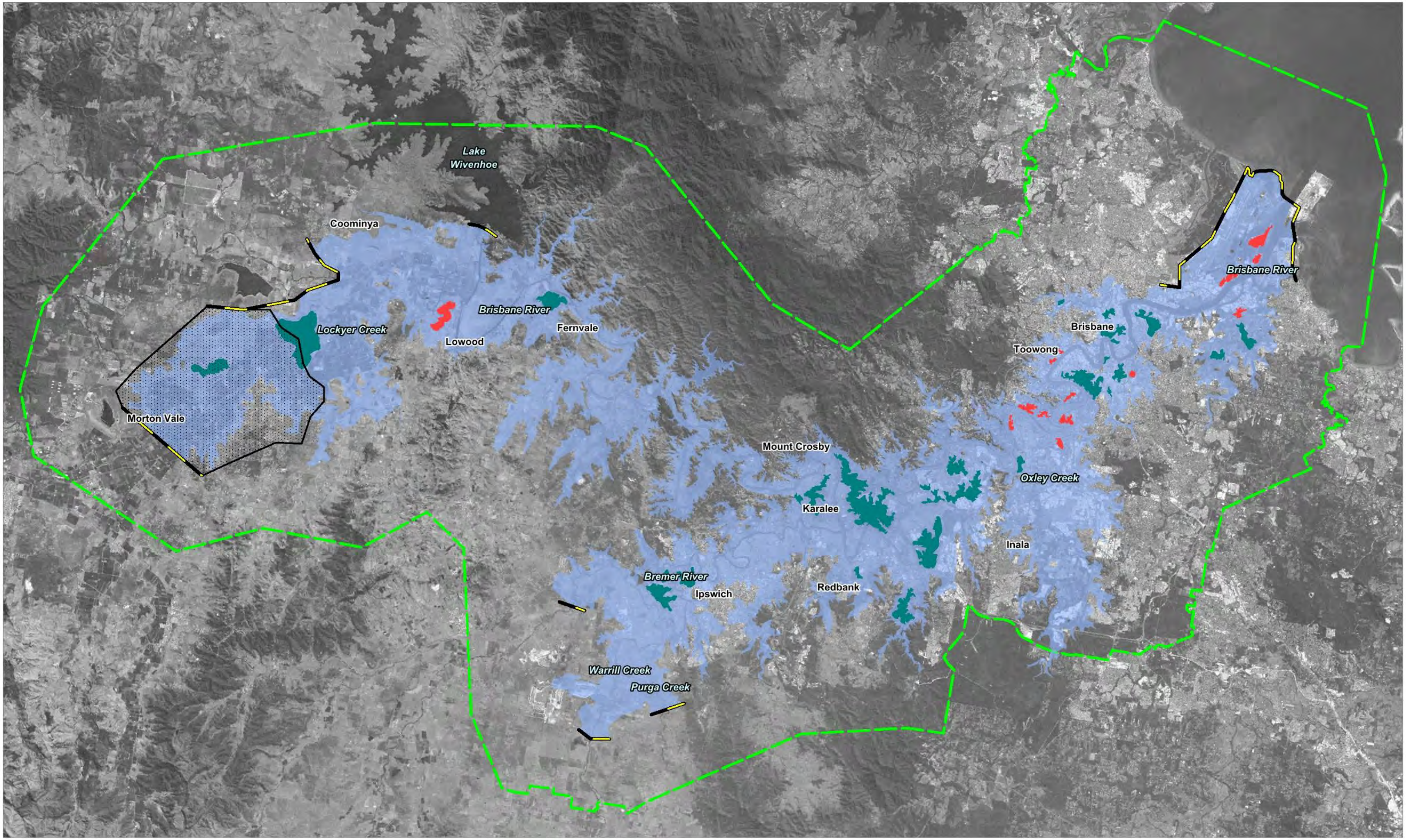


Figure 4-13 Low and High Islands Diagram

Low and high islands were mapped by interrogating the peak flood level envelopes for the seven AEPs used in the potential hydraulic risk assessment (i.e. 1 in 10 AEP, 1 in 20 AEP, 1 in 50 AEP, 1 in 100 AEP, 1 in 500 AEP, 1 in 2,000 AEP, and 1 in 100,000 AEP). The 1 in 100,000 AEP event has been treated as representative of the full known extent of the floodplain (probable maximum flood equivalent). As such, any floodplain islands in the 1 in 100,000 AEP event have been considered as high flood islands.

An overview map of the low and high flood islands within the study area is presented in Figure 4-14. Note that islands without substantial development (based on a visual inspection of the number and density of properties) were not considered to be regionally significant and therefore have not been mapped for this assessment.

Due to the topography and nature of the lower Brisbane River floodplain, flood islands do not generally occur in the smaller order flood events. During these small events, waterways tend to overtop and flood surrounding areas in a relatively linear way which does not promote the formation of flood islands.



LEGEND

- Strategic Floodplain Management Study Area
- Limit of Detailed Modelling
- Flooding in hatched area needs to be verified with the Local Council
- High Flood Island
- Low Flood Island
- 1 in 100,000 AEP Flood Extent

Refer to Councils for ocal flooding beyond limit

Brisbane River Catchment Flood Study
Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Title:
Low and High Islands: Study Area

Figure: **4-14**

Rev: **A**

0 7 14
Kilometers

Map Grid of Australia 1994, Zone 56

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A list of all identified regionally significant flood islands is provided in Table 4-8 along with the AEP event in which the island becomes fully inundated. Note that if a sizeable portion of the island remains dry in the 1 in 100,000 AEP, it is considered a high island (and noted as such in the table).

Table 4-8 Identified Flood Islands

Island Location (Suburbs)	Smallest AEP Event with Island (1 in Y)	AEP in which Island becomes Inundated (1 in Y)
Nudgee Beach	2	500
Mt Tarampa	5	High island
Coorparoo	100	500
Fernvale	100	High island
Milton	500	2,000
Tennyson	500	2,000
Kentville	500	High island
Chelmer	2,000	10,000
Pinkenba	2,000	10,000
Auchenflower	2,000	100,000
Yeronga	2,000	100,000
Hemmant	2,000	100,000
Indooroopilly	10,000	100,000
Lowood, Patrick Estate	10,000	100,000
St Lucia	10,000	100,000
East Brisbane	10,000	High island
Wacol	10,000	High island
West End, Dutton Park, Highgate Hill, Woolloongabba	100,000	High Island
Fortitude Valley, New Farm, Teneriffe	100,000	High island
Bellbowrie, Moggill, Anstead	100,000	High island
Nudgee, Banyo	100,000	High island
Bowen Hills	100,000	High island
Balmoral, Bulimba	100,000	High island
Jamboree Heights, Sinnamon Park, Darra	100,000	High island
Leichhardt, Wulkuraka	100,000	High island
Jindalee, Mt Ommaney	100,000	High island
Kangaroo Point	100,000	High island
Sadliers Crossing, Coalsalls, Woodend	100,000	High island

Island Location (Suburbs)	Smallest AEP Event with Island (1 in Y)	AEP in which Island becomes Inundated (1 in Y)
Bellbird Park, Goodna	100,000	High Island
Riverhills, Middle Park	100,000	High island
Corinda	100,000	High island
Woolloongabba	100,000	High island
Wulkuraka	100,000	High island
Westlake	100,000	High island
Karalee	100,000	High island
Tingalpa, Hemmant	100,000	High Island
Banyo	100,000	High island
Redbank	100,000	High Island
Tingalpa	100,000	High Island
Newmarket	100,000	High island

4.4.8 Summary of Isolation Risk

A summary is provided below describing the isolation risk in each of the reporting regions (A to E), based on information from the road inundation/immunity and isolation assessment. Note that guidance to support the application of information derived from the time of earliest road inundation and duration of road inundation is provided in Section 10 Disaster Management.

Overall, the following observations regarding isolation risk have been made:

- In general, the floodplain is not very wide – most residents in the floodplain are within a few kilometres of flood free land, which means that time required to successfully evacuate is generally short;
- Roads in the more urban Brisbane City area generally have higher flood immunity, however, there is generally a higher population within the floodplain that would require evacuation;
- Roads in more rural areas of Lockyer / Somerset Regional Councils are identified as having lower flood immunity. The number of residents in these areas is much lower than more downstream areas (e.g. Ipswich and Brisbane) however the warning time is shorter and so remains a concern;
- Roads servicing some of Brisbane's western suburbs (e.g. Moggill and Bellbowrie) have a lower flood immunity. Some of these areas were isolated during the 2011 floods, with residents needing special delivery of essential supplies; and
- Warning times vary significantly along the lower Brisbane River. The lack of effective warning time is more of a concern in the upper catchment for roads that have low immunity compared to roads in the lower parts of the catchment. Generally, by the time the flood peaks in Brisbane CBD, there has been ample warning time for residents to evacuate (>24 hours), and the peak flood level would be well forecasted. Warning time in the mid-catchment (e.g. Ipswich) is expected to be shorter and more variable, depending on coincident flooding conditions between the Bremer

and Brisbane Rivers, and the creek systems. It should be noted for all locations that road inundation may occur before the flood peak and that local flooding, obstruction of drainage infrastructure etc. can cause inundation prior to flooding from major creek and river systems.

4.4.8.1 Region A – Lower Lockyer Creek

Most roads within this region are susceptible to inundation at a regular frequency (generally less than 1 in 50 AEP, with many less than 1 in 10 AEP). Access between the villages of Forest Hill, Mount Tarampa and Coominya is cut by low AEP events. Being at the top of the floodplain, there would be relatively little warning time for inundation of these roads. There are also no feasible alternative roads for access across the floodplain, thus effectively isolating residents within these villages, some of which may become more threatened if floodwaters continue to rise to extreme levels. Mount Tarampa for example is a high island.

4.4.8.2 Region B – Wivenhoe Dam to the Bremer River Junction

Brisbane Valley Highway provides an arterial link across this part of the floodplain, and is susceptible to flooding around Wivenhoe Pocket, and between Fernvale and Ipswich (Warrego Highway). Glanmorgan Road and Fernvale Road are also both susceptible to flooding, although less so than Brisbane Valley Highway.

Lowood is a low island in this region, becoming completely isolated by the 1 in 10,000 AEP flood event and fully inundated by the 1 in 100,000 AEP flood event. This low island type could provide residents with a false sense of safety when evacuating from an extreme flood event. Fernvale is a high island is this region, and would likely provide safety and refuge for many surrounding residents affected by flooding, as long as sufficient and appropriate resources were available on the high island. Fernvale is completely isolated by the 1 in 100 AEP flood event, affecting a relatively large population of approximately 600 people.

4.4.8.3 Region C – Lower Bremer River

The region around Ipswich is susceptible to road inundation by flooding. Roads to the south of Ipswich that transect the Warrill Creek and Purga Creek floodplains are likely to be cut by low AEP events. Brisbane Road between the Ipswich Motorway and the CBD is also very susceptible to inundation, as is Mount Crosby Road and parts of the Warrego Highway.

Generally, the newer stretches of the Cunningham Highway and Ipswich Motorway offer a higher degree of flood immunity, however, most roads that cross the floodplain will be affected by inundation at more infrequent levels.

There are a few high islands around Ipswich, however, these do not form and completely isolate residents until flooding reaches extreme conditions.

4.4.8.4 Region D – Bremer Junction to St Lucia

Roads around Mount Crosby and Moggill are particularly susceptible to inundation at low AEP events (generally less than 1 in 20 AEP). As there are few alternative roads in this vicinity, road inundation would isolate these residents for some time. This was experienced during the 2011 events.

Ipswich Road in the vicinity of Rocklea (Oxley Creek floodplain) is also very susceptible to frequent inundation.

Significant ‘low islands’ are located in Tennyson, Chelmer and Yeronga, with substantial populations affected in each. The island at Tennyson forms in a 1 in 500 AEP, but is completely inundated by the 1 in 2000 AEP, directly affecting approximately 160 people. The islands at Chelmer and Yeronga do not form until a 1 in 2000 AEP, but become inundated at bigger events, with about 1,000 people affected in each area.

There are also several large ‘high islands’ in this region, including areas at Moggill, Wacol, Mount Ommaney, Riverhills and Middle Park. These islands generally do not form until flood levels are very high (i.e. extreme flood conditions).

4.4.8.5 Region E – St Lucia to Port of Brisbane

Most state controlled roads in this region are relatively resilient to flooding, including the busways that enter Brisbane CBD from the north and the south. The major exception to this is the Gateway Motorway around Kedron Brook, and the Gateway Motorway between Cleveland Road and Port of Brisbane Motorway. As the Port and the airport are both critical for supply and logistics to South-East Queensland, the susceptibility of these roads to flooding may require further detailed investigations.

A few ‘low islands’ form in this region, around Auchenflower, Milton, St Lucia and Coorparoo. Some of these islands contain a significant number of people. Complete inundation of these low islands does not generally occur until the more extreme events. There are also many high islands in this region containing significant populations (e.g. West End, Fortitude Valley / New Farm, Bulimba), but they would generally have substantial services as well, thus limiting the potential impacts of isolation.

4.5 Vulnerability

4.5.1 Assessment of Social Vulnerability to Flooding

QRA (2011) identifies seven aspects of social vulnerability to flooding. Table 4-9 describes these aspects, and how they have been captured within the Phase 3 (SFMP).

Table 4-9 Consideration of Social Vulnerability Aspects in this Study

Social Vulnerability Aspect	How Addressed in this Study
Personal safety	Hydraulic risk mapping (Section 4.2.6)
Vulnerable persons	Social vulnerability mapping and exposure assessment of vulnerable institutions (this Section)
Property impacts / built forms	Exposure assessment of properties in the floodplain (Section 4.3)
Isolation	Isolation mapping (Section 4.4.7)
Transport linkages	Evacuation route immunity assessment (Section 4.4.2)
Critical infrastructure	Critical infrastructure assessment (Section 4.3.6)
Vulnerable infrastructure	Sensitive use exposure assessment (Section 4.3.5)

Within this study, the assessment of vulnerable persons considers community-scale socio-economic and demographic characteristics that can magnify the effects of flood exposure, over and above physical impacts such as property damage. Vulnerability particularly relates to issues that can affect life safety. Vulnerable communities are impacted by flooding more than non-vulnerable communities due to the inherent characteristics of the community. Vulnerability to flood exposure is an important metric in the consideration of flood risk and the management measures used to address it.

A recent meta-analysis (Rufat *et al.*, 2015) of 67 flood disaster case studies undertaken between 1997 and 2013 sought to identify the key drivers of social vulnerability to floods. The meta-analysis recognised that demographic characteristics (particularly age), socio-economic status, and health (particularly in relation to mobility) are the social attributes most strongly related to vulnerability to floods. Assessment of these attributes has been undertaken in this study using information derived from Australian Bureau of Statistics census data, collected in 2016.

4.5.2 Vulnerability Indices

Four vulnerability indices have been developed to describe the social vulnerability to flooding of communities in the floodplain[6]. These indices generally seek to capture those attributes identified by Rufat *et al.* (2015), with an additional index to capture vulnerability due to poor flood awareness. Each index describes a different type of vulnerability: physical vulnerability; social and economic vulnerability; mobility vulnerability; and awareness vulnerability. By understanding these different types of vulnerabilities, it is intended that flood management measures can be suitably targeted.

Each vulnerability index comprises three or four vulnerability characteristics, as available through the census data. There is not sufficient research available to indicate whether certain characteristics are more strongly related to vulnerability than others (e.g. whether older people are more vulnerable than children), hence each characteristic has been given equal weighting within the index. The composition of the adopted vulnerability indices is provided below. The source of each of the attributes is provided in Appendix D.

4.5.2.1 Physical Vulnerability

The physical vulnerability index seeks to describe those communities with heightened vulnerability due to age and disability. It was calculated using the following attributes:

- Percentage of population under 5 years
- Percentage of population 65 years and over
- Percentage of population 65 years and over, and living alone
- Percentage of population who require assistance with everyday living.

4.5.2.2 Social and Economic Vulnerability

The social and economic vulnerability index seeks to describe those communities with heightened vulnerability due to limited financial capacity to recover from the impact of flooding. It was calculated using the following attributes:

- Percentage of population living in rental accommodation

[6] This approach is derived from the work presented in (Granger 2014)

- Percentage of households with low household incomes (less than $650/week)
- Percentage of population who are unemployed.

4.5.2.3 Mobility Vulnerability

The mobility vulnerability index seeks to identify those communities where households or families may have difficulty evacuating during a flood. It was calculated using the following attributes:

- Percentage of households with no private vehicles
- Percentage of single parent households
- Percentage of households with 5 or more people.

4.5.2.4 Awareness Vulnerability

The awareness vulnerability index seeks to identify those communities that may have a low level of awareness, or difficulties accessing and understanding flood warning messages. It was calculated using the following attributes:

- Percentage of population who are new to the area
- Percentage of population with little or no English skills
- Percentage of population with limited or no access to the internet.

4.5.2.5 Calculation of Vulnerability Indices

At a community-wide scale, community vulnerability is best considered as a relative measure. Although an individual might be classed as more or less vulnerable, it is not possible to say, for instance, that 'more than X% of the population over 65' represents a vulnerable community. Therefore, this study has sought to identify locations of relative vulnerability within the study area. Vulnerability indices were calculated at the Statistical Area 1 (SA1) scale, which is the finest resolution scale available for census data. The calculations used the following approach:

(1) Each of the attributes was calculated for each collection district as a percentage of residents within that collection district

(2) Each attribute was ranked based on these percentages to identify the least and most vulnerable SA1 locations in the study area

(3) These rankings were normalised (based on ranking) to assign each SA1 location a value of 0 to 1 for each attribute

(4) The normalised attribute values were summed for the collection of attributes within a given vulnerability index

(5) These final values were again normalised and mapped to highlight those SA1 locations where vulnerability is highest within the study area for each index

(6) The four individual indices were also summed and normalised again to highlight locations of combined vulnerability.

The results of the vulnerability assessment are presented in Figure 4-15 to Figure 4-18 for the four vulnerability indices, while Figure 4-19 shows the overall combined vulnerability. The figures and the results are discussed in detail in Section 4.5.3.

4.5.3 Lower Brisbane River Floodplain Vulnerability

Vulnerability indices have been calculated for the study area using the process described in Section 4.5.2.5. The relative values for each of the indices is mapped in Figure 4-15 to Figure 4-18, with combined vulnerability mapped as Figure 4-19. The term 'highly vulnerable' is used to describe the population living in SA1 census boundaries which are in the upper 20% of the relative vulnerability ranking for each of the individual and combined indices. A summary of the most vulnerable residents is provided in Table 4-10, where population is calculated as per Section 4.3.4 and it is assumed that all residents within an SA1 census boundary have the same degree of vulnerability (noting that SA1 is the smallest collection area available through Census).

Table 4-10 Estimated Number of Highly Vulnerable Residents in the Floodplain by Index

Vulnerability index	Hydraulic risk category					
	HR1	HR2	HR3	HR4	HR5	TOTAL
Physical	580	2,600	7,010	6,800	37,670	54,660
Social and economic	1,320	5,730	11,040	9,080	45,870	73,040
Mobility	1,380	4,320	9,520	7,330	39,460	62,010
Awareness	900	3,530	6,230	7,200	44,850	62,710
Combined	1,440	4,890	9,690	8,310	46,100	70,430
Total	1,660	7,880	17,600	17,180	88,240	132,560

Note the total number of highly vulnerable residents is less than the total of the individual indices as some people will be classified as highly vulnerable based on more than one index. The total number comprises all residents who are classified as highly vulnerable based on one or more index.

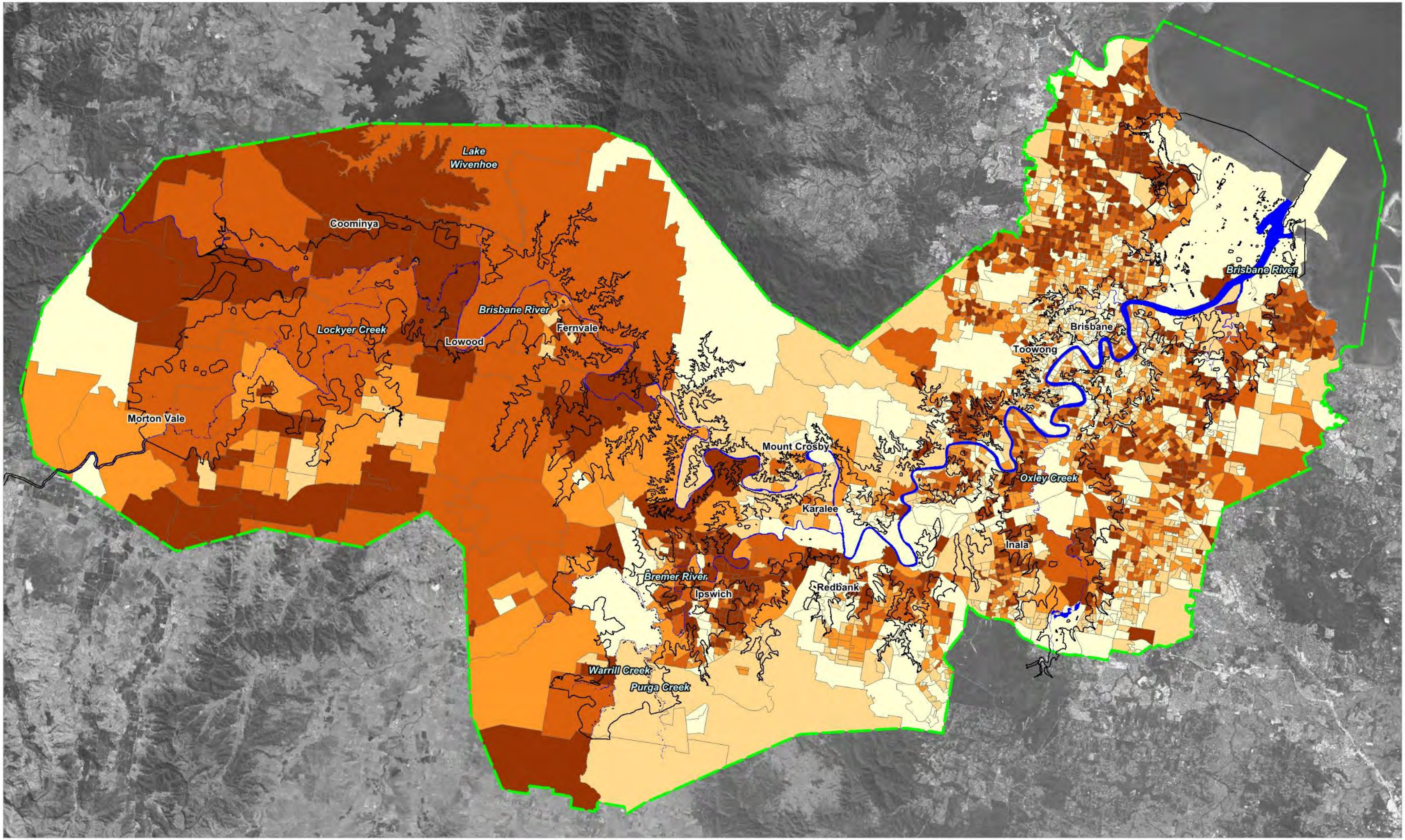
Overall, approximately 133,000 people in the floodplain are classified as highly vulnerable due to physical, socio-economic, mobility and / or awareness factors. That is approximately 47% of the 281,000 people who reside within the Brisbane River floodplain.

4.5.3.1 Physical Vulnerability

In terms of physical vulnerability, there are approximately 55,000 people living in the floodplain that are in the upper 20% of the index. Of these, some 17,000 people are located in potential hydraulic risk categories HR1 to HR4. The census data indicates that in each suburb there are different areas where residents are considered physically vulnerable due to each of the contributing factors.

Within Brisbane City, Graceville, Sherwood and Oxley have a significant number of physically vulnerable residents in the floodplain (all suburbs with more than 500 people in HR1 to HR4).

In Ipswich, there are more than 1,500 physically vulnerable people in each of Basin Pocket, Brassall, and East Ipswich in HR1 to HR4. Smaller populations in Somerset / Lockyer Valley have high physical vulnerability. The most significant area is Lowood, followed by Patrick Estate and Fernvale.



LEGEND

- Study Area Boundary
- Waterways
- 1 in 100,000 AEP Flood Extent

Vulnerability Quintiles

- Less Vulnerable
- More Vulnerable

Brisbane River Catchment Flood Study
Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Title:
Physical Vulnerability

0 7 14
Kilometers

Map Grid of Australia 1994, Zone 56

Figure:
4-15

Rev:
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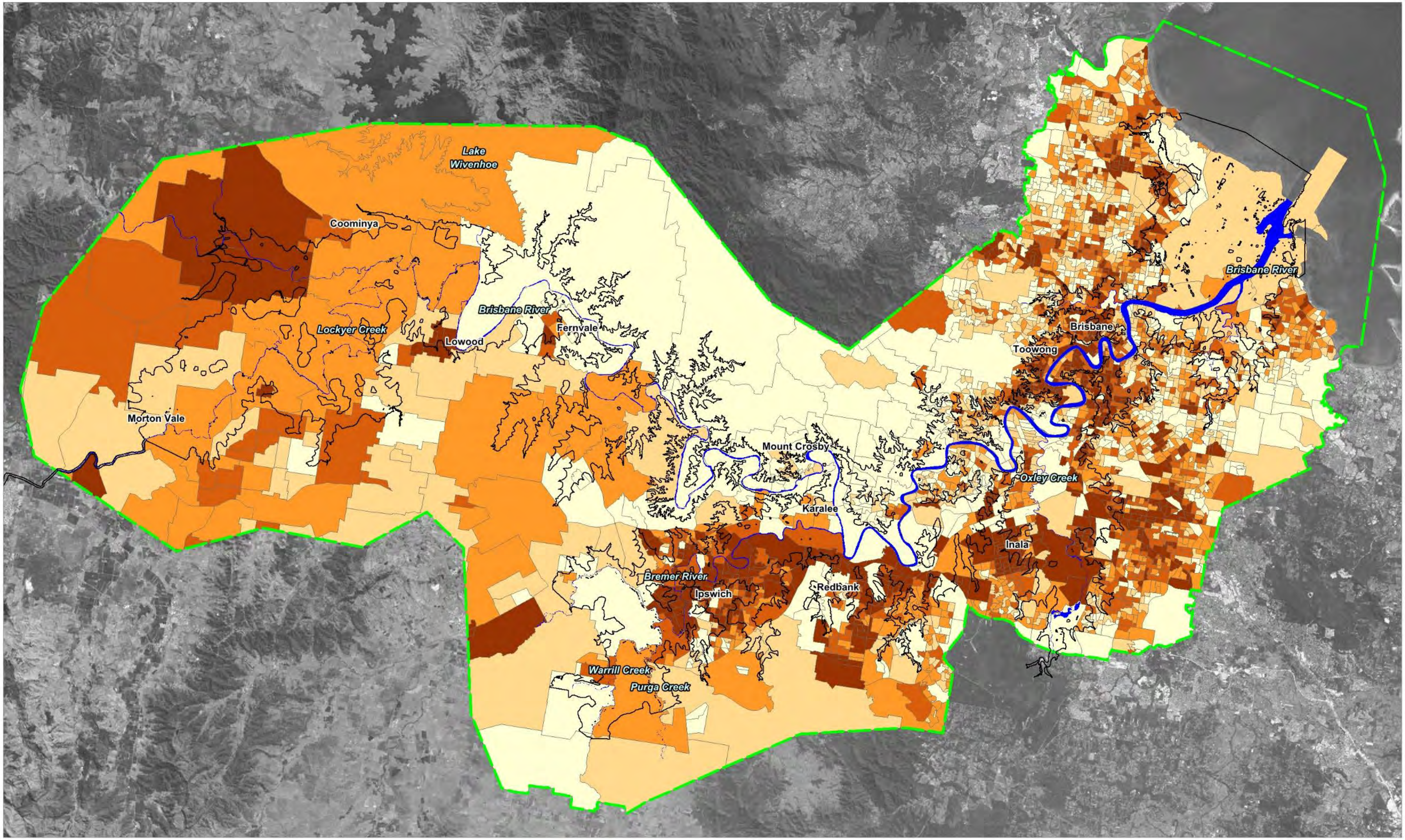

LEGEND

Study Area Boundary

Waterways

1 in 100,000 AEP Flood Extent

Vulnerability Quintiles

Less Vulnerable

More Vulnerable

Brisbane River Catchment Flood Study

Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Title:

Social and Economic Vulnerability

Figure: **4-16**

Rev: **A**

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Kilometers

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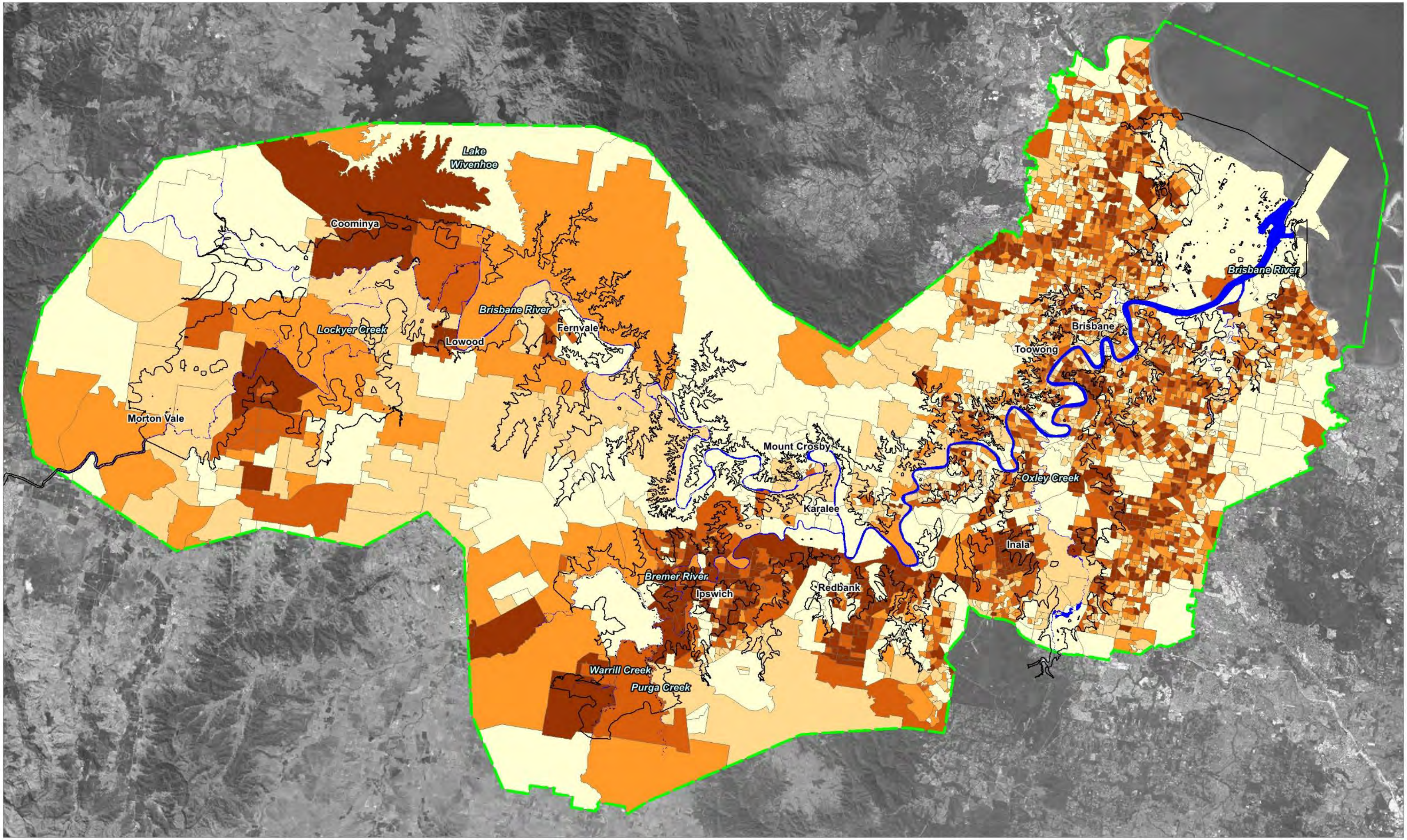

LEGEND

Study Area Boundary

Waterways

1 in 100,000 AEP Flood Extent

Vulnerability Quintiles

Less Vulnerable

More Vulnerable

Brisbane River Catchment Flood Study

Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Title:

Mobility Vulnerability

Figure: **4-17**

Rev: **A**

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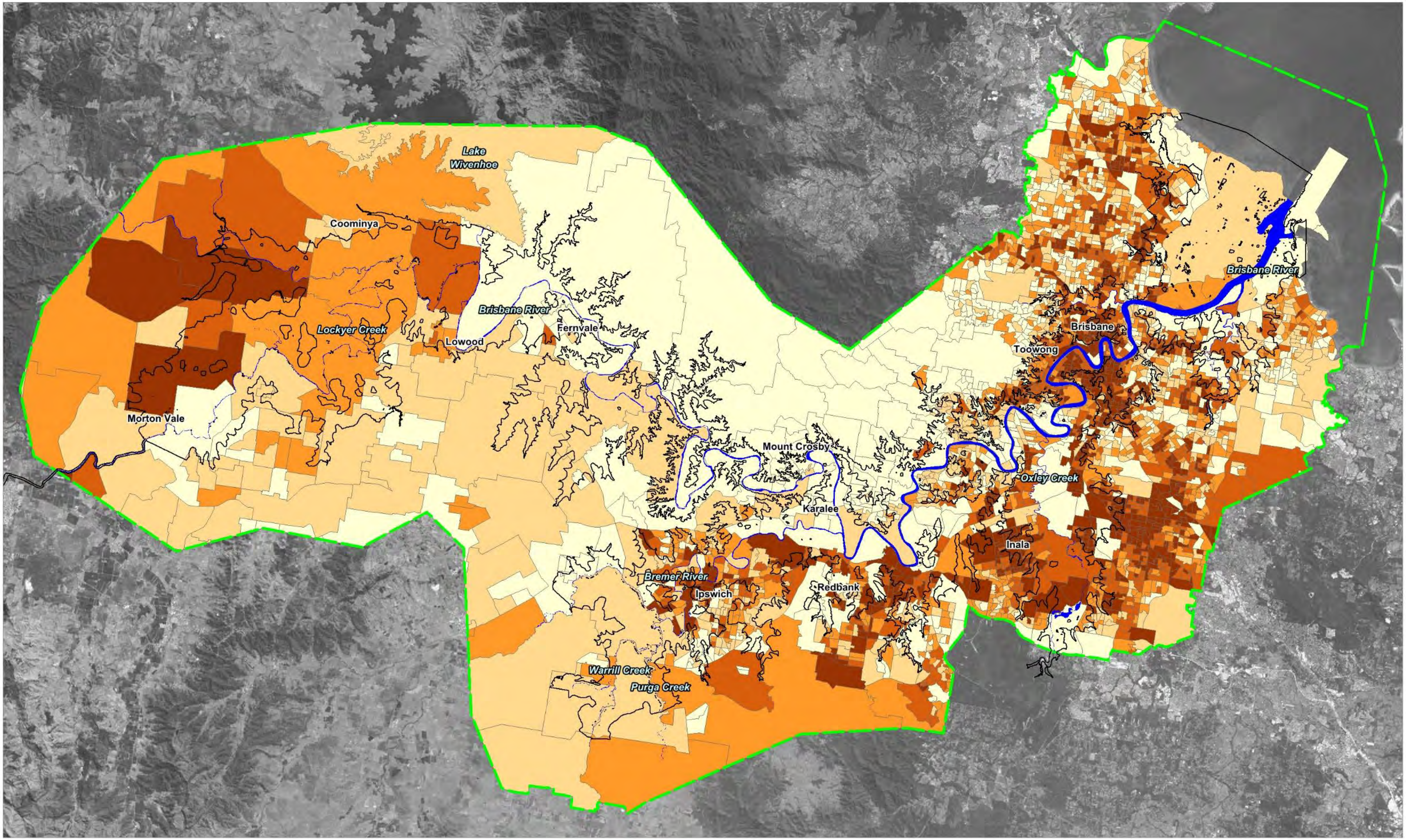

LEGEND

Study Area Boundary
Waterways
1 in 100,000 AEP Flood Extent

Vulnerability Quintiles

Less Vulnerable

More Vulnerable

Brisbane River Catchment Flood Study
Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Title:
Awareness Vulnerability

Figure:
4-18

Rev:
A

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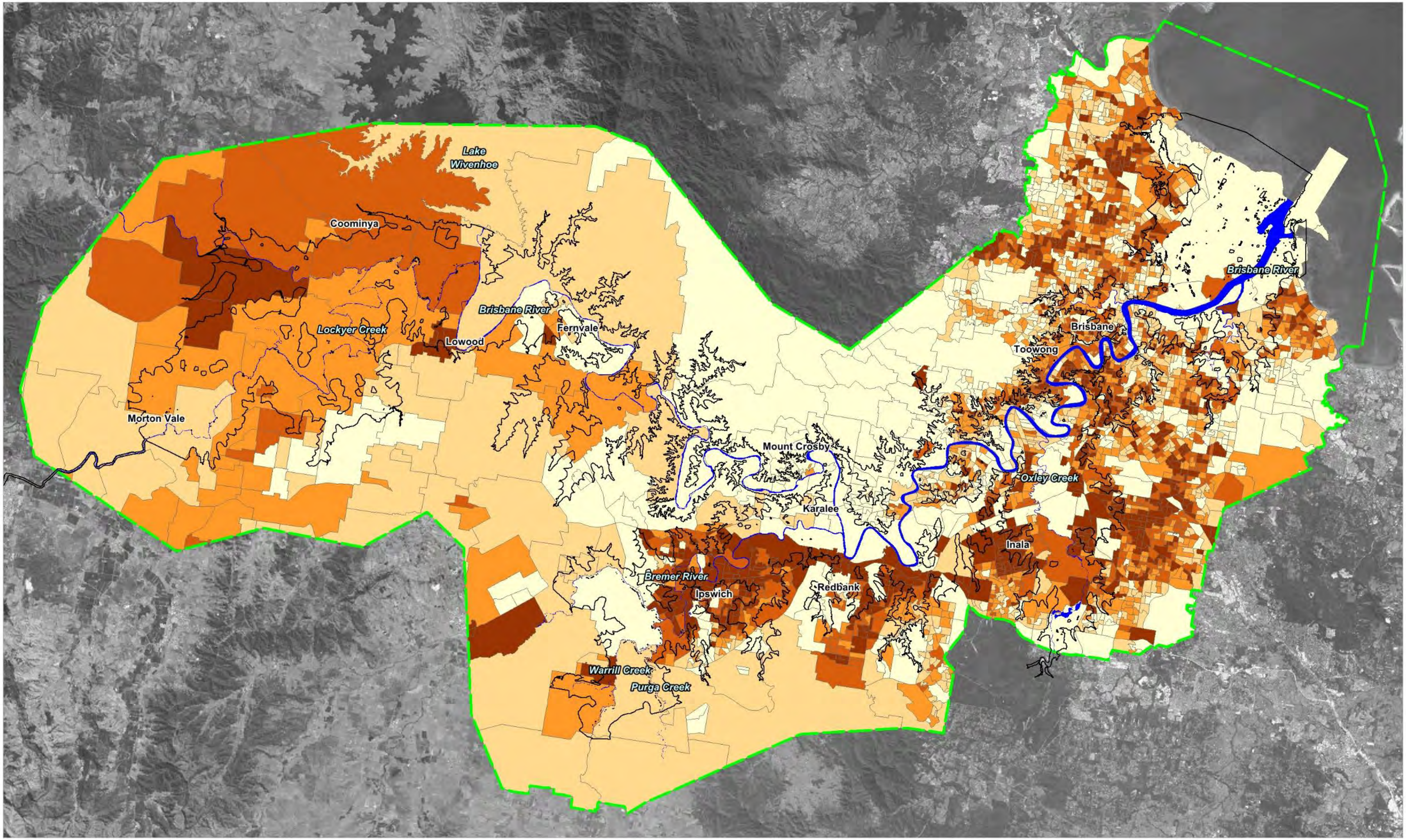

LEGEND

Study Area Boundary

Waterways

1 in 100,000 AEP Flood Extent

Vulnerability Quintiles

Less Vulnerable

More Vulnerable

Brisbane River Catchment Flood Study

Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Title:

Combined Vulnerability

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Kilometers

Map Grid of Australia 1994, Zone 56

Figure: **4-19**

Rev: **A**

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4.5.3.2 Social and Economic Vulnerability

There are significantly more people in the floodplain who are classified as highly vulnerable due to social and economic factors (i.e. renting, low income and / or unemployed) compared to physical factors. In total, there are approximately 73,000 people in the floodplain in the upper 20%. Of these, some 27,000 people are located in potential hydraulic risk categories HR1 to HR4.

The high numbers of socio-economic vulnerability in Brisbane City are primarily driven by the high proportion of people renting in inner Brisbane (in particular West End and St Lucia, Toowong and Taringa). Lower density areas such as Rocklea and Fairfield are also highly vulnerable.

In Ipswich, there are numerous suburbs that are highly vulnerable when compared to the average across the floodplain. The suburbs over 1,500 vulnerable people are in Goodna, East Ipswich, One Mile and North Booval in HR1 to HR4 and numerous other suburbs that are highly vulnerable but with smaller populations. Only Lowood is identified in the Somerset Region having a significant population in the flood zone with a high social and economic vulnerability.

4.5.3.3 Mobility Vulnerability

Approximately 62,000 people in the floodplain are considered highly vulnerable in terms of mobility (i.e. no vehicle, single parent and / or large families). Of these, some 23,000 people are located in potential hydraulic risk categories HR1 to HR4. A large portion of these people are in the inner Brisbane areas including, West End and St Lucia and along the Oxley Creek floodplain area.

Once again Ipswich has a significant population that is highly vulnerable along the floodplain, there are more than 1,500 vulnerable people in each of Goodna, East Ipswich and One Mile in HR1 to HR4 (essentially the same residents classified highly vulnerable due to socio-economic factors). Similar to the Social and Economic Vulnerability index, Lowood is identified in the Lockyer Valley as having a significant population in the flood zone with a high vulnerability.

4.5.3.4 Awareness Vulnerability

In total, there are approximately 62,700 people in the floodplain who are in the upper 20% of the awareness vulnerability rankings. Of these, some 17,900 people are located in potential hydraulic risk categories HR1 to HR4.

This high numbers of awareness vulnerability are primarily driven by the high proportion of new residents and those with limited English in Brisbane (in particular West End, St Lucia and around the Oxley Creek floodplain area – essentially the same residents classified highly vulnerable due to socio-economic factors) when compared to the average across the study area. There are also some areas within West End that have limited internet access.

The Ipswich region has fewer residents in the upper 20% of the awareness vulnerability, compared to other LGAs. Locations which are more vulnerable (and in HR1 to HR4 categories) include Brassall and Goodna, which are the same locations classified as highly vulnerable due to both socio-economic and mobility factors. In One Mile, high awareness vulnerability is primarily due to a high proportion of residents with limited internet access. In Goodna, there are more residents with limited English, in addition to limited internet access.

4.5.3.5 *Combined Vulnerability*

In many cases, people may be classified as highly vulnerable, not just due to one of the indices, but due to a combination of all indices. In terms of combined vulnerability, there are approximately 70,400 people in the floodplain who are in the upper 20% of all vulnerability indices. Of these, some 24,300 people are located in potential hydraulic risk categories HR1 to HR4.

Many these people are located in the inner Brisbane suburbs and the Oxley Creek floodplain. In Ipswich, there are more than 800 residents in each of Brassall, East Ipswich, Goodna, North Booval and North Ipswich areas who rank as highly vulnerable due to a combination of all indices. In Somerset, there are more than 200 residents in Lowood that are similarly highly vulnerable based on a combination of all four indices and Fernvale also has a high vulnerability across all indices.

4.6 Summary of Current Flood Risk

4.6.1 Assessment of Current Flood Risk

To understand current flood risk throughout the Brisbane River Catchment, all of the factors contributing to flood risk (potential hydraulic risk, flood exposure, evacuation and isolation, and vulnerability) have been assessed in combination. This has been undertaken on an individual property basis using the building database to develop a flood risk database. This flood risk database was used throughout the study to inform the identification and assessment of management measures in other components of the Phase 3 (SFMP). It will also be available to stakeholders on completion of the study for subsequent detailed investigations.

The following sections provide a summary of flood risk by reporting region, including estimated numbers of residential buildings, and highly vulnerable buildings (i.e. residential buildings in areas with combined vulnerability in the top 20% of the study area) within HR1 to HR3. Predominant potential hydraulic risk is based on a visual inspection of risk categories at locations of development as well as counts of properties by category. The summaries are reported on a locality / suburb basis, however, it must be noted that suburbs are not subject to a uniform degree of flood risk. A suburb that contains high flood risk properties does not mean that the entire suburb is high risk. Flooding is controlled by topography, meaning that properties that generally have a higher relative elevation will have less flood risk within the suburb.

More refined and detailed flood risk information is available at the street and building scale via the flood risk database.

4.6.2 Region A – Lower Lockyer Creek

Overall flood risk within Region A of the lower Brisbane River floodplain is summarised in Table 4-11.

There are no significant areas of development within the high potential hydraulic risk areas along the lower floodplain of Lockyer Creek. However, whilst there is relatively limited development at risk compared to other areas downstream, warning times are shorter and the proximity of some rural properties to the creek and the potential for bank erosion increases the risk to exposed properties.

Table 4-11 Region A – Lower Lockyer Creek: Overall Flood Risk Summary

Locality	Predominant Potential Hydraulic Risk Categories	Residential Buildings (HR1 – HR3)	Vulnerable Buildings (HR1 – HR3)	Critical Infrastructure (HR1 – HR3)
Regency Downs	HR3 and HR4	1	1	0
Mt Tarampa	HR1 and HR2	72	0	0
Patrick Estate	HR2 and HR3	27	27	0
Lockrose	HR2	1	1	1
Total	**N/A**	**101**	**29**	**1**

It is estimated that there are minimal residential buildings in the higher potential hydraulic risk categories of HR1 to HR3 in Regency Downs and Lockrose. However, there are an estimated 27 residential buildings in the Patrick Estate area which are within this risk category, and 72 in Mount Tarampa. Patrick Estate is also an area of high overall vulnerability, which increases the flood risk for those properties. In Mt Tarampa, there is also an isolation risk, with a number of properties becoming isolated in events larger than a 1 in 5 AEP flood event.

4.6.3 Region B – Wivenhoe Dam to the Bremer River Junction

Overall flood risk within Region B of the lower Brisbane River floodplain is summarised in Table 4-12.

Table 4-12 Region B – Wivenhoe to Bremer River Junction: Overall Flood Risk Summary

Locality	Predominant Potential Hydraulic Risk Categories	Residential Buildings (HR1 – HR3)	Vulnerable Buildings (HR1 – HR3)	Critical Infrastructure (HR1 – HR3)
Karalee	HR1 and HR2	458	0	1
Karana Downs	HR2 and HR3	323	0	6
Fernvale	HR2 and HR3	235	11	3
Barellan Point	HR1 and HR2	221	0	0
Lowood	HR2 and HR3	35	34	4
Kholo	HR2	37	0	0
Mount Crosby	HR3	1	0	3
Total	**N/A**	**1,310**	**45**	**17**

Most of the buildings at risk along the Brisbane River from Wivenhoe Dam to the Bremer River junction are located in Karalee, Karana Downs, Fernvale and Barellan Point.

Parts of Fernvale have an increased flood risk due to a combination of early isolation and high property exposure with many in potential hydraulic risk categories HR2 and HR3. Isolation occurs in the 1 in 100 AEP flood event, which is exacerbated by the relatively short warning times experienced at this location. There are approximately 35 buildings in Lowood in potential hydraulic risk categories HR1 to HR3 also with short warning times, the majority of which are considered vulnerable due to a combination of factors. There are also a number of critical infrastructure items in Lowood including a fire station, SES and sub-station.

There are approximately 800 properties at risk in Karalee and Karana Downs and more than 220 in Barellan Point. Most of the Karalee and Barellan Point properties are in the highest potential hydraulic risk categories HR1 and HR2, while most of the Karana Downs properties are within HR2 and HR3. There is also a child care centre located within HR3 in Karalee. This area is a high island which is isolated in extreme events.

In terms of critical infrastructure, there are several water and sewage pump stations located in Karana Downs, Fernvale, Lowood and Mount Crosby. In Mount Crosby, there are two critical infrastructure sites (SES and electricity substation) located within HR3. The Mount Crosby Water Treatment Plant is located within the lower potential hydraulic risk category HR5, however is a particularly critical item of infrastructure, as it services a population of 900,000 with water supply.

4.6.4 Region C – Lower Bremer River

Overall flood risk within Region C of the lower Brisbane River floodplain is summarised in Table 4-13.

Table 4-13 Region C – Lower Bremer River: Overall Flood Risk Summary

Locality	Predominant Potential Hydraulic Risk Categories	Residential Buildings (HR1 – HR3)	Vulnerable Buildings (HR1 – HR3)	Critical Infrastructure (HR1 – HR3)
North Booval	HR1 and HR2	930	930	1
Brassall	HR1 and HR2	799	666	1
East Ipswich	HR1 and HR2	499	499	2
One Mile	HR1 and HR2	414	414	0
Bundamba	HR1 and HR2	403	300	4
North Ipswich	HR1 and HR2	286	286	0
Basin Pocket	HR1 and HR2	278	278	0
Churchill	HR1, HR2 and HR3	211	211	2
Moores Pocket	HR1, HR2 and HR3	227	227	3
Woodend	HR1, HR2 and HR3	145	84	3
Tivoli	HR1, HR2 and HR3	126	109	2
Riverview	HR2 and HR3	122	122	3
Raceview	HR1, HR2 and HR3	115	56	0
Coalfalls	HR2	100	100	0
West Ipswich	HR1 and HR2	100	100	1

Locality	Predominant Potential Hydraulic Risk Categories	Residential Buildings (HR1 – HR3)	Vulnerable Buildings (HR1 – HR3)	Critical Infrastructure (HR1 – HR3)
Leichhardt	HR1 and HR2	133	133	3
Sadliers Crossing	HR2 and HR3	76	60	0
Wulkuraka	HR1 and HR2	69	69	0
Yamanto	HR1 and HR2	64	64	2
Ipswich	HR1 and HR2	46	40	3
Walloon	HR1, HR2 and HR3	44	0	0
Booval	HR3	25	25	0
Blackstone	HR3	5	0	1
Dinmore	HR3	4	4	1
Silkstone	HR3	11	6	0
Total	**N/A**	**5,232**	**4,783**	**32**

Inundation along much of the lower Bremer River floodplain is a result of backwater flooding within local creeks and tributaries. In terms of flooding from the Brisbane River, there is generally some warning time for Ipswich residents, though less than that available for Brisbane residents.

There are a significant number of suburbs which are dominated by the highest potential hydraulic risk categories of HR1 and HR2, including North Booval, Brassall, East Ipswich, One Mile, Bundamba, North Ipswich and Basin Pocket. These suburbs also have high numbers of residential properties in the HR1 to HR3 categories, with North Booval, Brassall and East Ipswich all having more than 400 residential properties in these categories.

There is also a child care facility in North Ipswich, an education centre in Brassall, and a substation in Yamanto, all of which are in the highest potential hydraulic risk category HR1.

Potential isolation could exacerbate flood risk in the region due to road inundation, particularly roads in the Warrill Creek and Purga Creek floodplains south of Ipswich, which may become inundated in low AEP events. There are a few flood islands identified around Ipswich, although these only become isolated in extreme events (i.e. 1 in 100,000 AEP flood event).

4.6.5 Region D – Bremer River Junction to St Lucia

Overall flood risk within Region D of the lower Brisbane River floodplain is summarised in Table 4-14.

Along the Brisbane River between the Bremer River junction and St Lucia, there are close to 11,300 buildings located in potential hydraulic risk categories HR1 to HR3. This includes the suburbs of Yeronga, Graceville, Fairfield, Chelmer, Oxley and Rocklea, which all have more than 600 residential properties in these categories.

There are also areas of high flood risk in Goodna, Redbank and Collingwood Park downstream of the confluence of the Bremer and Brisbane Rivers. In Goodna in particular, there are more than 700 residential buildings in the HR1 to HR3 potential hydraulic risk categories, more than half of which are considered vulnerable, as well as two child care centres within HR2, a primary school within HR3, and an SES and police station within HR3 and HR4.

Table 4-14 Region D – Bremer River Junction to St Lucia: Overall Flood Risk Summary

Locality	Predominant Potential Hydraulic Risk Categories	Residential Buildings (HR1 – HR3)	Vulnerable Buildings (HR1 – HR3)	Critical Infrastructure (HR1 – HR3)
Yeronga	HR2 and HR3	839	71	7
Sherwood	HR1, HR2 and HR3	498	133	2
Graceville	HR1, HR2 and HR3	912	174	1
Fairfield	HR2 and HR3	625	267	1
Chelmer	HR1, HR2 and HR3	771	0	2
Goodna	HR1 and HR2	724	683	3
Oxley	HR1 and HR2	941	173	1
Tennyson	HR2 and HR3	167	0	5
Rocklea	HR1, HR2 and HR3	731	726	9
Jindalee	HR2 and HR3	653	139	3
Sinnamon Park	HR2 and HR3	535	55	1
Westlake	HR2 and HR3	536	0	4
Fig Tree Pocket	HR2	422	0	5
Corinda	HR2 and HR3	330	106	1
Sumner	HR2	39	0	1
Riverhills	HR2	402	31	0
Bellbowrie	HR1, HR2 and HR3	254	95	1
Coopers Plains	HR2 and HR3	23	23	0
Kenmore	HR2 and HR3	242	116	6
Archerfield	HR2 and HR3	166	161	2
Middle Park	HR2 and HR3	149	123	0
Redbank	HR2 and HR3	118	118	3
Gailes	HR2 and HR3	111	111	0
Collingwood Park	HR2 and HR3	81	69	0
Gailes	HR2 and HR3	111	111	0
Darra	HR2	146	0	0
Moggill	HR2 and HR3	101	47	1

Locality	Predominant Potential Hydraulic Risk Categories	Residential Buildings (HR1 – HR3)	Vulnerable Buildings (HR1 – HR3)	Critical Infrastructure (HR1 – HR3)
Mount Ommaney	HR2 and HR3	79	1	1
Moorooka	HR2 and HR3	100	72	0
Durack	HR3	86	56	0
Acacia Ridge	HR3	39	38	0
Seventeen Mile Rocks	HR2	57	0	2
Anstead	HR2	57	0	1
Jamboree Heights	HR2	64	47	1
Salisbury	HR2 and HR3	48	16	2
Camira	HR3	14	1	0
Willawong	HR3	78	78	1
Wacol	HR3	10	10	3
Pinjarra Hills	HR1, HR2 and HR3	10	1	0
Pullenvale	HR2 and HR3	15	0	0
Annerley	HR3	3	3	0
Total	**N/A**	**11,287**	**3,855**	**70**

Yeronga has the highest number of residential properties at risk in the HR1 to HR3 categories (more than 800), particularly due to the number of multi-dwelling properties in the floodplain. Sherwood also has almost 500 buildings in those higher categories, including multi-dwelling properties, an education centre within HR2 and an emergency management facility. In Graceville, there are a significant number of properties at risk, as well as Graceville State School and Chelmer-Graceville Pre-School (7 buildings) within HR2. There is an additional education centre in Chelmer and a child care centre in Jindalee within HR2, and substations at risk in Jindalee, Tennyson and Fairfield.

Along Oxley Creek, there are more than 1,900 properties within HR1 to HR3 inundated by backwater flooding from the Brisbane River. This includes properties in Oxley, Rocklea, Moorooka, Archerfield and Coopers Plains, which generally have a higher proportion of vulnerable residents. There is usually sufficient warning time available in this region for an impending Brisbane River flood event (much less warning for a local Oxley Creek flood event though).

In Oxley, there is a child care facility within HR2 and a substation located within HR3. In Rocklea, Rocklea State School is located within HR2 along with two emergency management facilities and several water and sewage pump stations.

At Archerfield, the SES and fire station are within HR2 and HR3, and the airfield is within HR3 and HR4. There are also substations at Moorooka and Salisbury located within HR3.

Isolation is a significant issue for residents who rely on roads around Mount Crosby and Moggill with some road immunity as low as the 1 in 20 AEP. Inundation of these roads would isolate residents in the area for prolonged periods, as experienced during the 2011 flooding. Isolation is also a concern in the lower catchment for large flood events, with significant low flood islands forming in Tennyson, Chelmer and Yeronga areas.

4.6.6 Region E – St Lucia to Port of Brisbane

Overall flood risk within Region E of the lower Brisbane River floodplain is summarised in Table 4-15.

Table 4-15 Region E – St Lucia to Port of Brisbane: Overall Flood Risk Summary

Locality	Predominant Potential Hydraulic Risk Categories	Residential Buildings (HR1 – HR3)	Vulnerable Buildings (HR1 – HR3)	Critical Infrastructure (HR1 – HR3)
West End	HR1, HR2 and HR3	385	149	0
Brisbane City	HR2 and HR3	11	10	39
South Brisbane	HR2 and HR3	29	29	6
St Lucia	HR2 and HR3	456	452	4
Newstead	HR2	15	1	1
Toowong	HR2 and HR3	161	143	4
Milton	HR1 and HR2	149	101	3
New Farm	HR2 and HR3	344	169	0
Kangaroo Point	HR2 and HR3	10	0	2
Auchenflower	HR2 and HR3	283	147	0
Taringa	HR2 and HR3	168	136	2
Fortitude Valley	HR1, HR2 and HR3	2	2	0
Bulimba	HR1	273	151	1
Teneriffe	HR1 and HR2	4	0	0
Coorparoo	HR2 and HR3	107	75	0
Paddington	HR2 and HR3	223	32	0
Indooroopilly		327	35	6
Hamilton	HR1, HR2 and HR3	12	0	0
Windsor	HR3	233	46	0
East Brisbane	HR2 and HR3	136	59	2
Norman Park	HR2 and HR3	192	63	2
Hawthorne	HR3	160	0	1
Albion	HR2 and HR3	47	14	0
Woolloongabba	HR3	116	116	0
Highgate Hill	HR2 and HR3	11	0	0

Locality	Predominant Potential Hydraulic Risk Categories	Residential Buildings (HR1 – HR3)	Vulnerable Buildings (HR1 – HR3)	Critical Infrastructure (HR1 – HR3)
Balmoral	HR3	37	0	0
Bowen Hills	HR3	0	0	0
Chapel Hill	HR3	26	1	0
Hemmant	HR1, HR2 and HR3	11	0	3
Morningside	HR1	5	5	1
Wilston	HR3	9	0	0
Brookfield	HR2 and HR3	8	0	0
Herston	HR3	2	1	0
Camp Hill	HR3	12	11	0
Greenslopes	HR3	14	9	0
Kenmore Hills	HR3	242	116	0
Petrie Terrace	HR3	5	5	0
Murarrie	HR3	0	0	1
Total	**N/A**	**4,225**	**2,078**	**78**

There are significant number of areas of high flood risk along the lower Brisbane River from St Lucia to the Port of Brisbane, due in particular to the density of development, the vulnerability of some residents, and the location of critical infrastructure in the floodplain. However, the region does benefit from substantial warning time for preparation and evacuation during a flood event (generally more than 24 hours warning).

In Brisbane City, parts of the central business district are within potential hydraulic risk categories HR2 to HR3. There are also approximately 40 critical infrastructure assets (the majority of which are substations), an emergency management facility, and 4,200 residential buildings in the higher hydraulic risk categories of HR1 to HR3. There are additional emergency management centres (SES, police and fire stations) at risk in South Brisbane, Toowong and Taringa, and additional substations at risk throughout the region. Brisbane International Airport is within the lowest potential hydraulic risk category HR5, however, the airport is recognised as particularly critical infrastructure for transport and logistics. Some access roads in and around the airport are within HR2 to HR4 potential hydraulic risk categories.

The majority of residential properties at risk in this region are due to the density of development, particularly in the inner city suburbs. Some of these suburbs including West End, South Brisbane, St Lucia and New Farm have a high proportion of vulnerable residents due to a combination of the high proportion of renters, people without cars, new residents, and / or limited English. In some areas, the nature of multi-storey development means that many of the properties may not be inundated above floor level. However, multi-storey properties in the floodplain are still likely to experience issues relating to services and access and, if located in areas of extreme hazard, potential structural damage and risk to life.

There are also more than 100 sensitive institutions located in the region. This includes four child care centres within HR2 in Indooroopilly, Auchenflower and two in St Lucia. There are also education centres within HR2 in Woolloongabba, Indooroopilly, Milton, East Brisbane and St Lucia.

4.7 Limitations

The limitations of the Brisbane River flood risk assessment are set out below, and apply to most of the components of the Phase 3 (SFMP) which are based on this assessment. These limitations capture the currently known constraints, and primarily relate to the application of the hydraulic model for floodplain management purposes, together with additional limitations of the assessments undertaken in this section. Whilst the Phase 2 (Flood Study) represents the most comprehensive hydrologic and hydraulic modelling assessment of the Brisbane River undertaken to date, all modelling contains limitations as it is a simplification of real world physical process.

4.7.1 Riverine versus Local Flooding

Hydraulic modelling outputs are for riverine flooding, not local flooding or overland flow, and must be interpreted as such. Riverine flooding in the context of this study is flooding due to elevated levels in the Brisbane and Bremer Rivers, and in the lower Lockyer, Warrill and Purga Creeks, as covered by the modelling. Flooding in side tributaries is only represented insofar as being caused by the elevated riverine levels.

4.7.2 Design Flood Mapping Approach

The Phase 2 (Flood Study) hydraulic modelling was undertaken in two stages: a ‘fast’ hydraulic model was developed to allow thousands of flood events to be simulated quickly, with the model providing a simplified representation of the behaviour of floodwater; and a ‘detailed’ hydraulic model was developed to provide a more detailed representation of the complexity of flow in both channel and floodplain areas, but with a necessarily slower simulation time.

A large collection (11,340) of potential storm events of all sizes, combinations of conditions, timing and storm patterns was developed and tested in the fast hydraulic model. A statistical analysis was then undertaken of the peak (maximum) flood levels produced by the fast model at 26 key locations around the catchment. This analysis identified the peak flood level for each AEP flood event (e.g. 1 in 100 AEP) at each location and then selected one of the 11,340 events that provided the identified peak flood level at each reporting location. Because of the natural variability in the catchment, there was no single flood event from the 11,340 tested which appropriately represented a given design event for all of the reporting locations. As a result, it was necessary to select multiple flood events and combine the results from these events to form an overall representation of a design event. For instance, the 1 in 100 AEP comprises five separate events from the original 11,340. Those selected five events were simulated in the detailed hydraulic model and the results were combined to form an ‘envelope’ of results. It is these enveloped results which were mapped and provided in the Phase 2 (Flood Study). Envelopes were provided for each of the 11 AEP design events. In total, 60 events from the initial 11,340 were simulated in the detailed hydraulic model and used to map the 11 AEPs.

From this process, it is important to emphasise that the 60 events were selected based on peak heights at certain locations only. The 60 events are not considered 'representative' in other ways, and are not necessarily representative of typical flood timings or evolution. Further, the peak levels may have been generated through a collection of catchment conditions which are not 'typical' or don't tell the full story for all possible flood types.

For reaches between reporting locations a small amount of uncertainty is introduced. Outside the area covered by the reporting locations, the assumptions that underpin the Monte Carlo assessment can become less valid, and therefore the assigned AEP less certain. This issue primarily affects the mid-section of Lockyer Creek. The model extends 26 km upstream from the most upstream reporting location at Lyons Bridge, therefore the flood extents and levels may begin to deviate from the AEP at the reporting locations. The map output is still considered of value for assisting with understanding the flood behaviour on a complex floodplain. Within this area, the advice of the relevant local council should be sought if seeking to establish design flood levels for an AEP. Other areas that may be influenced by this "edge" effect are the areas upstream of the reporting locations on the Bremer River, and Warrill and Purga Creeks, however these areas are smaller in extent.

4.7.3 Backflow Prevention Devices

The base case flood model results assume that no backflow prevention devices have been fitted to the stormwater pipes or trunk drainage systems. There are several such devices now installed throughout the BCC area. Exclusion of back flow devices from the analysis will result in a conservative (worst case) flood level and flood extent in those local areas that are now protected by the devices.

4.7.4 Structure Blockage

The flood model assumes no blockage allowance to the openings of hydraulic structures (culverts, bridges etc.) other than that directly as a result of the structure itself, such as a bridge deck. Application of blockage to structures (due to debris for example) may increase peak flood levels in some locations (typically upstream of the structure) and decrease them in others (typically downstream of the structure).

4.7.5 Flood Model Accuracy and Uncertainty

The accuracy of design flood levels and flows calculated by the Detailed Model is subject to various sources of potential errors inherent in a large and complex flood study. Sources of errors that can give rise to residual uncertainty in the estimated flood levels and flows, include:

- Any uncertainties inherent in the Hydrologic Assessment that affect the inflows to the Detailed Model – attempts to minimise these uncertainties have been made through calibration of hydrologic and hydraulic models to the same historical events, and through cross-checks and reviews of stage-discharge relationships (rating curves) at key locations covered by both the hydrologic and hydraulic modelling.
- Uncertainties in hydraulic modelling parameters and Detailed Model discretisation – attempts to minimise these uncertainties have been made through adopting industry standard parameter

values proofed and fine-tuned through calibration and verification of the Detailed Model to observed tide and flood behaviour.

- Assumptions with regard to dam operations under these hypothetical events, including a no dam failure assumption.
- Statistical uncertainties associated with the Monte Carlo analyses carried out in both the Hydrologic and Hydraulic Assessments.
- The in-bank topographic data where the 2D bathymetry or 1D cross-sections are reliant on LiDAR. These areas are notably:
    - Lockyer Creek;
    - Between Wivenhoe Dam and Kholo Bridge;
    - Downstream of Mt Crosby Weir to the start of the bathymetric survey; and
    - Non-tidal reaches of Bremer, Warrill and Purga Creeks.
- Limited historical flood data for rare and extreme floods for the calibration and verification of the hydrologic and hydraulic models.
- The calibration of the hydraulic models to the 2011 flood highlighted unusually high energy losses in the vicinity of the Fernvale Quarry, therefore, any assessments in this area should be considered with caution. However, the losses adopted are based on calibration to the 2011 event, and therefore represent best estimates.
- The influence of farm levees and other works either not well defined or captured by the available LiDAR surveys, or that have been built subsequent to the LiDAR surveys, particularly on the flood levels in the Lockyer Creek floodplains.
- For the 1D sections of the Detailed Model, where there are high in-bank velocities causing a significant variation in water level across the river/creek at a sharp bend (i.e. superelevation).

4.7.6 1 in 2 AEP Event

The hydraulic modelling carried out in the Phase 2 (Flood Study) simulates catchment runoff flows in combination with tides to determine probable flood levels. For the 1 in 2 AEP flood event, the peak flows in the tidal reaches are dominated by tidal influence and these flows are higher than the catchment runoff flow. Reporting 1 in 2 AEP peak flood levels from the model simulations in the tidal zone is reasonable as they are caused by storm tide conditions within Moreton Bay, however, it is not possible to report a meaningful peak catchment flow from the hydraulic model for the 1 in 2 AEP within the tidal influence.

For areas upstream of the tidal zone, the Phase 2 (Flood Study) analysis to derive AEP levels at Reporting Locations for the 1 in 2 AEP considered levels to be influenced by the water storage level in Wivenhoe Dam and variable antecedent conditions in Lockyer Creek and the Brisbane and Bremer Rivers above the tidal limits. There is therefore significant uncertainty associated with the 1 in 2 AEP levels outside of the areas influenced by the storm tide. The Phase 2 (Flood Study) concluded that use of the 1 in 2 AEP levels beyond the tidal limits is not recommended.

4.7.7 Velocity and Hydraulic Hazard Results

Mapping of velocity and DxV (depth times velocity, referred to as *hydraulic hazard*) in 2D areas is based on a depth averaged velocity over a 30m grid. To quantify variations in velocity with depth and sub-grid features would require higher resolution 2D or 3D modelling.

Mapping of velocity and hydraulic hazard for 1D in-bank channel sections, for example Lockyer Creek and upstream of One Mile Bridge on the Bremer River, uses an estimate of velocity and depth based on parallel channel flow analysis and should be interpreted with caution.

4.7.8 Flood Mapping Resolution

The regional flood mapping for both the Phase 2 (Flood Study) and the Phase 3 (SFMP) has been produced on the same 30m grid as the underlying hydraulic model. Finer resolution or refinement of the mapping was not included in the scope of either study. If required, this should be undertaken at a regional scale to ensure consistency of use and application across the study area.

4.7.9 Building Database

Two separate building databases were developed during the course of this study:

- A preliminary building database, which enabled early risk-characterisation prior to the collection of detailed floor level survey; and
- A detailed building database, which was developed through site survey of all properties up to the 1 in 2,000 year AEP, and a combination of LiDAR and building footprints for remaining properties in the floodplain.

Supporting the building database is a critical infrastructure database developed from land use zoning, and other primary source data. The critical infrastructure database should be considered ‘preliminary’ only, and verified with asset owners if information is required for planning purposes.

Multi-dwelling residential building numbers were determined from the building database. Due to necessary limitations in the building database, multi-storey buildings (or high-density properties) do not provide the number of dwellings attached to each floor level, and therefore only one dwelling was counted per storey. This assessment therefore limits counting of multi-dwelling buildings to the number of buildings, rather than individual dwellings.

4.7.10 Population Exposure

The population at-risk was assessed by assigning a ‘person-to-dwelling’ ratio (derived from 2016 Census and calculated at the smallest SA1 resolution) to each building location in the building database. In locations with single dwelling buildings, this provides a sound approach to understanding the spatial distribution of residents across the floodplain. However, in SA1 areas where there are multi-dwelling buildings (e.g. high rises), this approach will underestimate populations. As an example, if a person-to-dwelling ratio of 2.5 is applied to a building with 10 dwellings, this approach will ‘assign’ 2.5 people to that building location, instead of 25 (since information about the number of dwellings is not provided in the building dataset). This is a known limitation of the building dataset, and subsequent calculations that rely on the dataset. Because of this issue, building exposure is generally considered a more reliable descriptor of flood risk.

4.7.11 Road Flood Immunity

In the absence of local roads data, State controlled roads (and some local roads identified by Somerset Regional Council) were used as a proxy for evacuation routes for this regional-scale assessment, recognising that further assessment will be required within the detailed studies to understand the flood immunity of feeder roads connecting to the state controlled roads. The specific immunity of bridges on these roads has not been assessed due to a lack of specific infrastructure detail.

Information about the flood immunity of these roads should be viewed as indicative only, subject to the following caveats:

- The flood immunity relates only to flooding from the lower Brisbane River (as modelled in the Phase 2 (Flood Study)) and does not account for creek dominated events, or local flooding
- The hydraulic model is based on the Phase 2 (Flood Study) and as such does not include minor cross-drainage structures. Absence of these structures may cause flood immunity to overstate the risk (i.e. a road may show as inundated in the flood model, when in reality, flood waters may pass through under-road drainage structures)
- Immunity has been assessed using depth-based results from the Phase 2 (Flood Study) which was developed on a 30m grid size. This resolution may not pick up local high or low points, which may affect the reported immunity
- During flood events, flood immunity may be lowered if drainage structures such as bridges and culverts become blocked with debris.

Despite these caveats, the immunity assessment provides general trends and highlights locations in the study area which might be constrained by poor flood immunity. It is noted that areas upstream of the study area may also be inundated and isolated during the same weather events that cause flooding along the lower Brisbane River. These areas will also need to be considered as part of network continuity and disaster management planning.

4.7.12 Road Inundation and Isolation Assessment

The following limitations have been identified for the road inundation and isolation assessment:

- As described in Section 4.7.11 above, evacuation routes adopted in the assessment are state controlled roads only. Even if they display high flood immunity, detailed studies will need to investigate immunity of local roads to enable residents to reach state roads;
- State roads are not necessarily the roads with highest immunity. These are not necessarily defined evacuation routes;
- Roads may become inundated earlier than identified in the assessment due to local flooding, creek flooding, or debris/obstructions;
- Most roads are not modelled with cross-drainage so the assessment may indicate them to be flooded, when in fact the cross-drainage (e.g. culverts under the roadway) may provide a higher level of flood immunity; and

- The time to inundation values shown on the box-and-whisker plots reference 'time zero', which is the start of the main rainfall burst in the relevant flood design event. For real-time applications, this time will have no real world meaning. However, the plots do provide valuable information about relative timing, i.e. X section of road is likely to become inundated much earlier than Y section. Information from plots might therefore be used in pre-planning to estimate the relative sequencing of inundation, informing disaster managers of those areas which are likely to be isolated earlier in the event. Challenges with 'time zero' can be reduced by identifying a new reference point for 'time zero'. For instance, for a given location, the new 'time zero' might be set as the time that the local gauge reaches a certain level, or when some other observable impact occurs (such as the river breaking out of banks, or a bridge deck becoming overtopped). This approach could be applied during Phase 4 (LFMPs) using local information about impacts.

4.7.13 Vulnerability Indices

There are numerous factors which may increase a community's vulnerability which could not be assessed as part of this study, primarily levels of household insurance and community resilience, which can influence a resident's ability to withstand and recover from flooding. A market research activity was undertaken as part of the Phase 3 (SFMP) to better understand the community's existing level of resilience (see Section 11.3.4). Insurance information is not available for this study, however, it might be assumed there is a correlation with the social and economic vulnerability index.

Some vulnerability characteristics, such as age, are not necessarily clear indicators of community vulnerability. Rufat *et al.* (2015) note that although young children are generally considered to be more vulnerable than adults, children can also "serve as resilience drivers by bringing together community networks through their schooling, or by providing assistance to the household during recovery processes".

The approach used to represent aspects of vulnerability via the indices (which combine multiple vulnerability characteristics) provides indicative and relative results only. The assessment is also reliant on the 2016 Census data (which was found to have internal errors) and the population estimates (which have known limitations, as discussed in Section 4.7.10).

This information may be improved upon during more detailed floodplain management studies and plans based on local knowledge.

5 Future Flood Risk

Based on the same risk-based approach to assessing existing risk, future flood risk for the lower Brisbane River has also been investigated. This was based on an assessment of the potential impacts of future development on existing property, and a sensitivity assessment to three climate change scenarios for varying increases in rainfall intensity and sea level.

5.1 Future Development

5.1.1 Background

Increased development in the floodplain can potentially affect the hydraulic behaviour of floods by:

(1) Impacting the flow of water through the floodplain by blocking or constraining flowpaths (i.e. an impact on flood conveyance);

(2) Reducing the available volume of the floodplain by filling (i.e. an impact on flood storage); and

(3) Increasing runoff due to an increase in impermeable surfaces.

Testing of future development scenarios across the study area (including land within the four local government areas) has been undertaken to understand how future development may change flood behaviour within the lower Brisbane River study area due to (1) and (2). The assessment has not included the hydrologic impacts of development within the study area such as the increased runoff that might be expected from an increase in impermeable surfaces (3), or changes in the catchment area upstream of the study area. Outcomes of the assessment have been used to highlight areas of the catchment that may be more sensitive to changes in the floodplain due to future development. This provided a basis for regional-scale flood risk management of future development (in Section 9 Land Use Planning).

It is important to note that the future development scenario analysis is not intended to be predictive or provide an accurate forecast of future conditions. It also does not reflect Council policies regarding filling within the 1 in 100 AEP extent. Rather, it has been undertaken principally for exploratory purposes and to understand the floodplain's sensitivity to changes in development.

5.1.2 Future Development Scenarios

Three future development scenarios are being considered in this study:

- Development scenarios 1 and 2 (DS1 and DS2) reflect material changes to the floodplain which might occur in the short to medium-term. These two scenarios have been assessed in the hydraulic model to understand the potential impact that increased development has on flood levels and potential hydraulic risk. Both scenarios are based on the same development areas, however scenario 1 was undertaken to assess the change in surface roughness based on development density, whilst scenario 2 assessed the impact of changes in both surface roughness and ground elevations (i.e. fill).
- Development scenario 3 (DS3) addresses more qualitative considerations of increased density in the urban footprint, in line with projections provided in ShapingSEQ: South-East Queensland

Regional Plan 2017 (DILGP, 2017). DS3 has not been assessed in the hydraulic model but is considered further in Section 9 Land Use Planning.

5.1.2.1 Development Scenarios 1 and 2

Development scenarios 1 and 2 consider land within the full known extent of the Brisbane River catchment floodplain and assumes that development is undertaken in accordance with the intent for existing zoned land across the four local government areas, as indicated by the respective existing[7] planning schemes:

- Brisbane City Plan 2014
- Somerset Region Planning Scheme 2016
- Ipswich Planning Scheme 2006
- Lockyer Valley Region:
  - (a) Gatton Shire Planning Scheme 2007
  - (b) Laidley Shire Planning Scheme 2003

It has been assumed that land is appropriately zoned and serviced (or planned to be serviced within the priority infrastructure areas) and is realistically available for development over the next 15 to 25 years.

For each zone across the five planning schemes, a review of relevant scheme provisions that may influence the nature of future development was undertaken. These provisions were limited to factors which could be readily included in the hydraulic model assessment, namely:

- Land use type (via zone code and zone code description)
- Site cover.

All parameters are taken from Acceptable Outcomes in relevant zone codes (where specified) as this indicates Council's preferred way to achieve a performance outcome and are clearly measurable. Note that development of this scenario has not taken account of more detailed provisions in local plans or neighbourhood plans which can alter development requirements such as site cover. Similarly, the scenario has not taken account of other constraints or overlays that may limit the development footprint, such as setbacks from waterways, significant vegetation or biodiversity values. The scenario also assumes that future development of airport and port land will be managed on site and not result in any regional-scale flood impacts.

5.1.2.2 Development Scenario 3

Development scenario 3 (DS3) has not been assessed in the hydraulic model but is discussed in Section 9 Land Use Planning to better understand the planning implications of increased density in the floodplain.

[7] Zoning and development assumptions are based on existing planning schemes currently in force and effect. The assumptions have not considered draft planning schemes under preparation or development approvals that may override or vary the effect of planning schemes.

5.1.3 Model Representation

Two different approaches (representing the scenarios DS1 and DS2) were undertaken to reflect future development in the flood model as follows:

- Modifying surface roughness
- Modifying surface roughness and ground elevations.

These two approaches are deemed to represent a lower and upper limit for potential flood impacts resulting from increased development. In both cases, only land parcels identified as being of an existing urban use were modified. Urban land uses were identified from LGA zone coding and/or descriptions and have been categorised into one of four general categories, namely: Residential, Community, Commercial and Industrial.

Appendix E contains tables that list the categorisation applied to Zone Codes and Zone Code Descriptions (as applicable). Further details on how the two approaches have been implemented in the Detailed Model are given below.

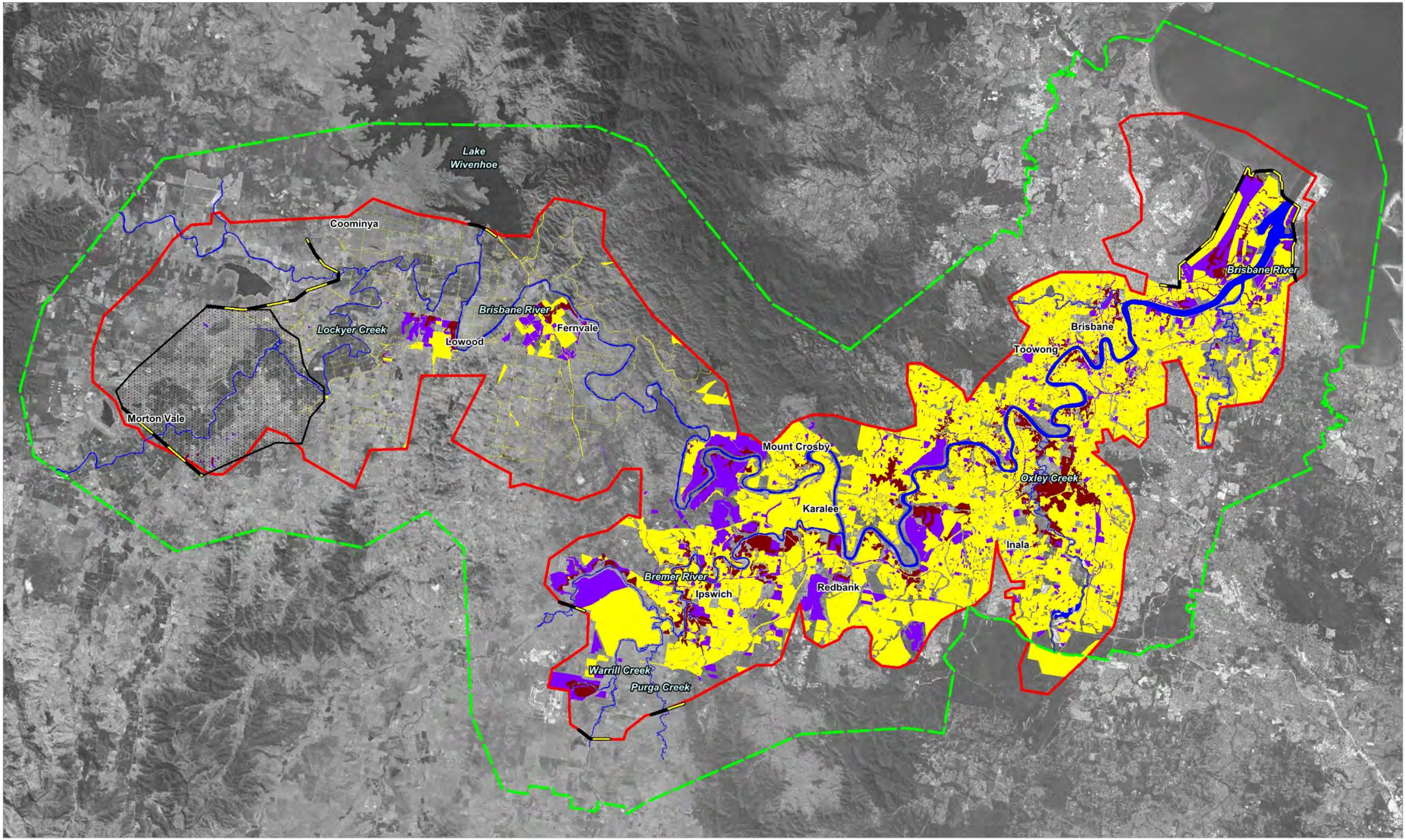
5.1.3.1 Development Scenario 1 (Modify Roughness)

Under Development Scenario 1 (DS1) each general land use category, for example ‘commercial’, was attributed a Manning’s n roughness value in accordance with values adopted in the calibrated Phase 2 (Flood Study) model (BMT WBM, 2017). Further sub-categorisation was applied to the residential category by specifying Manning’s n values for Low, Low-Medium, Medium and High Density classes. Figure 5-1 shows those areas represented as urban footprints in the base case and DS1 scenarios.

This approach ensures consistency with the base case in that the scenario compares like with like. However, since future development may involve associated filling within the floodplain, this scenario is likely to overall understate hydraulic impacts and is therefore considered the lower bound of potential impacts of future development.

Table 5-1 summarises the approximate change in overall developed floodplain area by AEP. It should be noted that this only includes the floodplain within the hydraulic model extent.

It can be seen from Table 5-1 that changes in developed area are relatively minor for events less than a 1 in 100 AEP flood event with notable changes (increases) in developed area for events larger than the 1 in 100 AEP flood. This is in line with expectations as stricter planning controls are likely to be factored into development in areas of more frequent flooding.



LEGEND

- Strategic Floodplain Management Study Area
- Hydraulic Model Boundary
- Limit of Detailed Modelling
- Flooding in hatched area needs to be verified with the Local Council
- Base Case Urban Footprint
- Development Scenario Urban Footprint
- DS2 Extent of Fill
- Waterways

Refer to Councils for ocal flooding beyond limit

Brisbane River Catchment Flood Study
Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Title:
Urban Footprint in Base Case and Development Scenario: Study Area

Figure: **5-1**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

0 7 14
Kilometers

Map Grid of Australia 1994, Zone 56

BMT
www.bmt.org

Filepath: B:\B22374 BRCFMS\GIS\MXD\MXD_OUTPUT\Risk Mapping\FLD_018_170426_Urban Footprint in Base Case and Development Scenario.wor

Table 5-1 Change to Developed Floodplain Area in DS1

		Approximate % Developed Floodplain	
AEP (1 in Y)	**Floodplain area (km^2)**	**Base case**	**DS1**
10	195	4%	8%*
20	258	3%	6%*
50	318	20%	20%
100	397	17%	21%
500	500	17%	25%
2,000	568	21%	29%
100,000	852	29%	40%

** The majority of the additional development for the 1 in 10 and 1 in 20 AEP floodplain is associated with an assumed expansion of the urban footprint of Amberley Airbase.*

5.1.3.2 Development Scenario 2 (Modify Roughness and Topography)

Development Scenario 2 (DS2) modifies the surface roughness representing development, as undertaken for DS1, but also assumes some filling of the floodplain associated with the development. The locations and amount of filling that would actually occur for future development are unknown and would likely be decided on a case by case basis. The following criteria were used for selecting land parcels to be filled for this scenario:

- Land parcels within the 1 in 100 AEP extent *and* with more than 50% site coverage expected as guided by planning scheme provisions;
- Land parcels attributed with a higher density land use.

Filling was assumed to be to the maximum base case 1 in 100 AEP peak flood level within that parcel. It is recognised that this approach will overstate fill in some locations (i.e. areas which are only expected to have 50% site coverage but are being represented as 100% fill), and understate fill in other locations (i.e. areas which are expected to have less than 50% fill will be represented as no fill). Note that the fill level did not include any freeboard as would often be required in practice.

The higher density land uses are based on the site coverage provided in Appendix E. This indicates that areas of more than 50% site coverage are as follows:

- Centre zones – all
- Residential zones – most
- Industry zones – some
- Emerging community zones – some
- Township zones – some.

In total, filling was applied to approximately 12.5 km^2 of floodplain for scenario DS2 (around 3% of the 1 in 100 AEP extent).

Overall, DS2 is expected to generally overstate hydraulic impacts, because these fill scenarios do not necessarily reflect council policies with regard to filling within the 1 in 100 AEP extent.

While DS1 is expected to provide a lower bound to hydraulic impacts and DS2 is expected to provide an upper bound, it should be noted that these overall trends will not necessarily be evident at all locations throughout the catchment. For instance, if there are large areas of fill in the upper catchment, this may greatly increase flood levels upstream, and lower flood levels in the downstream area (this effect was observed in the development sensitivity assessment carried out during the Phase 2 (Flood Study)).

5.1.4 Impact of Future Development on Flooding

5.1.4.1 Introduction

The impact of the future development scenario on flood risk has been assessed in terms of change in peak flood level and change in potential hydraulic risk. The following key outputs have been produced:

- Peak flood level difference mapping (shown for the 1 in 100 AEP flood only);
- Change in potential hydraulic risk category; and
- Tabulated peak flood level differences for all simulated AEP floods at 28 locations along the main rivers (refer Appendix F).

Peak flood level differences were obtained by simulating the ensemble of events for each respective AEP flood for each development scenario (for example, the 1 in 100 AEP is comprised of 5 component events) and comparing with the base case. A positive difference is an increase in peak flood level as a result of the development scenario, while a negative difference is a decrease in peak flood level.

5.1.4.2 Impact on Flood Level

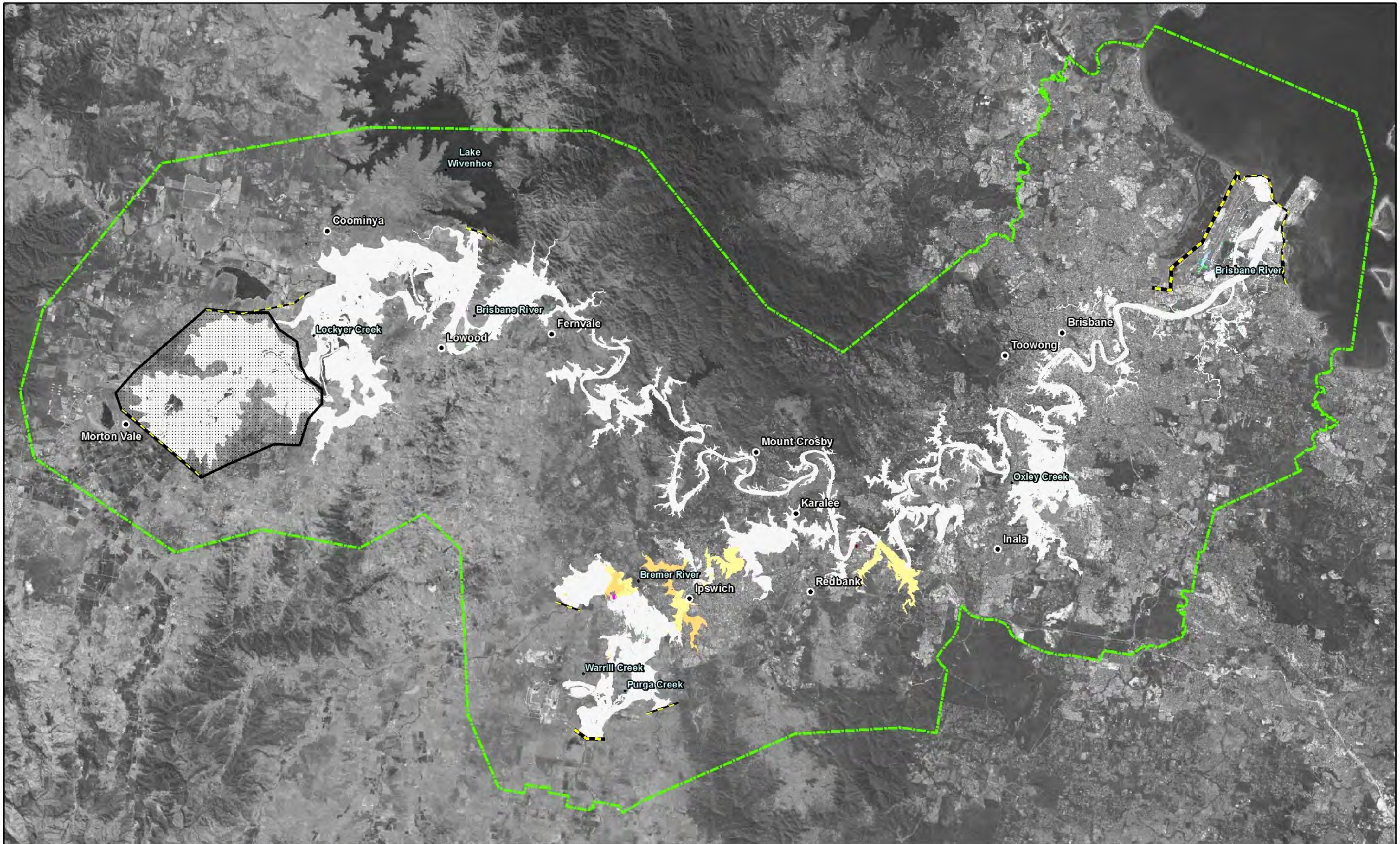
The two development scenarios provide an estimated lower and upper bound for cumulative impacts on flooding. At the local level, some impacts may combine to make a greater impact whereas some may offset each other. The impacts on flood levels in a 1 in 100 AEP for DS1 and DS2 are shown in Figure 5-2 and Figure 5-3, respectively. Changes in the flood level from base case levels are summarised for Brisbane, Moggill, Jindalee and Ipswich for all AEPs in Table 5-2 for both development assessment scenarios.

Table 5-2 Future Development Flood Level Impacts

	Increase in Peak Flood Level from Base Case (m)							
AEP	Ipswich (David Trumpy Bridge)		Moggill		Jindalee		Brisbane (City Gauge)	
1 in Y	DS1	DS2	DS1	DS2	DS1	DS2	DS1	DS2
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
50	0.0	0.4	0.0	0.1	0.0	0.1	0.0	0.1
100	0.0	0.9	0.0	0.3	0.0	0.4	0.0	0.1
500	0.0	0.4	0.0	0.2	0.0	0.2	0.0	0.0
2,000	0.2	0.3	0.1	0.1	0.0	0.1	0.0	0.0
100,000	0.4	0.5	0.4	0.5	-0.2	-0.1	-0.1	-0.1

The following conclusions are drawn from the flood level impact assessment:

- For lower magnitude floods (1 in 10 and 1 in 20 AEP) impacts are mainly observed on the Bremer River (upstream of Ipswich) and within the Oxley Creek catchment (upper limit impacts of around 0.2m in 1 in 10 AEP for both locations). This is mainly associated with the fill encroaching into the 1 in 10 AEP flood extent and the associated 'squeeze' on the floodplain at these locations.
- For moderate floods such as the 1 in 50 AEP, the areas impacted the most remain the Bremer River and Oxley Creek but smaller impacts are also apparent on much of the lower Brisbane River.
- For the 1 in 100 AEP flood the upper bound impacts are widespread on the Brisbane River from Colleges Crossing at the upstream end through to the Gateway Bridge. The impacts are most pronounced on the Bremer River near Ipswich CBD with predicted increases in levels of around 0.8m. Notably the lower bound shows only minor increases of 0.04m at Ipswich, indicating that flood behaviour is particularly sensitive to filling as opposed to changes in surface roughness. Impacts are also evident on the Brisbane River between Wivenhoe Dam and Lowood with predicted increases of up to 0.5m under the upper bound which diminish to a near zero impact under the lower bound. This is attributed to assumed filling in the vicinity of Lowood and again highlights the sensitivity of flood levels to floodplain filling.
- For more extreme events (1 in 500 AEP or larger), the impacts remain spatially extensive but the magnitude of the impacts begins to diminish as the proportion of active floodplain occupied by fill also diminishes. The exception is for the 1 in 100,000 AEP flood where much of the modelled extent shows moderate increases in flood level. These increases appear to be driven by the change in surface roughness rather than any filling and are thought to be the result of the relatively large area of new development within the floodplain of this extreme event.



LEGEND

- Limit of Detailed Modelling
- Study Area Boundary
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

Change in Peak Level (m)

- <-1.0
- -1 to -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.05
- -0.05 to 0.05
- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- 0.5 to 1
- >1.0
- Was Wet Now Dry
- Was Dry Now Wet

Brisbane River Catchment Flood Study
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Somerset Regional Council
Seqwater

Flood Level Impact in 1 in 100 AEP from DS1 Development Scenario

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0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

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Fig 5-2

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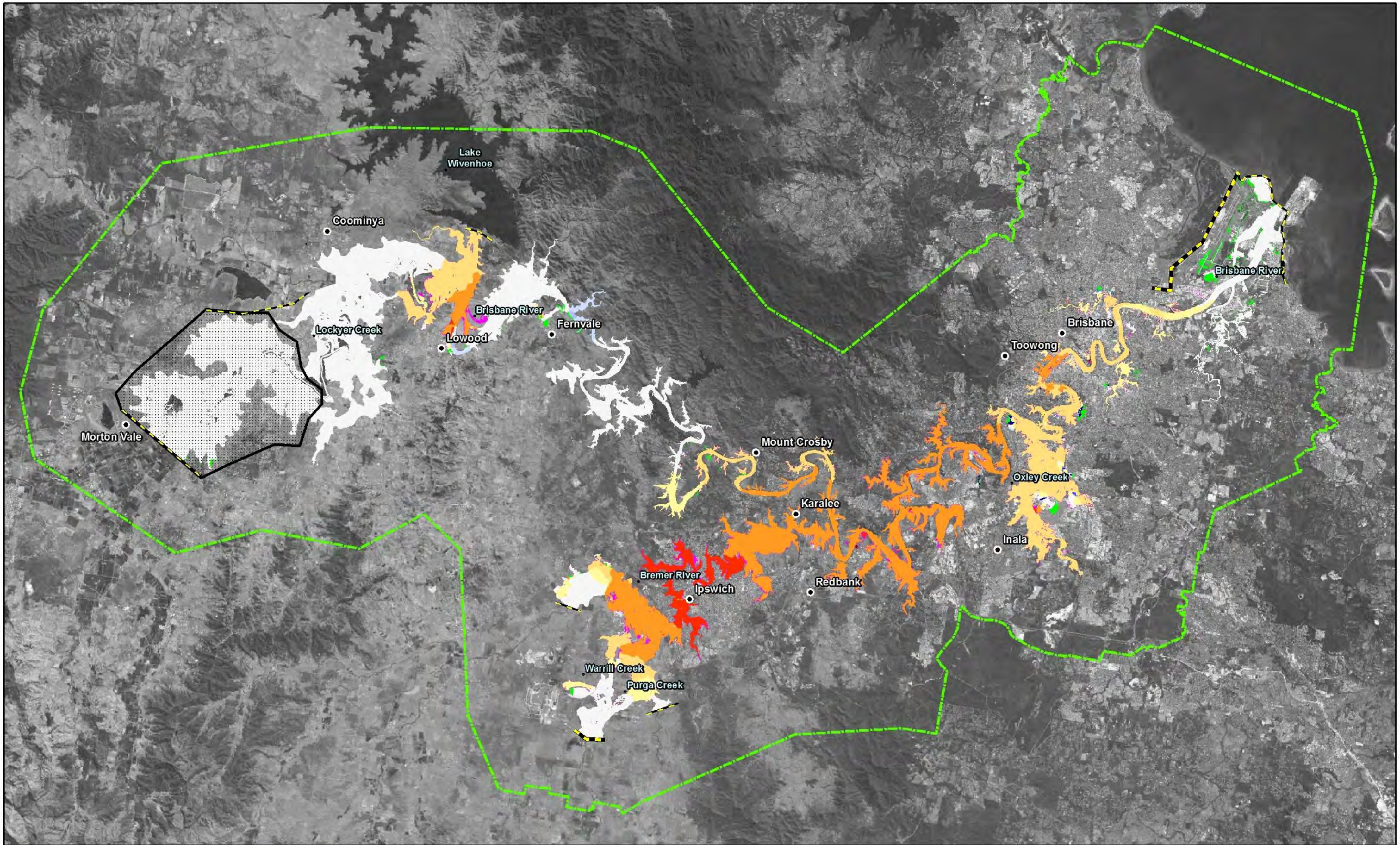

LEGEND

- Limit of Detailed Modelling
- Study Area Boundary
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

Change in Peak Level (m)

- <-1.0
- -1 to -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.05
- -0.05 to 0.05
- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- 0.5 to 1
- >1.0
- Was Wet Now Dry
- Was Dry Now Wet

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Flood Level Impact in 1 in 100 AEP from DS2 Development Scenario

0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

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Fig 5-3

A

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Overall, the impacts shown in the development scenario are largely driven by filling within the floodplain. The 1 in 100 AEP flood is generally the most sensitive to the filling assumptions employed as the proportional displacement of water is at a maximum compared to other AEP floods. The exception to impacts driven by fill is for the 1 in 100,000 AEP in which impacts are largely driven by increases in surface roughness. This is likely due to much of the additional development being located in areas only affected by extreme floods where filling would not ordinarily occur. In extreme floods the cumulate effect of the development is most pronounced.

1 in 100 AEP peak flood levels in Ipswich are sensitive to future development under the scenarios assessed, particularly when filling is applied to parts of the floodplain. Whilst flood levels in Brisbane are less sensitive, the increase in 1 in 100 AEP flood levels due to filling in the floodplain are not insignificant.

A summary of flood level impacts across the 28 reporting locations of the lower Brisbane River floodplain for the future development scenarios is provided in Appendix F.

5.1.4.3 Impact on Potential Hydraulic Risk

Under Development Scenario 1, which is considered to represent the lower bound of impacts, there is no discernible change in potential hydraulic risk throughout the study area (see Figure 5-4). This is to be expected given the minimal change in flood levels.

Under Development Scenario 2, which is considered the upper bound for impacts, there is still relatively minor change to the potential hydraulic risk across the study area (see Figure 5-5). Small increases are observed in the Bremer catchment upstream of Ipswich and on the Brisbane River upstream of Lowood where increases in risk are associated with deeper floodwater as a consequence of the simulated floodplain fill. However, the most notable change for Development Scenario 2 is a decrease in risk (shown in green shades) in several locations throughout the catchment. This difference is due to the filling itself, which, as a consequence, has effectively removed parts of the 1 in 100 AEP floodplain and reduced flood depths within the affected land parcels during larger floods.

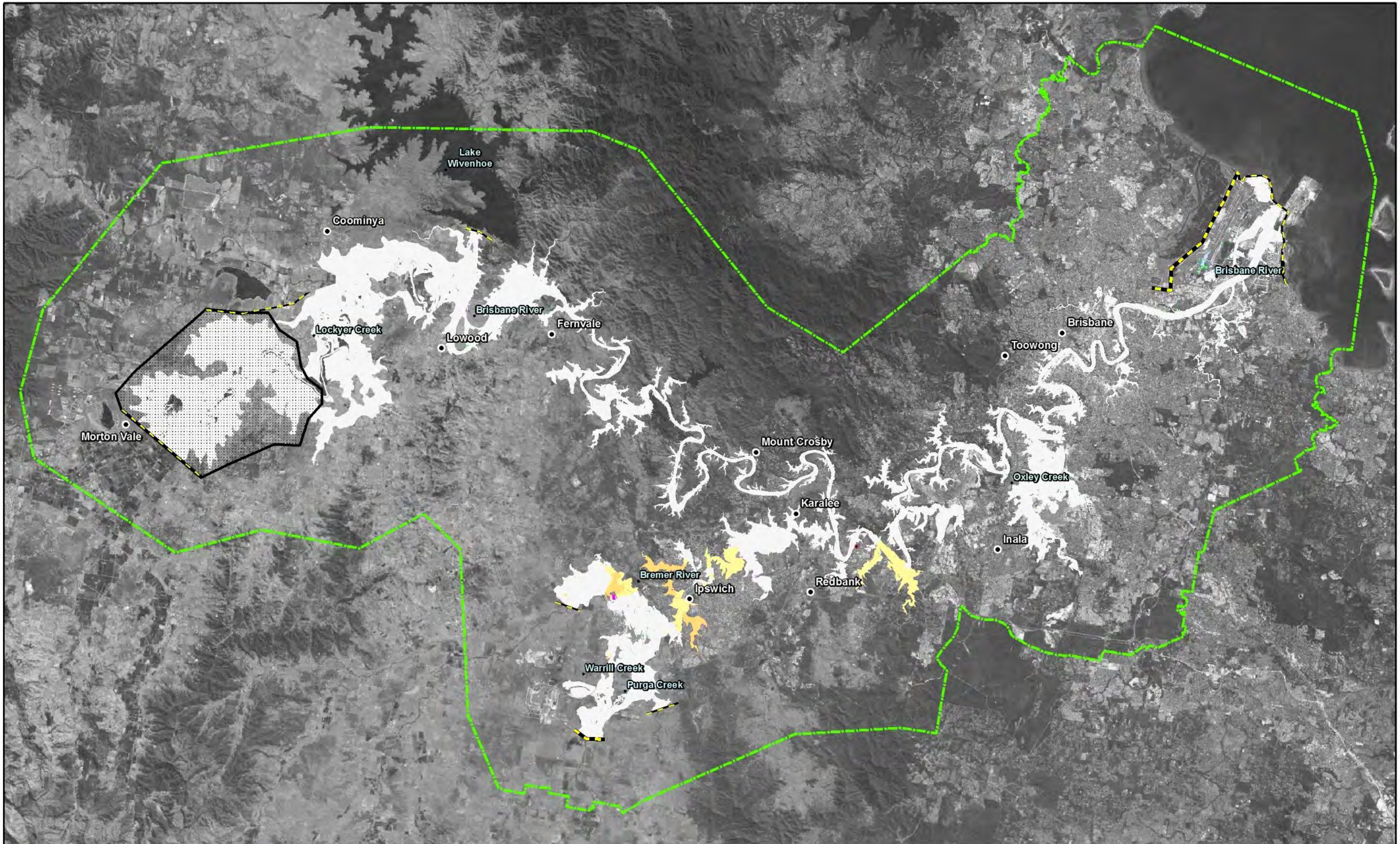
Table 5-3 outlines the area of floodplain within each of the potential hydraulic risk categories for the Base Case and two development scenarios. It can be seen that there is minimal change to potential hydraulic risk under DS1, and a decrease overall in most risk categories for DS2 (with the exception of HR3) due to the reduction in potential hydraulic risk as a result of filling.

Table 5-3 Area of Floodplain in Potential Hydraulic Risk Categories: Base Case and Development Scenarios

	Area by Potential Hydraulic Risk Category (km^2)				
	HR1	HR2	HR3	HR4	HR5
Base Case	210	111	114	100	314
DS1 Increase in category Decrease in category	210 0 0	112 1 1	114 1 1	100 2 2	319 6 2
DS2 Increase in category Decrease in category	201 2 2	95 5 20	139 23 5	104 5 6	318 9 5

5.1.5 Summary of Future Development Impact on Flooding

Generally, the future development scenario does not result in significant changes in potential hydraulic risk except for parts of the Bremer River, however there are significant increases in flood levels across much of the floodplain. This is primarily a consequence of filling within parts of the 1 in 100 AEP floodplain. The results demonstrate the sensitivity of flood behaviour to such landform changes in the floodplain when assessed at a cumulative or regional scale.



LEGEND

- Limit of Detailed Modelling
- Study Area Boundary
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

Change in Peak Level (m)

<-1.0	0.05 to 0.1
-1 to -0.5	0.1 to 0.2
-0.5 to -0.2	0.2 to 0.5
-0.2 to -0.1	0.5 to 1
-0.1 to -0.05	>1.0
-0.05 to 0.05	
Was Wet Now Dry	Was Dry Now Wet

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Flood Level Impact in 1 in 100 AEP from DS1 Development Scenario

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0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

Filepath : B:\B22374 BRCFMS\GIS\MXD\MXD_OUTPUT\DS1\D0100\DS1-D0100-dH-Study Area.mxd

Fig 5-4

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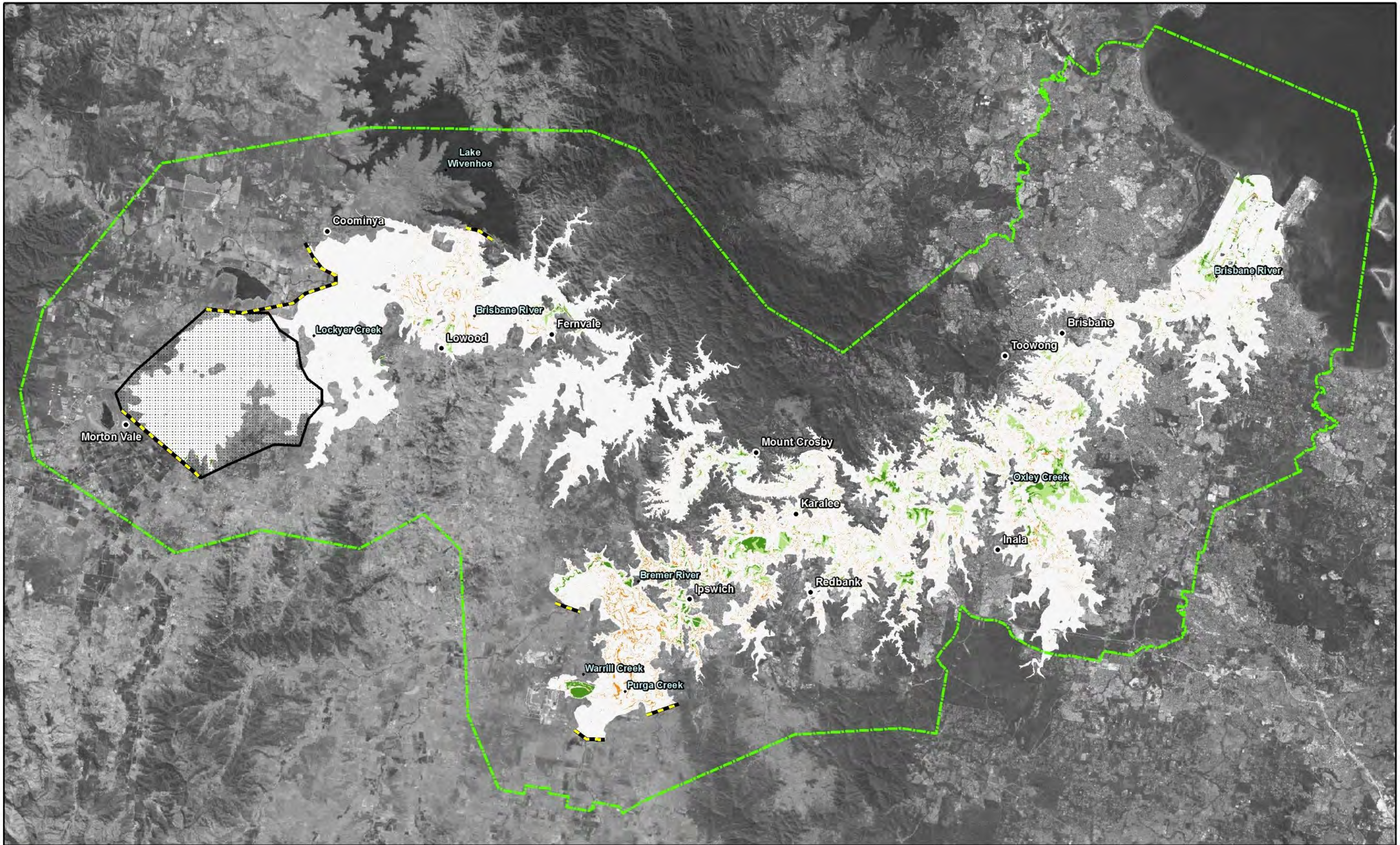

LEGEND

- Limit of Detailed Modelling
- Study Area Boundary
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

Change in Flood Risk

- Increase in flood risk by 2 or more Category
- Increase in flood risk by 1 Category
- No change in Flood Risk
- Decrease in flood risk by 1 Category
- Decrease in flood risk by 2 or more Category

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Change in Hydraulic Risk for DS2 Development Scenario

5-5

A

0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

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5.2 Climate Change Sensitivity

5.2.1 Climate Adaptation Policies and Strategies

Last year the State Government released the Queensland Climate Adaptation Strategy (Q-CAS) which provides a framework for ensuring Queensland manages the risks and harnesses the opportunities of a changing climate. Under the Q-CAS there are four pathways to action including: People and Knowledge, State Government, Local Governments and Regions and Sectors and Systems. Programs have been established under these pathways to provide a co-ordinated response to climate change.

Land use planning is one of the most cost-effective ways to reduce the exposure of people and the built environment to climate exacerbated risks both now and in the future. The Queensland Planning Act is supported by a range of new state planning instruments, development assessment requirements and guidelines which work together to facilitate the achievement of ecological sustainability – including addressing the impacts of climate change.

For example, the State Planning Policy has been amended to specifically require that the projected impacts of climate change be avoided and mitigated in strategic land use planning and development assessment. In addition, statewide coastal hazards mapping has been updated to include the internationally accepted climate change projection of 0.8 metre sea level rise to 2100, so these projections can be used in the land use planning and development assessment process. These policies and guidelines are being implemented over time and will become increasingly embedded in the planning and development framework as local and regional plans are renewed and updated.

The Queensland Climate Resilient Councils (QCRC) Program is a three year program working with Queensland local councils and aims to strengthen internal council decision-making processes to respond to climate change. This program has funded 32 councils and funds will shortly be made available for all councils to be involved. Part of the QCRC program includes development of a resource toolkit to build the capacity of councils to respond to climate change.

The Queensland Reconstruction Authority is part of a high level steering group that has been established to endorse materials for the toolkit. The QCRC Program is also making 2 grants available for councils to develop a multi sectoral climate change strategy for a local government or region.

Sectoral adaptation plans are also being developed to co-ordinate responses to climate change. These plans help prioritise adaptation activities, identify emerging opportunities, share knowledge and encourage collaboration on complex issues. To date an agriculture sector adaptation plan, built environment and infrastructure sector adaptation plan and a tourism plan have been delivered. There is a number of others under way, including a biodiversity and ecosystem sector adaptation plan.

This work is being done in cooperation with Natural Resource Management groups to improve and incorporate climate adaptation and resilience responses into regional natural resource management plans, and to deliver on-the-ground adaptation projects relating to natural resource management.

In addition, the QCoast2100 Program is providing the funding, tools and technical support to enable all Queensland coastal local governments to progress the preparation of plans and strategies to address climate change related coastal hazard risks over the long-term. QCoast2100 is facilitating improved capacity for effective local adaptation decision-making across land use planning and development assessment, infrastructure planning and management, asset management, community planning, and emergency management. Brisbane, Gold Coast, Moreton Bay, Noosa, Logan, and Redland Councils are receiving funding under the program.

5.2.2 Future Climate Scenarios

IPCC (2013) provides a basis for projections for future climate conditions across the globe. More refined research and analysis has been carried out by institutions such as CSIRO, Bureau of Meteorology, Engineers Australia and various universities in Australia that provide future conditions for Australia relevant to the Phase 3 (SFMP).

With respect to impacts on hydraulic behaviour in the Brisbane River, the two primary climate variables assessed for this study were i) rainfall; and ii) sea level rise. Any future changes to Wivenhoe Dam or its operations were not considered in the sensitivity assessment.

Climate change scenarios incorporating sea level rise alone, and sea level rise coupled with increased design rainfall depth, were undertaken during the Phase 2 (Flood Study) as sensitivity assessments. These scenarios considered only four flood likelihoods (1 in 5 AEP, 1 in 20 AEP, 1 in 100 AEP and 1 in 10,000 AEP).

The stakeholders have agreed that three climate change scenarios be investigated for the Phase 3 (SFMP) and simulated across the seven AEPs as used for defining potential hydraulic risk (see Section 4.2.2). The three climate change scenarios are presented in Table 6-28.

Table 5-4 Climate Change Scenarios

Scenario (model reference)	Conditions Description	Rainfall	Sea Level Rise
CC2	RCP 8.5 conditions at 2050	10% increase	0.3m
CC4	RCP 8.5 conditions at 2090	20% increase	0.8m
CC5	RCP 4.5 conditions at 2090	10% increase	0.63m

These scenarios are based on the following assumptions:

- Hydraulic model input files for 10% and 20% increases in rainfall were generated as part of the Phase 2 (Flood Study). Assessment using any alternative rainfall conditions would require significant effort and time for re-running of the hydrology models to generate hydraulic model input files. This was not considered to be warranted given the uncertainty inherent in the assessment;
- Sea level rise projections were derived from IPCC (2013) and Engineers Australia (2012) and are consistent with values adopted in the Queensland State Planning Policy (DILGP, 2017);
- Rainfall increases were derived from IPCC (2013) and CSIRO / BoM (2015) (which generally indicates an increase in the order of 5% per 1^{o}C temperature increase);
- Rainfall conditions are similar (but not exactly the same) and conservative compared to AR&R (Ball *et al.*, 2016). RCP8.5 conditions calculated from AR&R for the Brisbane River catchment are 8.8% for 2050 and 18.6% for 2090, while RCP4.5 conditions calculated from AR&R are 9.1% for 2090;

- Scenarios do not consider changes to other rainfall parameters, antecedent conditions or storm surge activity, which could be significant.

5.2.3 Model Representation and Scenarios

The climate change sensitivity analysis requires hydrologic boundary inputs (flows and tidal levels) to be modified. The Phase 2 (Flood Study) URBS hydrologic model was used to derive the modified flow inputs by applying revised model input parameters (i.e. increased design rainfall depth) as a result of predicted climate change. These inputs were generated for the seven AEPs, namely 1 in 10, 1 in 20, 1 in 50, 1 in 100, 1 in 500, 1 in 2000 and 1 in 100,000 AEP floods.

Sea level rise is implemented for the scenarios listed in Table 6-28 by adjusting upwards the Moreton Bay tide/storm tide hydrograph for each of the events in the AEP ensembles by these amounts for each respective scenario.

5.2.4 Impact of Climate Change on Flooding

5.2.4.1 Introduction

The impacts of the three climate change scenarios on flood risk have been assessed in terms of change in peak flood level and change in potential hydraulic risk. The following key outputs have been produced:

- Peak flood level difference mapping (shown for the 1 in 100 AEP flood only);
- Change in risk category; and
- Tabulated peak flood level differences for all simulated AEP floods (refer Appendix F).

Peak flood level differences were obtained by simulating the ensemble of events for each respective AEP flood for each climate change scenario (for example, the 1 in 100 AEP is comprised of 5 component events) and comparing with the base case. A positive difference is an increase in peak flood level as a result of climate change.

5.2.4.2 Impact on Flood Level

Peak flood level results for the three climate change scenarios at Brisbane CBD and Ipswich CBD are summarised in Table 5-5, while maps of flood level change are provided in Figure 5-6, Figure 5-7, and Figure 5-8 for scenarios CC2, CC4 and CC5, respectively.

All scenarios show rises in peak flood level at all locations considered, which is in line with expectations as rainfall has increased substantially.

For much of the Brisbane River, the 1 in 100 AEP CC2 scenario (0.3m rise in sea level and 10% increase in rainfall intensity) produces similar peak levels to the Base Case (B15) 1 in 200 AEP flood levels (refer Figure 5-6).

The 1 in 100 AEP CC4 scenario (0.8m rise in sea level and 20% increase in rainfall intensity) produces peak levels around 2.5m above Base Case (B15) 1 in 100 AEP levels for Brisbane CBD and for parts of the lower Bremer (downstream of Ipswich) peak levels for this scenario are around 3.8m higher than the Base Case (refer Figure 5-7).

Table 5-5 Change in Peak Flood Level under Climate Change Sensitivity Scenarios

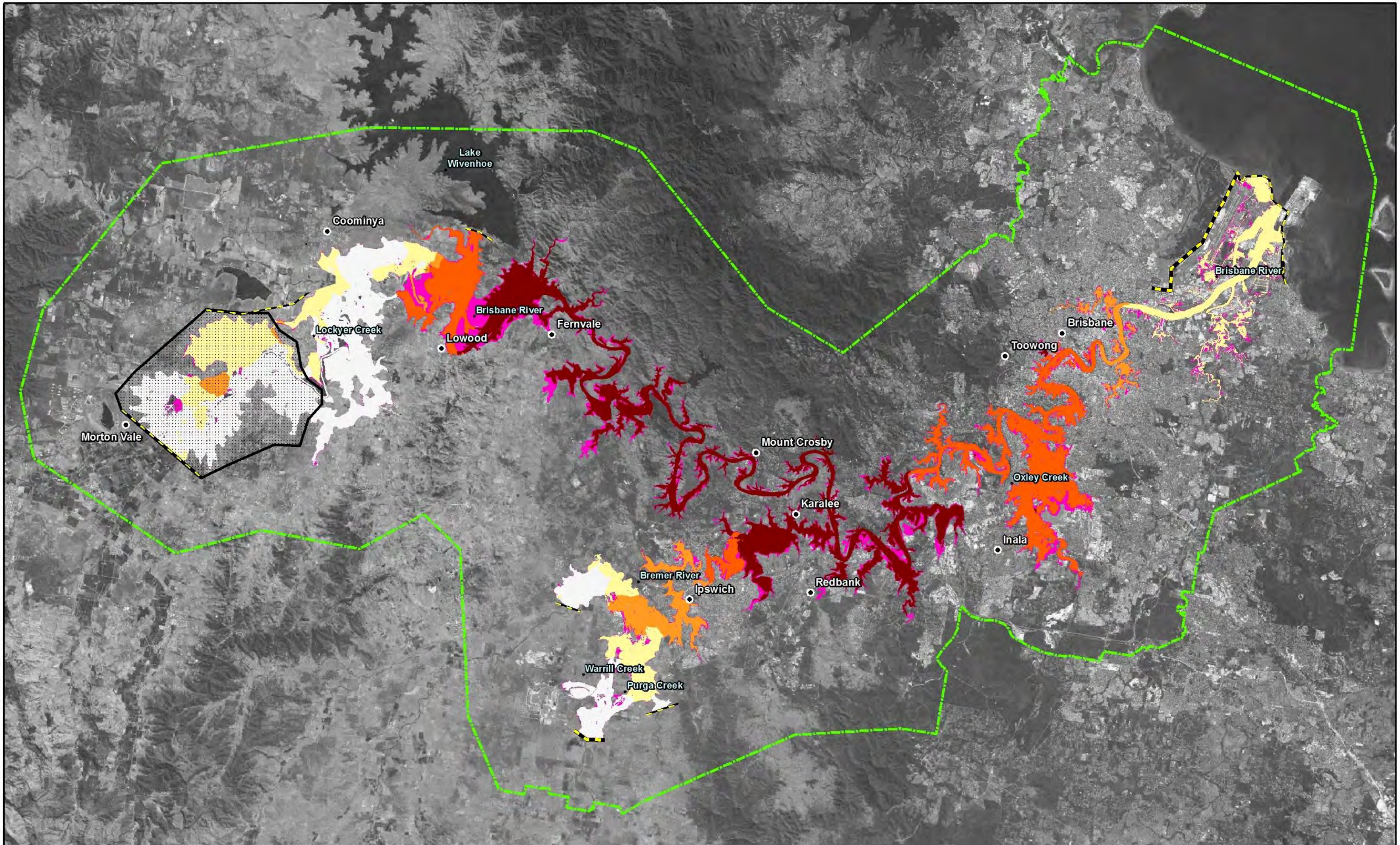
	Increase in Peak Flood Level from Base Case (m)					
AEP	Brisbane (City Gauge)			Ipswich (David Trumpy Bridge)		
1 in Y	CC2	CC4	CC5	CC2	CC4	CC5
10	0.3	0.9	0.7	0.8	1.5	0.8
20	0.5	1.1	0.7	0.8	1.5	0.8
50	0.7	1.3	0.9	0.8	1.5	0.8
100	1.2	2.5	1.4	0.9	2.4	0.9
500	1.5	2.9	1.6	1.3	2.5	1.3
2,000	1.3	2.9	1.3	1.4	2.5	1.4
100,000	1.25	2.3	1.3	1.1	2.1	1.1

Scenario CC5, which has the same increase in rainfall intensity as CC2 but a higher sea level rise, results in the same predicted increases in peak flood levels at Ipswich. This is expected as the impact of future sea level rise would be minimal in Ipswich under flood conditions at this location (refer Figure 5-8).

It was noted during the Phase 2 (Flood Study) that typically the increases in flows are greater than either the 10% or 20% rainfall increases applied in the respective scenarios. This is partially attributed to the non-linearity of the catchment rainfall-runoff response. For example, a 10% increase in rainfall intensity causes greater than 10% increase in runoff rate (or flow) as the losses are assumed to not change (note that the increase in rainfall intensity due to climate change is an increase to the total rainfall falling on the catchments). Furthermore, outflow from the dam may similarly increase non-linearly due to the way in which the dam operates when inflows increase and because dam outflows are also sensitive to inflow volume.

As discussed above, the climate change scenarios do not produce equivalent AEP peak flood levels for that scenario unless the selection of AEP flood event ensembles is repeated for each sensitivity test. The climate change sensitivity test results therefore need to be treated as indicative only and with an appropriate degree of caution.

A summary of flood level impacts across the 28 reporting locations of the lower Brisbane River floodplain for the future development scenarios is provided in Appendix F.



LEGEND

- Limit of Detailed Modelling
- Study Area Boundary
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

Change in Peak Level (m)

- Was Wet Now Dry
- < -2.0
- -2.0 to -1.0
- -1.0 to -0.5
- -0.5 to -0.2
- -0.2 to 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- > 2.0
- Was Dry Now Wet

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Flood Level Impact in 1 in 100 AEP for CC2 Scenario

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0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

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Fig 5-6

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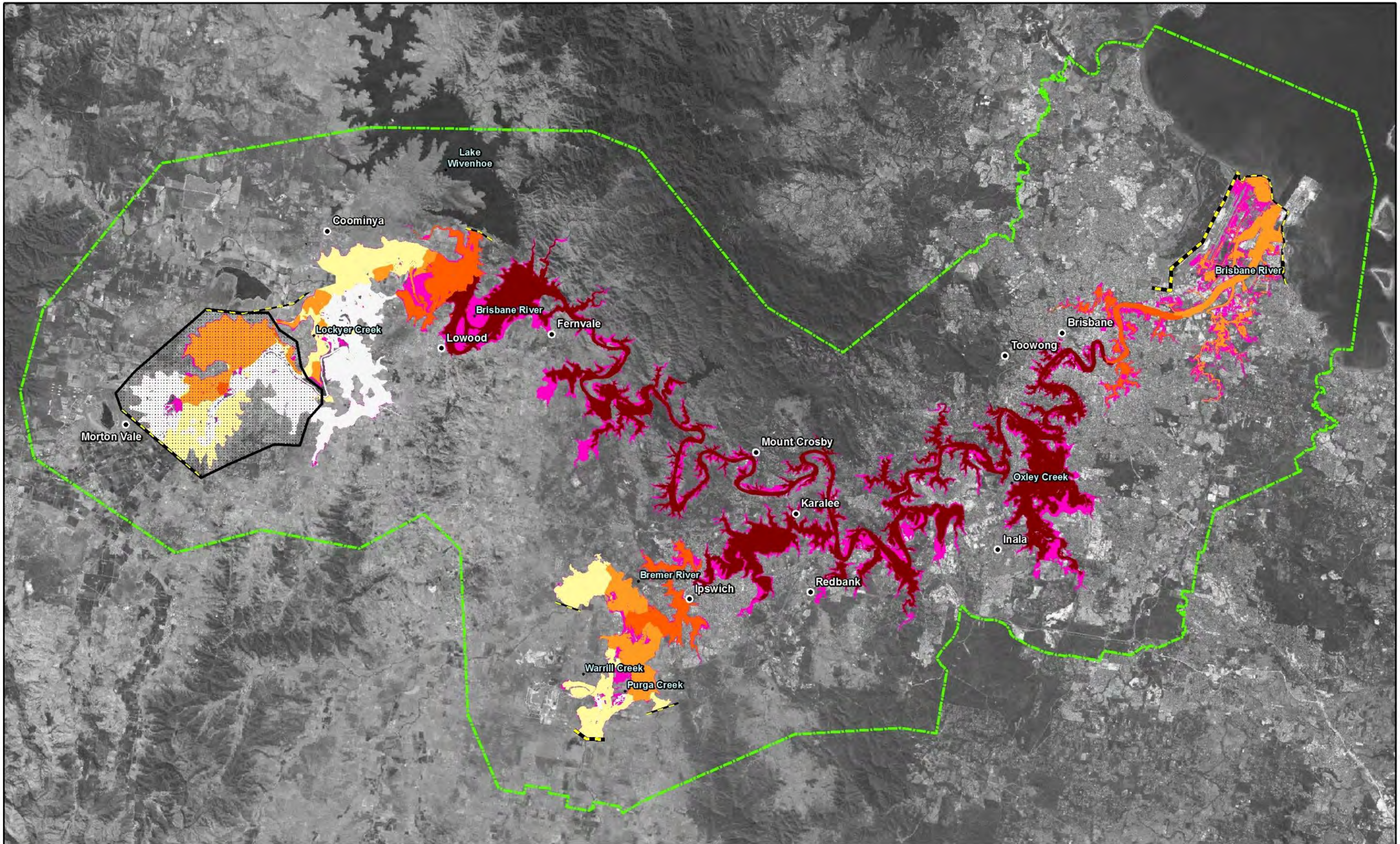

LEGEND

- Limit of Detailed Modelling
- Study Area Boundary
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

Change in Peak Level (m)

- Was Wet Now Dry
- < -2.0
- -2.0 to -1.0
- -1.0 to -0.5
- -0.5 to -0.2
- -0.2 to 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- > 2.0
- Was Dry Now Wet

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Flood Level Impact in 1 in 100 AEP for CC4 Scenario

Fig 5-7

A

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0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

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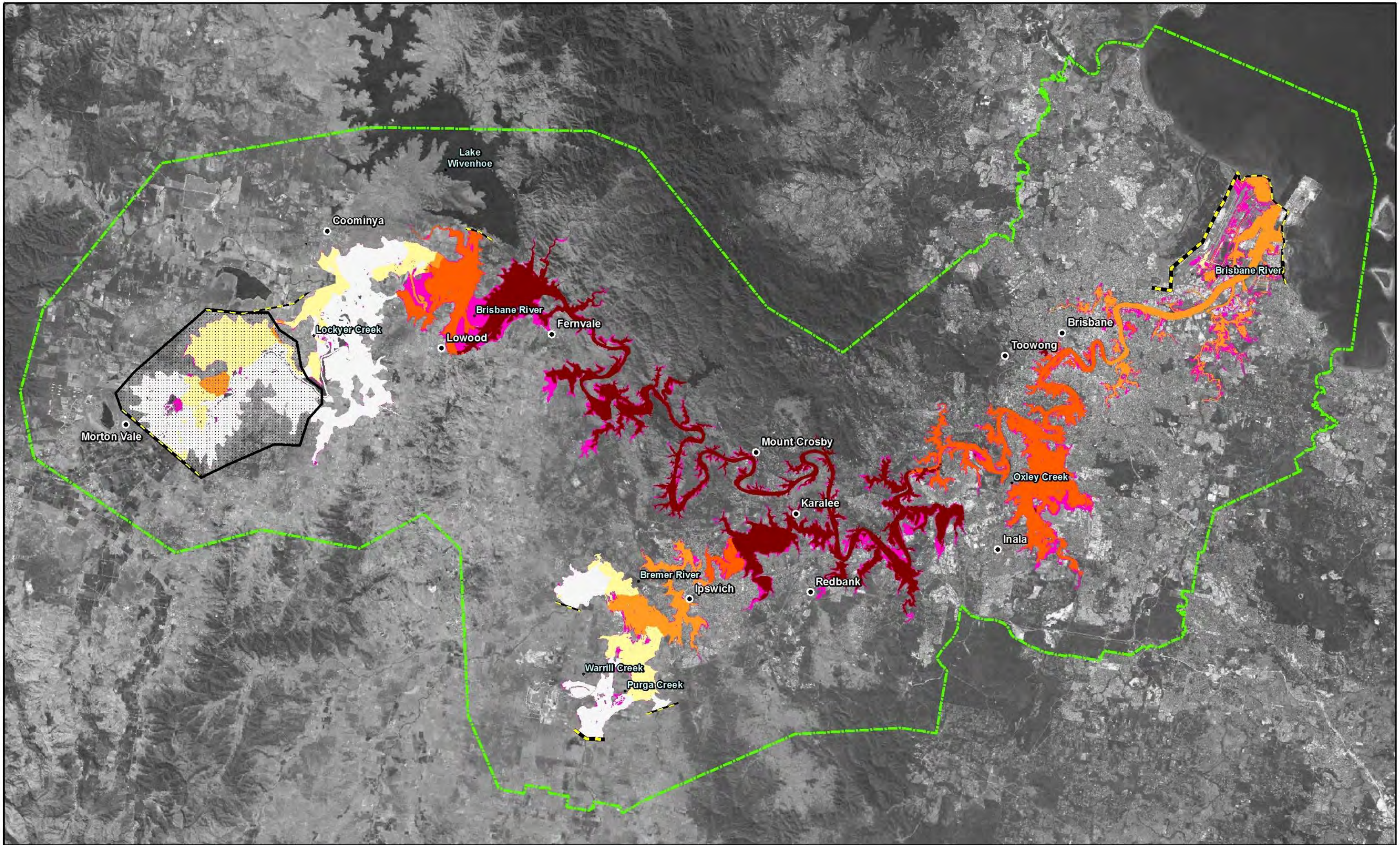

LEGEND

- Limit of Detailed Modelling
- Study Area Boundary
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

Change in Peak Level (m)

- Was Wet Now Dry
- < -2.0
- -2.0 to -1.0
- -1.0 to -0.5
- -0.5 to -0.2
- -0.2 to 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- > 2.0
- Was Dry Now Wet

Brisbane River Catchment Flood Study
Study Partners

Queensland Government

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Lockyer Valley Regional Council
Somerset Regional Council
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Flood Level Impact in 1 in 100 AEP for CC5 Scenario

Fig 5-8 | **A**

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0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

BMT
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5.2.4.3 *Impact on Potential Hydraulic Risk*

All climate change scenarios have resulted in widespread increases in potential hydraulic risk across the study area. As expected, these increases are most pronounced for the scenario CC4 which simulates a 20% increase in rainfall to the base case ensemble events and applies a 0.8m increase in sea level. Typically the increases in risk are by a single potential hydraulic risk category with the notable exception being near the mouth of the Brisbane River where the additional depth generated from the sea level increases results in increases in potential hydraulic risk of 2 or more categories at some locations near the airport and in parts of Bulimba Creek.

Table 5-6 presents the area of floodplain within each potential hydraulic risk category for the baseline and climate change scenarios. It can be seen that the greatest increases in high risk categories occur under the CC4 scenario.

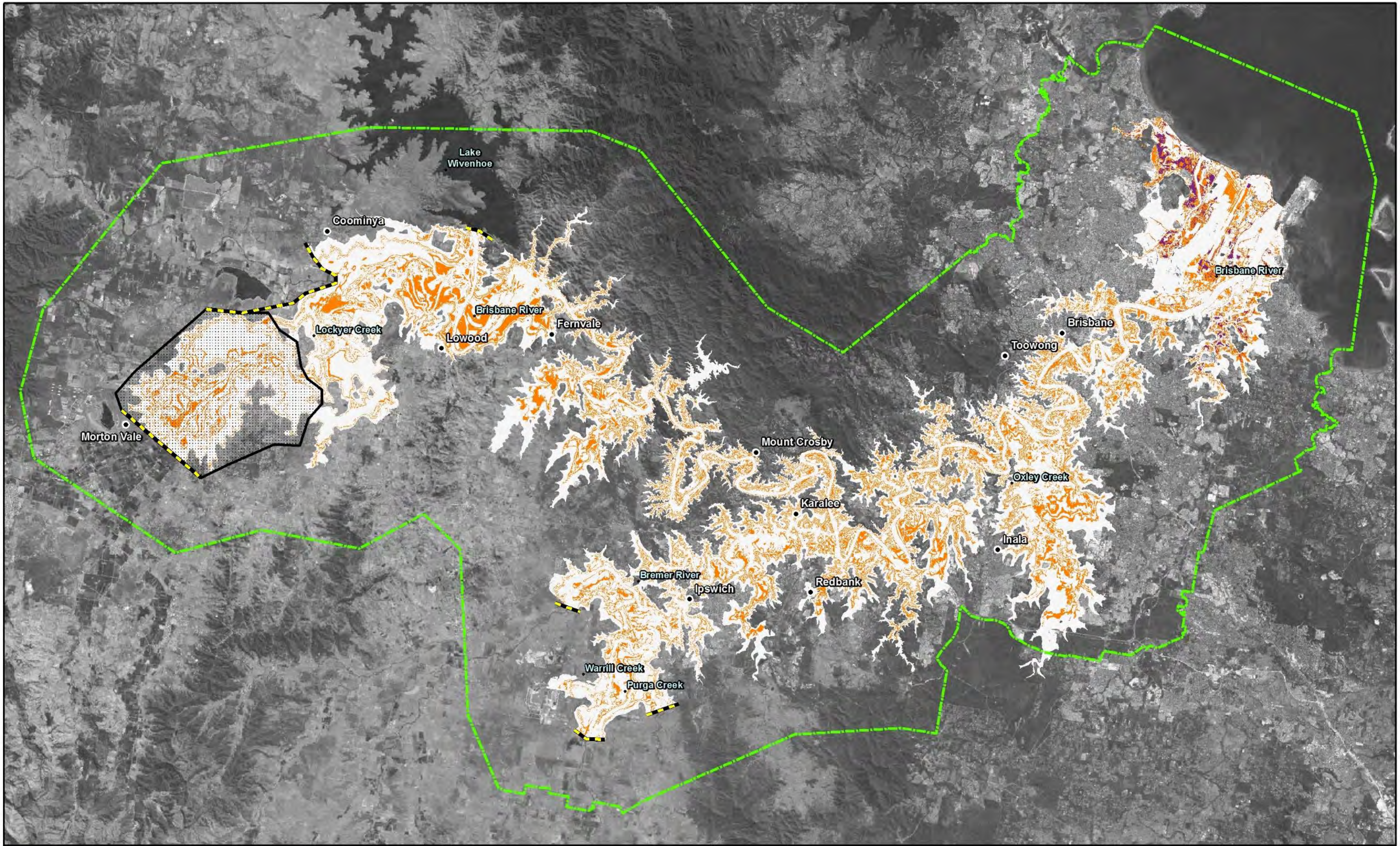
Table 5-6 Area of Floodplain in Potential Hydraulic Risk Categories: Base Case and Climate Change Scenarios

	Area by Potential Hydraulic Risk Category (km^2)				
	HR1	**HR2**	**HR3**	**HR4**	**HR5**
Base Case	210	111	114	100	314
CC2	241	142	97	96	307
CC4	288	149	91	90	293
CC5	252	142	97	95	299

Figure 5-9 to Figure 5-11 present maps showing change in potential hydraulic risk for the three assessed climate change scenarios.

5.2.5 Summary of Climate Change Impact on Flooding

It can be seen from the maps showing changes in peak level and the tabulated values of change in peak level (refer Appendix F), that flood levels in the Brisbane River catchment are very sensitive to changes in rainfall and hence catchment inflow. This is essentially due to the incised nature of much of the river valley with limited floodplains resulting in a containment of flow pushing flood levels up rather than out onto additional floodplain. The maximum increases in peak flood level occur under scenario CC4 and are mostly affected by an increase in rainfall of 20%. In Brisbane and Ipswich CBDs, this would increase the baseline 1 in 100 AEP levels by around 2.5m with increases approaching 4m near the Brisbane /Bremer confluence and well over 4m on parts of the Brisbane River downstream of Wivenhoe Dam (e.g. Fernvale). The increases in flood depth drive increases in potential hydraulic risk.



LEGEND

- Limit of Detailed Modelling
- Study Area Boundary
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

Change in Flood Risk

- Increase in Flood Risk
- No change in Flood Risk
- Decrease in Flood Risk

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Change in Hydraulic Risk for CC2 Scenario

0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

Fig 5-9 A

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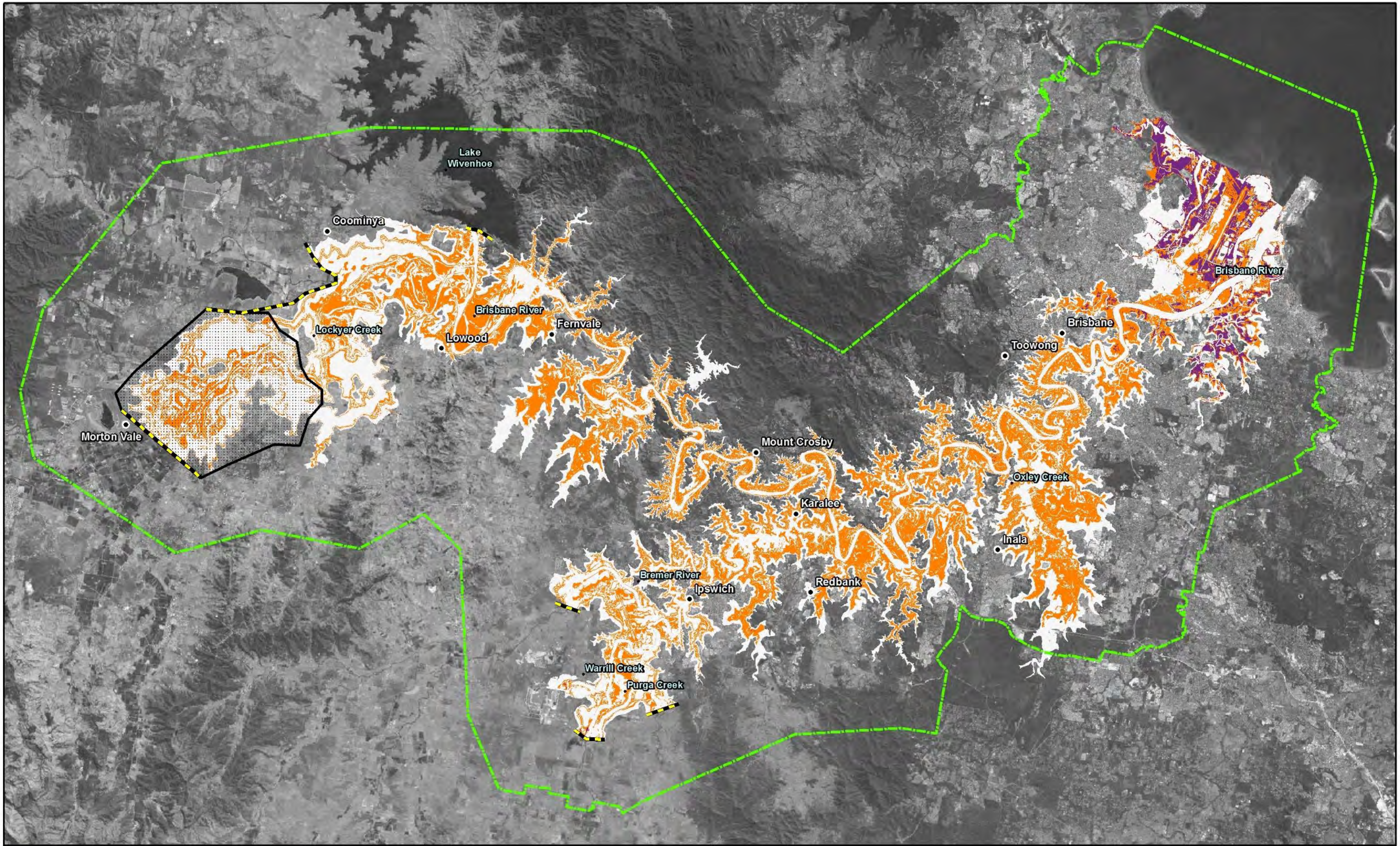

LEGEND

- Limit of Detailed Modelling
- Study Area Boundary
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

Change in Flood Risk

- Increase in Flood Risk
- No change in Flood Risk
- Decrease in Flood Risk

Brisbane River Catchment Flood Study

Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Change in Hydraulic Risk for CC4 Scenario

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

Fig 5-10 A

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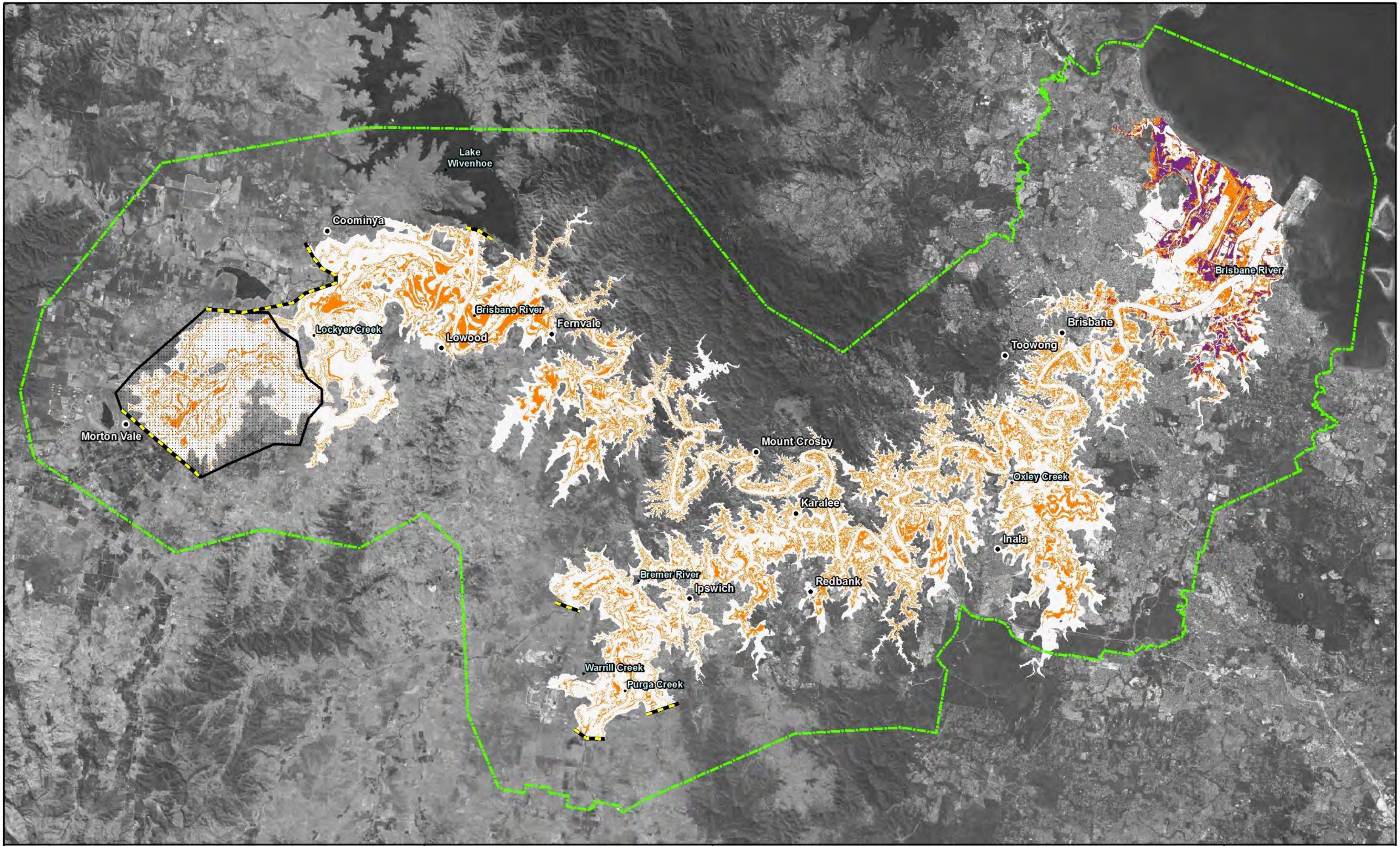

LEGEND

- Limit of Detailed Modelling
- Study Area Boundary
- Flooding in hatched area needs to be verified with the Local Council

Refer to Councils for local flooding beyond limit

Change in Flood Risk

- Increase in Flood Risk
- No change in Flood Risk
- Decrease in Flood Risk

Brisbane River Catchment Flood Study

Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Change in Hydraulic Risk for CC5 Scenario

0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

Filepath : B:\B22374 BRCFMS\GIS\MXD\MXD_OUTPUT\CC5\Change in Flood Risk\CC5-Change in Flood Risk-Study Area.mxd

Fig 5-11 A

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5.3 Limitations

5.3.1 Future Development Scenarios

Future developments may have more localised impacts on flooding which could be significant, particularly for local creek flood events. Furthermore, the development scenarios do not consider the hydrological impacts of development such as the increased runoff that might be expected from an increase in impermeable surfaces, or changes in the catchment area upstream of the study area.

The future development scenario analysis is not intended to be predictive or provide an accurate forecast of future conditions. It also does not reflect Council policies regarding filling within the 1 in 100 AEP extent. Rather, it has been undertaken principally for exploratory purposes and to understand the floodplain's sensitivity to changes in development.

5.3.2 Climate Change Sensitivity

Climate change conditions have been assessed as 'sensitivity tests' only. They do not represent specific probabilistic conditions at these future timeframes. Importantly, the scenarios adopted do not produce new equivalent AEP conditions for that scenario. For example, simulation of climate change using the events selected in the 1 in 100 AEP event ensemble will not necessarily produce the 1 in 100 AEP climate change ensemble. This is because the hydrological impact due to climate change alters the hydrograph volumes, which may have a non-linear effect on the outflow hydrograph due to dam operations. The resulting flood levels are also dependent on hydrograph volume and timing in the mainstream waterway, tributaries and local inflows. The impacts on flood levels are also not uniform across all events for each AEP at each location.

For a true probabilistic assessment of future climate change conditions, all 11,340 Monte Carlo events using the fast model would need to be re-run with the altered rainfall and sea level rise conditions, and then repeat the specific event selection process using Total Probability Theorem analysis to produce new AEP event ensembles (as described in the Phase 2 (Flood Study)). It was agreed by stakeholders that to meet the objectives of this Phase 3 (SFMP), this higher level statistical analysis of hydrology modelling results was not necessary.

The results of the climate change assessment therefore need to be interpreted with caution, however they can be considered to provide an indication of the sensitivity of the various parts of the floodplain to future increases in rainfall and sea level.

6 Flood Damages Assessment

6.1 Overview

6.1.1 General

The Phase 3 (SFMP) has established a framework to assess tangible (direct and indirect) damages, as well as intangible damages, associated with flooding in the study area for both current and future catchment conditions (as described in Sections 4 and 5 respectively). This has been based on an extensive literature review to establish current best practice in flood damage estimation.

This flood damage assessment framework was used to estimate flood damages to residential, commercial and industrial properties, and public infrastructure, as well as intangible damages associated with Brisbane River flooding across the full range of flood events.. The average annual damages (AAD) in the study area have also been estimated. All damage values presented in this report are in 2017 dollars (as at June 2017).

6.1.2 Types of Flood Damage

Figure 6-1 shows various commonly recognised types of flood damage, which can be divided into two major types:

- Tangible damages; and
- Intangible damages.

6.1.2.1 Tangible Damage

Tangible damage can be incurred by both urban and rural properties, as well as infrastructure, and are classed as either direct or indirect. Direct damage is the loss in value of an object or a piece of property caused by direct contact with floodwaters. Indirect damage is the loss in production or revenue, the loss of wages, additional accommodation and living expenses and any other additional expenditure that occurs as a consequence of a flood. Indirect costs are typically incurred during a flood event and in the post-flood recovery phase.

6.1.2.1.1 Direct Damage

Direct damage on a property can be incurred either as a replacement cost if a flood-damaged item is discarded, a repair cost if the item is repaired, or a loss in value if the item is neither discarded nor repaired. Direct damage is normally divided into three categories: ‘internal’, ’external’ and ‘structural’ damage.

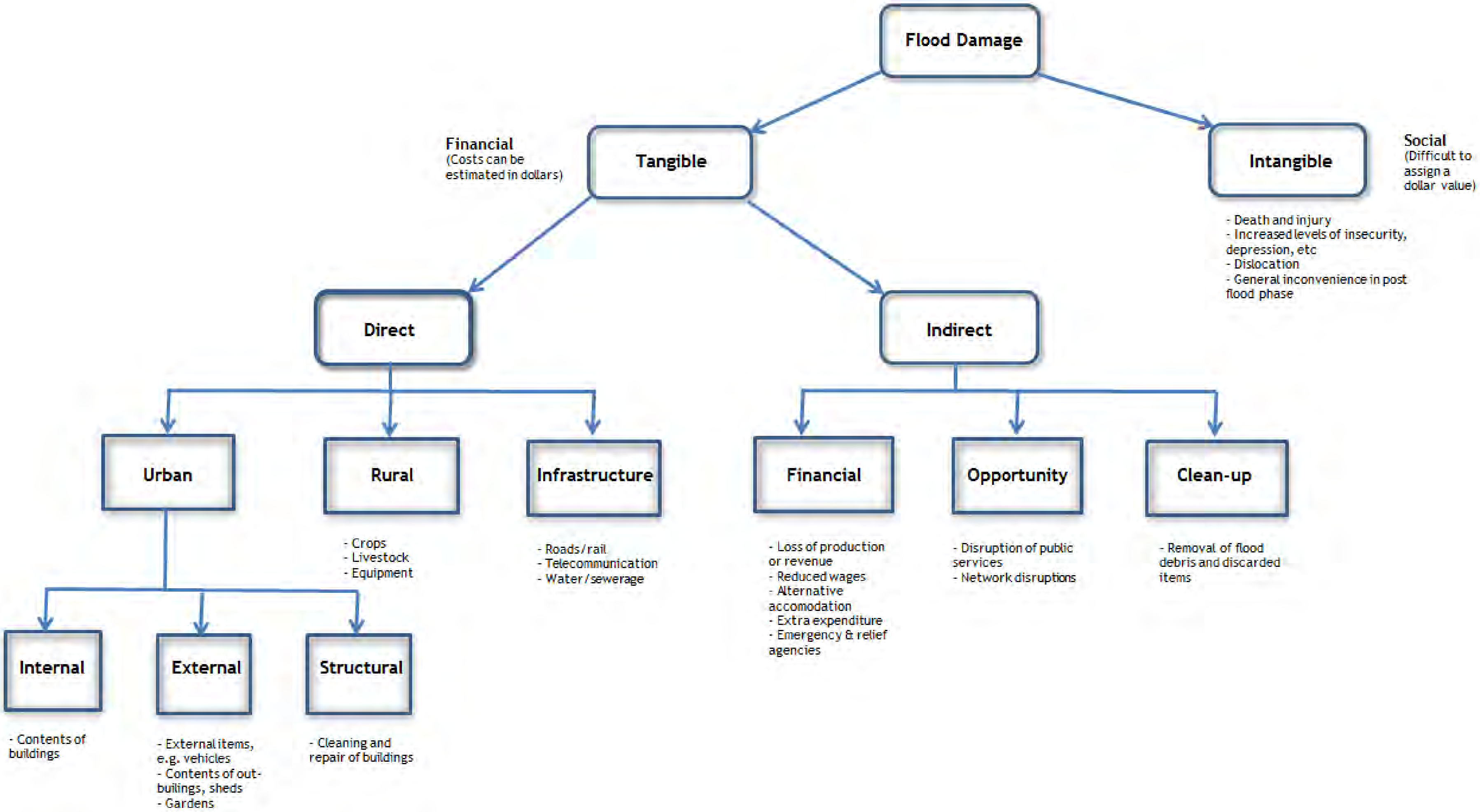


Figure 6-1 Types of flood damage

- Internal damage refers to damage to the contents of the main building(s) on a property;
- External damage refers to damage to items external to the main building (motor vehicles, fences, gardens, the contents of sheds or outbuildings, etc.); and
- Structural damage refers to the damage sustained by the fabric of a building (foundations, floors, walls, doors, windows, etc.) and the damage sustained by permanent fixtures in the building such as built-in cupboards, benches, etc.

6.1.2.1.2 Indirect Damage

Indirect damage can also be divided into three categories: financial costs, clean-up costs and opportunity costs (see Figure 6-1):

- Financial cost refers to the loss of income or increased expenditure caused by a flood;
- Clean-up costs refer to the cost of labour and materials required to clean out a flooded property; and
- Opportunity costs arise from direct damage to public assets. Because of this damage, a period elapses when the public is not provided with some services or is provided with a reduced level of service.

6.1.2.2 Intangible Damage

Intangible damage is difficult to measure and impossible to meaningfully quantify in dollar terms. Nevertheless, it is a very real, significant and often enduring 'cost' that emerges during the recovery phase of a flood disaster. Intangible damages include the social costs of flooding and are reflected in increased levels of emotional stress, and psychological and physical illness including loss of life. Intangible damage also includes environmental, cultural and heritage losses.

6.1.2.3 Potential Versus Actual Damage

Flood damage can be estimated as potential or actual damage. Potential damage refers to the damage that would be sustained by a property if nothing was done to attempt to reduce this damage, i.e. the damage that would occur if the occupants were absent when the flood occurred. The actual damage sustained by a property is normally always less than the potential damage. Notwithstanding the shortness or absence of flood warnings, people will attempt to save items by lifting them onto benches or shelves, by shifting motor vehicles, by evacuating their possessions, etc.

Potential and actual damage costs are generally the same for structural damage, as it is generally impossible to reduce structural damage to buildings at the onset of a flood except perhaps in some instances where property owners employ temporary flood mitigation measures such as sand bagging and demountable defences.

6.1.3 Average Annual Damage

Over a long period of time, a flood liable community will be subject to a succession of floods. In many years, no floods may occur or the floods may be too small to cause damage. In some years, the floods will be large enough to cause damage, but the damage will generally be small because the floods are of small to medium size. On rare occasions, major floods will occur and cause great damage.

The average annual damage (AAD) is equal to the total damage caused by all floods over a long period of time divided by the number of years in that period (assuming that the population and development does not change over the period of analysis). The AAD can also be viewed simply as the amount of money that would need to be set aside each year on a recurring basis to cover the cost of flood damage over a long period of time (i.e. equivalent to an insurance premium). By estimating the damage caused by floods of different severity, e.g. the 1 in 2 up to the 1 in 100,000 AEP flood events in the study area, it is possible to combine the likelihood of a flood occurring with the damage it causes and so estimate the AAD (DIPNR, 2005).

6.2 Literature Review

6.2.1 Tangible Damage

6.2.1.1 Overview

Flood damage estimates are generally used by floodplain managers to assess benefit/cost ratios of different flood mitigation options. Therefore, any estimates of flood damage should be reliable and as accurate as possible for the purpose they are used.

Current Australian and international literature was reviewed to assess best practice on tangible flood damage estimation. The review included an assessment of existing flood stage-damage curves for residential and non-residential property types and public infrastructure to assess their relevance and appropriateness for use in this study.

Recent developments in flood damage estimation in Australia and overseas, including Europe and USA, are discussed in a number of publications (e.g. Meyer and Messner, 2005; Penning-Rowsell *et al*., 2005, Merz *et al*., 2010; Jongman *et al*., 2012; Hammond *et al*., 2014). The literature shows that there is no common methodology that is applied to estimate flood damage internationally (Hammond *et al*., 2014). Often, simple approaches are used, mainly due to limitations in available data and knowledge on damage mechanisms (Merz *et al*., 2010).

The review has shown that there are significant gaps in existing data and information in relation to flood damage estimation, and in particular flood stage-damage curves for different types of floodprone properties in South East Queensland. Although some work has recently being undertaken in Australia (see Section 6.2.1.5), there are no up-to-date stage-damage curves at present in a form suitable for use in flood damage assessment in South East Queensland.

6.2.1.2 Factors Affecting Flood Damage

Many factors affect flood damage (e.g. depth of flooding, flow velocity, duration of flooding, time of occurrence, debris/sediment loads, water quality). Very little guidance and information is available on how to take the relevant factors other than depth of flooding into account when estimating flood damage.

In most studies, flood damages are related to only the depth of flooding because the other factors are heterogeneous in space and time, difficult to predict, and there is limited information on their quantitative effects (Merz *et al*., 2010). The flood damage estimates in this study also are related to only the depth of flooding.

6.2.1.3 Stage-Damage Curves

Flood stage-damage curves, which relate the depth of flooding at a property to the cost of flood damage, are an important tool for floodplain managers to estimate flood damage costs and assess benefit/cost ratios of different flood mitigation options. They also assist insurers to assess their flood insurance exposure costs. Accurate flood damage estimates cannot be made without flood stage-damage curves that are representative and relevant.

Stage-damage curves currently being used in Australia are based on assessments of property characteristics, building materials, labour costs, and contents and their repair/replacement costs that are at least 15 to 20 years old. These valuations are not considered representative of the type of buildings and contents in Australia today due to changes in construction materials, typical household contents and other factors.

The replacement value of flood exposed items or repair costs of assets vary from geographical area to area. Further, items and values change with time making the use of old stage-damage curves questionable. To obtain reliable results, stage-damage curves should be regularly updated.

In most studies, available stage-damage data are adjusted to bring flood damage costs to present day dollar values. While inflation can be corrected by price indices (Consumer Price Index (CPI), Average Weekly Earnings (AWE), etc.), other changes in time can only be absorbed by regular updates of the stage-damage curves. Variation across geographical areas also occurs because the same object type has a different asset value in one area than in another due to regional specifications or differences in material costs, wages, etc. The variation is normally taken into account by the use of regional or local data instead of national data.

For reasons discussed above, stage-damage curves are strongly influenced by the area for which they have been derived. Locally representative curves are required for each geographical area because of varying socio-economic conditions, building styles and ages, materials, etc. across different geographical areas.

6.2.1.4 Australian Guidelines

There are no published Australian national guidelines for the selection and use of stage-damage curves for flood damage estimation studies. The Queensland Department of Natural Resources and Mines (DNRM) published a set of guidelines for flood damage estimation in 2002 (DNRM, 2002). These guidelines strongly recommend that local authorities in Queensland, where possible, develop their own stage-damage curves (for local conditions and building types). NSW Department of Environment & Climate Change (DECC) published a set of guidelines for flood damage estimation in 2007 (DECC, 2007). These guidelines do not attempt to provide a methodology for definitive assessment of flood damages but instead provide a consistent basis for calculation and comparison of flood damages between different flood mitigation projects in NSW. In addition, the Victorian Department of Natural Resources and Environment has developed guidelines for a rapid appraisal of flood damages on a regional basis in 2000 (VDNRE, 2000). These guidelines have not been updated since their original publication. They are now outdated and are not representative of flood damage that would be experienced today.

6.2.1.5 Recent Work in Australia on Stage-Damage Curves

6.2.1.5.1 Residential Curves

General

Following the major floods in Queensland in 2010 and 2011, Geoscience Australia (GA) and Queensland Reconstruction Authority (QRA) conducted flood damage surveys. However, the GA and QRA surveys had been designed to gather data for flood damage exposure assessment purposes rather than for the estimation of the monetary values of flood damage or derivation of stage-damage curves. Therefore, these surveys have not collected data on potential or actual flood damage at the surveyed properties. Various research projects (e.g. Mason *et al*., 2013, Hasanzadeh *et al*., 2016) have subsequently attempted to use the data gathered by GA and QRA to develop new residential stage-damage curves for different parts of the country. In South East Queensland, O2 Environmental (O2), commissioned by Ipswich City Council (ICC), reviewed and attempted to update stage-damage curves that were previously used for Ipswich City by WRM Water & Environment (O2, 2012).

Geoscience Australia

GA undertook a major flood damage assessment survey across the flood-affected areas of Brisbane, Ipswich and Grantham soon after the January 2011 Brisbane River flood. The objective of the survey was to collect information on the impact of flooding for a representative portion of residential buildings affected by slow rising and flash flooding. Flood impacts at 817 buildings (514 in Brisbane suburbs and 265 in Ipswich and 38 in Grantham) were surveyed (Mason *et al*., 2013).

The survey collected information by visual observation of damaged buildings from the street, by internal and external inspections including some interviews with property owners or occupants (where possible) and follow up postal surveys. The survey collected building attribute data such as building type, size and age, building material, etc. and flood impact data such as extent of damage, floor height above ground level and maximum depth of flooding (where possible), etc. Since the survey was not a flood damage survey they did not estimate damage cost to each of the properties surveyed. However, GA collected some flood damage estimates via their follow up postal surveys.

GA identified a set of 11 ‘generic’ residential building types in South East Queensland based on building sub-elements of foundation type, floor type, roof type and attributes of age, fit-out quality, height, floor, building material, etc. (Wehner, 2012, Maqsood *et al*., 2014). Based on photographs provided by GA identifying their different typical building types, the 11 building types defined for South East Queensland can be grouped into four broad fully-detached residential building categories, namely single storey (on stumps), single storey (on slab foundation), highset and double storey buildings. The GA building types do not include semi-detached and non-detached buildings.

GA have derived potential internal and structural stage-damage curves for each of their 11 generic building types, but not external stage-damage curves.

The GA stage-damage curves are presented as relative damage curves in the form of Damage Index (ratio of repair to total replacement cost) vs Depth of Flooding (DOF) above floor level (Maqsood, *et al.*, 2014). Total replacement cost values (in dollars) per unit floor area and the floor area of the building for each building type, which are not readily available for others to use, are required to convert the Damage Index values to absolute dollar damage values.

The available GA residential stage-damage curves are discussed further and compared with the stage-damage curves used in this study in Section 6.6.

Queensland Reconstruction Authority

Queensland Fire and Emergency Services (QFES) on behalf of QRA collected flood damage assessment data in the Brisbane and Ipswich areas immediately after the January 2011 Brisbane River flood. They also collected data in Roma after the February 2012 flood and Bundaberg after the January 2013 flood.

The above data was collected using QFRS's Rapid Damage Assessment (RDA) methodology and the datasets were compiled soon after the above floods to rapidly provide information on damage to housing, infrastructure and property to support disaster declaration, response and recovery decisions. RDA data was collected for 5,221 properties in Brisbane suburbs and 678 in Ipswich, 592 properties in Bundaberg and 150 properties in Roma (Mason *et al.*, 2013; Simon Dorrington, Queensland Reconstruction Authority, pers. comm., May 2016).

The data collected by QRA include building type, type of construction, approximate depth of flooding and level of flood damage (qualitative). Given the nature of rapid acquisition of the data, the level of detail and accuracy in each record is less than that found in the GA survey.

National Climate Change Adaptation Research Facility

The National Climate Change Adaptation Research Facility (NCCARF) have derived a set of flood stage-damage curves for typical residential building types in Australia (Mason *et al*., 2013) based on the flood damage data sets collected by GA (for Brisbane, Ipswich and Grantham) and QRA (for Bundaberg and Roma), together with insurance loss data for these areas obtained from an unnamed major insurer.

NCCARF simplified the 11 GA curves to four by grouping building types (fully-detached single storey (on stumps), single storey (on slab foundation), highset and double storey) and then adjusting the GA damage curves to produce actual damage curves based on their interpretation of insurance loss data. The adjustments were reported to have taken into account perceived response of Brisbane/Ipswich residents to flood warnings and evacuation, and resident behaviour during flood events.

NCCARF had only limited insurance loss data to separate building and contents damages. Therefore, their adjusted curves are derived for total damages (building plus contents) rather than separate curves for building and contents. Structural (building) and internal (contents) damages are presented as a proportion of their total combined damage value to represent mean expected losses. Similar to GA, the four stage-damage curves produced by NCCARF were relative damage curves. NCCARF also have not estimated external stage-damage curves.

NCCARF used a subset of QRA data to validate their adjusted stage-damage curves. In using this data NCCARF has acknowledged that there are significant uncertainties in the various data sets. For example, depth of flooding above floor level was a source of uncertainty because some depth values have been recorded above floor level and others above ground level without making a distinction. Also, the QRA depth values were estimates of depth of flooding ranges rather than absolute depth values. In some instances, NCCARF found significant differences between depths of flooding recorded in the GA and QRA databases for the same property, possibly due to the above reason.

O2 Environmental

In 2011, O2 reviewed the then available stage-damage curves for use in flood damage estimation studies ICC were undertaking at that time (O2, 2012). O2 reviewed available information, including DNRM (2002) and DECC (2007) guidelines, ANUFLOOD (CRES, 1992) stage-damage curves and the stage-damage curves WRM Water & Environment had developed for Maroochy Shire Council (MSC) and ICC in 2006 (WRM, 2006a,b).

O2 found that residential construction has changed significantly in the 30 years since ANUFLOOD curves recommended in DNRM (2002) were developed. O2 also found that updating old curves only for Consumer Price Index (CPI) increase led to significant underestimation of current flood damages, and that the residential stage-damage curves in Ipswich City should not be estimated using the old curves. In the absence of better data, O2 developed a set of interim curves, modifying the old curves based on a desktop study, for use in Ipswich City until more appropriate curves became available.

O2 derived potential stage-damage curves for five types of residential properties in Ipswich City, namely detached single storey lowset, single storey highset and two storey houses, and semi and non-detached single and double storey units as follows:

- For internal damages, the WRM (2006b) curves were adjusted to reflect average house contents insurance cover in Ipswich (assuming $80,000 average cover for detached buildings and $60,000 average cover for units in 2011 dollars). The maximum possible contents damage using these curves for detached houses was limited to $80,000 and for semi-detached and non-detached units was limited to $60,000.
- For external damages, the WRM (2006b) curves were updated for CPI increases.
- For structural damages, new curves were estimated using reconstruction/renovation costs (as given by Cordell's online cost estimating). Damages were estimated for single storey (brick and tile) houses of 150 m^2 and 200 m^2 floor area and double storey houses of 300 m^2 floor area.

The O2 residential stage-damage curves are discussed further and compared with the stage-damage curves used in this study in Section 6.6.

Insurance Companies

It is understood that the Insurance Council of Australia (ICA) and major Insurance companies have undertaken considerable work on developing stage-damage curves for residential properties around Australia for both buildings and contents damage following the 2010 and 2011 floods. This data has not been available for review in this study.

Other Recent Work

Hasanzadeh *et al*. (2016) have derived a set of stage-damage curves for four types of residential buildings using QRA's RDA data set for Bundaberg and Roma. The focus of their work was on direct damage to residential structures. For each building type, Hasanzadeh *et al*. (2016) have derived potential stage-damage curves using the inventory method (see Section 6.2.1.6.1). Their investigations did not include internal (contents) or external damage to properties. Further, Hasanzadeh *et al.* (2016) curves are based on indicative flood damage data rather than accurate data. In the absence of accurate data, they had to make significant assumptions and judgements on the depth of flooding and percentage damage data at each of their sample properties.

Risk Frontiers have developed structural stage-damage curves for use by some of their insurance and reinsurance clients for three broad residential property types (single storey, double storey and highset) with variations for different building styles, sizes and foundation types. Their work has not been published (Ryan Crompton, Risk Frontiers, pers. comm., May 2016).

6.2.1.5.2 Non-Residential Curves

Although commercial, industrial, public infrastructure and utility damage can be a significant component of overall urban flood damage, little work (as compared to residential damages) has been done to date to obtain reliable stage-damage curves for these property damage types. It appears that no detailed field investigations on commercial and industrial damage estimates (except for some limited work currently being undertaken by GA) have been undertaken in Australia since the early 1990's and most studies continue to use stage-damage curves based on limited data from floods in the 1970s and 1980s. Commercial and industrial premises have changed much since the 1970s and 1980s, particularly with changes in technology as well as changes to the industries that occupy commercial and industrial space.

Little or no work (again, except for some limited work currently being undertaken by GA) has been done to obtain reliable stage-damage curves for public and community owned infrastructure and assets since the 1970s and 1980s.

6.2.1.5.3 Gaps in Existing Data and Information

Reliability of flood damage estimates is strongly dependent on the representativeness of the selected stage-damage curves, in addition to the quality of the available topographic data, flood modelling results, property land use and floor level data, etc. Although stage-damage curves are internationally accepted as the standard approach to assess urban flood damage (Middlemann-Fernandes, 2010; Mason, *et al*., 2013), there are relatively few published accounts that give full details of the methodology for their derivation or their application (Hasanzadeh *et al*., 2016). Based on information available for review, there are significant gaps in existing data and information in relation to flood damage estimation, and in particular stage-damage curves for different types of floodprone properties.

To use stage-damage curves accurately, it is important to understand how they have been derived, and any limitations in the data used to derive them. Different studies have used different terminology, definitions, inclusions/exclusions, etc. for specific stage-damage curves. This is a significant issue especially when comparing data and information provided by insurance companies, researchers and consultants. Consistency is required in the terminology and definitions used, and what is included and what is excluded in the different types of stage-damage curves that have been derived.

Recent work undertaken by different groups is of limited scope and does not cover the full spectrum of property types and damage types in the Phase 3 (SFMP) study area. For example, GA work covers only a limited range of residential property types and their stage-damage curves are only for internal and structural damages. Similarly, NCCARF work is only for a limited range of residential property types and only for total damages (excluding external damages). Hasanzadeh *et al*. work is also limited to a few residential property types and only structural stage-damage curves. All of these studies have developed relative damage curves rather than absolute damage curves. If relative damage curves are to be used for any future studies in the Phase 3 (SFMP) study area, the replacement value of the contents and the particular building type has to be estimated to convert the relative damage to an absolute monetary (dollar) value for each property type investigated. None of these studies have published estimates of replacement (dollar) values they used to derive their relative stage-damage curves.

The emphasis of recent studies has been limited to deriving stage-damage curves for a few key types of residential properties. There is very little reliable data on flood damage to commercial, industrial and public properties and public infrastructure. The stage-damage curves used for non-residential properties do not appear to have been put under the same level of scrutiny as residential stage-damage curves. There is very little information on how available stage-damage curves have been derived and validated.

In addition to the depth of inundation, many other factors affect flood damage (e.g. velocity, mud/sediment deposition, duration of inundation and time of occurrence). Most of these factors are not taken into account in standard stage-damage curves used in most studies. Very little guidance and information is available on how to take these factors into account, if they are relevant for a particular floodplain.

6.2.1.6 Property Damage Estimation

6.2.1.6.1 Potential Residential Damage

There are two types of stage-damage curves, namely, actual damage curves and potential damage curves. Actual damage curves are usually derived by undertaking detailed surveys of flood damaged properties soon after a flood event. Actual damage curves are influenced by the characteristics of the specific flood event and local factors (such as available flood warning time, varying levels of flood awareness and preparation, insurance cover, etc.). Actual damage curves are not easily transportable from one floodplain to another due to local factors affecting both the flood characteristics and property characterisations. Therefore, most flood damage assessments are undertaken based on potential damage curves.

Potential stage-damage curves are also sometimes referred to as synthetic stage-damage curves. Potential damage curves do not rely on information from actual flood events but are based on hypothetical analyses. Potential damage curves are normally derived via a 'valuation survey' method or an 'inventory' method (Smith, 1994).

In the 'valuation survey' method, detailed surveys are undertaken by a quantity surveyor of the different types of properties at risk in the study area. The surveyor would select a representative sample of properties of each designated type and have a comprehensive check list of possible contents, usually by type of room (bedroom, lounge, dining room, kitchen, bathroom, etc.). For each property, the valuer would note all items and their current value based on type, quality and degree of wear, and the height above floor that each item is stored. The information collected for the sample of each property type is then processed to derive a representative stage-damage curve for the particular property type and for 'internal', 'structural' and 'external' damages. The accuracy and representativeness of the derived stage-damage curve would increase with increasing sample sizes of the properties surveyed for each designated property type and building category.

When using the 'inventory' method, a quantity surveyor (valuer) would first identify and select a set of representative property types from a property characterisation survey or existing property databases. Then, for each property type, the valuer would develop an inventory of contents found in a 'typical' property of the selected type, and identify (assume) details of the fabric and contents of a typical building of the selected type. The building and contents inventory data are then allocated by depth of flooding to quantify potential damage at different inundation depths to derive a representative stage-damage curve for that property type and for internal (contents) and structural (building) damage. External (sheds and items stored therein, garages, vehicles, fences, etc.) damages do not appear to be taken into account under this method.

Potential stage-damage curves can be presented as 'absolute' damage or 'relative' damage curves. Absolute damage curves express the magnitude of damages at different inundation depths in monetary values (i.e. dollar amounts), while relative damage curves express the magnitude of damages at different inundation depths as a percentage of the total replacement value (i.e. replacement cost of all contents or the full structure). If relative damage curves are used, the replacement value of the contents and the particular building type (dollars per unit floor area and the floor area of the building) should be known to convert the relative damage to a monetary (dollar) value.

In this study, new potential stage-damage curves have been developed for the Phase 3 (SFMP) study area from a property damage survey that was undertaken using the valuation survey method as described in Section 6.5.

6.2.1.6.2 Potential Commercial and Industrial Damage

For commercial and industrial properties, the internal damages can vary significantly depending on variables such as size of building, value of plant and equipment, amount of stock kept on premises, and the ability of occupiers to respond efficiently to flood warnings. External damages also can vary significantly from enterprise to enterprise. In contrast, damage to building structure is less variable for both commercial and industrial buildings. Since both commercial and industrial buildings share common attributes with respect to flood damage, stage-damage curves for commercial and industrial properties are often combined.

In Australia, commercial and industrial property damage estimation models (e.g. ANUFLOOD, RAM) are generally based on depth of flooding and the size of the enterprise, whereas, some of the international models also consider other factors such as susceptibility, warning time, flood experience, flood duration, business sector, object value, etc. (Merz *et al*., 2010). In the USA, FEMA distinguishes 16 main company classes with several sub-classes for damages to buildings for flood damage estimation. The Rapid Appraisal Method (RAM) in Australia outlined in VDNRE (2000) differentiates companies only by size (i.e. smaller or larger than 1000 m^2).

DNRM (2002) guidelines recommend the adoption of ANUFLOOD (CRES, 1992) curves for a range of commercial enterprise types and building sizes. In the ANUFLOOD methodology, commercial enterprises are classified by size and by value class. There are three size classes. 'Small' (<186 m^2) corresponds to the average main street shop and 'medium' (186 to 650 m^2) to a small supermarket. For larger premises the actual area (in m^2) is recorded. Each commercial building is given a value class that indicates the susceptibility of contents to flood damage. These are in the range of 1 (very low) to 5 (very high).

One of the difficulties with standardised synthetic stage-damage curves for commercial and industrial properties is that premises within one classification can exhibit large variations. An example given by Smith (1994) is that a women's dress shop can vary from a fashion house with a small number of highly priced items to an outlet with many hundreds of dresses. The damage to the latter, per m^2, would be much higher. The allocation of value class during the field survey goes some way to overcome this problem. ANUFLOOD used the Australian New Zealand Standard Industrial Classification codes for all buildings in the commercial sector.

It is noted that for large buildings, the damage curves currently available may provide very large damage estimates and these very large values could distort overall damage estimates for the floodplain investigated. Therefore, damage assessment using stage-damage curves is inappropriate for large commercial enterprises and industrial plants and they should be analysed using questionnaires (Smith, 1994). If it is possible, flood damage for very large commercial and industrial properties should always be assessed individually on a case by case basis.

Of the available stage-damage curves, ANUFLOOD curves appear to have the widest level of acceptability in recent studies in Australia. In addition, these curves have been recommended for use in flood damage studies undertaken in Queensland (DNRM, 2002). Therefore, the commercial stage-damage curves available for the Phase 3 (SFMP) study area have updated based on a property damage survey using the ANUFLOOD methodology as described in Section 6.6.3. In the absence of better information, commercial damage curves are also applied in this study for industrial properties.

6.2.1.6.3 Actual Damage

Actual property damage incurred during a flood is usually less than the potential damage and the ratio of actual to potential damage generally increases with flood depth. The amount by which the actual damage is less than potential is dependent upon the level of flood awareness of the community (i.e. flood preparedness), the available flood warning time and the ability of the residents to effectively save their goods and possessions (i.e. depth of flooding). Under certain flood situations, the third factor is the most important in determining the actual internal damage, irrespective of whether or not flood warnings were issued. For example, residents can do very little to keep their possessions safe from flood damage during a severe flood event causing deep flooding (say, >1.5 m) compared to a minor flood event causing shallow flooding (say, <0.2 m). This means that the ratio of actual to potential (A/P) flood damage for a given location may vary depending on the severity of the flood event.

The available literature shows three different approaches to estimate the actual damage from potential damage (WRM, 2006a):

(1) Vary the A/P ratio depending on property type and damage type (i.e. internal, external, structural) and available warning time and level of flood awareness. With this approach, A/P ratios used for residential properties are usually different to non-residential properties A/P ratios. Further, the A/P ratios for internal, external and structural damages are also different.

(2) Vary the A/P ratio depending on the depth of flooding and on available warning time and level of flood awareness. With this approach, A/P ratios are applied to the total direct damage value, irrespective of the property type and damage type, but separately to each property to account for variations in the depth of flooding.

(3) A constant A/P ratio is applied to the cumulative (i.e. total) direct damage for the study area investigated. With this approach, the adopted A/P ratio is dependent only on available warning time and level of flood awareness.

With regards to the three approaches described above:

- The first approach requires a greater effort because the ratios have to be applied separately to internal, external and structural damages and to different property types.
- The second approach is less rigorous but requires a family of A/P ratio curves for different flood depths.
- The third approach is the most simple and easiest to use, but its simplistic nature may lead to more inaccurate results.

There are a wide range of A/P ratios used in Australian flood damage estimation studies depending on the expected warning times and the community's flood experience. The curves (solid lines) in Figure 6-2 show the ratios of actual to potential direct damages recommended in DNRM (2002) for flood experienced and inexperienced communities. These curves have been developed for use in the RAM by VDNRE (2000) after analysing actual flood damage data collected by various surveys in Victoria and NSW. Figure 6-2 also shows ratios estimated for 11 Australian floods by Read Sturgess and Associates (2000) for the development of the RAM (VDNRE, 2000) guidelines (Mason *et al.*, 2012).

There is very little data in the literature on A/P ratios for non-residential properties. Limited data presented in Water Studies (1992) suggest that A/P ratios for commercial properties are similar to equivalent residential properties, but A/P ratios for industrial and public properties are higher than for equivalent residential properties.

The approach adopted in this study to estimate actual damages is described in Section 6.7.1.2.1.

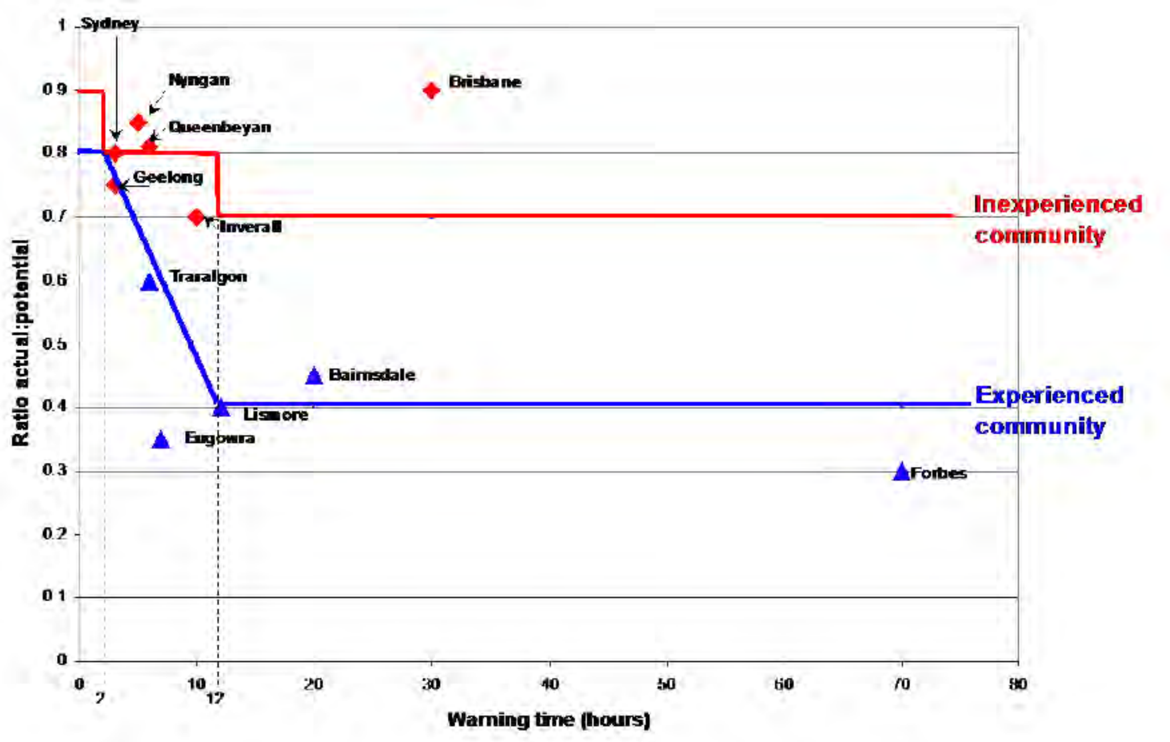


Figure 6-2 Ratio of actual to potential damage (A/P) (source: NCCARF, 2012)

6.2.1.7 Rural/Agricultural Damage Estimation

The estimation of rural/agricultural damages can be complex, relating damage to not just to the peak flood level and value of the rural property, but also flood velocity, depth and duration of inundation as well as the time of year that the flood occurs.

There is no standard methodology to estimate agricultural flood damages (Anthi-Eirini K *et al*., 2013). For agricultural flood damage estimation, many studies use synthetic stage-damage curves derived using data from specially targeted questionnaires. Based on the completed questionnaires, stage damage curves are developed for each crop and for different crop growth phases at the time of flooding with the assistance of experienced agronomists. The reliability of any agricultural flood damage estimate is questionable, since damage models are rarely validated due to limited or missing loss data (Thieken *et al*., 2008).

The approach adopted in this study for the estimation of rural/agricultural damages is described in Section 6.7.1.2.4.

6.2.1.8 Transport Infrastructure Damage Estimation

Damage to transport infrastructure caused by flood inundation is generally considered to comprise an initial repair cost, followed by additional costs for the subsequent accelerated deterioration of the road.

Although there are established methods to estimate damage to transport infrastructure using standard costs for length units (e.g. km railway, km road) reliable data available to estimate transport infrastructure damage is limited (Merz *et al*., 2010).

In Australia, there is a methodology to estimate road and bridge damages for sealed (major and minor) and unsealed roads based on the RAM guidelines, which have been developed from actual damage caused to roads and bridges during 1993 and 1998 floods in north-east and East Gippsland regions of Victoria. These values, which have been estimated by VDNRE (2000) for use in Victorian floodplain management studies, have been recommended by DNRM (2002) for use in public infrastructure damage estimation in Queensland.

The approach adopted in this study for the estimation of transport infrastructure damage is described in Section 6.7.1.2.2.

6.2.1.9 Public and Community Owned Buildings and Assets Damage Estimation

Public and community owned buildings and assets include:

- Hospitals, schools, police and fire stations, and other government owned buildings;
- Telecommunication, electricity, water supply, sewerage and stormwater drainage systems;
- Cemeteries, swimming pools, car parks, etc.;
- Ferry terminals, boat ramps, boardwalks, wharves, jetties, etc.,
- Parks, playgrounds and recreational facilities; and
- Sporting arenas.

The damages for the above type of buildings and assets vary significantly depending on variables such as size of building or facility, value of plant and equipment and the ability of occupiers to respond efficiently to flood warnings. Little or no work has been done to obtain reliable stage-damage curves for public and community owned buildings and assets since the 1970s and 1980s. Ideally, damage to these properties should be estimated on a case by case basis.

The approach adopted in this study for the estimation of public and community buildings and assets damage is described in Section 6.7.1.2.3.

6.2.1.10 Indirect Damage Estimation

The indirect damage is the sum of clean up, financial and opportunity costs associated with a flood event. The clean-up and financial costs are applicable to all property types but the opportunity cost normally applies only to non-residential properties.

The literature refers to techniques that range from simple empirical methods (derived from post-event surveys) to detailed econometric models to estimate indirect damages. Most studies, justified for practical reasons, appear to use simple empirical methods that assume indirect damage could be estimated as a fixed proportion of the estimated direct damage (Hammond *et al*., 2014).

Traditionally indirect losses, essentially due to disruption caused by the flooding rather than the ‘direct’ effects of flood waters, have been estimated in Australia as a fixed proportion of direct damages. Based on previous studies, the most difficult category to assess is the cost of clean-up and services recovery. There is considerable variation both in the estimates of the time required and in how the time should be costed (Water Studies, 1992). The opportunity costs are also difficult to identify and quantify because it requires a good understanding of the likely consequential chain of impacts across inter-related functioning of community and infrastructure, and estimation of the capacity and timeframe to recover impacted functioning. An example of this is the loss of water supply for power station cooling due to a pump station inundation resulting in loss of power supply for a prolonged period, even if the power station itself is not inundated. The indirect consequential impacts of services loss in more extreme floods would significantly increase indirect losses. However, the data required for such assessments is not readily available.

The most common form of expressing indirect damage is as a percentage of direct (actual) damage. This percentage could vary with the magnitude of the flood. For residential properties, the percentage applied is usually in the 15%-20% range (WRM, 2006b). For commercial properties, the adopted values range from 55% to 65%. There is little or no reported data for other property types.

Based on ANUFLOOD (CRES, 1992), DNRM (2002) recommends indirect damages for residential and commercial properties to be calculated as 15% and 55% of direct damage respectively. VDNRE (2000) recommends indirect damages to be calculated as 30% of total direct damage (i.e. combined damage to residential and non-residential buildings, agriculture and public infrastructure). However, it is noted that this rate should be varied when the characteristics of the study area suggest different rates.

The approach adopted in this study to estimate indirect damages is described in Section 6.7.1.3.

6.2.1.11 Previous Studies for the Phase 3 (SFMP) Study Area

There have been two previous flood damage studies of significance for the Phase 3 (SFMP) study area in recent years. These are the Brisbane Valley Flood Damage Minimisation Study (BVFDMS) undertaken in 2006 and the Wivenhoe and Somerset Dams Optimisation Study (WSDOS) undertaken in 2014. In addition, a significant flood damage estimation study has been undertaken in 1977 as part of an examination of the economic, financial, social and environmental effects for a report titled ‘A Comprehensive Evaluation of the Proposed Wivenhoe Dam on the Brisbane River (CEPWDBR) (Grigg, 1977). A brief description of the flood damage assessment methodology and the stage-damage curves used in BVFDMS, WSDOS and CEPWDBR is provided below.

6.2.1.11.1 Brisbane Valley Flood Damage Minimisation Study

The Brisbane Valley Flood Damage Minimisation Study (BVFDMS) undertaken by Brisbane City Council in conjunction with Ipswich City and Esk Shire Councils included an assessment of flood damages in the Phase 3 (SFMP) study area (WRM 2006b,c,d). The study estimated indicative potential flood damages in the study area in order to assess the impact of flood operation rules for the Wivenhoe Dam flood gates on downstream flood damages, and to determine whether the operation rules can be modified to reduce downstream flood damage.

BVFDMS estimated only potential tangible direct flood damage (internal, external and structural damage) to residential, commercial, industrial and public properties. For residential properties, the study used stage-damage curves that WRM Water & Environment had developed in 2006 for Maroochy Shire (WRM, 2006a). For non-residential properties, the study used ANUFLOOD (CRES, 1992) stage-damage curves adjusted for CPI increases.

6.2.1.11.2 Wivenhoe and Somerset Dams Optimisation Study

The Wivenhoe and Somerset Dams Optimisation Study (WSDOS) assessed flood damages in the Phase 3 (SFMP) study area (DEWS, 2014). This study estimated direct tangible damage to buildings (residential and non-residential), public utilities, public infrastructure (roads and bridges) and public assets, and indirect tangible damage to roads and bridges associated with clean-up, road closure and repair/reconstruction. Due to significant limitations identified in the adopted data and analysis, including the assumptions that had to be made, the damage estimates were reported only as indicative.

Based on the findings of a literature review undertaken for the WSDOS (Aurecon, 2013), WSDOS used the methodology adopted by WRM (2006b,c,d) for the BVFDMS, with simplified O2 (2012) residential and ANUFLOOD non-residential stage-damage curves, for residential and non-residential flood damage estimation. The O2 residential stage-damage curves used in the WSDOS are discussed and compared with the stage-damage curves used in this study in Section 6.6.4.5.

6.2.1.11.3 A Comprehensive Evaluation of the Proposed Wivenhoe Dam on the Brisbane River (Grigg, 1977)

The CEPWDBR investigations assessed flood damages in the Brisbane River floodplain for the level of development in the floodplain and flood damage costs that were applicable for mid-1974 conditions, Flood damages were assessed for flooding without the presence of Wivenhoe Dam, as well as for different dam design and downstream floodplain management (including development control) options.

CEPWDBR estimated only potential tangible flood damages (both direct and indirect) to residential and non-residential properties. It appears that this study used stage-damage curves specifically developed for the different property types in the study area following an extensive property damage survey similar to the survey undertaken in this study.

6.2.2 Intangible Damage

6.2.2.1 Overview

Intangible damages occur when there are impacts/costs that have no direct economic market. Thus, intangible damages are very difficult to define and value in dollar terms. This is in direct contract to Tangible Damage (refer Section 6.2.1) where costs can be estimated through direct damage or loss of productivity, revenue etc.

Definitions of intangible damage can differ from study to study. The Productivity Commission (2014, p 276) defines intangible costs as including:

- Stress, injury and loss of life; and
- Ecosystem damage.

In Aither (2014, p 33) intangible costs include:

- Physical health impacts including loss of life;
- Psychological health impacts;

- Environmental damage; and
- Loss of culture and heritage.

The Emergency Management Australia Guidelines (EMA 2002, page 41) conceptualise intangibles more broadly to include loss of life, health impacts, other personal losses (such as loss of memorabilia) disruptions to personal routine, as well as cultural, heritage and environmental losses. A recent Deloitte Access Economics report (DAE 2016, page 26) contains a yet broader definition that includes education, employment and community costs. Differing definitions of the scope of intangible costs arise firstly from the wide range of potential impacts of flooding and secondly from the lack of market information about valuations.

In economic terms, an intangible impact can be defined as any impact that the community would be willing to pay to avoid and for which there is no market valuation. Inclusion of intangibles in damages estimates is a practical matter of identifying impacts, measuring them and valuing them in monetary terms. There is no theoretical reason for excluding intangibles from damages estimates. As illustrated below, recent analysis suggests that intangible costs might be more important as contributors to total costs than has previously been thought.

The difficulties inherent in measuring and valuing intangibles are not a reason for ignoring them. BTE (2001, p 88) commented that difficulty in estimation is not a justification for ignoring intangibles and went on to say that:

> *"Even though there is an acknowledgment of the importance of intangible costs, the absence of estimates of costs often means that they are discounted in the evaluation of mitigation proposals. In that case, the analyst is implicitly assuming the intangible costs are low if not zero. Even if they are not discounted, the process of weighting the importance of different impacts involves some form of relative valuation. Therefore, there seems to be an advantage in attempting to place an estimate on the intangibles to the extent possible."*

6.2.2.2 Recent Work in Australia and Overseas

Consistent with variations in the defined scope of intangibles, estimates of their value also vary widely according to the type and size of events. A recent Environment Agency of England and Wales study (EA, 2010) when compared with the Deloitte Access Economics study of intangible costs for the 2010-11 Queensland floods and the 2009 Victorian bushfires (DAE, 2016) (see Table 6-1), also illustrates how much estimates can vary using different valuation methods (and context). The UK study estimated the cost of health and well-being impacts from a series of floods in Britain by drawing on an earlier 2004 study that concluded that affected residents would be prepared to pay GBP200 per year[8] per household to avoid the 'negative intangible, mainly health related impacts of flooding' (EA, 2010). The UK paper equated that annual willingness to pay to a capital sum (one off valuation) of GBP4,700 per household. When extrapolated to the Queensland floods estimates in Table 6-2 of 55,000 persons affected, the willingness to pay to avoid health impacts in the Queensland context would be in the vicinity of $200 million[9]. Affected residents comprised those who had been affected by a flood as those who were at risk of flooding (see Defra/EA 2004). By comparison, the DAE

[8] The willingness to pay relates to the avoidance of the impacts of flood events more severe than the range 1 in 75 year (mainly) to 1 in 200 year ARI (see UK EA, 2010, p17).
[9] Assuming a long term exchange rate of $A1 = 50 GB pence and average household size in Queensland to be 2.6 persons.

(2016) study quoted below estimated mental health costs alone of $5.9 billion for the 2010-11 Queensland floods, or about **30 times** the UK estimate.

DAE (2016) presents information indicating that intangibles may be more costly than other forms of loss with intangibles being 1.1 times tangibles in the Queensland event[10] and 1.3 times tangibles in the Victorian event.

Table 6-1 Tangible and intangible costs in DAE (2016)

	2010-2011 Queensland floods		2009 Victorian bushfires	
	$m	%	$m	%
Insured losses	$2,388	19.8%	$1,266	21.2%
Other tangible losses	$3,334	27.8%	$1,378	23.1%
Total tangibles	$5,722	47.7%	$2,644	44.4%
Total intangibles	$6,821	52.3%	$3,315	55.6%
Total all costs	$12,003	100.0%	$5,959	100.0%
Ratio intangibles to tangibles	1.10		1.30	
Ratio intangibles to total	0.52		0.56	
Ratio insured to total	0.20		0.22	

Source: Estimated from DAE (2016)

DAE (2016) compared the 2010-11 Queensland floods and the 2009 Black Saturday bushfires and estimated intangible costs as a proportion of total costs of 61% (Queensland floods) and 56% (Victorian bushfires)[11]. There is also great variation in the composition of intangibles between the two incidents. Mental health costs dominate the Queensland flood estimates but fatalities were a relatively small proportion of costs. In the Victorian bushfires fatalities and mental health issues were equal in extent. The DAE results in a broad sense mirror the impacts of the 1974 Brisbane floods. Some 14 months after that event, 23% of survey respondents said they had not recovered from their experience of the floods.

In addition, those who experience intangible loss might not have been directly affected by an event. In this respect, the Victorian Bushfires Royal Commission (2010) found that at least 1,000 people were directly affected (in organising funerals, liaising with the Coroner and other officials, cleaning up property) by the 173 fatalities that the fires caused. The DAE study did not estimate business, cultural or heritage losses, nor did it estimate intangible personal losses (particularly memorabilia). Environmental losses (Victoria only) are confined to ecosystem services. Broader ecological losses were not estimated.

The BTE (2001) commented that for natural disasters, most intangible costs occur in the residential sector. Business intangible costs (loss of confidence, loss of future contracts) are relatively small as are environment and heritage losses. Otherwise there appears to be little information available about

[10] DAE's definition appears to cover 2010-11 floods throughout Queensland as well as Cyclone Yasi. See page 33 in the DAE report.
[11] The percentages are not entirely consistent with the data presented elsewhere in the DAE report but they nonetheless serve to illustrate the point about the relative importance of intangibles.

business intangibles. Molino Stewart (2012) cite unnamed US research findings that 'approximately 30% of businesses go out of business following a natural hazard' but how this compares with the underlying rate of business failure is not stated.

Table 6-2 Breakdown of intangible costs – Queensland floods 2010-11 and Victorian bushfires 2009

Cost category	2010-2011 Queensland floods		2009 Victorian bushfires	
	Cost* ($m)	% of total intangibles	Cost* ($m)	% of total intangibles
Lifetime cost of deaths and injuries	$320	4.3%	$930	24.2%
Mental health	$5,900	79.8%	$1,000	26.0%
Risky or high intake alcohol consumption	$20	0.3%	$190	4.9%
Exacerbation of diabetes and COPD	$430	5.8%	$320	8.3%
Family violence	$720	9.7%	$990	25.8%
Short term unemployment		0.0%	$0	0.0%
Environmental (ecosystem services)**			$410	10.7%
Total	$7,390	100%	$3,840	100%
Number of fatalities	19		173	
Persons injured (est.)	300		414	
Number of people affected#	Up to 55,000		Up to 31,000	
Number of homes and businesses affected++	29,000		3,500	

*Note: * Present values in 2015 terms; ** Environmental costs of Queensland floods not estimated*

++The Victorian estimate includes houses, commercial properties and farm structures. #In both events, the most widespread impacts were mental health related, affecting 55,000 people in the 2010-11 Queensland floods and 31,000 people in the 2009 Victorian bushfires.

Source: DAE (2016, pp 33-42)

Handmer (2014), in a submission to the Productivity Commission's natural disaster funding inquiry, noted that 'estimation of intangible losses remains a major limitation of most disaster estimates…[M]emorabilia and cultural heritage are still a gap, and ecosystem services are valued as a 'service to us' rather than for their overall benefit to the earth system.'

BTE (2001) quoted a study from the UK which for households showed intangible losses from floods (loss of memorabilia, health effects, stress, evacuation disruption and worry) to be generally much more impactful than direct losses (damage to house structure and replaceable contents).

Even if values from a number of events could be established for some of these 'missing' benefit categories, the resulting averages (per dwelling, per business or per person affected) might not be extendable to larger or smaller incidents (see EMA, 2002). The Productivity Commission (2014) presented evidence that most natural disaster losses are caused by a relatively small number of natural disasters. According to the Commission, in Australia over the last four decades, the top 10% of disasters accounted for nearly 80% of total insurance losses, of which less than 4% of disasters accounted for 48% of insurance losses. Of these events, the 2010-11 Queensland floods were Australia's largest natural disaster in absolute dollar terms since 1970. It follows in part from these findings that mitigation measures that are unable to minimise the losses from large events might not be worth undertaking. It also follows that if intangible damages are more likely to be associated with a small number of large events, it will be difficult to develop any form of stage-damage relationship for intangibles in the same way that they are developed for other categories of loss.

6.2.2.3 Intangible Damage Estimation Methods

Intangible damages are estimated using a range of techniques that attempt to place monetary values on intangible impacts. Generally, methods for determining intangible damages cover the following:

- Resource costs, including for example the treatment of physical and mental injury and the costs of ameliorating other impacts of natural disasters such as substance abuse or family violence; and
- The willingness to pay among members of a community to avoid premature death, pain, suffering, and inconvenience and to avoid the community, heritage and environmental consequences of flooding.

Resource costs, are, relatively speaking, the easiest of these costs to measure, being estimated empirically for example by analysis of health system costs.

Willingness to pay benefits might be estimated using:

- Revealed preference methods (for example, costs that individuals actually or potentially affected by floods incur to protect items of sentimental value might serve as a measure of the value of memorabilia); or
- Stated preference methods in which various forms of survey are used to elicit and value individuals' preferences.

Some economists tend to prefer revealed preference methods provided that a strong link can be identified between an activity (e.g. lifting of houses, relocating to avoid flood risk) and the related risk (flood inundation). With this proviso, revealed preference methods portray actual behaviour. Stated preference methods on the other hand yield hypothetical estimates and valuations of impact which makes them useful as a 'before and after' estimating tool (for which revealed preference methods are not suitable). On the other hand, there are considerable conceptual difficulties in the application of stated preference valuation methods.

The stated preference methods have particular weaknesses or disadvantages because firstly they are hypothetical and secondly because they ask individuals to respond to situations with which they might not be familiar (how much do you value the ecosystem of the Brisbane River; how would you rate the impact of losing all your personal effects in a flood). Markantonis *et al*. (2012) identify three weaknesses with stated preference methods:

- They are subject to various biases (e.g. strategic bias – respondents may provide responses that are crafted towards their own advantage);
- They are expensive due to the need for survey design and testing; and
- They are controversial for non-use applications (can a respondent place an existence value on the Brisbane River ecosystem if they have little familiarity with it or can they propose a value for heritage at risk of flooding if they are unfamiliar with the sites).

Both revealed preference and stated preference measures are limited in their capacity to address long term impacts.

The DAE (2016) estimates of intangible costs contain both stated preference valuations of cost (to the extent that the monetary valuation of life is established using stated preference techniques) and estimates of resource costs, whereas the UK estimates of costs (EA 2010) use stated preference measures.

6.3 Available Data

6.3.1 Overview

A range of data required for property (residential and non-residential) flood damage estimation and other types of flood damage estimation was collected and collated for use in this study.

The key data required for property damage estimation can be classified into five types:

- Property data;
- Topographic data;
- Floor level data;
- Flood level data; and
- Flood stage-damage data.

The available data was collected and processed and then the relevant data was combined to form a comprehensive property information database that could be used in this study for flood damage estimation. Most of the relevant property details including floor level data required for this study have come from a property survey that was carried out specifically for this study by NorthGroup Consulting surveyors, a building footprint dataset generated by AAM, and floor level data set compiled for this study by the Department of Natural Resources and Mines (DNRM).

A range of other data was also obtained for the estimation of flood damage to assets and infrastructure in the study area including transport infrastructure, public and community owned buildings and assets, public utilities, rural/agricultural properties, mining leases, etc.

6.3.2 Property Data

The property data was obtained from a number of sources including Brisbane City Council (BCC), Ipswich City Council (ICC), Somerset Regional Council (SRC), Lockyer Valley Regional Council (LVRC), Queensland Government (through the Queensland Spatial Catalogue – Qspatial), NorthGroup Consulting (NGC), AAM and the Department of Natural Resources and Mines (DNRM). The property data used in the study included:

- Property location (geographic coordinate for the building footprint);
- Local government area;
- Postcode;
- Suburb;
- Cadastral lot and plan number;
- Land use (residential, commercial, industrial, rural/agricultural, public utility etc.);
- Building footprint area (m^2);
- For residential properties, the type of dwelling (fully detached lowset on stumps and slabs, fully detached highset, fully detached double storey, multi-unit single storey and multi-unit double storey); and
- For non-residential properties, type of the enterprise.

6.3.3 Topographic Data

Topographical data was supplied in the form of a 5 metre grid digital elevation model (DEM) used for the Phase 2 (Flood Study). The vertical accuracy of this data is understood to be ± 0.15m.

The building database supplied by NGC contained a ground level at the entrance to each building, while the processed (AAM) building footprint database supplied by DNRM contained multiple ground levels (minimum level, maximum level, centroid level) for each footprint.

6.3.4 Floor Level Data

The floor level data for properties within the 1 in 2,000 AEP design flood extent was obtained from the NGC property survey undertaken in 2017. These floor levels have been obtained from mobile laser survey (MLS) and aerial laser survey (ALS). The surveyed floor levels were required to have ± 0.3m accuracy for up to the 1 in 50 AEP flood extent (using ALS), ± 0.15m accuracy for between 1 in 50 and 1 in 200 AEP flood extents (using MLS), and ± 0.3m accuracy for between 1 in 200 and 1 in 2,000 AEP flood extents (using ALS).

For properties outside the 1 in 2,000 AEP design flood extent, floor levels were estimated by DNRME using a building footprint database obtained for this project. Floor levels at each building footprint have been estimated by DNRM using an automated GIS based classification algorithm. The accuracy requirement specified for this data has not been reported.

The floor levels of a number of buildings that experienced flooding in 2011 have since been raised or demolished. Therefore, the NGC survey data used in this study will not accurately reflect the total number of buildings that were flooded above floor level in 2011.

6.3.5 Flood Level Data

The Brisbane River peak flood levels for an ensemble of 11 design flood events ranging from 1 in 2 to 1 in 100,000 AEP produced in the Phase 2 (Flood Study) were used for existing (current climate and catchment development) floodplain conditions, as well as the five potential future (development and climate change scenario) floodplain conditions The peak flood level surfaces generated for each of the above design events were used to determine peak flood levels at each floodprone property in the study area.

6.3.6 Property Damage Survey

A property damage survey was undertaken in this study to collect data required to develop up to date relationships between depth of flooding and flood damage (i.e. flood stage-damage curves) for different types of residential and commercial properties. Details of this survey are given in Section 6.5.

6.3.7 Other Data

The non-property related data used in this study was obtained from a number of sources including BCC, ICC, SRC, LVRC, DNRME, Qspatial, Geoscience Australia (GA), Seqwater, Queensland Reconstruction Authority (QRA), Insurance Council of Australia (ICA), Energex, Queensland Fire and Emergency Services (QFES), Queensland Rail (QR), Department of Transport and Main Roads (DTMR), Queensland Urban Utilities (QUU) and the former Department of Environment and Heritage Protection (DEHP, now Department of Environment and Science, DES) and Department of Energy and Water Supply (DEWS, now Department of Natural Resources, Mines and Energy, DNRME). The data used in the study from these sources included:

- Aerial photography used for the Phase 2 (Flood Study);
- GIS data for cadastre, transport infrastructure, landmarks, mining leases, water and wastewater infrastructure, utility installations, environmental authorities and emergency services facilities;
- Infrastructure and utility damage (National Disaster Relief and Recovery Arrangements, NDRRA) repair costs associated with January 2011 and other recent South East Queensland flooding events;
- January 2011 flood damage estimates for BCC infrastructure and assets;
- Flood damage results from the Wivenhoe and Somerset Dams Optimisation Study (WSDOS);
- Flood stage-damage curves developed for Brisbane by GA;
- QRA’s 2011 post-flood survey data;
- Insurance claim data for the January 2011 flood event; and
- Planning scheme datasets.

6.3.8 Data Limitations and Assumptions

6.3.8.1 Limitations

Key limitations in the data available for this study are summarised below:

- The accuracy and limitations of the NGC floor level survey are reported in Appendix G.
- Floor levels derived by DNRME were entirely algorithm based and therefore have a lower accuracy, estimated to be by approximately ± 0.5m;
- There are gaps and inconsistencies in some of the property data available for this study, including:
    - Land use data – although land use code definitions are largely consistent across all council databases, there are some inconsistencies between the different databases. GIS mapping of land use codes often have cadastral lots with multiple land uses assigned to one lot, while other lots have null or blank entries for land use. Land use definitions are often non-specific (i.e. too vague) to accurately identify the specific land use for the purpose of flood damage estimation;
    - Building type data – there are inconsistencies between the building databases supplied by DNRME and NGC. Inconsistencies exist in definitions of building type (particularly the single storey lowset and single storey highset buildings). No delineation of residential multi-unit structures in the building type is available outside of the 1 in 2,000 AEP design flood extent. Some buildings have "unknown" assigned as building type. Accuracy of building type classifications outside the 1 in 2,000 AEP design flood extent is poor with incorrect building types assigned for a significant number of properties (e.g. lowset on stumps being classified as lowset slab-on-ground);
    - Building size data – groups of closely spaced buildings are often grouped in the database as a single footprint giving incorrect building sizes;
    - Building footprint data –The AAM building footprint data was derived from 2014 LiDAR survey, whereas the 2017 NGC survey involved acquiring new MLS data. Due to this, some floor levels have been obtained in locations without building footprints due to buildings being constructed between the two survey dates;
    - The building footprint dataset contains all footprints in the study area including all outbuildings; some large shadecloth and greenhouse type structures (non-buildings) are also included; some footprints overlap other footprints; and outside of the 1 in 2,000 AEP design flood extent, the number of multi-unit residences within a single footprint has not been identified;
    - Building material – no building material information is provided (i.e. listed as "other") for a significant number of buildings within the 1 in 2,000 AEP flood extent and no building material data is available outside of this extent;
    - Building age – no building age data is available for the study area;
    - Building floor level – a small number of buildings outside of the 1 in 2,000 AEP design flood extent have no floor level data available. Outside the 1 in 2,000 AEP design flood extent the level of upper floors in multi storey buildings has not been provided; and

  - Building ground level – there is an inconsistency between the location of the reported building ground level between the NGC (at building entrance) and DNRME (at building footprint centroid) datasets.

- There are gaps and inconsistencies in some of the non-property data available for this study, including:
  - GIS databases of infrastructure – levels of infrastructure (e.g. road crown levels, pump station levels) are often not provided in the database; and
  - NDRRA costs for January 2011 flood damage repairs – repair costs often include improvements to the asset (to bring it up to a higher standard than the original) and hence are not always representative of actual damage repair costs.

6.3.8.2 Assumptions

Wherever the available information is incomplete or insufficient, assumptions and simplifications were made for flood damage estimation purposes. These assumptions and simplifications include:

- Land use data – it was assumed that the primary land use allocated to each lot was representative of each building on that lot. Where it was identified that two land uses were assigned to a lot the most representative land use, based on aerial photography and Google Street View, was assigned. Where the primary council land use definition was unclear (e.g. shop single – but with no information on what type of shop) the secondary land use (e.g. professional offices) was consulted for further information. Where the secondary land use gave no further information, assumptions were made as to what damage curve should be assigned. Outliers in each land use category were visually checked (e.g. properties assigned a residential land use but with footprints greater than 1,200 m^2) and the council land use was overwritten where aerial photography and other datasets justified this;
- Building type data – inconsistencies in building type definition between the NGC and DNRME data sets were noted, but the reported classifications were not altered. As a result, the building type classification was accepted as supplied, with preference given to the NGC data set. Delineation of multi-unit residential properties outside the 1 in 2,000 AEP design flood extent was based on the land use assigned to each DNRME footprint (as this is not provided in the building type data). Properties assigned an “unknown” building type were assigned a type based on the estimated difference between the floor level and ground level;
- Building size data – within the 1 in 2,000 AEP design flood extent, each individual entity within a building footprint (or collection of buildings) was identified. Outside of this extent it was assumed that one entity was present per footprint (as no other information was available);
- Building footprint data – where a property was identified but no building footprint was available the building area was assigned based on the mean footprint area for the corresponding building land use. Buildings with a footprint area less than 60 m^2 were filtered out from the data as they were assumed to be outbuildings (sheds, carports etc.). The filter removed 49,030 building footprints from the database. Overlapping footprints were identified and adjusted so only one footprint covered any given point in the study area. Building data was only supplied up to the extent of the existing conditions 1 in 100,000 AEP design flood event. It was assumed that

flooding under future conditions (including climate change impact scenarios) does not extend beyond this extent. Outside of the 1 in 2,000 AEP design flood extent where buildings were assigned residential multi-unit but no data was available on the number of residences (e.g. a 5,000 m^2 apartment block with no indication on the number of apartments) the building footprint land use was reassigned to allow a reasonable damage estimation to be made;

- Building material – it was assumed that the structural damage estimates for buildings do not vary with building material;
- Building age – it was assumed that the structural damage estimates for buildings do not vary with building age;
- Building floor level – buildings with no assigned floor level were assumed to be slab-on-ground construction with a floor level 0.3 m above ground level. Where properties outside the 1 in 2,000 AEP flood extent were identified as multi storey, extra floor levels were added at 2.7 m intervals;
- Building ground level – inconsistencies in the location of the reported property ground level in NGC and DNRME datasets were noted but the reported level was accepted as representative of the ground level at the property;
- GIS databases of infrastructure – all infrastructure within a specific design flood extent was assumed to be at natural ground level (i.e. is flood impacted when within the extent); and
- NDRRA costs for January 2011 flood damage repairs – unless noted in the supplied data, it was assumed that all costs provided were damage repair costs and did not include infrastructure improvement costs.

6.4 Property Characteristics

6.4.1 Overview

Flood damage varies with land use; e.g. the nature and cost of damage caused to a commercial establishment is quite different to the nature and cost of damage caused to a residential property. Therefore, flood damage estimation requires flood stage-damage curves for different land uses and different building types in each land use.

One of the keys to deriving representative stage-damage curves is to decide on the number of building types to be included in flood damage estimation. This usually represents a trade-off between the time spent collecting data, survey costs and accuracy required of the derived stage-damage curves. To decide on the number of building types included in flood damage estimation, it is required to accurately characterise building types across the study area.

Property types are normally classified first according to general land use and then according to damage category within each land use. The standard land use categories are residential, commercial, industrial, rural/agricultural, public authority, public utility and recreational. Residential properties can be further classified according to size (small, medium and large), age (old, moderate and new) and style (attached, detached, house, unit, flat, town house, single storey, multi storey, hotel, motel, etc.). Non-residential property types are normally classified according to expected damage (size and type of business, industry or public use): very low damage, low damage, medium damage, high damage and very high damage. Property classifications appropriate for the study area have been determined based on a review of the distribution of property types in the flood damage property information database created for this study.

6.4.2 Number of Floodprone Buildings

There are 215,710 entries in the flood damage building database created for this study after the removal of some 49,030 outbuildings. Of these, there are 69,800 entries which represent upper levels of multi storey buildings. There are a total of 145,910 ground (bottom) floor entries in the database (hereafter referred to as the number of buildings).

Table 6-3 gives a breakdown of the total number of the current floodprone buildings that would be inundated above ground level (AGL) and above floor level (AFL) in each of the four local government areas for each of the 11 design flood events investigated in this study. Figure 6-3 shows the variation of the total number of buildings flooded above ground level and floor level with AEP. Figure 6-4 shows the variation in the number of buildings flooded above ground level and floor level in each of the LGA's in the study area with AEP.

6.4.3 Distribution of Property Types

Of the total of 145,910 buildings captured within the study area, 119,800 (82.1%) are residential, 17,230 (11.8%) are commercial/industrial, 2,290 (1.6%) are rural/agricultural and 6,060 (4.1%) are buildings that are classified under public & community, public authority, mining, vacant land, outbuildings and other/miscellaneous land uses. The remaining 530 (0.4%) buildings have no land use specified.

Table 6-4 and Table 6-5 provide a breakdown of the land uses of buildings and properties respectively, flooded above ground level in the study area for 1 in 2 AEP to 1 in 100,000 AEP design flood events. Figure 6-3 and Figure 6-4 show the percentages of building types flooded above ground level within the 1 in 100 AEP and 1 in 100,000 AEP design flood events respectively. Data available was insufficient to breakdown the number and type of buildings in the study area by building age and construction materials.

Table 6-3 Number of buildings flooded above and below floor level, 1 in 2 AEP to 1 in 100,000 AEP design flood events

AEP (1 in x)	Type of inundation	BCC	ICC	LVRC	SRC	Total
2	AGL	17	0	0	0	17
	AFL	10	0	0	0	10
5	AGL	25	14	6	16	61
	AFL	12	8	0	3	23
10	AGL	117	169	79	59	424
	AFL	51	74	10	15	150
20	AGL	518	502	218	240	1,478
	AFL	228	281	63	75	647
50	AGL	2,836	2,418	282	360	5,896

AEP (1 in x)	Type of inundation	BCC	ICC	LVRC	SRC	Total
	AFL	1,430	1,664	89	144	3,327
100	AGL	11,509	4,797	348	697	17,351
	AFL	7,900	3,773	142	376	12,191
200	AGL	18,314	7,782	396	1,152	27,644
	AFL	14,025	6,541	187	833	21,586
500	AGL	26,965	10,340	451	1,415	39,171
	AFL	21,445	8,983	224	1,104	31,756
2,000	AGL	39,973	13,452	510	1,749	55,684
	AFL	33,736	12,238	291	1,461	47,726
10,000	AGL	59,597	17,946	570	2,266	80,379
	AFL	56,014	17,183	356	2,017	75,570
100,000	AGL	100,802	28,554	781	3,782	133,919
	AFL	97,930	27,912	615	3,632	130,089

AEP – annual exceedance probability; AGL – above ground level; AFL – above floor level;

BCC – Brisbane City Council; ICC – Ipswich City Council; LVRC – Lockyer Valley Regional Council; SRC – Somerset Regional Council;

Note that results in this table represent the total numbers of buildings inundated and not the total number of properties (where a multi storey building may contain multiple properties)

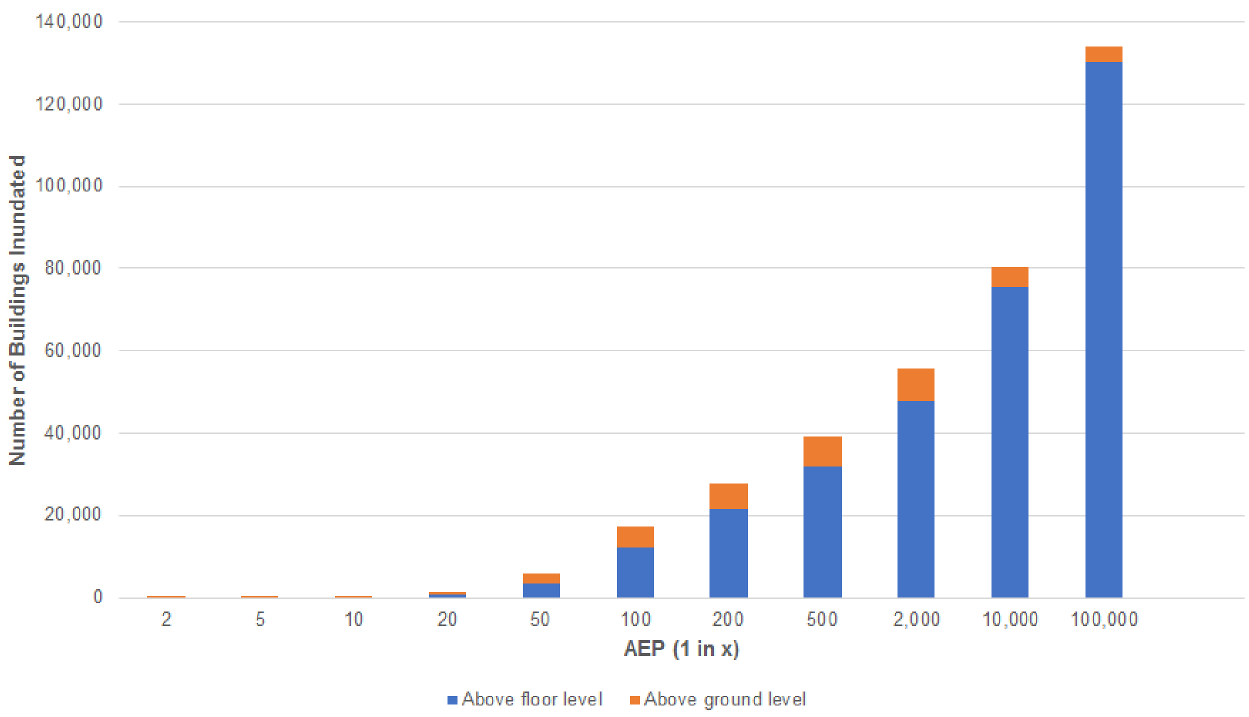


Figure 6-3 Variation in the number of buildings flooded above and below floor level for design flood events up to 1 in 100,000 AEP

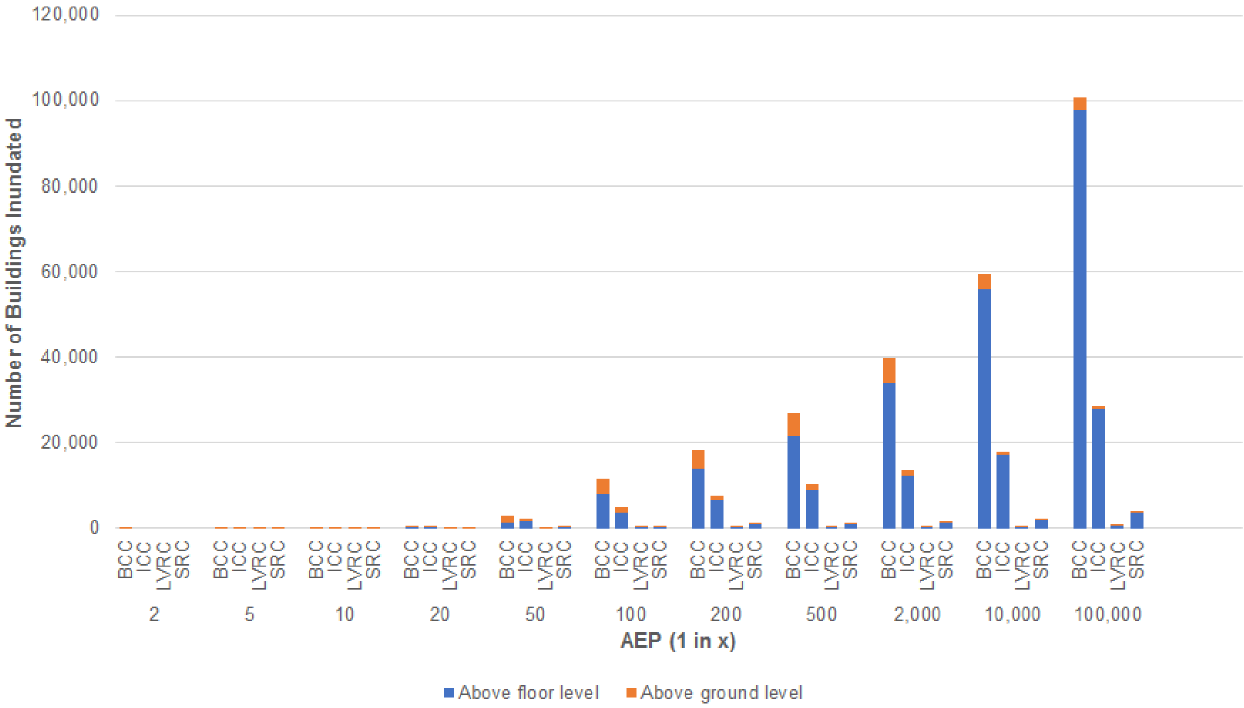


Figure 6-4 Variation in the number of buildings flooded above and below floor level in each LGA for design flood events up to 1 in 100,000 AEP

Table 6-4 Breakdown of land uses of buildings flooded above ground level, 1 in 2 AEP to 1 in 100,000 AEP design flood events

AEP (1 in x)	Residential (detached)	Residential (multi-unit)	Commercial	Industrial	Public & community	Public utility	Mining	Other/ miscellaneous	Vacant	Outbuildings	Blank	Rural/ agricultural	Total
2	3	-	5	4	2	-	-	1	-	-	2	-	**17**
5	24	3	8	7	3	1	-	4	-	1	2	8	**61**
10	152	57	27	55	8	2	-	27	7	1	3	85	**424**
20	616	119	86	212	48	4	2	56	13	5	5	312	**1,478**
50	3,211	538	394	859	165	16	10	139	78	18	15	453	**5,896**
100	10,100	2,013	1,147	2,350	393	36	21	367	164	40	48	672	**17,351**
200	16,506	3,479	1,886	3,428	592	51	21	487	236	55	78	825	**27,644**
500	24,009	5,047	2,602	4,506	810	72	24	597	317	66	134	987	**39,171**
2,000	34,280	7,534	3,821	6,077	1,089	87	29	783	507	82	217	1,178	**55,684**
10,000	51,692	10,635	5,010	7,651	1,701	119	37	1,037	684	107	327	1,379	**80,379**
100,000	92,612	17,134	6,955	9,437	2,594	168	44	1,430	996	163	485	1,901	**133,919**

Table 6-5 Breakdown of land uses of properties flooded above ground level, 1 in 2 AEP to 1 in 100,000 AEP design flood events

AEP (1 in x)	Residential (detached)	Residential (multi-unit)	Commercial	Industrial	Public & community	Public utility	Mining	Other/ miscellaneous	Vacant	Outbuildings	Blank	Rural/ agricultural	Total
2	3	-	14	5	2	-	-	2	-	-	3	-	**29**
5	24	5	25	8	3	2	-	5	-	1	3	9	**85**
10	152	71	52	63	11	3	-	36	11	1	4	96	**500**
20	616	137	136	246	64	5	3	67	19	5	6	342	**1,646**
50	3,211	687	599	1,041	213	22	14	160	119	18	20	504	**6,608**
100	10,100	2,752	2,074	3,053	540	49	25	436	253	40	63	759	**20,144**
200	16,506	4,583	3,458	4,559	836	68	25	571	374	61	99	931	**32,071**
500	24,009	6,665	4,917	5,982	1,157	96	29	716	501	72	171	1,117	**45,432**
2,000	34,280	9,762	7,153	7,964	1,603	119	38	931	729	88	288	1,331	**64,286**
10,000	51,692	14,280	9,629	10,613	2,591	161	49	1,306	1,004	116	474	1,547	**93,462**
100,000	92,612	23,955	13,330	14,368	3,992	233	56	1,959	1,557	192	720	2,148	**155,122**

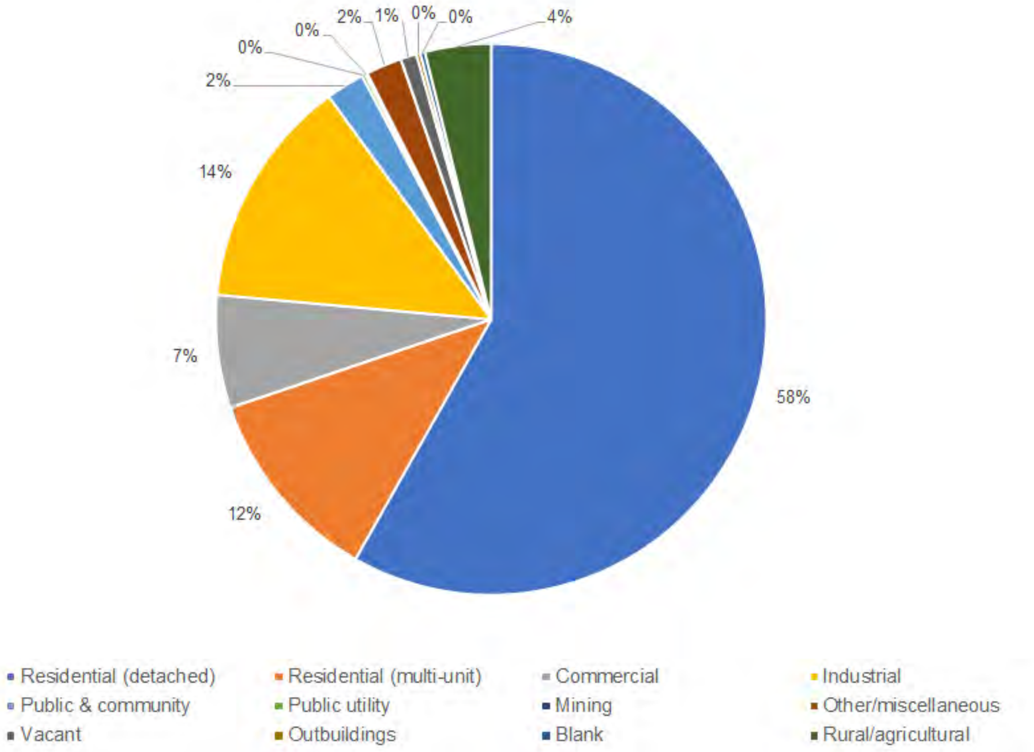


Figure 6-5 Percentages of floodprone building types for the 1 in 100 AEP design flood event

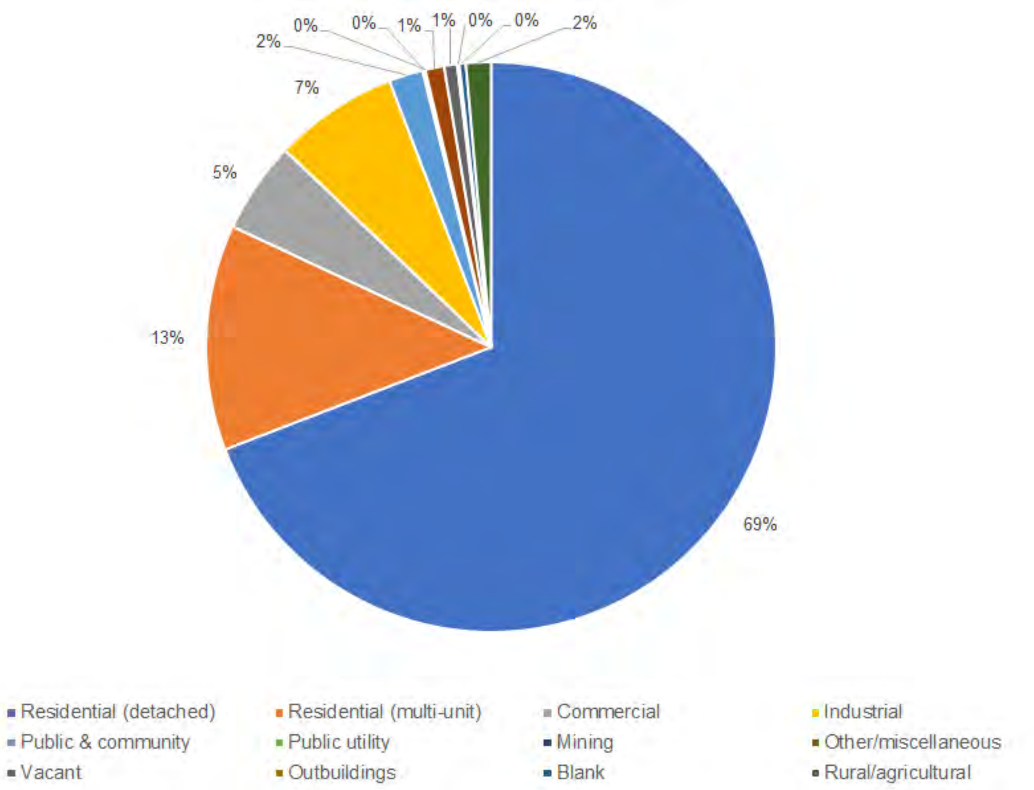


Figure 6-6 Percentages of floodprone building types for the 1 in 100,000 AEP design flood event

6.4.4 Residential Property Characteristics

The building database shows that there is a clear mix of residential building types across the study area. Key characteristics of the building database include:

- The largest group of residential properties are detached, single storey, lowset houses on slab-on-ground or stumps;
- There are also large numbers of detached, double storey and highset properties (31% and 10% respectively);
- The other main property types can be classified as semi-detached or non-detached duplexes (single storey); town houses (two storey); and multi storey units/flats (15%);
- With respect to size, there is a mixture of small, medium and large residential properties:
  - There are more large detached residential properties when compared to small and medium sized properties; and
  - This trend continues with semi-detached and non-detached properties.

Based on the property characterisation undertaken using the flood damage building database, the significant residential property types requiring stage-damage curves in study area are as follows:

- Fully detached residential properties:
  - Lowset, single storey, slab-on-ground (FDSS-SOG);
  - Lowset, single storey, stumps (FDSS-Stumps);
  - Highset (FDHS); and
  - Double storey (FDDS).
- Semi and non-detached (multi-unit) residential properties (town houses, duplexes, units, flats, etc.):
  - Single storey (MUSS); and
  - Double or more stories (MUDS).

The six residential property types identified were then sub-divided according to size (Small: <140 m^2, Medium: 140 to 210 m^2, Large: >210 m^2). Table 6-6 provides a breakdown of the number of the different residential building types flooded above ground level for 1 in 2 AEP to 1 in 100,000 AEP design flood events. Figure 6-7 and Figure 6-8 show the percentages of residential building types flooded above ground level during a 1 in 100 AEP and 1 in 100,000 AEP design flood event respectively.

Table 6-6 Breakdown of residential building types flooded above ground level, 1 in 2 AEP to 1 in 100,000 AEP design flood events

AEP (1 in x)	FDSS-SOG	FDSS-Stumps	FDHS	FDDS	MUSS	MUDS	Total
2	2	-	-	1	-	-	**3**
5	14	4	5	1	3	-	**27**
10	60	37	43	12	34	23	**209**
20	214	150	192	60	90	29	**735**
50	978	791	1,027	415	380	158	**3,749**
100	2,924	2,111	2,761	2,304	1,097	916	**12,113**
200	5,076	3,445	4,137	3,848	1,943	1,536	**19,985**
500	7,497	5,087	5,938	5,487	2,719	2,328	**29,056**
2,000	10,904	7,437	8,410	7,529	3,815	3,719	**41,814**
10,000	17,581	9,734	9,982	14,395	5,239	5,396	**62,327**
100,000	35,533	12,261	11,865	32,953	8,269	8,865	**109,746**

FDSS – fully detached single storey; FDHS – fully detached highset; FDDS – fully detached double storey;

MUSS – multi-unit single storey; MUDS – multi-unit double storey; SOG – slab-on-ground

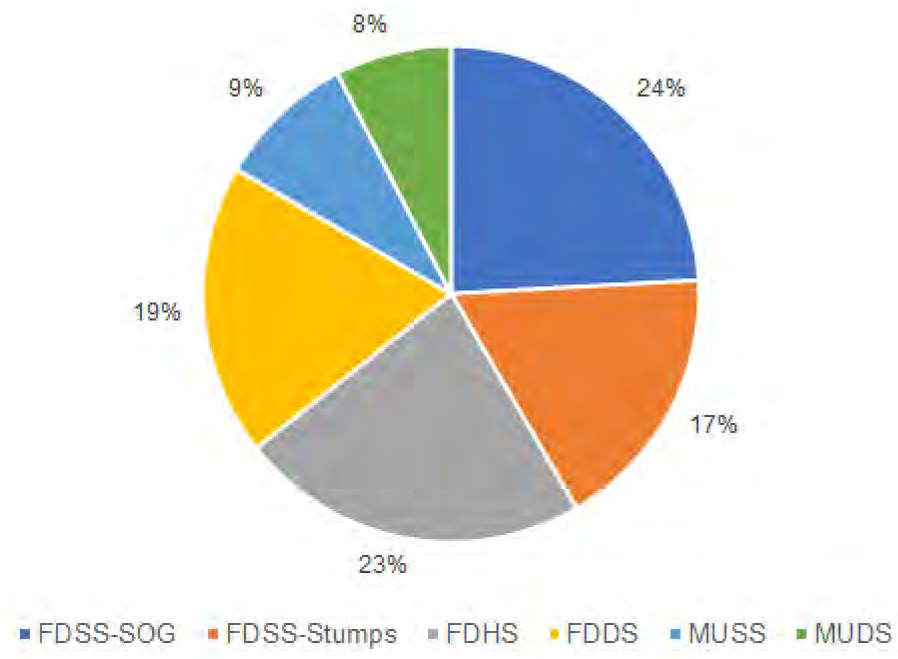


Figure 6-7 Percentages of floodprone residential building types, 1 in 100 AEP design flood event

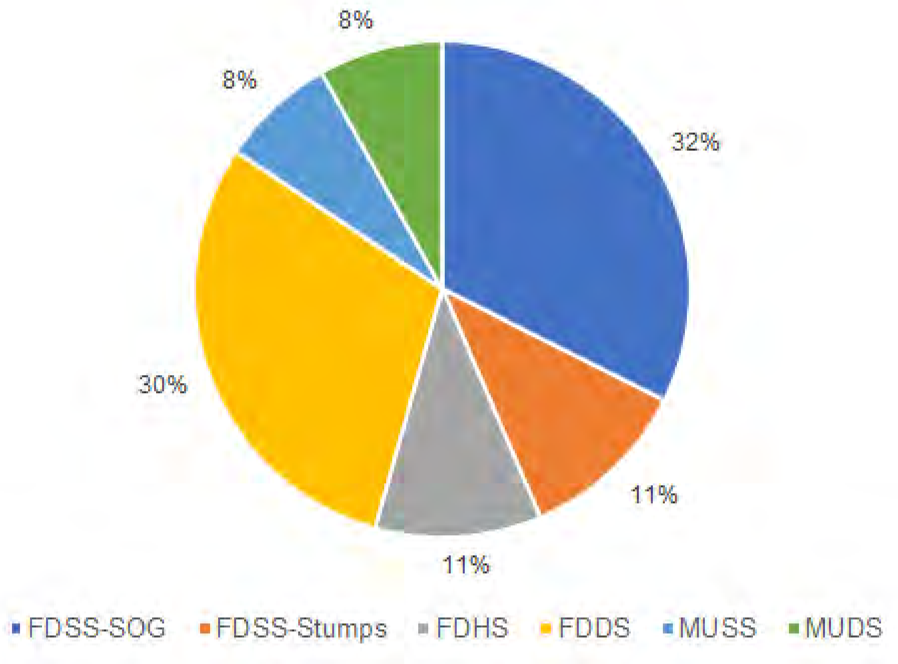


Figure 6-8 Percentages of floodprone residential building types, 1 in 100,000 AEP design flood event

6.4.5 Commercial, Industrial and Public Property Characteristics

The commercial properties in the database varied from small retail shops to large shopping centres. Most of these premises are single storey and either semi-detached or non-detached. However, there are also significant numbers of double or multi storey commercial buildings in the study area. Many of the commercial properties had more than one commercial enterprise operating within the property. About 69% of the floodprone commercial buildings in the study area are of small to medium size. A large proportion of these commercial entities are categorised as ‘food’, ‘retail shops’ or ‘offices’.

Although there are a significant number of industrial properties in the study area, very little detail is available for these properties except for the building footprint size. Based on the building footprint data, about 15% of the industrial properties are small, 38% are medium size and 47% are large. The industrial properties are likely to vary from small low technology to large high technology manufacturing enterprises.

The database also records significant numbers of rural/agricultural properties and a range of public authority and utility buildings in the study area (e.g. telecommunication, electricity, sewerage, water supply), community (e.g. hospitals, kindergartens, schools, community halls), and recreational (e.g. social clubs, sports pavilions) buildings. However, little detail (apart from the basic land use allocation and building size) is available on these properties.

Non-residential properties identified were sub-divided according to the type of business, industry or public use, building size (small: <186 m^2, medium: 186 to 650 m^2, large: >650 m^2) based on building footprint area, and building type (single storey, multi storey).

6.5 Property Damage Survey

6.5.1 Overview

The underlying data in the existing flood stage-damage curves in Australia are now generally outdated due to reasons discussed in Section 6.2. Therefore, a new property damage survey was undertaken to derive locally representative stage-damage curves for the predominant residential and commercial property types identified in the study area. The survey was conducted by an experienced valuer visiting and physically inspecting the selected properties and estimating potential internal, external and structural damages at different depths of flooding using the valuation survey method described in Section 6.2.1.6. The survey also captured general property information on size, style, age, construction material, ownership, etc.

A damage survey was conducted of 96 properties, 66 of which were residential and 30 of which were commercial properties. The properties for survey were selected from volunteers across the four LGA’s. Comprehensive property damage assessment forms were designed and used to capture the specific data required for the derivation of stage-damage curves for the surveyed property types. The damage assessment was based on the estimated cost of repairing a damaged item or replacing it, if the replacement cost is less than the repair cost.

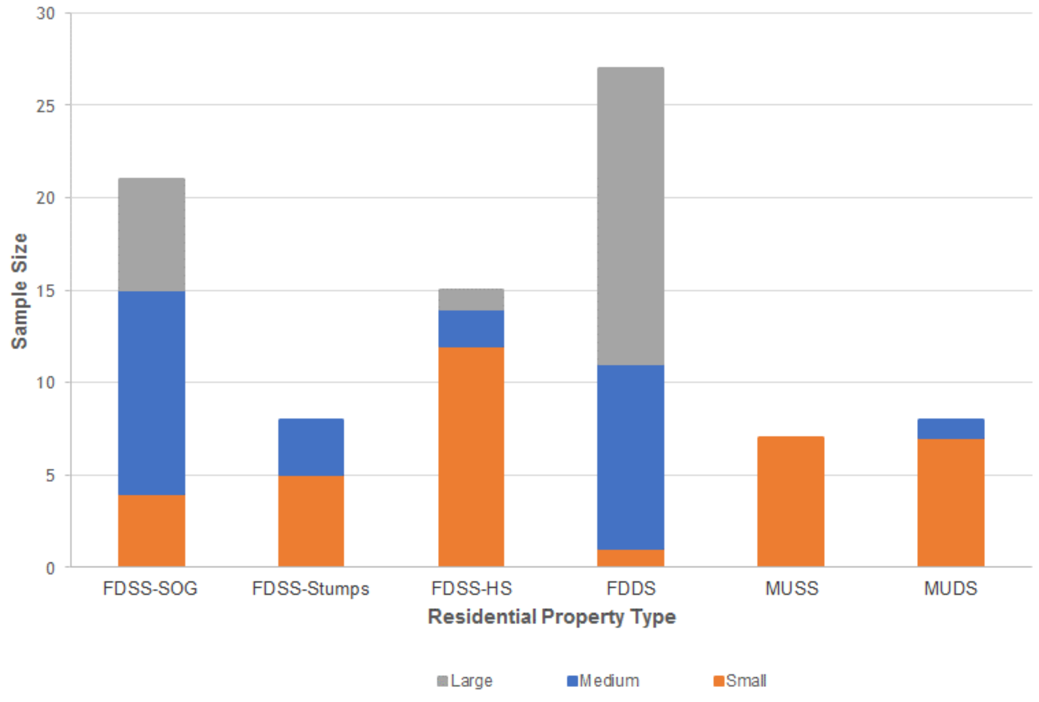
Potential internal damage was assessed on a room-by-room basis (bedroom, lounge, dining room, kitchen, bathroom, etc. for residential properties, and reception, office, meeting room, store room, toilet, etc. for commercial properties) for various depths of flooding. The valuer was guided by a comprehensive check list of typical contents likely to be found in each room to note all items and their current value based on type, quality and degree of wear, and the height above floor that each item is stored prior to estimating the potential damage each of the items in each room would sustain at each of the nominated depths of flooding to determine the total potential internal damage at the property surveyed.

A similar process was followed to estimate external and structural damages at each of the surveyed properties. External damage includes damage to contents of outbuildings, vehicles usually located on the property, fences, gardens, swimming pools, etc. Structural damage includes damage to external and internal walls, floors, doors and windows, and also the non-removable fixtures such as built-in fittings and cupboards.

6.5.2 Survey Breakdown by Property Type

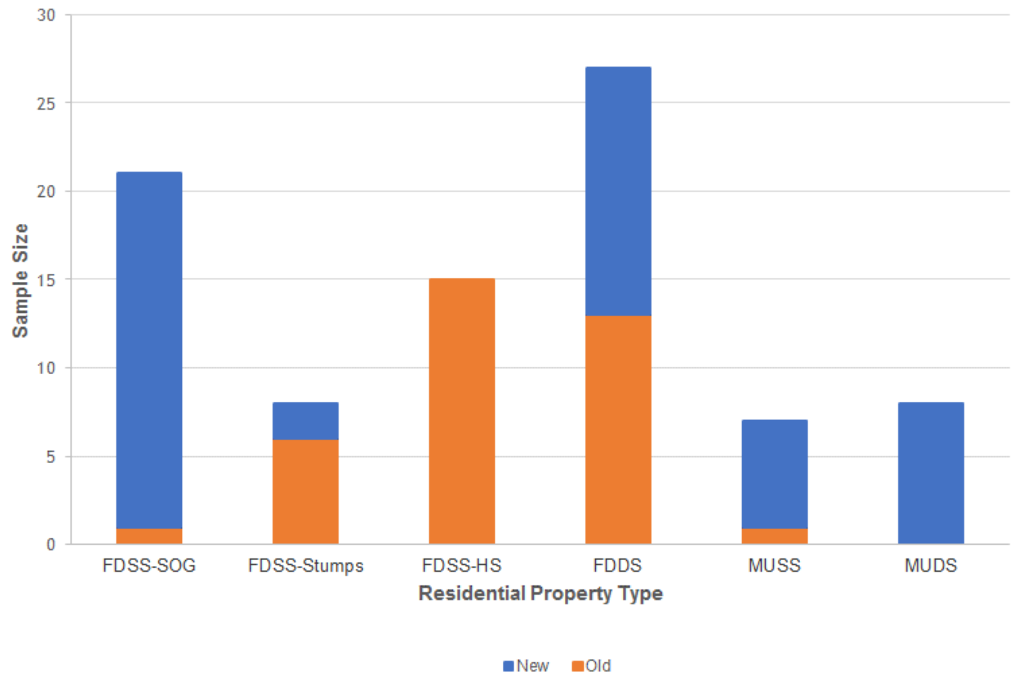
6.5.2.1 Residential Properties

The numbers of small (< 140 m^2), medium (140-210 m^2) and large (> 210 m^2) properties, as well as the numbers of old and new properties that were surveyed for each of the six key residential property types are shown in Figure 6-9 and Figure 6-10 respectively. The breakdown of surveyed residential property types and the range of surveyed property sizes are shown in Table 6-7. For survey purposes, a property was considered to be old if it was constructed prior to 1970 and new if it was constructed after 1970.



FDSS – fully detached single storey; FDHS – fully detached highset; FDDS – fully detached double storey; MUSS – multi-unit single storey; MUDS – multi-unit double storey; SOG – slab-on-ground

Figure 6-9 Distribution of surveyed residential property sizes for different property types



FDSS – fully detached single storey; FDHS – fully detached highset; FDDS – fully detached double storey; MUSS – multi-unit single storey; MUDS – multi-unit double storey; SOG – slab-on-ground

Figure 6-10 Distribution of surveyed residential property ages for different property types

Table 6-7 Distribution of surveyed residential properties and their sizes

Property type	Property size (floor area in m^2)								
	Small			Medium			Large		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Lowset, slab-on-ground	77	125	105	140	204	170	216	341	252
Lowset, on stumps	60	130	98	153	201	185	-	-	-
Highset (not built-in)	64	138	108	140	140	140	224	224	224
Double storey / Highset (built-in)	130	130	130	144	210	191	220	400	287
Multi-unit (single storey)	60	136	105	-	-	-	-	-	-
Multi-unit (multi storey)	80	125	107	205	205	205	-	-	-

6.5.2.2 Commercial Properties

The commercial properties were classified as small, medium or large (based on building footprint sizes) according to the ANUFLOOD size classifications (small: < 186 m^2, medium: 186-650 m^2; and large: >650 m^2). Only small to medium size commercial properties were surveyed. Based on land use information in the database, these buildings comprised about 69% of the total number of commercial buildings within the 1 in 100 AEP design flood extent, and 69% of the total number of commercial buildings within the 1 in 100,000 AEP design flood extent. A large proportion of these properties are categorised as ‘food’, ‘retail shops’ or ‘offices’. The numbers of properties of each of these three types that were surveyed are shown in Table 6-8. Of the ‘retail shops’, approximately 61% are single shops or shops within a small complex (i.e. six or less shops).

Table 6-8 Distribution of surveyed commercial properties

Property type	Small	Medium	Total
Food outlets	6	2	8
Retail shops	5	6	11
Offices	8	3	11
Total	**19**	**11**	**30**

6.6 Stage-Damage Curves for the Brisbane River Catchment

6.6.1 Overview

All property damage survey results were collated and reviewed for consistency and reasonableness prior to detailed processing. The survey results were then grouped into different property types and sub-types and analysed to derive representative stage-damage curves for each designated property type and sub-type. The accuracy and representativeness of the derived stage-damage curves would increase with increasing sample sizes of the properties surveyed for each designated property type and sub-type. The data set collected for this study was expanded and enhanced, prior to analysis, by combining it with data for 20 additional residential properties surveyed in June 2017 for a similar study in Mackay. All damage values presented in this study are in 2017 dollars (as at June 2017).

The stage-damage curves derived in this study were compared with data available from other sources (e.g. GA, O2, ANUFLOOD) as a ‘reality check’ and to determine how the new damage estimates compare with equivalent estimates from other sources. These comparisons are discussed in Section 6.6.4. The damage estimates obtained from these curves were then validated against some data provided by the ICA.

6.6.2 Residential Damage Curves

A total of 66 residential properties were surveyed across the four LGA’s to get a representative cross-section of residential properties in the study area. When combined with the 20 additional residential properties surveyed in Mackay[12] a total dataset of 86 residential properties was available for use in this study.

Data was collated by building type and then by building size to combine properties with common characteristics. Stage-damage curves relating the depth of flooding to potential flood damage were developed for each surveyed property for external, internal and structural damages. The stage vs surveyed potential flood damage data were plotted for each building type and size, and separate plots were prepared for external, internal and structural damages. From these plots, representative stage-damage curves that best fits the surveyed data over the full range of flood depths were then derived for each building type and size.

For this study, fully detached highset properties that were built-in and contained a living area (e.g. bedroom, rumpus room), garages, workshops, etc. in the lower floor were treated as fully detached double storey properties.

6.6.2.1 Internal Damage Curves

Internal stage-damage curves were derived using the property damage survey data for the six residential property types and three property sizes (18 curves). When the sample sizes were too small for some property types and/or sizes (e.g. large FDSS-Stumps), stage-damage curves were derived using information extrapolated from similar property types and sizes from the surveyed properties.

Table 6-9 provides a summary of the variation in building (floor area) sizes and potential internal damages for the surveyed properties used to derive representative potential internal stage-damage curves. Figures 8-1 to 8-6 show the potential internal stage-damage curves derived for adoption in this study for different residential property types. The individual stage-damage curves show a moderate degree of spread across the property range as would be expected.

[12] Although combining data from different studies is not ideal, the same valuer and same valuation methodology was used for both the Brisbane River Catchment and Mackay studies. As such, combining the data is considered appropriate in this circumstance and improves the dataset by expanding the number of properties captured within different categories and socio-economic groupings.

Table 6-9 Summary of the variation in sizes and internal damages of the surveyed properties

Property size	Sample size	Floor area range	Mean floor area	Range of maximum potential damage	Mean of maximum potential damage
FDSS-SOG					
Small	4	77-125 m^2	105 m^2	$45,100 - $65,250	$53,338
Medium	11	140-204 m^2	170 m^2	$39,640 - $114,500	$83,095
Large	6	216-341 m^2	252 m^2	$85,600 - $128,600	$105,275
FDSS-Stumps					
Small	5	60-130 m^2	98 m^2	$51,950 - $75,000	$60,408
Medium	3	153-201 m^2	185 m^2	$70,070 - $111,200	$93,257
Large [a]	0	-	-	-	-
FDSS-HS					
Small	12	64-138 m^2	108 m^2	$62,200 - $141,100	$90,583
Medium [b]	2	140 m^2	140 m^2	$47,000 - $93,000	$70,000
Large	1	224 m^2	224 m^2	$134,600	$134,600
FDDS					
Small [c]	1	130 m^2	130 m^2	$56,650	$56,650
Medium	10	144-210 m^2	191 m^2	$63,650 - $146,000	$94,500
Large	16	220-400 m^2	287 m^2	$93,350 - $220,300	$140,269
MUSS					
Small	7	60-136 m^2	105 m^2	$31,200 - $61,300	$44,871
Medium [d]	0	-	-	-	-
Large [d]	0	-	-	-	-
MUDS					
Small [c]	7	80-125 m^2	107 m^2	$37,150 - $101,500	$59,857
Medium	1	205 m^2	205 m^2	$64,590	$64,590
Large [e]	0	-	-	-	-

FDSS – fully detached single storey; FDHS – fully detached highset; FDDS – fully detached double storey;
MUSS – multi-unit single storey; MUDS – multi-unit double storey; SOG – slab-on-ground

[a] – due to the absence of data, the stage-damage curve for large sized FDSS-Stumps was derived by extrapolating medium sized property damages based on the ratio of large to medium size FDSS damages.

[b] – due to the small sample size and both samples being almost of small size, the stage-damage curve for medium sized FDSS-HS was derived by interpolating between the small and large FDSS-HS curves.

[c] – due to the small sample size, the small sized FDDS and small sized MUDS samples were lumped and a combined small sized double storey stage-damage curve was derived using the larger lumped sample size.

[d] – due to the absence of data, the medium sized MUSS and large sized MUSS stage-damage curves were derived based on equivalent damage ratios for the FDSS-SOG sample.

[e] – due to the absence of data, the large sized MUDS stage-damage curve was derived based on equivalent damage ratios for the FDDS sample.

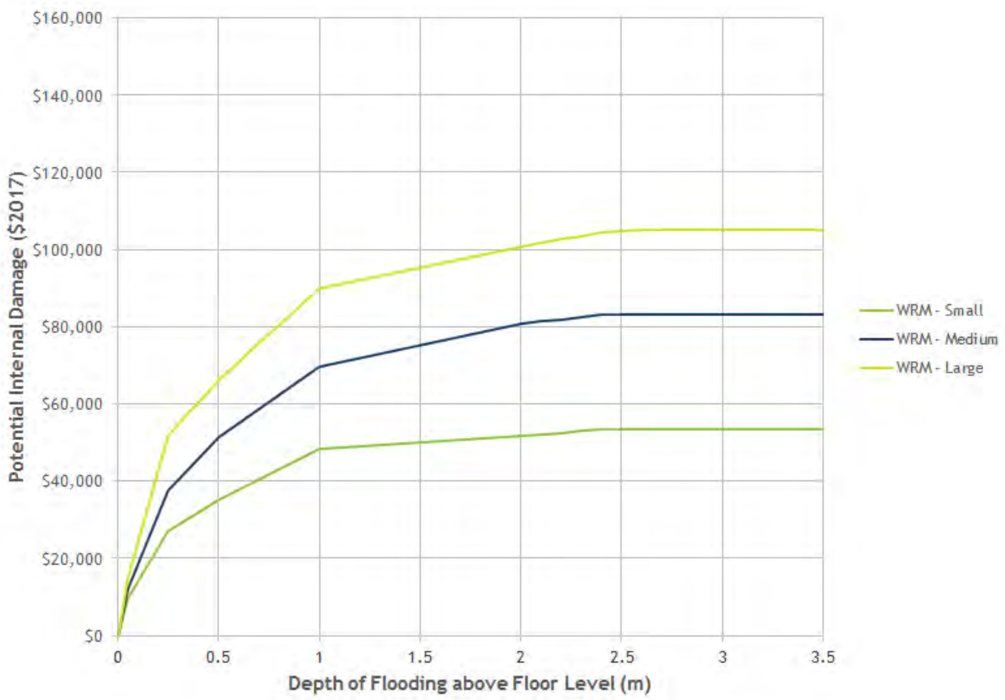


Figure 6-11 FDSS-SOG internal stage-damage curves

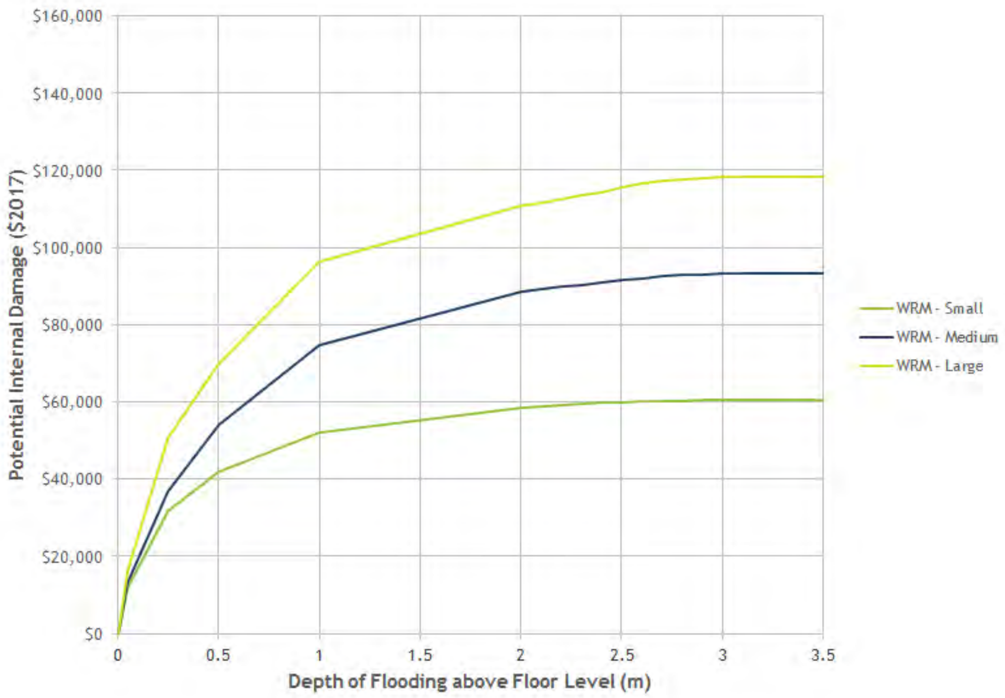


Figure 6-12 FDSS-Stumps internal stage-damage curves

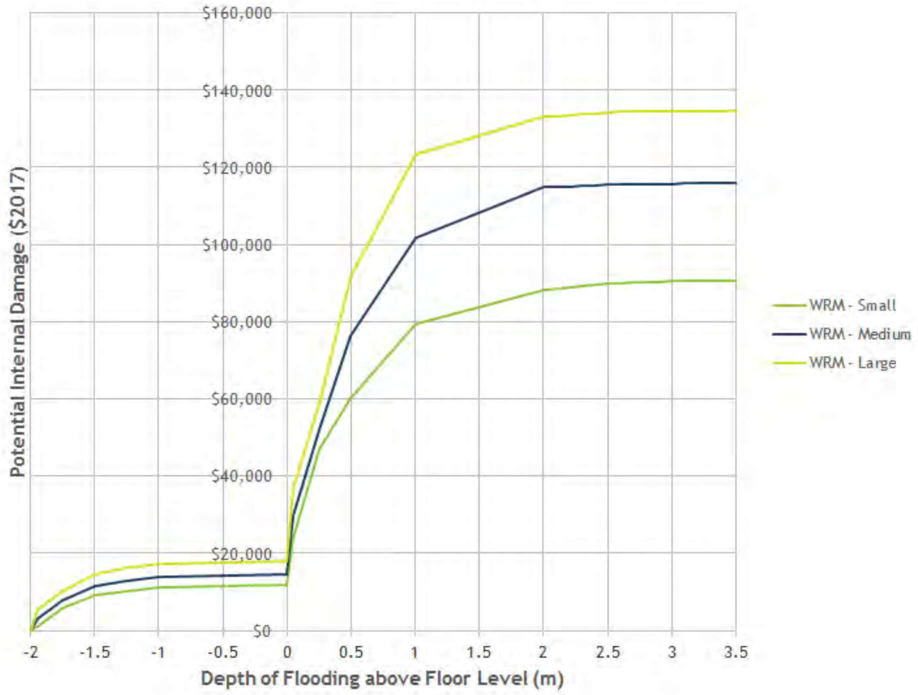


Figure 6-13 FDSS-HS internal stage-damage curves

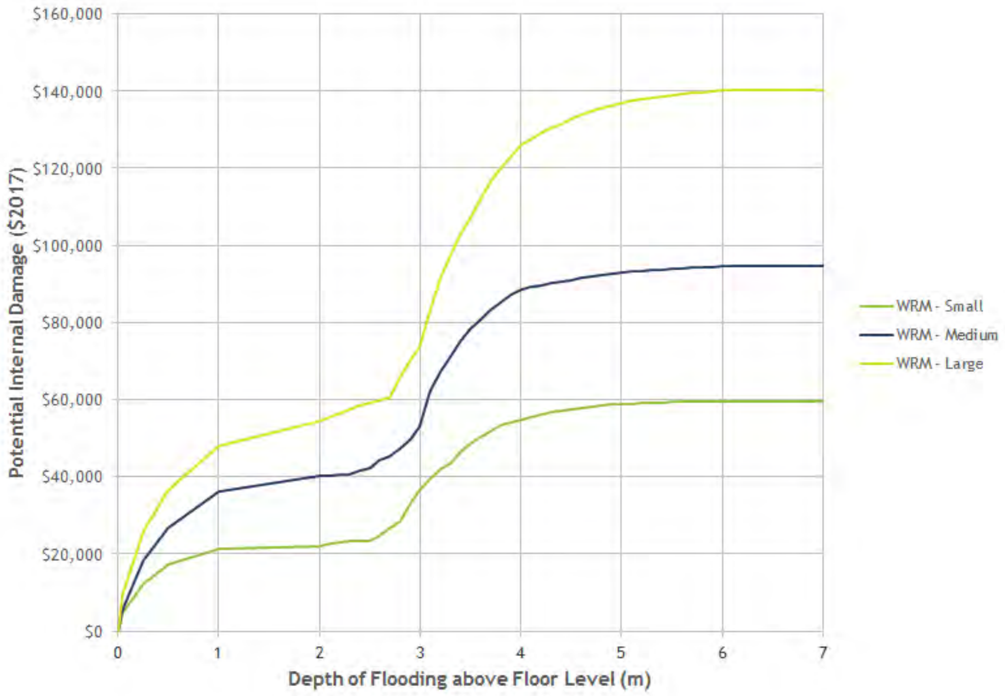


Figure 6-14 FDDS internal stage-damage curves

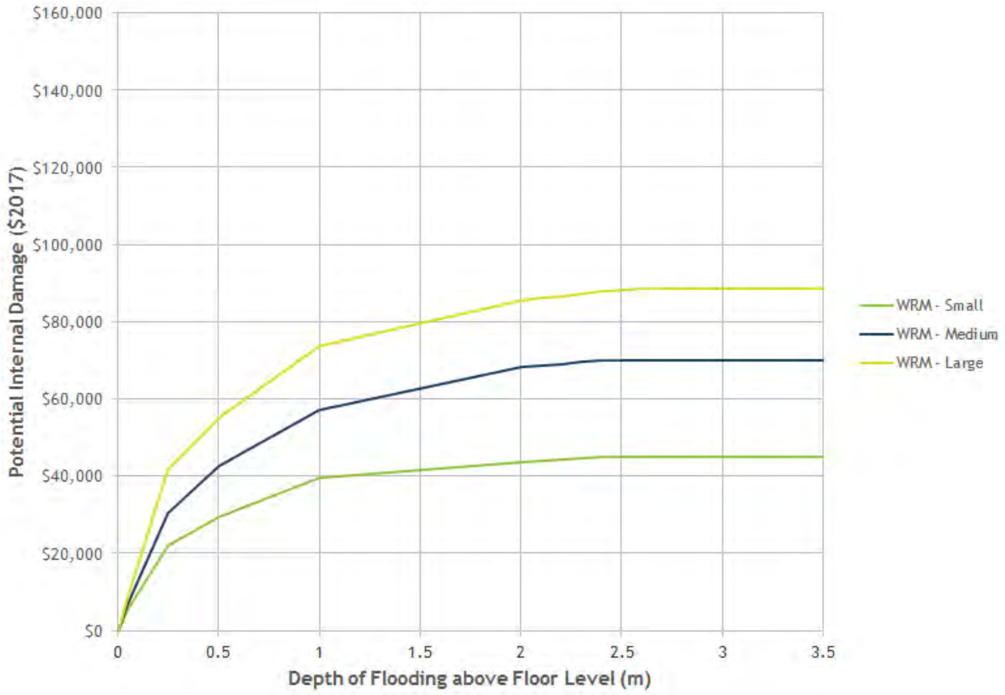


Figure 6-15 MUSS internal stage-damage curves

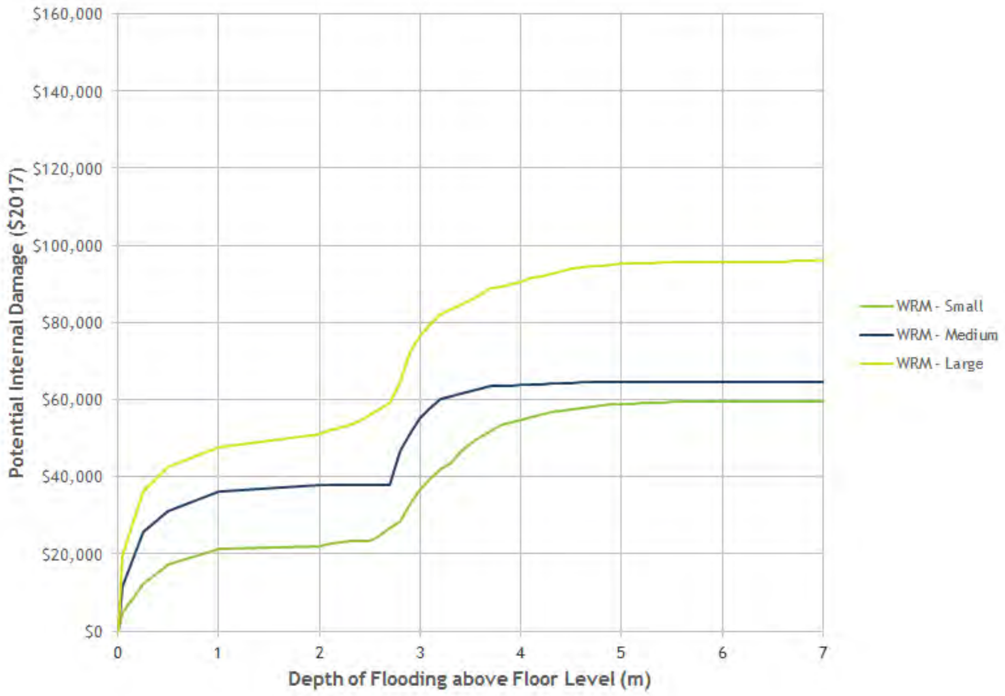


Figure 6-16 MUDS internal stage-damage curves

6.6.2.2 Structural Damage Curves

Structural stage-damage curves were derived using the residential property damage survey data for the six residential property types and three property sizes (18 curves). When the sample sizes were too small for some property types and/or sizes (e.g. large FDSS-Stumps), stage-damage curves were derived using information extrapolated from similar property types and sizes.

Table 6-10 provides a summary of the variation in building (floor area) sizes and potential structural damages for the surveyed properties used to derive representative potential internal stage-damage curves. Figures 6-17 to 6-22 show the potential structural stage-damage curves derived for the adoption in this study for different residential property types. The individual stage-damage curves generally show a small spread across the property range as would be expected.

Table 6-10 Summary of the variation in sizes and structural damages of the surveyed properties

Property size	Sample size	Floor area range	Mean floor area	Range of maximum potential damage	Mean of maximum potential damage
FDSS-SOG					
Small	4	77-125 m^2	105 m^2	$77,600 - $122,100	$102,475
Medium	11	140-204 m^2	170 m^2	$110,100 - $207,000	$149,091
Large	6	216-341 m^2	252 m^2	$184,400 - $227,100	$213,583
FDSS-Stumps					
Small	5	60-130 m^2	98 m^2	$86,500 - $125,500	$100,800
Medium [a]	3	153-201 m^2	185 m^2	$107,800 - $222,600	$180,800
Large [b]	0	-	-	-	-
FDSS-HS					
Small	12	64-138 m^2	108 m^2	$72,000 - $150,400	$103,042
Medium [a]	2	140 m^2	140 m^2	$109,700 - $115,000	$112,350
Large [c]	1	224 m^2	224 m^2	$138,600	$138,600
FDDS					
Small	1	130 m^2	130 m^2	$148,700	$148,700
Medium	10	144-210 m^2	191 m^2	$105,900 - $217,600	$170,880
Large	16	220-400 m^2	287 m^2	$145,700 - $400,000	$229,150
MUSS					
Small	7	60-136 m^2	105 m^2	$55,400 - $126,800	$83,900
Medium [d]	0	-	-	-	-
Large [d]	0	-	-	-	-
MUDS					

Property size	Sample size	Floor area range	Mean floor area	Range of maximum potential damage	Mean of maximum potential damage
Small	7	80-125 m^2	107 m^2	$56,800 - $98,900	$83,286
Medium	1	205 m^2	205 m^2	$126,700	$126,700
Large [e]	0	-	-	-	-

FDSS – fully detached single storey; FDHS – fully detached highset; FDDS – fully detached double storey;
MUSS – multi-unit single storey; MUDS – multi-unit double storey; SOG – slab-on-ground

[a] – due to the small sample size, the medium sized FDSS-Stumps and medium FDSS-HS were lumped and a combined medium sized SS detached raised property curve was derived using the larger lumped sample.

[b] – due to the absence of data, the large sized FDSS-Stumps stage-damage curve was obtained by extrapolating medium size damages based on the ratio of large to medium size FDSS-SOG damages.

[c] – due to the small sample size, the large sized FDSS-HS curve was derived based on equivalent ratios for the FDSS-SOG sample.

[d] – due to the absence of data, the medium sized MUSS and large sized MUSS stage-damage curves were derived based on equivalent ratios for the FDSS-SOG sample.

[e] – due to the absence of data, the large sized MUDS stage-damage curve was derived based on equivalent ratios for the FDDS sample.

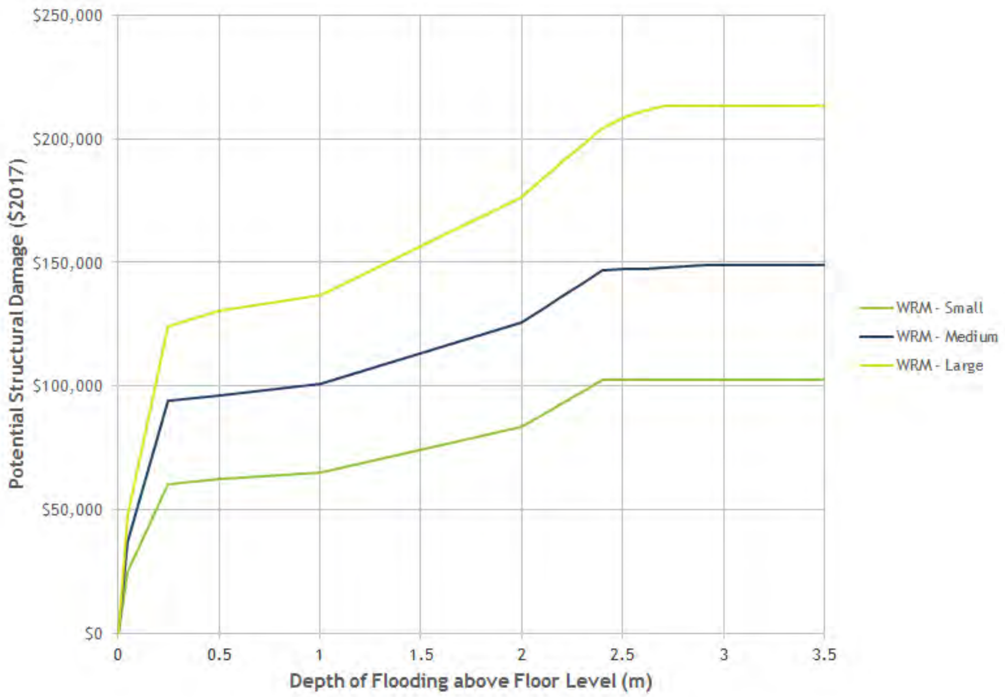


Figure 6-17 FDSS-SOG structural stage-damage curves

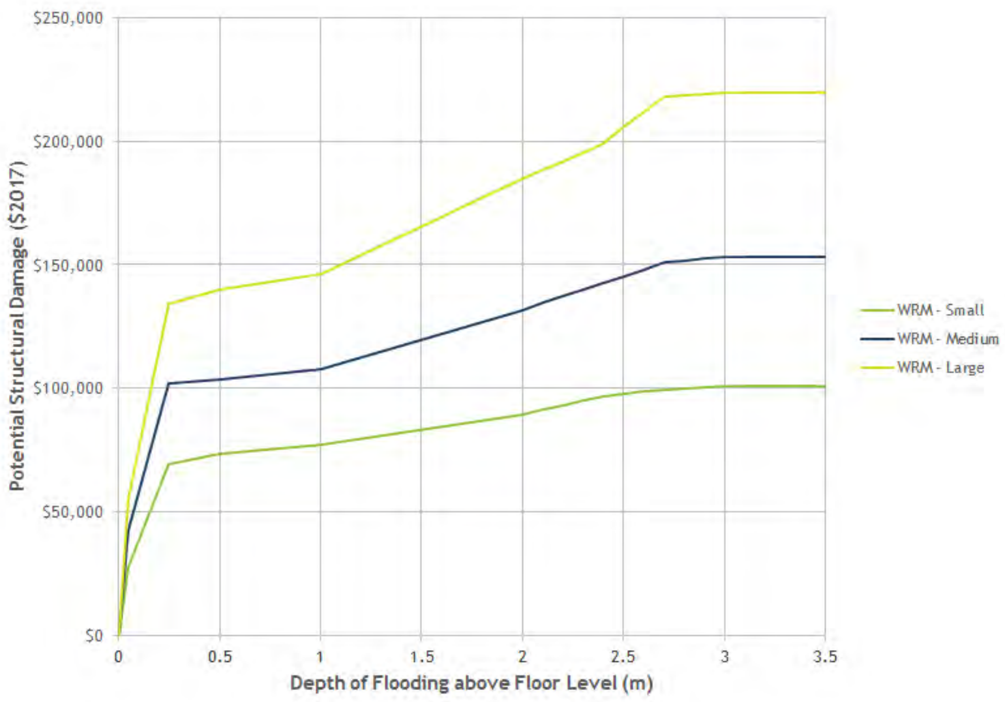


Figure 6-18 FDSS-Stumps structural stage-damage curves

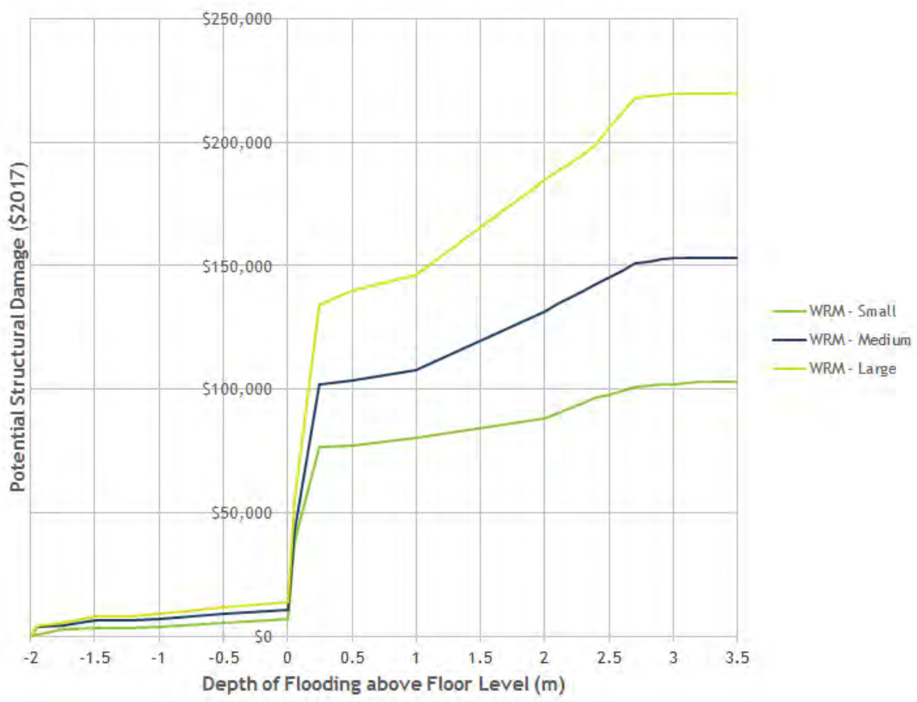


Figure 6-19 FDSS-HS structural stage-damage curves

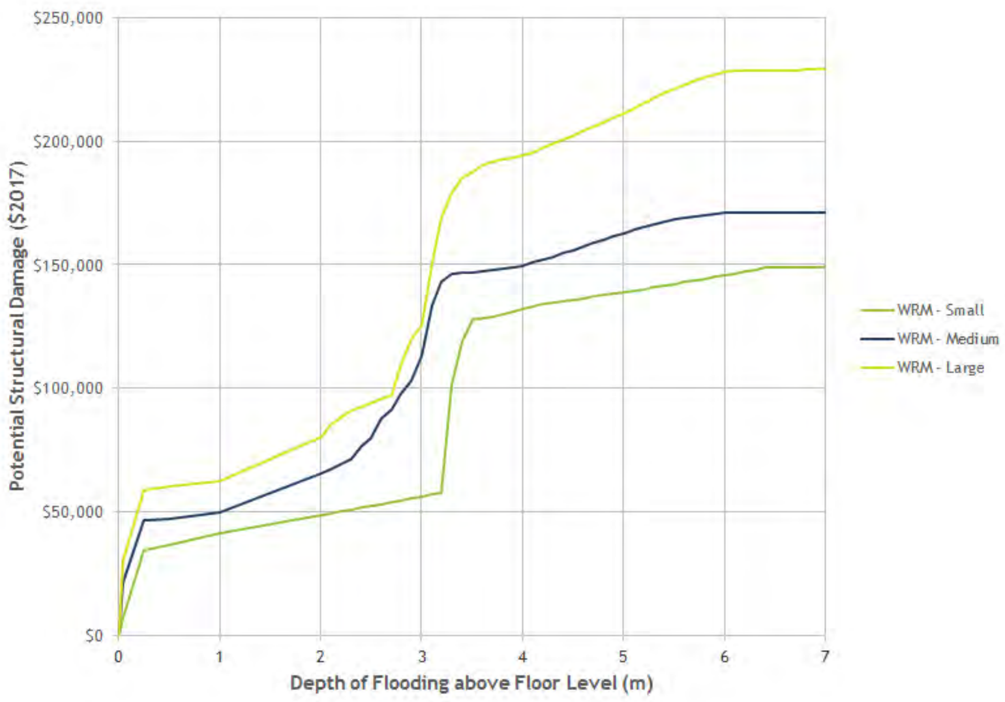


Figure 6-20 FDDS structural stage-damage curves

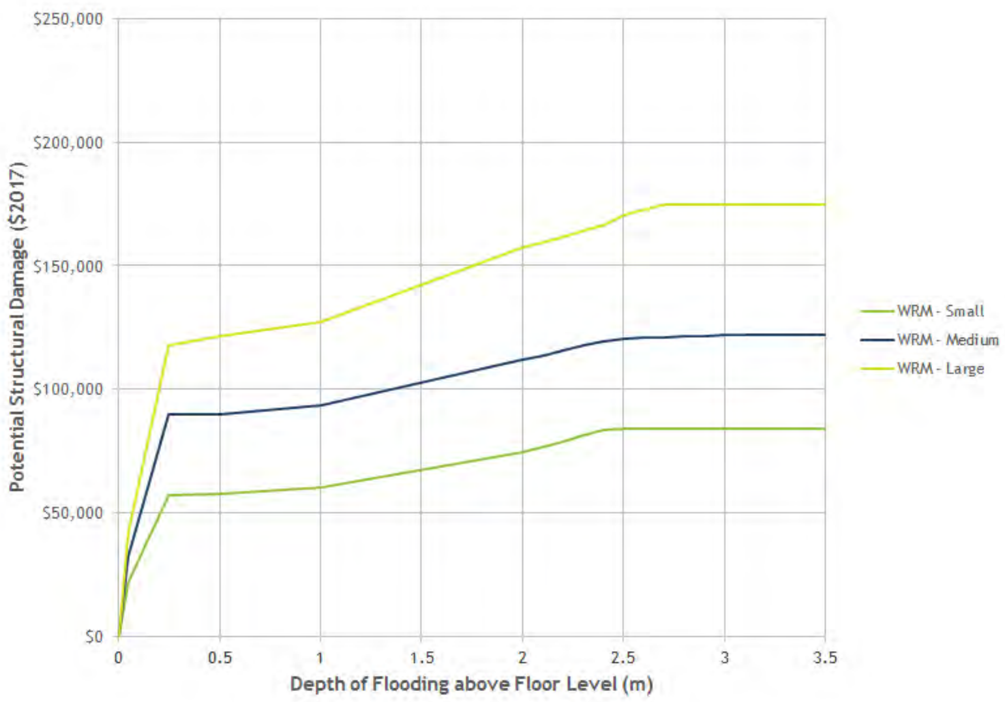


Figure 6-21 MUSS structural stage-damage curves

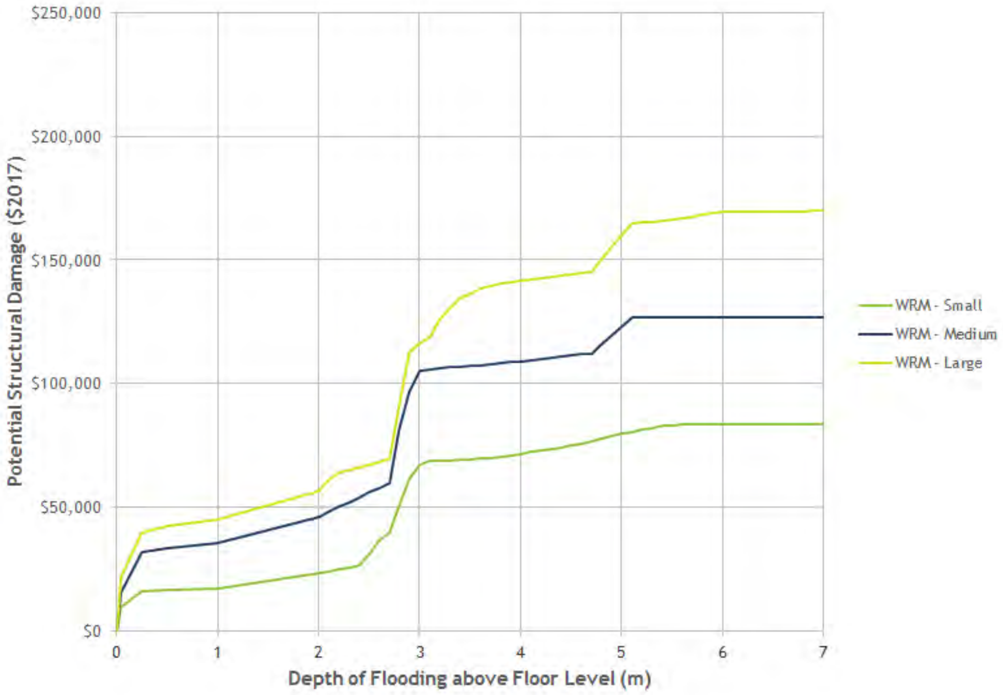


Figure 6-22 MUDS structural stage-damage curves

6.6.2.3 External Damage Curves

A set of six potential external stage-damage curves were derived for surveyed detached and non-detached property types and sizes. The spread in potential external damages is large (primarily due to some surveyed properties having multiple cars and sheds and other properties having no cars and/or sheds), Therefore, for the purposes of deriving external stage-damage curves, all detached property data was combined, as was all non-detached property data to derive representative potential external stage-damage curves for small, medium and large detached and non-detached properties. The stage-damage curves for external damage relate depth of flooding above ground level to flood damage, whereas the internal and structural stage-damage curves relate depth of flooding over floor level to flood damage.

Table 6-11 provides a summary of the variation in building sizes and potential external damages for surveyed properties used to derive the representative external stage-damage curves. Figures 6-23 to 6-28 show the external stage-damage curves derived for the adoption in this study for different residential property types.

Table 6-11 Summary of the variation in sizes and external damages of the surveyed properties

Property size	Sample size	Floor area range	Mean floor area	Range of maximum potential damage	Mean of maximum potential damage
FDSS-SOG					
Small [a]	4	77-125 m^2	105 m^2	$20,250 - $77,550	$38,575
Medium [a]	11	140-204 m^2	170 m^2	$13,000 - $101,550	$47,550
Large [a]	6	216-341 m^2	252 m^2	$39,600 - $196,750	$84,225
FDSS-Stumps					
Small [a]	5	60-130 m^2	98 m^2	$32,200 - $175,800	$69,150
Medium [a]	3	153-201 m^2	185 m^2	$33,900 - $64,900	$44,267
Large [a]	0	-	-	-	-
FDSS-HS					
Small [a]	12	64-138 m^2	108 m^2	$23,600 - $138,200	$58,063
Medium [a]	2	140 m^2	140 m^2	$46,800 - $117,300	$82,050
Large [a]	1	224 m^2	224 m^2	$146,000	$146,000
FDDS					
Small [a]	1	130 m^2	130 m^2	$32,200	$32,200
Medium [a]	10	144-210 m^2	191 m^2	$7,800 - $75,000	$50,970
Large [a]	16	220-400 m^2	287 m^2	$32,800 - $305,800	$102,953
MUSS					
Small [b]	7	60-136 m^2	105 m^2	$0,000 - $55,000	$18,686
Medium [b]	0	-	-	-	-
Large [b]	0	-	-	-	-
MUDS					
Small [b]	7	80-125 m^2	107 m^2	$0,000 - $30,700	$12,443
Medium [b]	1	205 m^2	205 m^2	$17,200	$17,200
Large [b]	0	-	-	-	-

FDSS – fully detached single storey; FDHS – fully detached highset; FDDS – fully detached double storey;
MUSS – multi-unit single storey; MUDS – multi-unit double storey; SOG – slab-on-ground

[a] – the small detached surveyed properties were lumped and a combined to derive a stage-damage curve for all small detached properties. The same was done for the medium and large detached properties

[b] – the small multi-unit surveyed properties were lumped and a combined to derive a stage-damage curve for all small multi-unit properties. The same was done for the medium and large multi-unit properties

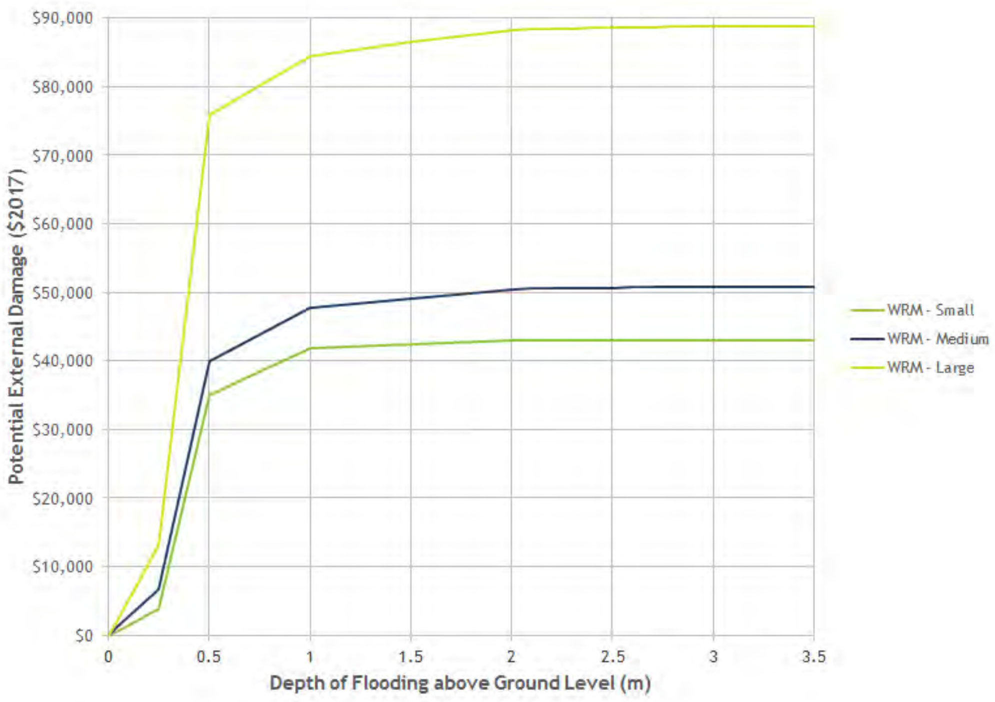


Figure 6-23 FDSS-SOG external stage-damage curves

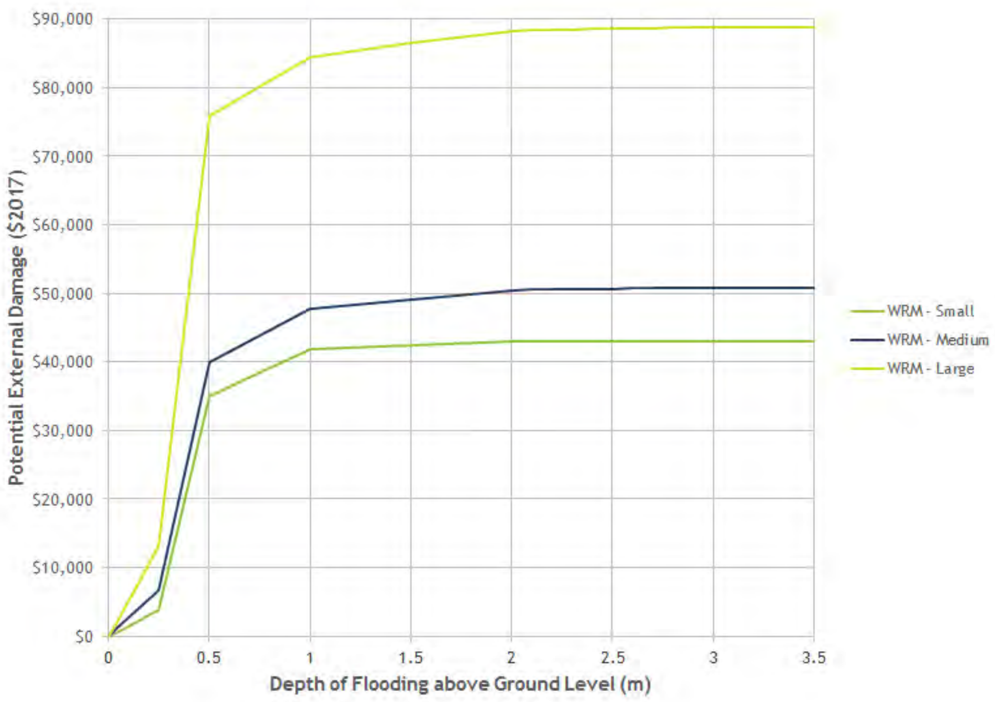


Figure 6-24 FDSS-Stumps external stage-damage curves

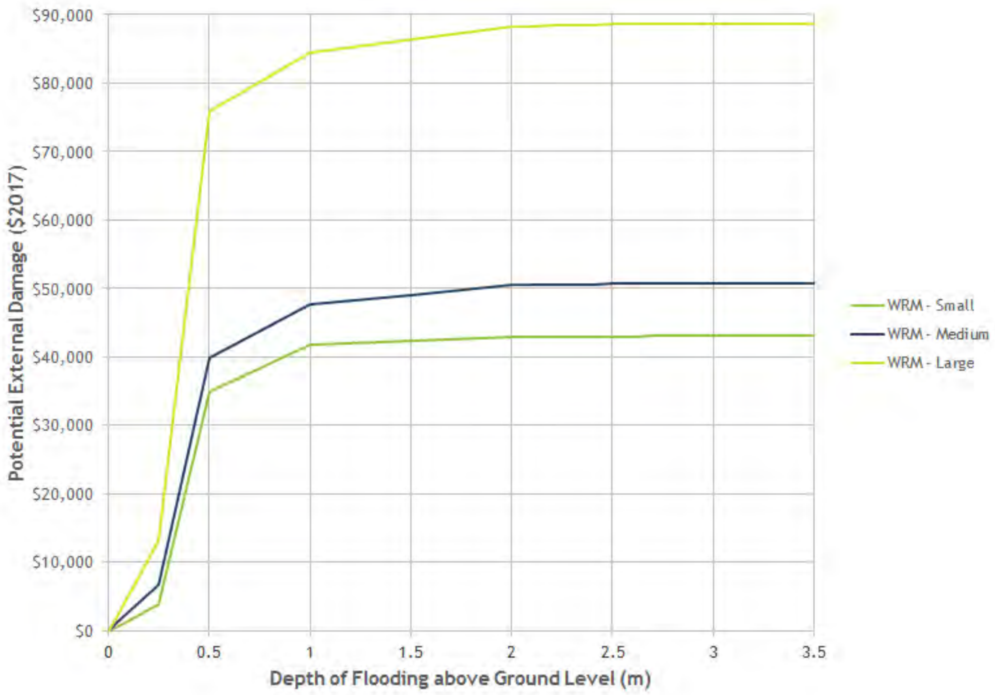


Figure 6-25 FDSS-HS external stage-damage curves

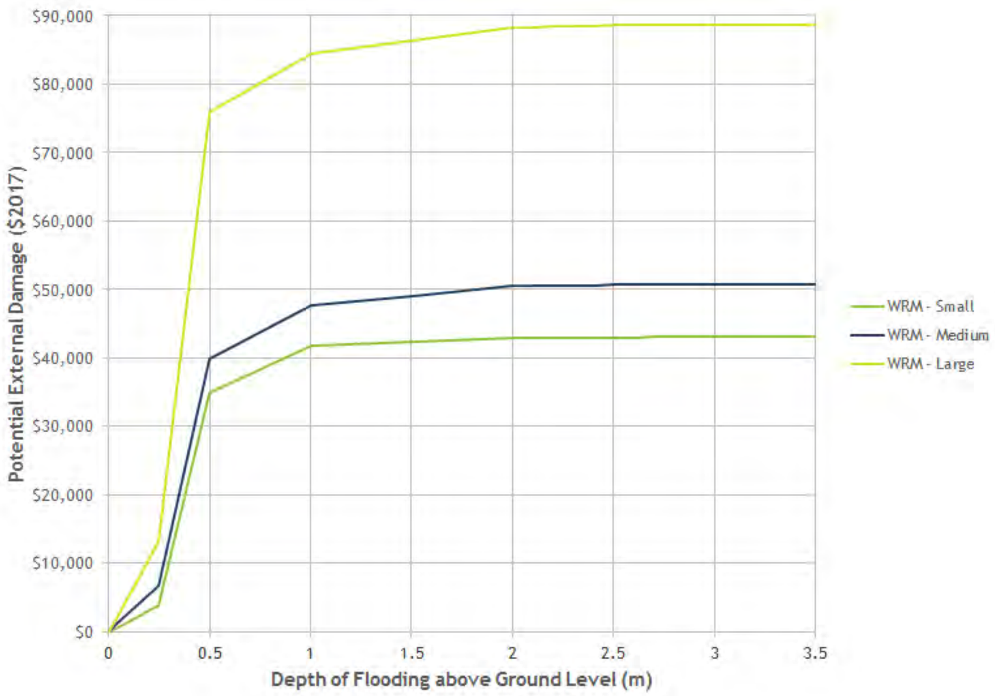


Figure 6-26 FDDS external stage-damage curves

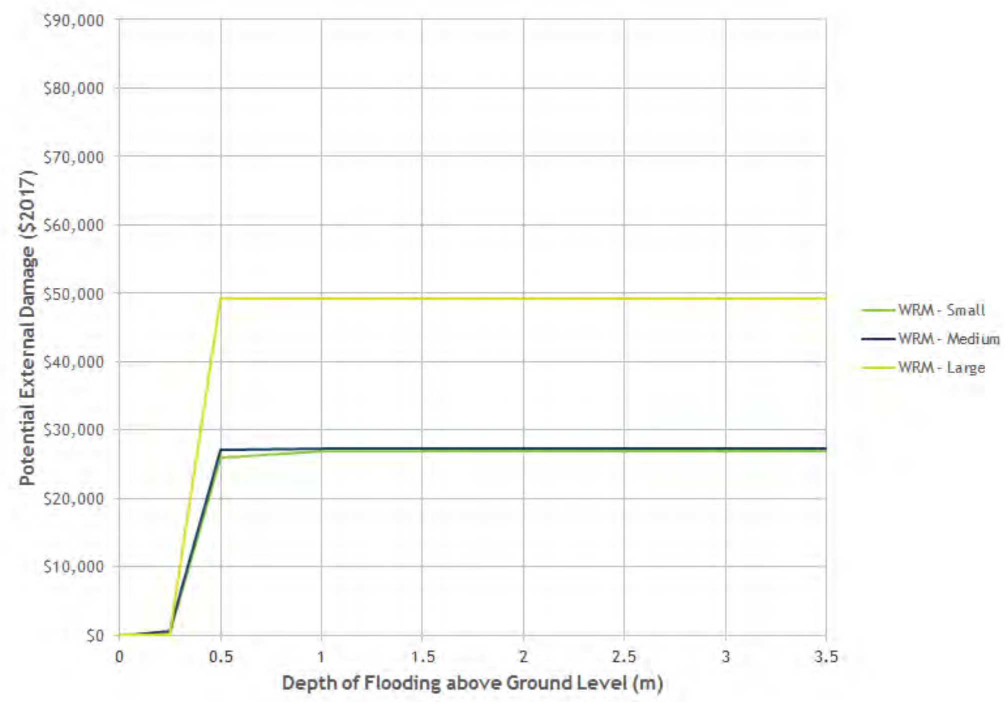


Figure 6-27 MUSS external stage-damage curves

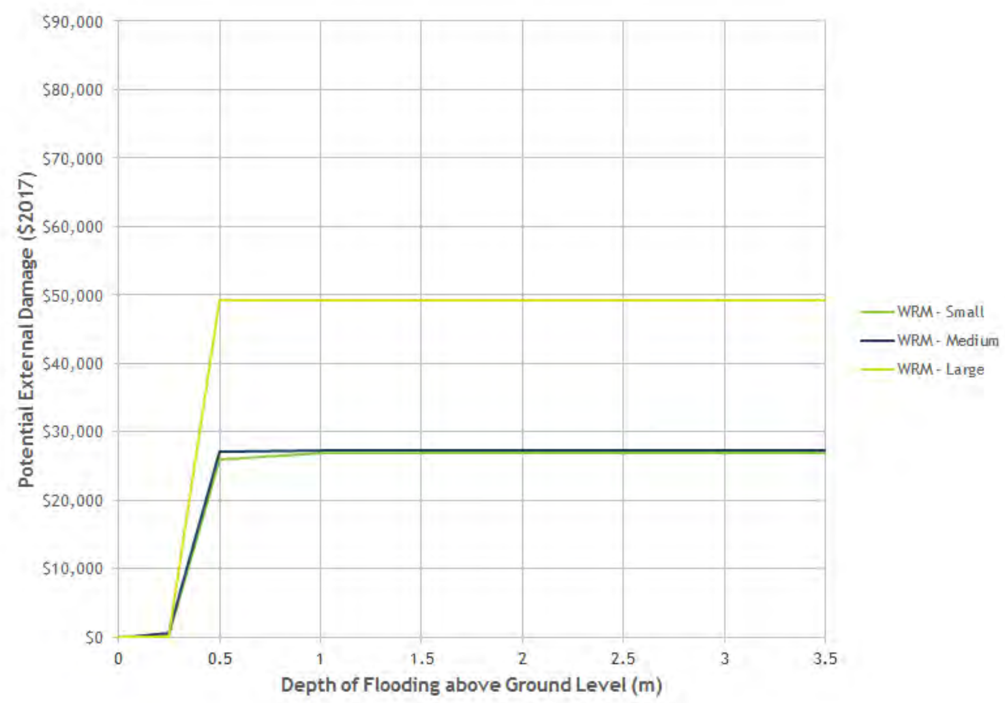


Figure 6-28 MUDS external stage-damage curves

6.6.3 Commercial Damage Curves

A total of 30 commercial properties were surveyed across the four LGA's to get a representative cross-section of small and medium commercial enterprises in the study area. Each surveyed enterprise was assigned a value class (VC1 to VC5) based on the enterprise information noted in the survey and in accordance with the guidelines given in ANUFLOOD (CRES, 1992) (see Figure 6-29).

Stage-damage curves relating the depth of flooding to potential total (external, internal and structural) flood damage were developed for each surveyed enterprise. Data for each property was then plotted against the equivalent existing ANUFLOOD damage curve, updated (using the CPI increase for Brisbane) to provide damage estimates in 2017 dollar values.

The ANUFLOOD damage curves for small and medium sized enterprises for each value class were then updated to produce new stage-damage curves that would be representative of flood damages under present day conditions and for the different value classes. In the absence of survey data, the existing stage-damage curves for large sized enterprises were adjusted based on the adjustment ratios applied to the small and medium sized enterprise curves.

Figures 6-30 to 6-32 show the commercial stage-damage curves derived for adoption in this study for different commercial property types.

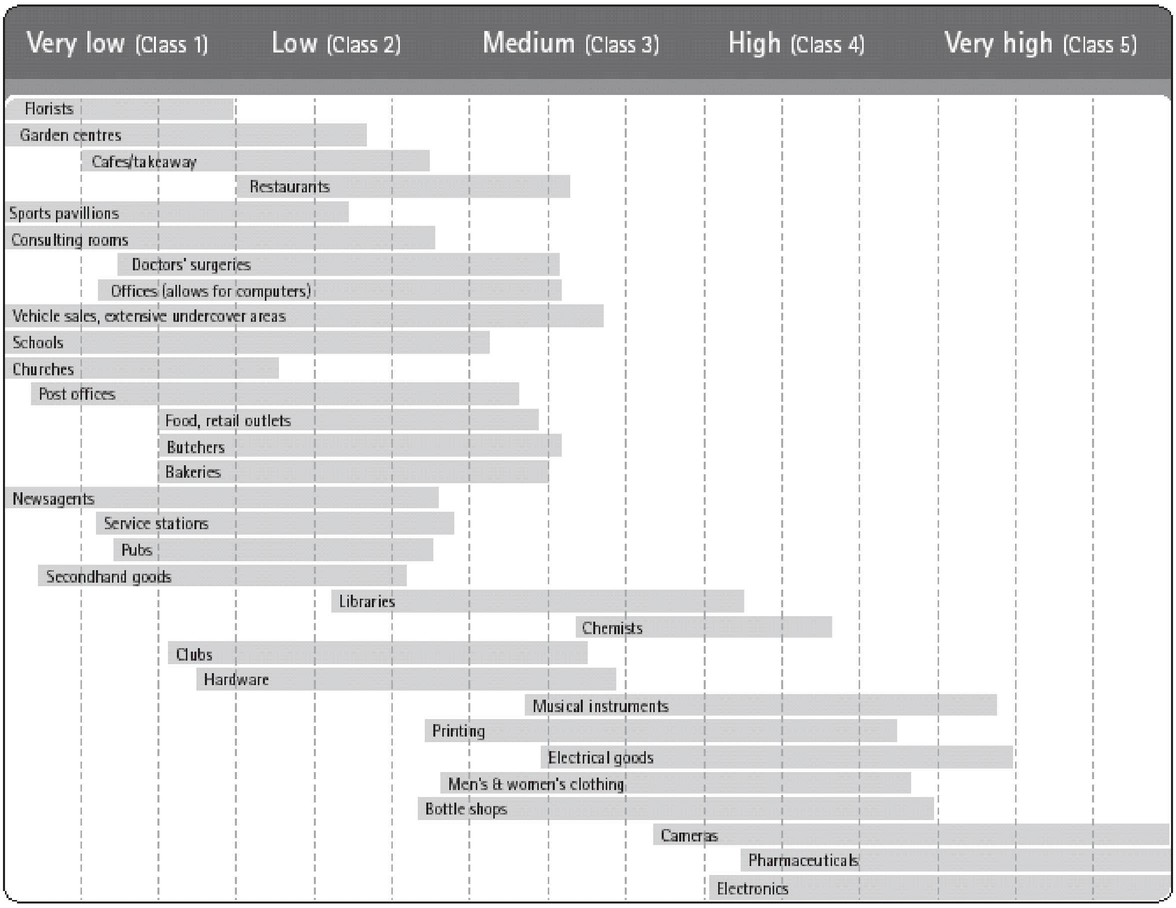


Figure 6-29 Commercial property damage categories (source: DNRM, 2002)

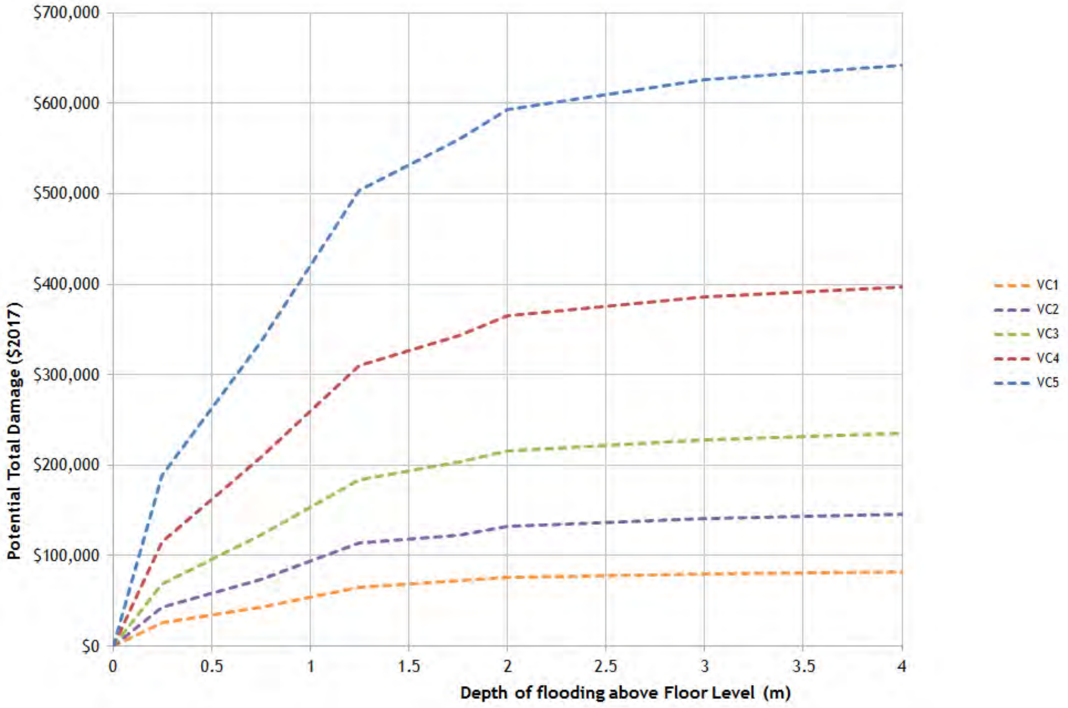


Figure 6-30 Adopted small commercial stage-damage curves

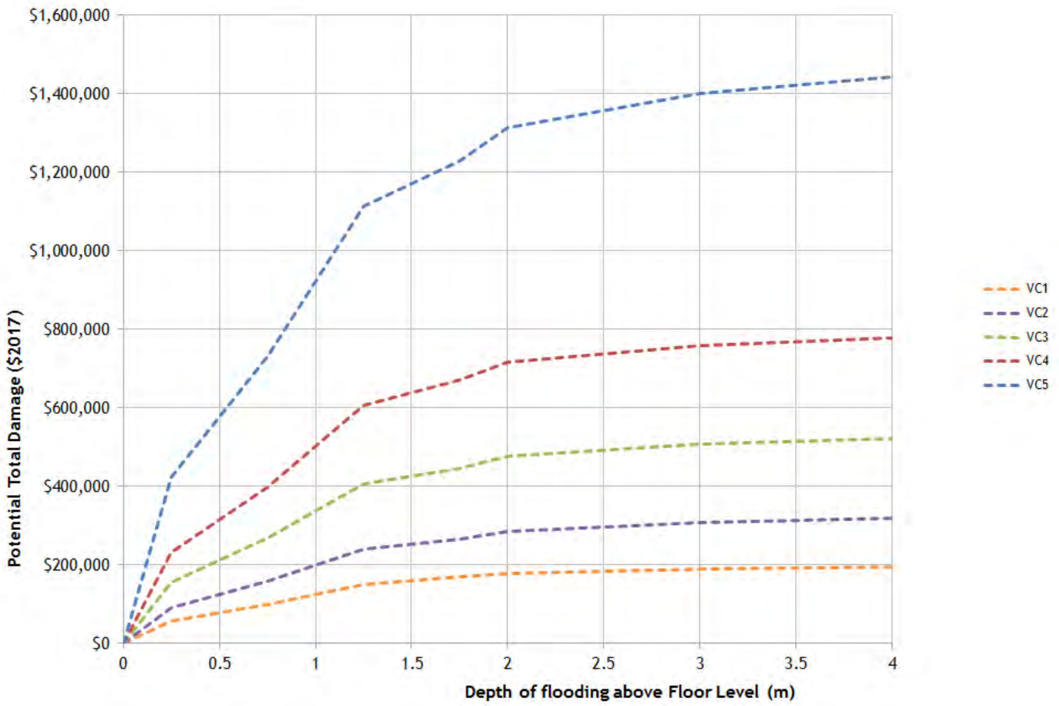


Figure 6-31 Adopted medium commercial stage-damage curves

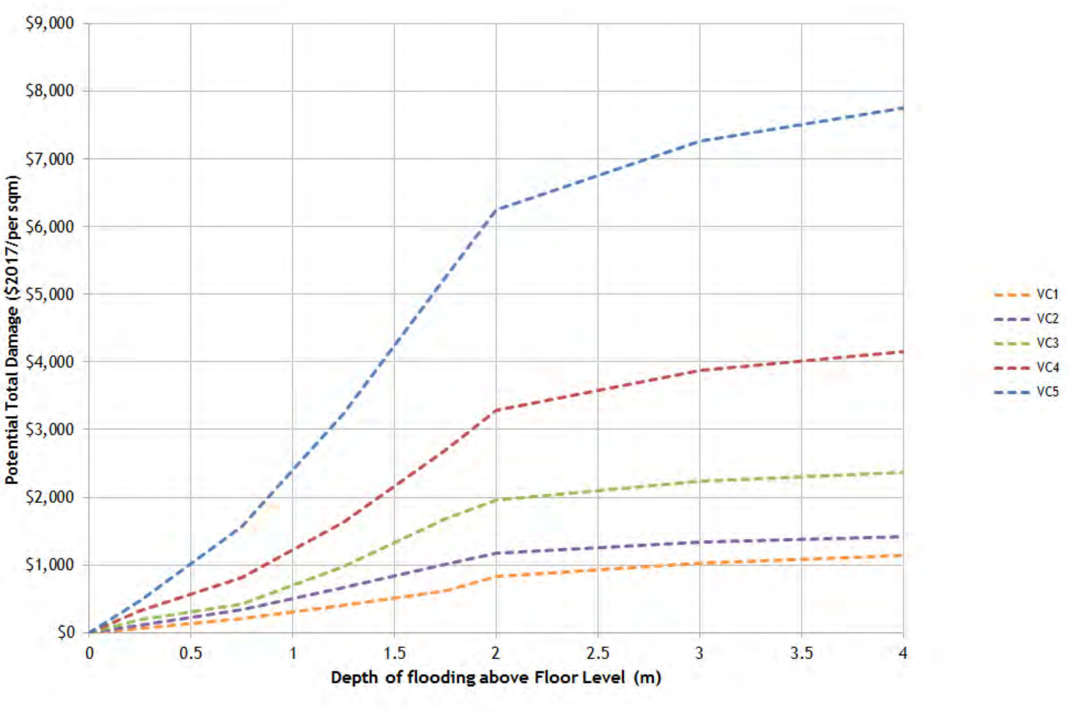


Figure 6-32 Adopted large commercial stage-damage curves

6.6.4 Comparison of Stage-Damage Curves

6.6.4.1 Overview

Some data to check and compare the stage-damage curves derived in this study was available from Geoscience Australia (GA), O2 Environmental (O2), ANUFLOOD and the Insurance Council of Australia (ICA). Therefore, the stage-damage curves derived in this study were compared with data available from these sources.

GA provided residential flood stage-damage index curves (for internal and structural damages only) they developed after the January 2011 Brisbane River flood. It does not appear that these stage-damage curves have been used to date on any major flood damage investigations in Australia. A discussion on these damage curves is given in Section 6.2.1.5.1. GA also provided some industrial and commercial stage-damage index curves that are currently in draft format. These commercial and industrial stage-damage index curves are for structural damage only and have been developed mainly for very large and highly specific enterprises and hence are of little use for this study.

The O2 validation data comes from residential and commercial stage-damage curves developed for ICC in 2012. The O2 stage-damage curves are based on modifications and updates made to the curves developed for Maroochy Shire Council by WRM Water & Environment (WRM, 2006a) and used in BVFDMS. The O2 stage-damage curves were used in WSDOS, with some simplification for residential properties. A discussion on the O2 damage curves is given in Section 6.2.1.5.1.

The ICA have provided insurance (buildings and contents) claim data for 60 selected residential properties inundated in the study area in January 2011.

6.6.4.2 GA Stage-Damage Curves

Table 6-12 compares the GA residential property type classifications with the equivalent Phase 3 (SFMP) study property classifications. The GA classifications do not include semi or non-detached buildings (i.e. multi-unit single and double storey buildings). Therefore, the GA stage-damage curves cover only four out of the six key residential property types identified in the Phase 3 (SFMP) study area. Further, the stage-damage curves developed by GA cover internal and structural damages only i.e. no external damages can be estimated using GA stage-damage curves.

Table 6-12 Comparison of GA to Phase 3 (SFMP) residential property classifications

GA's building type ID	GA specified building attributes	Equivalent Phase 3 (SFMP) building classification
FCM1	single storey, raised floor, weatherboard cladding, plaster board lining, no integral garage	FDSS-Stumps
FCM2	single storey, raised floor, weather board or panel cladding, timber lining, no integral garage	FDSS-Stumps
FCM3	two storey (highset), slab-on-grade, cavity masonry lower storey, weatherboard upper storey, metal roof, no integral garage	FDDS
FCM4	two storey (highset), slab-on-grade, cavity masonry lower storey, weatherboard upper storey, metal roof, integral garage	FDDS
FCM5	two storey (highset), slab-on-grade, weatherboard cladding, plaster board lining, partial lower floor, integral garage	FDHS
FCM6	two storey (highset), raised floor, weatherboard cladding, plaster board lining, no integral garage	FDDS
FCM7	single storey, slab-on-grade, masonry veneer, plaster board lining, integral garage	FDSS-SOG
FCM8	single storey, slab-on-grade, masonry veneer, plaster board lining, no garage	FDSS-SOG
FCM9	single storey, raised floor, masonry veneer, plaster board lining, no garage	FDSS-Stumps
FCM10	single storey, slab-on-grade, cavity masonry, no garage	FDSS-SOG
FCM11	single storey, raised floor, cavity masonry, no garage	FDSS-Stumps

To convert GA's stage-damage index values to dollar damage estimates for the different types and sizes of residential properties, the damage index value was multiplied by the unit cost of damage ($ per m^2 of floor area) provided by GA and the mean floor area for each residential building type and size range extracted from the building database created for this study. For comparison with the results of this study, the GA damage estimates were updated to 2017 dollar values using the CPI increase for Brisbane for internal (contents) damages and the building price index (BPI) increase for Brisbane for structural damages.

6.6.4.3 O2 Stage-Damage Curves

As described in Section 6.2.1.5.1, O2 developed interim stage-damage curves for both residential and commercial properties for ICC. The residential and commercial property classifications used by O2 are consistent with the property equivalent classifications adopted in this study. O2 damage estimates were updated to 2017 dollar values using the CPI increase for Brisbane for internal and external damages and the building price index (BPI) increase for Brisbane for structural damages.

The O2 classifications do not include detached lowset buildings on-stumps. Therefore, the O2 stage-damage curves cover only five out of the six key residential property type identified in the Phase 3 (SFMP) study area. Further, O2 did not develop separate stage-damage curves for different property sizes, except for detached single storey slab-on-ground buildings. In effect, O2 assumed that a single stage-damage curve is representative of all property sizes for each property type.

6.6.4.4 Insurance and Other Data

ICA have provided some data on structural (building) and internal (contents) damage insurance claims for 60 properties inundated by the January 2011 flood in the study area. The peak flood levels estimated in the Phase 2 (Flood Study) for the January 2011 flood at each of the ICA property locations, together with the respective flood stage-damage curves derived in this study, were used to estimate flood damages for each of these properties and then compare the insurance claim damage values with the damage values predicted using the adopted stage-damage curves.

Several properties that were included in the property damage survey used for developing the stage damage curves had been inundated in January 2011. Two of these property owners provided details of their contents and structural damage costs during the survey. These two damage estimates were also included in this comparison.

6.6.4.5 Comparison with GA and O2 Curves

Figures 6-33 to 6-46 compare the adopted residential Phase 3 (SFMP) stage-damage curves with the corresponding GA and O2 stage-damage curves. The GA curves shown in these figures represent the average of damage values for the group of GA property types that fall within the particular property types used in this study. For example, for FDSS-SOG property type, the GA curves presented in Figure 6-33 are the average of equivalent curves for GA property types FCM7, FCM8 and FCM10 identified in Table 6-12.

The comparison shows that the GA curves provide lower estimates of internal damage and higher estimates of structural damage when compared to the curves derived in this study. Possible reasons for this difference include:

- Damage curves derived using different methodology: GA curves were based on an analytical assessment (based on the inventory method), while the Phase 3 (SFMP) curves were based on a physical survey of properties (valuation method);
- GA damages are based on a fixed unit (repair/replacement) cost per m^2 of floor area and the damage value varies linearly with floor area of the property. The damage cost per unit floor area for GA curves remains unchanged with increases in floor area (i.e. the damage cost per unit floor area is independent of the size of the property). These factors result in large damage estimates

for larger properties because there is no upper limit/cap imposed. For this study, the damage cost per unit floor area reduces with increasing floor area;

- The items included and excluded from particular damage categories in the two sets of curves: e.g. air-conditioners were included in the Phase 3 (SFMP) internal damage but in GA's structural damage;
- The differences in structural damage estimates could be also due to the use of different repair/replacement strategies and costs identified for different building components; and
- The GA structural damage costs may be based on higher quality products and fittings adopted for their 'hypothetical' house when compared to the quality of products and fitting found in the properties surveyed for this study.

The O2 stage-damage curves show a closer correlation to the stage-damage curves derived in this study. Most of the O2 stage-damage curves compare well to the medium sized property damage curves derived for this study, however, the shapes of the O2 structural curves, particularly at small flood depths, are quite different to the Phase 3 (SFMP) curves. This difference is likely due to differing assumptions regarding building materials in a 'typical' residence and the damage cost at the onset of inundation (repair vs replacement costs) of building materials.

Based on the comparison with the GA and O2 data, the stage-damage curves derived for this study are considered fit for purpose. The curves represent to most extensive full re-assessment of stage-damage profile for different property types undertaken in Australia in many years, and are a valued resources for other projects of this type.

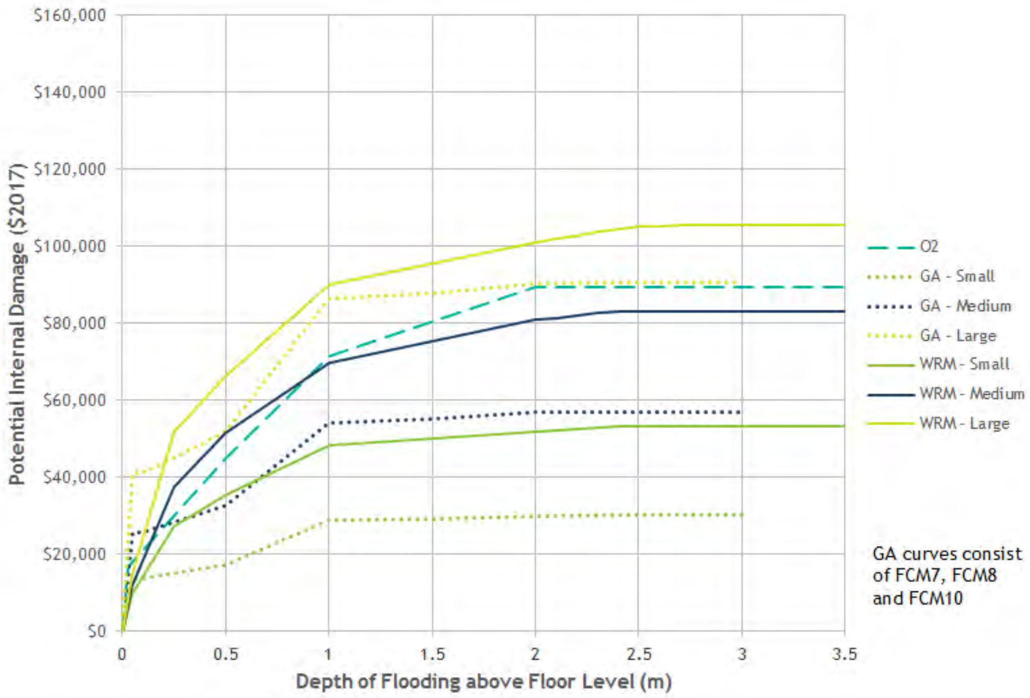


Figure 6-33 FDSS-SOG internal stage-damage curve comparison

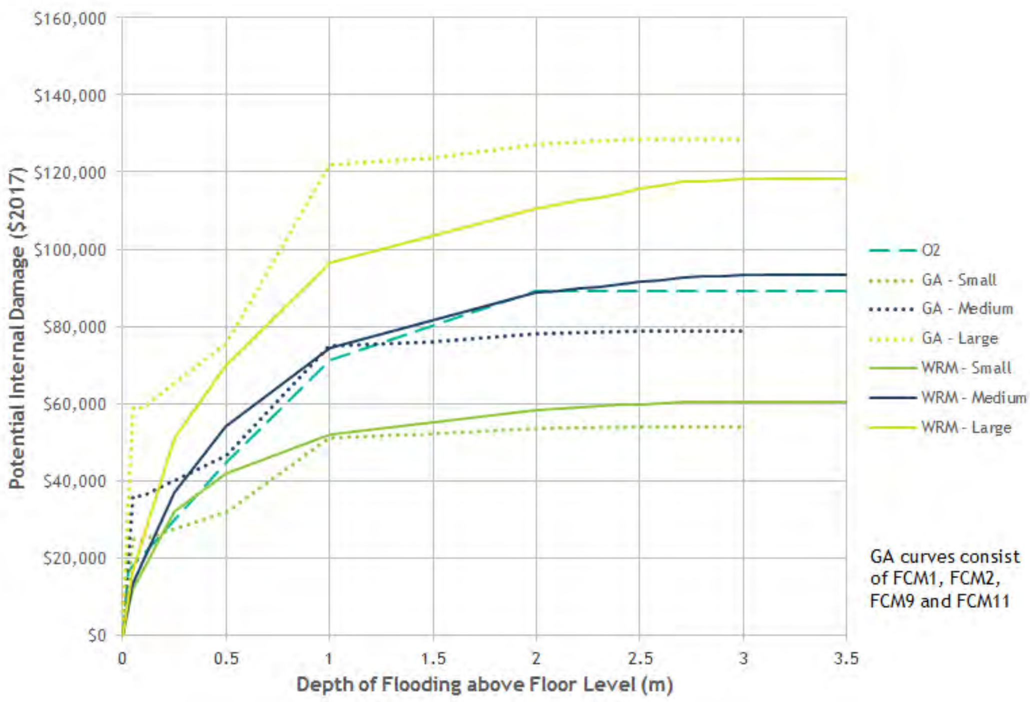


Figure 6-34 FDSS-Stumps internal stage-damage curve comparison

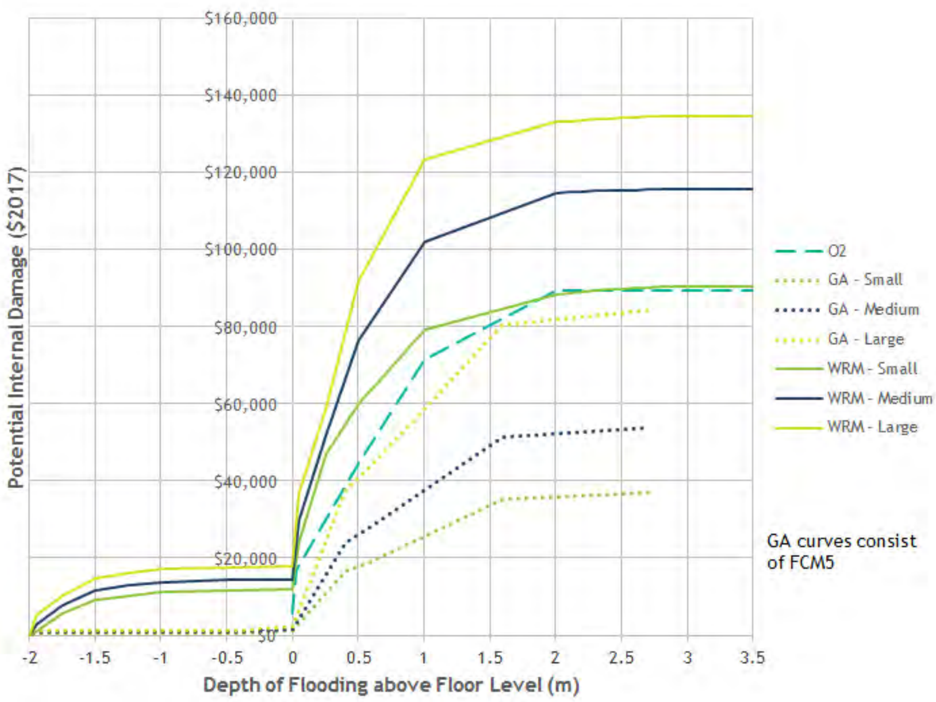


Figure 6-35 FDHS internal stage-damage curve comparison

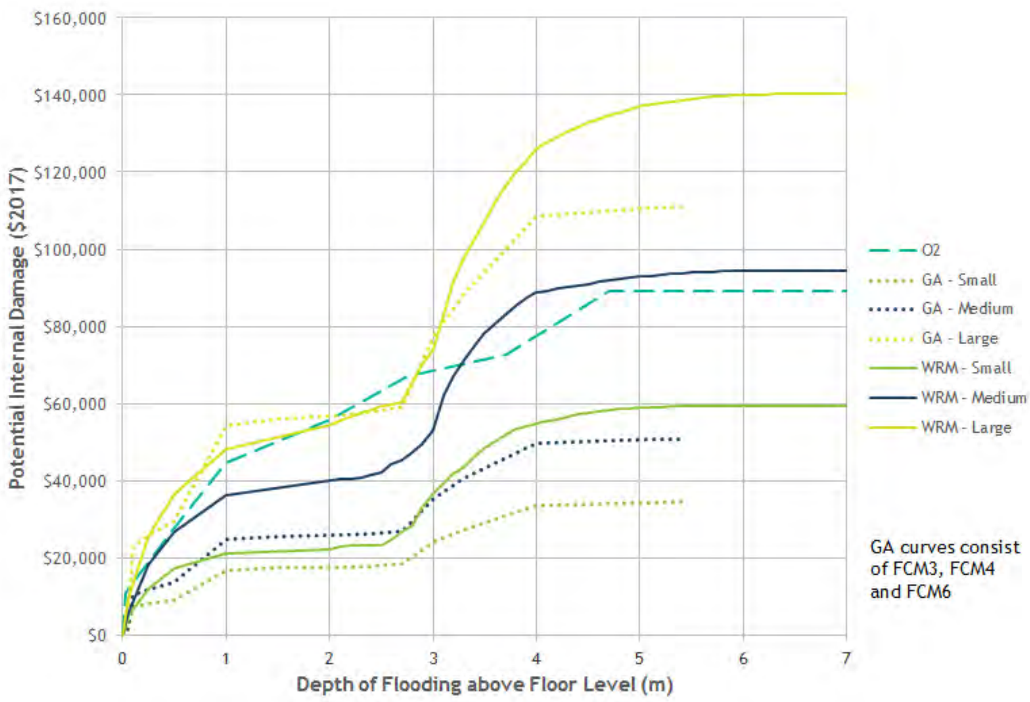


Figure 6-36 FDDS internal stage-damage curve comparison

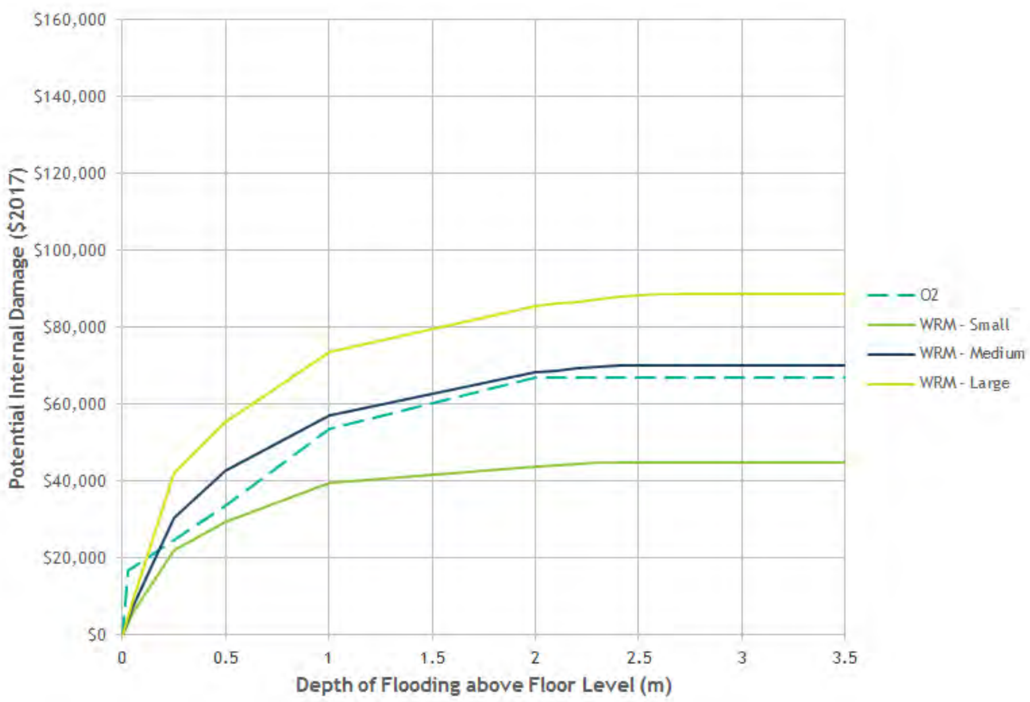


Figure 6-37 MUSS internal stage-damage curve comparison

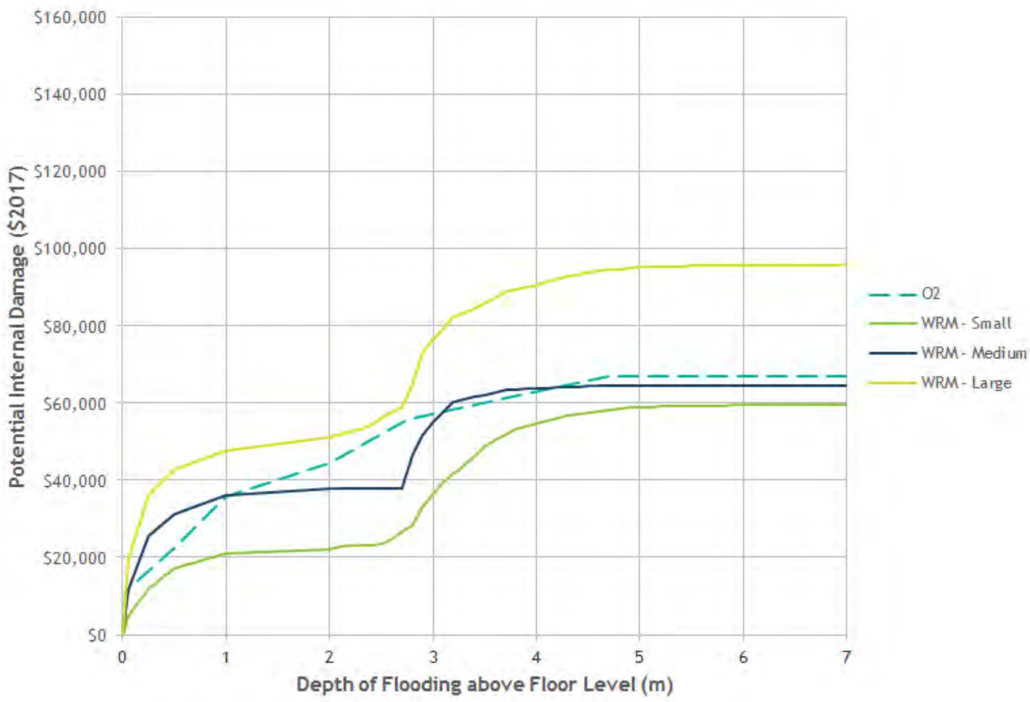


Figure 6-38 MUDS internal stage-damage curve comparison

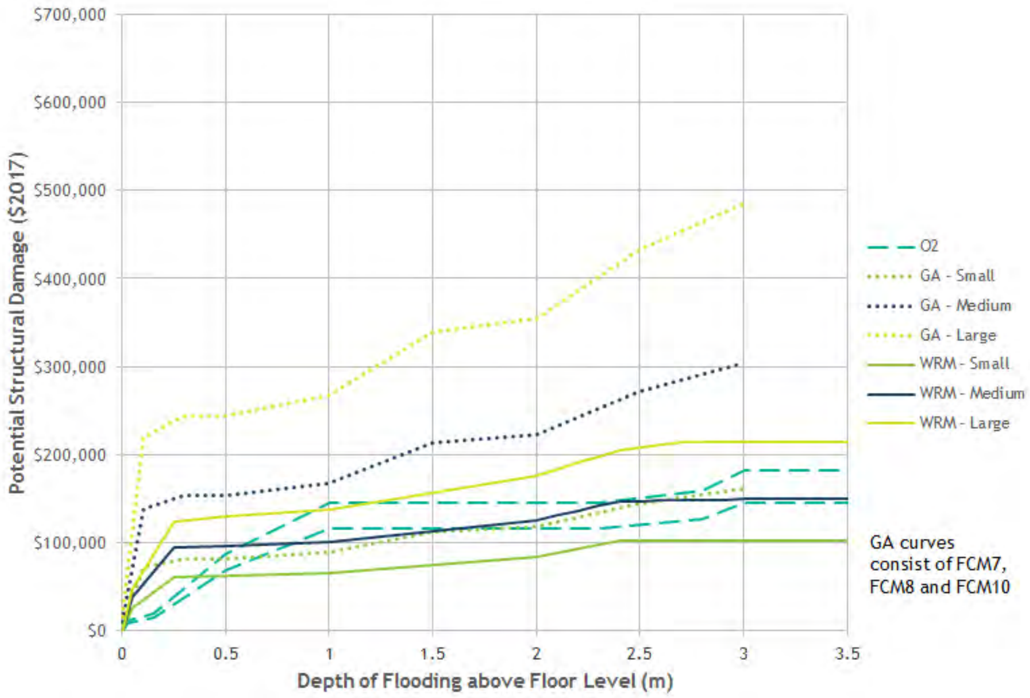


Figure 6-39 FDSS-SOG structural stage-damage curve comparison

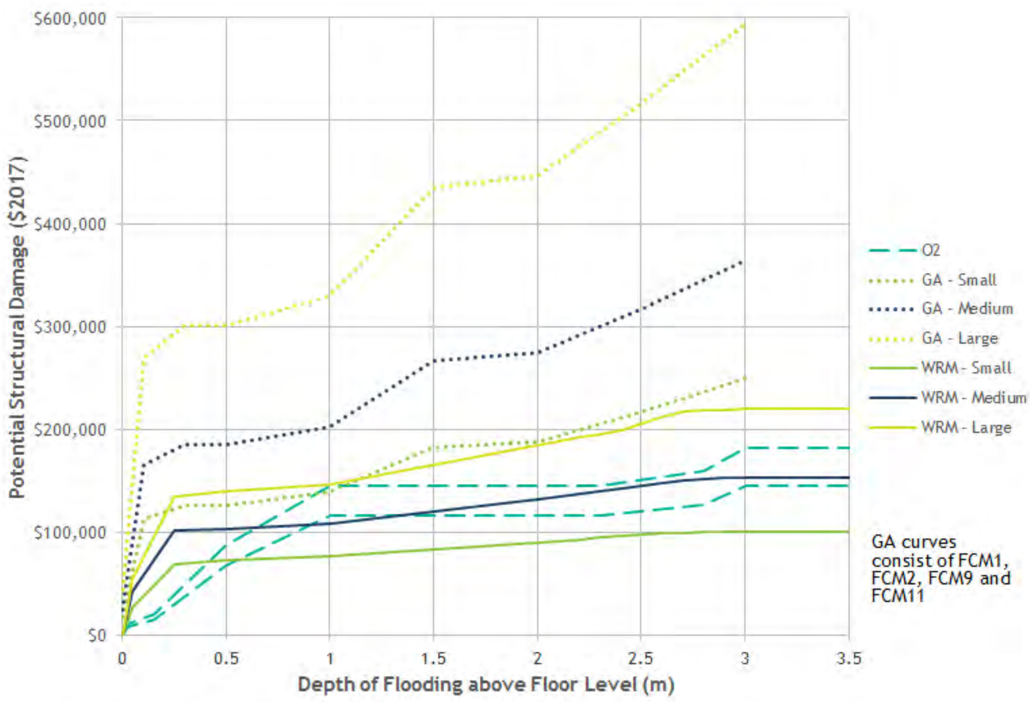


Figure 6-40 FDSS-Stumps structural stage-damage curve comparison

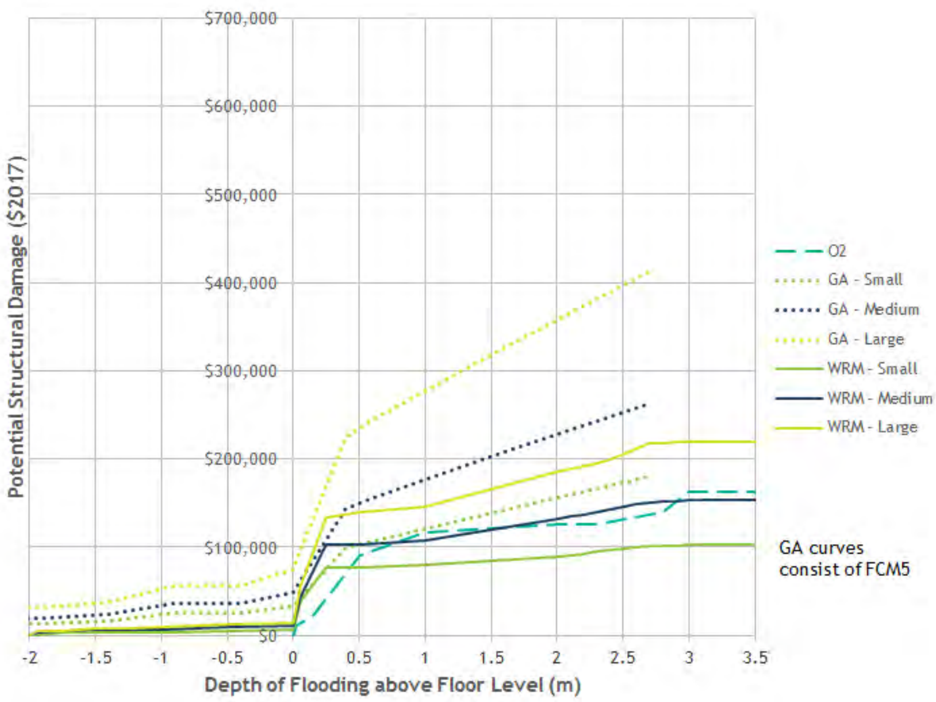


Figure 6-41 FDHS structural stage-damage curve comparison

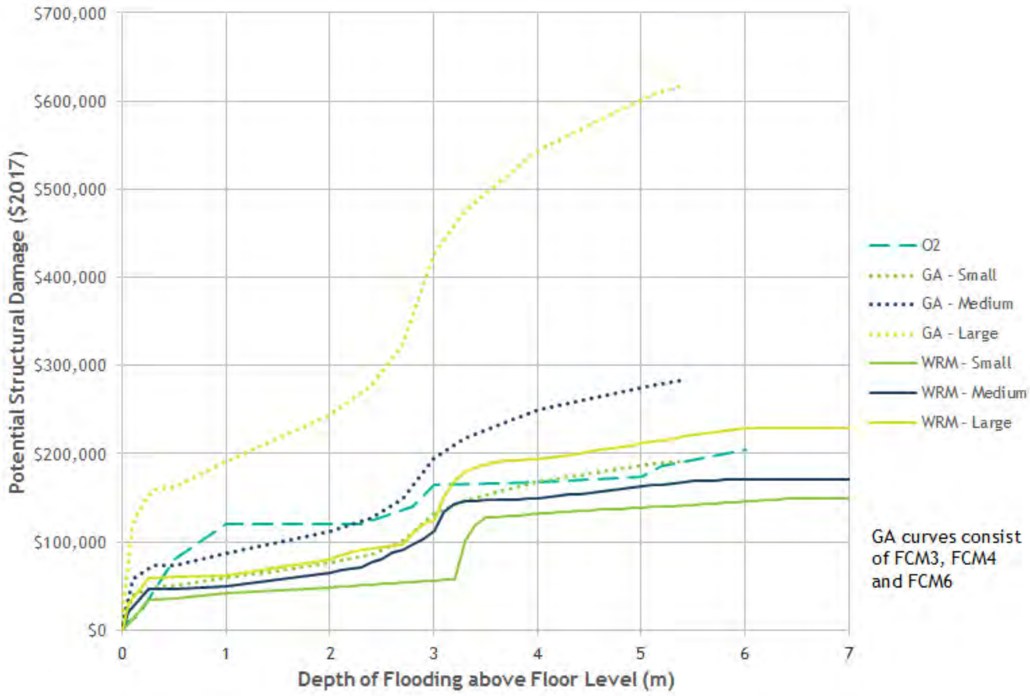


Figure 6-42 FDDS structural stage-damage curve comparison

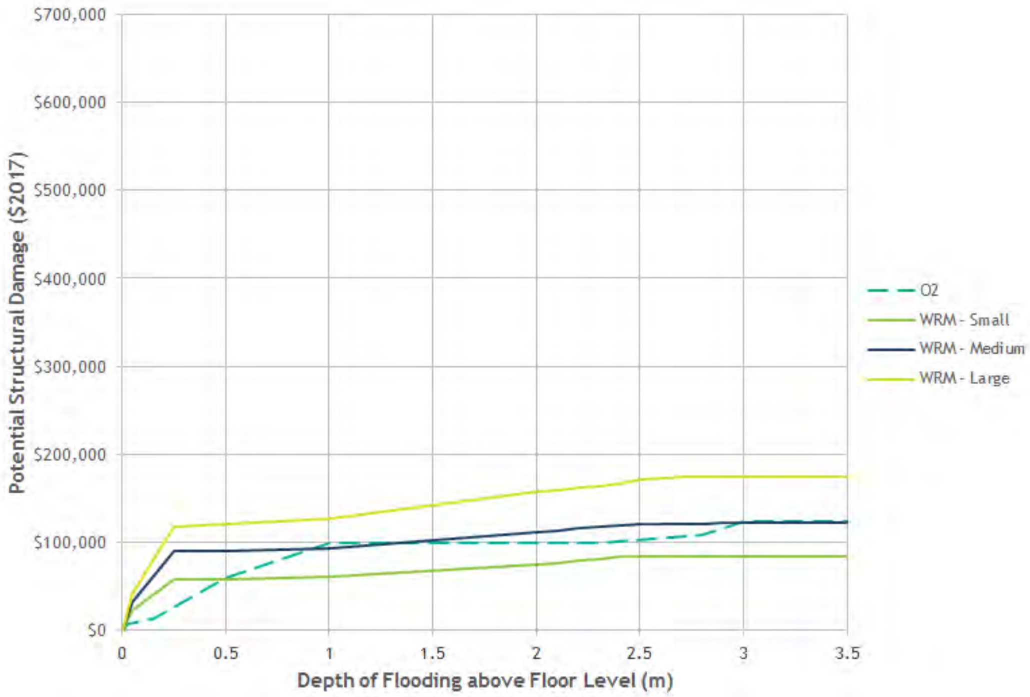


Figure 6-43 MUSS structural stage-damage curve comparison

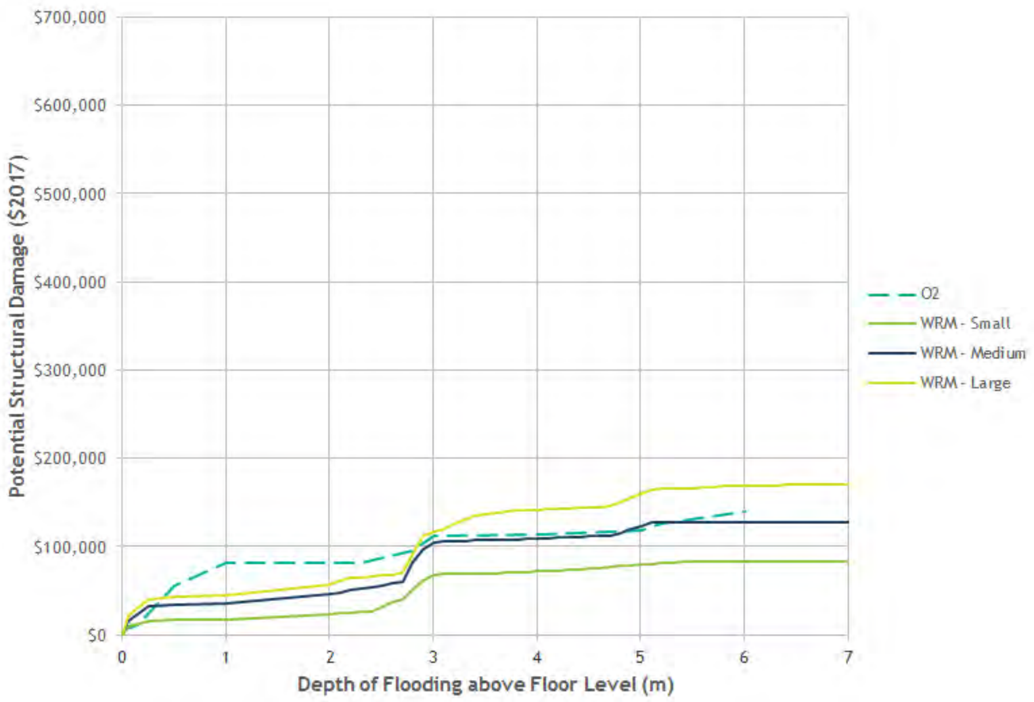


Figure 6-44 MUDS structural stage-damage curve comparison

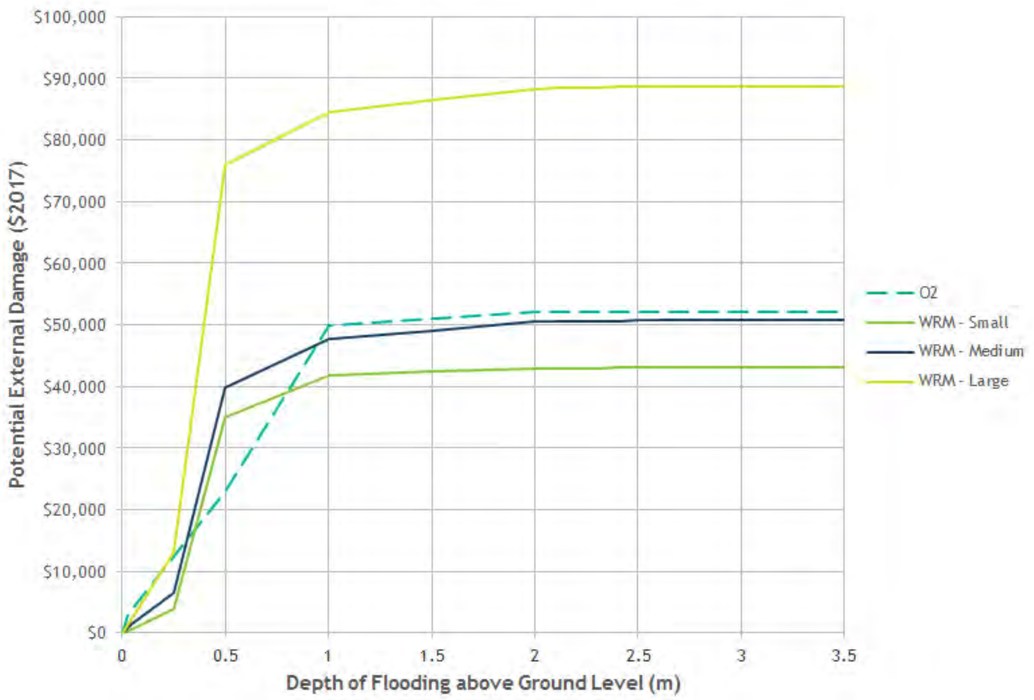


Figure 6-45 Detached (FDSS-SOG, FDSS-Stumps, FDSS-HS, FDDS) external stage-damage curve comparison

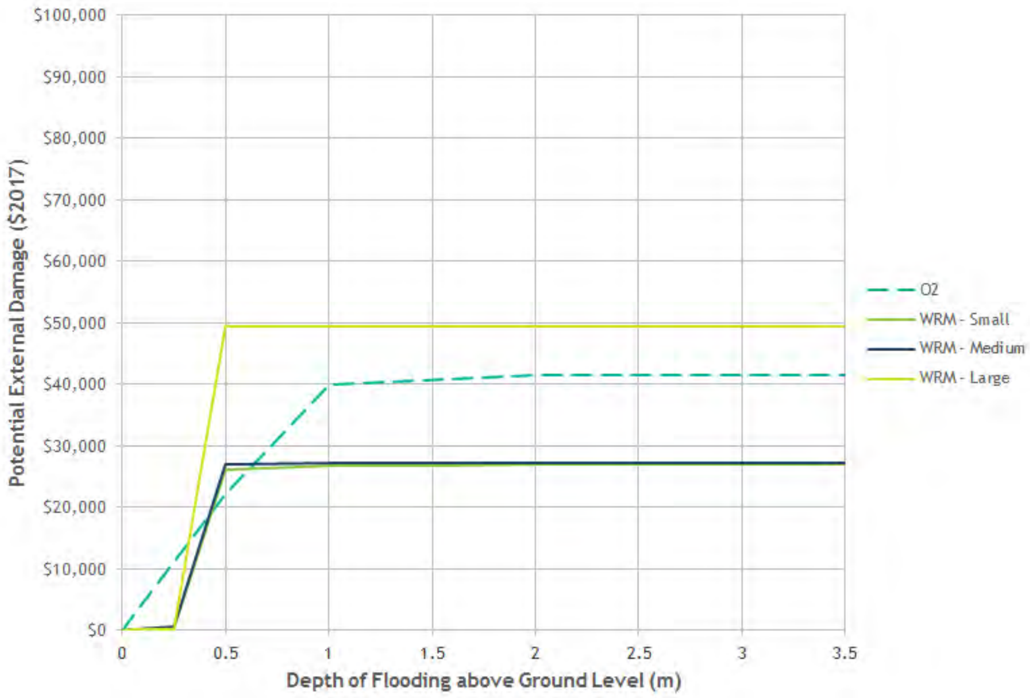


Figure 6-46 Multi-unit (MUSS, MUDS) external stage-damage curve comparison

6.6.4.6 Comparison with ANUFLOOD Curves

Figures 6-47 to 6-49 show the commercial flood stage-damage curves adopted in this study and the corresponding ANUFLOOD stage-damage curves. The comparison shows that the updated ANUFLOOD curves significantly underestimate flood damages, especially for small and medium sized commercial entities. The higher flood damages estimated in this study can be attributed to changes in businesses that have occurred over the last 20 to 30 years since the development of the ANUFLOOD curves (e.g. the presence of electronic equipment and less flood resistant building materials in modern commercial properties).

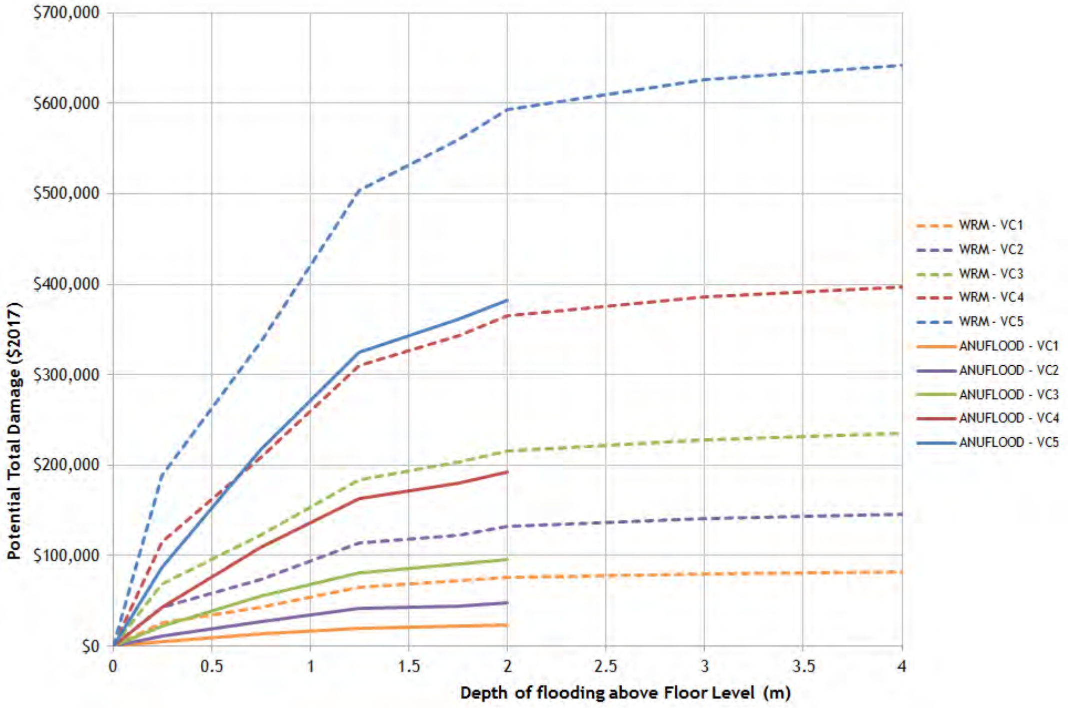


Figure 6-47 Small commercial stage-damage curve comparison

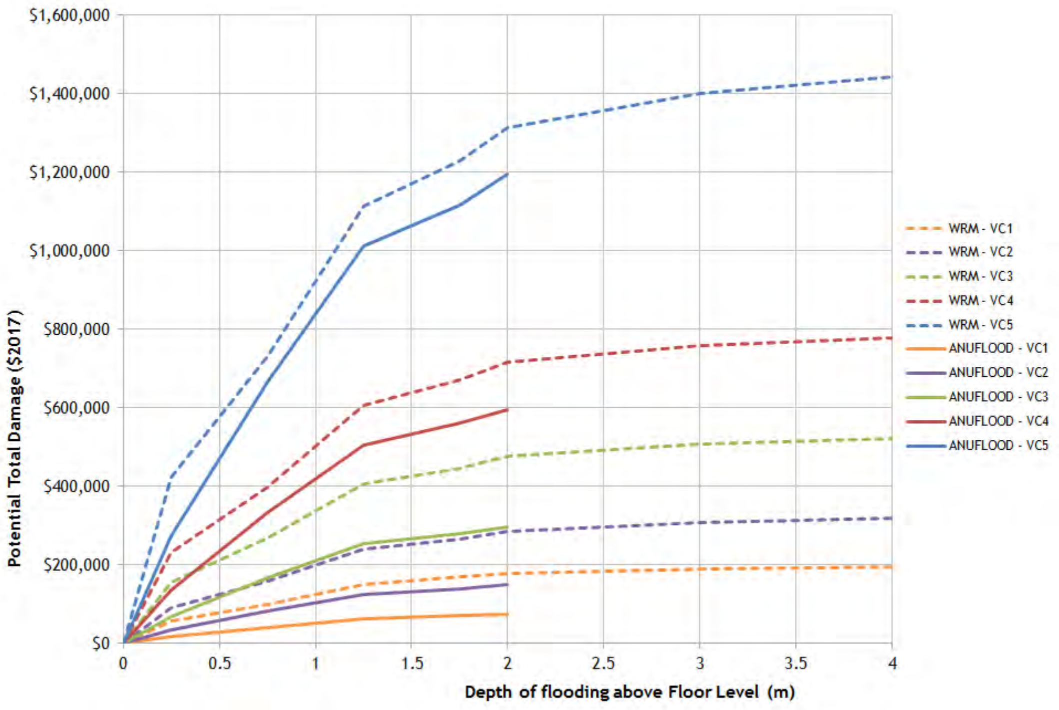


Figure 6-48 Medium commercial stage-damage curve comparison

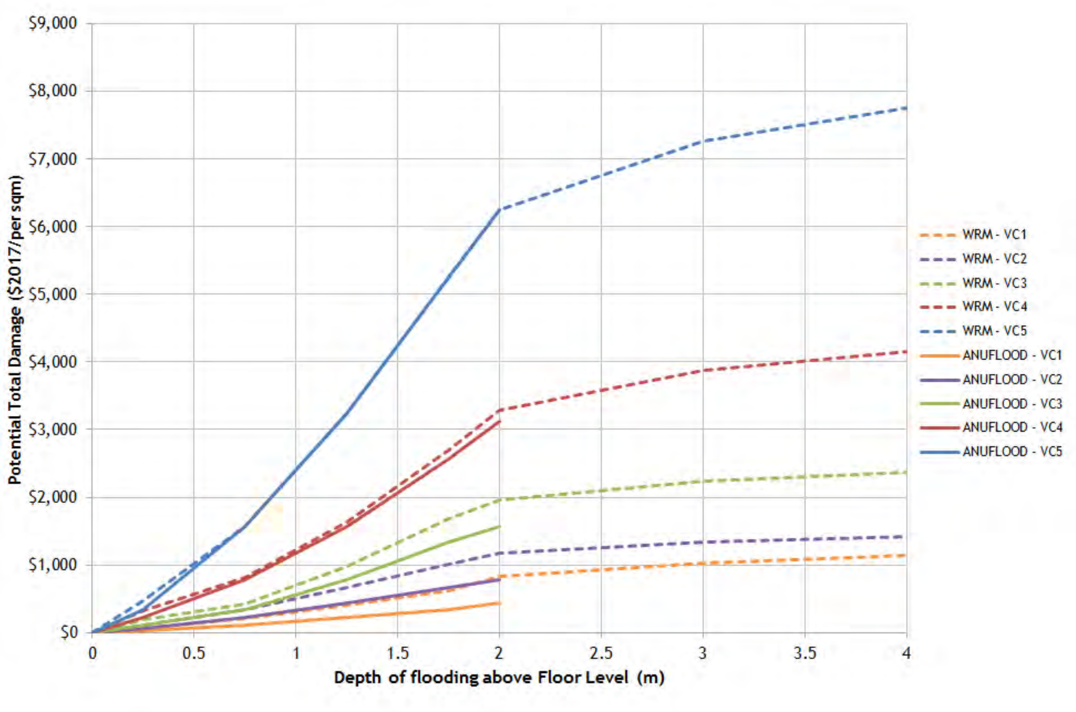


Figure 6-49 Large commercial stage-damage curve comparison

6.6.4.7 Validation with Insurance and Other Data

The ICA provided data on buildings (structural) and contents (internal) damage claims received by insurers for the January 2011 flood for 60 residential properties in the study area. The total (building plus contents) claims for these properties ranged from $700 to $348,100. Details of items included and/or excluded from the building and contents components of these claims were not provided and are unknown. Therefore, the validation of the flood stage-damage curves derived in this study was undertaken against the combined (total) building and contents damage value.

Figure 6-50 shows the relationship between the total insurance claim value (building and contents) and the modelled 2011 depth of flooding above floor level at the 60 ICA properties. There is a large scatter in the data with a number of points with small inundation depths having very large insurance claim values and vice versa. Further, the flood model results show significant negative depths of flooding for some properties.

When reviewing details of the 60 properties for which ICA provided data, it was found that nine of the houses for which ICA had provided data no longer exist (i.e. it appears that these buildings have been demolished). These properties were removed from the validation data set. It was also apparent that some houses for which ICA has provided data have been modified significantly since the January 2011 flood. It appears that these houses have been raised and/or modified (i.e. enlarged and/or improved) since the January 2011 flood. The scatter in Figure 6-50 reflects the potential errors and/or uncertainties in the data used for this plot (e.g. floor levels, flood levels, flood damage estimates).

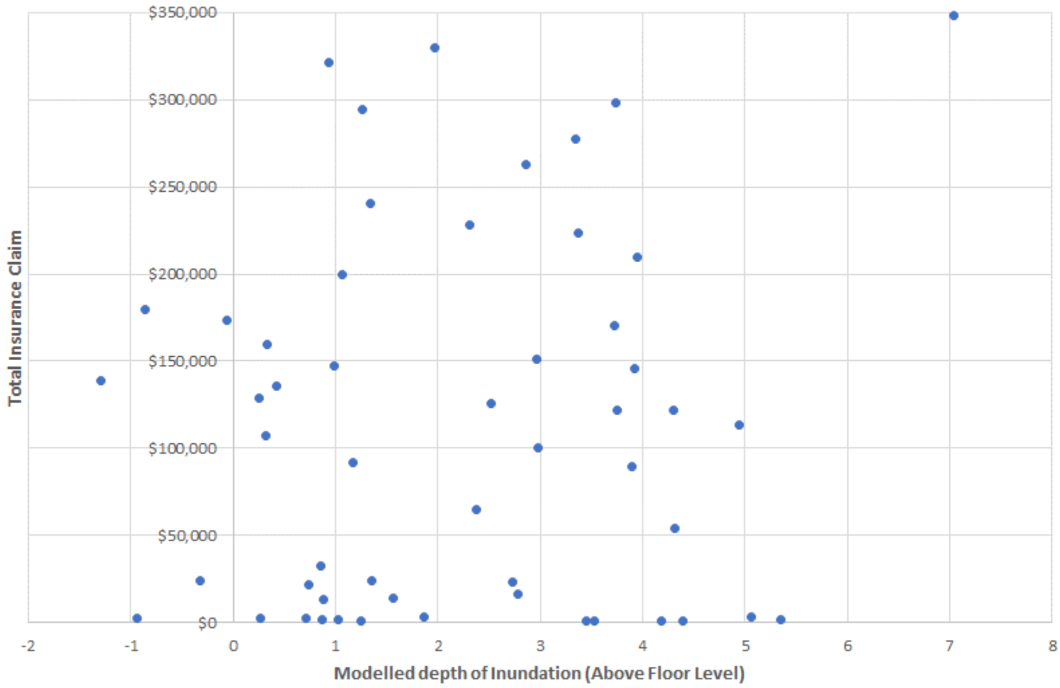


Figure 6-50 Comparison of ICA damage claims with modelled depth of flooding for January 2011 flood

Figure 6-51 shows a comparison between the actual (internal plus structural) damages predicted using the flood stage-damage curves derived and the building database adopted in this study and the equivalent validation data (for the 51 property sample). Although there are some significant over-predictions and under-predictions (for reasons discussed earlier), the results generally show no distinct bias. The total actual damage predicted for the 51 sample properties is approximately 13% higher than the total of insurance claims. However, if the insurance claims that are less than $5,000 and the predicted actual damage values of $0 are removed from the dataset (to remove properties for which the predicted flood levels is below floor level or significantly overestimated), the predicted total actual damage is approximately 11% lower than the total insurance claim.

There is a high level of uncertainty associated with the insurance claim data and the characteristics of some of the properties at the time of the January 2011 flood. Further, the adopted flood stage-damage curves are not expected to provide accurate flood damage estimates for each individual property because they are based on ‘average’ (i.e. representative) stage vs damage relationships. The derived stage-damage curves are only expected to provide reasonable total damages for the overall area analysed with no bias.

In summary, the average flood damage predicted with the adopted stage-damage curves for the 51 properties assessed is similar to the average calculated for the validation data set, and there is no apparent bias in the results. Therefore, considering the uncertainties in the available data set, the stage-damage curves adopted in this study are considered to provide acceptable results.

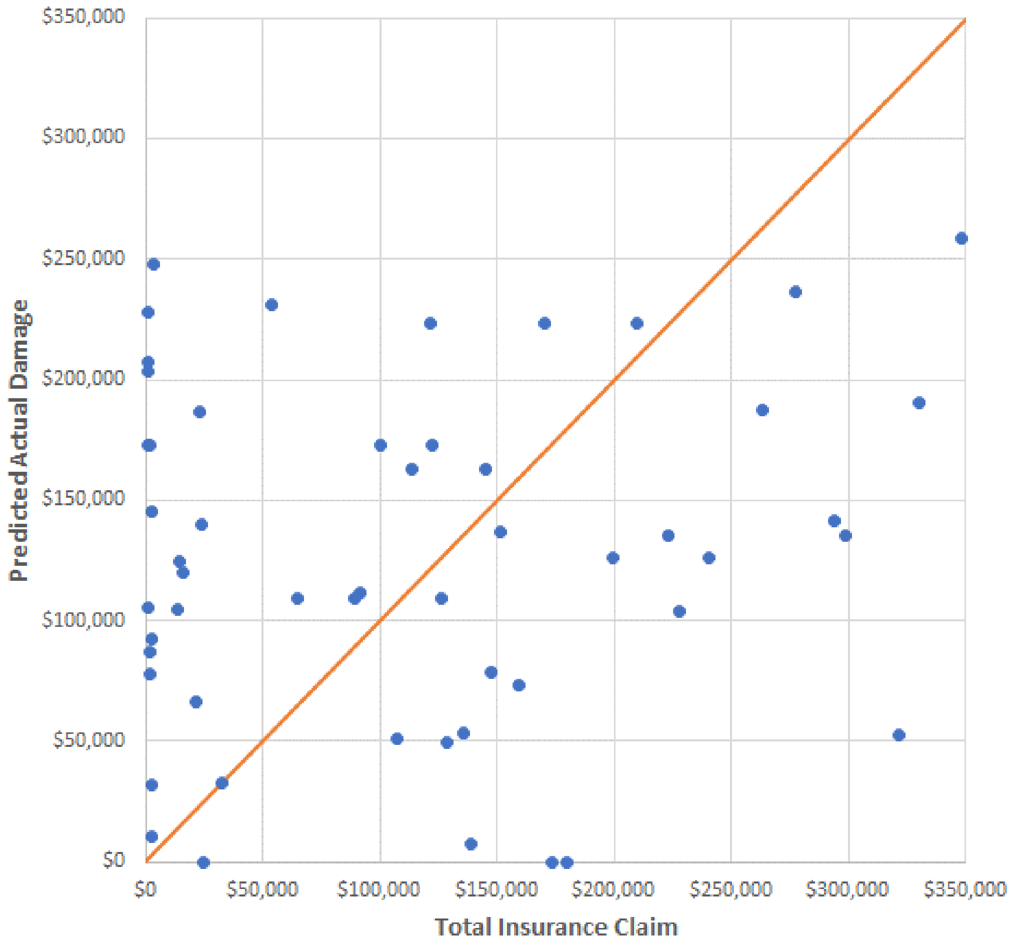


Figure 6-51 Comparison of predicted actual damages with insurance claim values

6.7 Methodology Adopted for Damage Estimation

6.7.1 Tangible Damages

6.7.1.1 Approach

A GIS based flood damage database has been developed for use in this study. The database uses data obtained and combined from various sources (see Section 6.3). GIS software has been used to collate and combine the property and infrastructure data, incorporate the DEM and flood surface data, and then perform the necessary calculations and extract the required results.

The residential and non-residential direct and indirect flood damages are calculated at an individual property level for each flood event using the stage-damage curve that best represents the particular property type and size. The individual property costs are then summed to estimate the total property damage cost. The estimated transport and other infrastructure, public and community owned buildings and assets damage cost for the corresponding flood event is then added to the sum of individual property damage cost to determine the total tangible damage cost for the particular flood event. The estimated total tangible damage costs for the particular flood events are then combined with the AEP's for the corresponding design flood events to estimate the tangible AAD. A discussion on how each of the above damage components is estimated is given in Section 6.7.1.2 to Section 6.7.1.4.The adopted approach enables the estimation of flood damage at each floodprone property and then to accumulate individual property flood damages over a prescribed flood event and region (e.g. LGA, Postcode). This approach is not designed to provide accurate flood damage estimates for each individual property because they are based on 'average' (i.e. representative) stage-damage curves, however it is fit-for-purpose for total damages estimations for the overall area analysed.

6.7.1.2 Direct Damages

6.7.1.2.1 Property Damage

Potential Damage

The residential potential damages were estimated using the stage-damage curves developed in this study for each of the six surveyed residential property types (see Section 6.6). For the small number of miscellaneous non-surveyed residential property types (i.e. the property types that do not readily fall into the six key surveyed property types) the available stage-damage curves were allocated as appropriate.

The commercial and industrial potential damages were estimated using the stage-damage curves developed in this study for the various commercial property types (see Section 6.6). In the absence of better data, the commercial property stage-damage curves were used for industrial properties as well.

Actual Damage

Section 6.2.1.6.3 discusses the three available approaches to estimate actual damages from potential damages for residential properties.. The second approach was used in this study. The family of curves used were limited to the two curves corresponding to 'flood aware' and 'flood unaware' curves as given in Figure 6-2.

The Phase 3 (SFMP) study area encompasses a wide range of flood warning times and different degrees of flood awareness. Warning times are likely to vary from a several hours to a day or longer. The degree of flood awareness is also likely to vary significantly. Even when a community is 'flood aware' and it receives timely flood warnings, its ability to reduce flood damage is limited when the depth of flooding is significant. Therefore, these variations would be reflected in the flood damage estimates through the use of varying A/P ratios at each of the properties. Considering the level of residents' flood awareness and their ability to effectively save their goods and possessions with increasing flood depths, the 'flood aware' (experienced community) curve was used for flood depths ≤0.5 m and the 'flood unaware' (inexperienced community) curve was used for flood depths ≥2.0 m. For intermediate depths of flooding, an interpolated value from the two curves (corresponding to the appropriate warning time) was used. This way, an appropriate A/P ratio is applied on a per building per flood event basis.

As discussed in Section 6.2.1.6.3, there is very little data in the literature on A/P ratios for non-residential properties. In the absence of better information, and taking into consideration the flood warning times for Brisbane River flooding, an A/P ratio of 0.8 was adopted for non-residential properties irrespective of the depth of flooding.

6.7.1.2.2 Transport Infrastructure Damage

Natural Disaster Relief and Recovery Arrangements (NDRRA) data on flood damage repair costs to DTMR and council road infrastructure in the study area following the 2011 flood event was used to estimate indicative (but separate) flood damage costs to DTMR and council road infrastructure per unit length of road inundation ($ per km) for the 2011 flood event. The estimated 2011 damage costs per km for DTMR and council roads and bridges were $8.484 million (based on 79 km) and $75,580 (based on 504 km) respectively.

The estimated unit cost for council road infrastructure appears to be reasonable for application for the full range of design flood events from 1 in 2 to 1 in 100,000 AEP. Although the unit cost estimated for DTMR road infrastructure appears to be reasonable for rare flood events such the 2011 event, it appears too high for more frequent events. Based on unit cost estimates provided in VDNRE (2000), the unit cost for major (DTMR type) road infrastructure should be about 3.14 times the unit cost for minor (council type) road infrastructure. In the absence of better data, this ratio was used to estimate TMR road infrastructure damage for design flood events up to 1 in 50 AEP.

The length of DTMR and council roads inundated in the study area was determined by identifying all road assets located within each flood extent and calculating their total length. The indicative unit damage costs, together with estimates of the length of DTMR and council roads inundated for the different flood events, were used to estimate flood damages to road infrastructure.

No damage data is available for rail infrastructure. Therefore, it has not been possible to estimate flood damages to rail infrastructure. However, total rail line lengths inundated for each of the ensemble of 11 design flood events modelled in this study have been identified.

6.7.1.2.3 Public and Community Owned Buildings and Assets Damage

Little or no data and no stage-damage curves are available to estimate damage to public and community owned buildings and assets. Ideally, damage to these buildings and assets should be estimated on a case by case basis.

For public buildings and community owned assets for which some historical flood damage data is available, the following approach was adopted to estimate flood damages and/or estimate the number of buildings/assets inundated for each of the flood events investigated:

- for hospitals, schools, police and fire stations etc., the number of inundated buildings was identified but no flood damage estimates were made.
- for telecommunication utilities and stormwater drainage assets, available data is insufficient to make any assessments and therefore no flood damage estimates were made.
- for water supply and sewerage assets, flood damage estimates were made based on 2011 flood NDRRA cost estimates. In addition, the number of these utilities inundated for each of the flood events was identified.
- for all other public and community assets such as cemeteries, swimming pools, car parks, terminals, boat ramps, boardwalks, wharves, jetties, parks, playgrounds and recreational facilities, sporting arena, etc., available data is insufficient to make any assessments and therefore no flood damage estimates were made.

Based on the 2011 flood damage estimates, WSDOS (DEWS, 2014) estimated the total damage (direct and indirect) to the above types of buildings and assets, excluding the public utilities, to be 80% of the total road transport infrastructure damage. Similarly, WSDOS estimated the total damage to public utilities (telecommunication, electricity, water supply and sewerage) to be 7.5% of the total residential damage. In the absence of better data, the same approach and percentage values have been adopted in this study to estimate overall damage to public and community owned buildings and assets.

6.7.1.2.4 Rural/Agricultural Damage

There is a variety of rural/agricultural properties within the study area with their land uses ranging from cropping to livestock. However, there is no information available to estimate rural/agricultural damage in the study area. Ideally, damage to these properties should be estimated on a case by case basis.

Past studies and investigations do not provide guidance for reliable estimation of rural/agricultural damages. Therefore, it has not been possible to estimate rural/agricultural damage in this study. However, the number of inundated land parcels (lots) designated as agricultural properties and the total land area of inundation of these properties for the different flood event investigated in this study have been identified.

6.7.1.2.5 Mine Damage

There is a variety of mining leases within the study area. However, there is no information available to estimate flood damage to mines in the study area. Ideally, damage to these properties should be estimated on a case by case basis.

Past studies and investigations do not provide guidance for reliable estimation of the flood damages to mining leases. Therefore, it has not been possible to estimate damage to mines. However, the number of inundated mining leases and the total land area of inundation within these leases for the different flood events investigated in this study have been identified.

6.7.1.3 Indirect Damages

In the absence of better information, the indirect damage relationships for residential and commercial properties recommended in DNRM (2002) have been adopted:

- For residential properties: indirect damage = 15% of actual direct damage; and
- For commercial properties: indirect damage = 55% of actual direct damage.

In the absence of better data, the relationship recommended for commercial properties has been adopted for other non-residential properties as well (i.e. indirect damage = 55% of actual direct damage).

Based on 2011 flood damage estimates, WSDOS has assumed that the post flood clean-up and rehabilitation costs for public buildings and assets in the study area are about 4% of the total damage costs. In the absence of better data, the same value has been adopted in this study.

6.7.1.4 Average Annual Damages

The flood damage model developed for this study was applied to the ensemble of 11 design flood events produced in the Phase 2 (Flood Study) to estimate the direct and indirect damages in the study area for each of the 11 design flood events. The flood damage model was applied to existing (current climate and catchment development) floodplain conditions, as well as the five potential future (development and climate change) floodplain conditions that have been modelled in this study.

The flood damages associated with each flood event were estimated and the results were used to calculate the average annual damages (AAD), which represents the cost of flooding on average each year. The AAD was calculated by combining estimated damages for each magnitude event with the probability of its exceedance.

6.7.2 Intangible Damages

6.7.2.1 General Approach

Although the available data for estimating intangible damages is limited, there are estimates in DAE (2016) from two recent major Australian natural disaster events – the 2009 Black Saturday bushfires in Victoria and the 2011 Queensland floods - that provide some contrast in the composition of intangible damages. The Victorian event which caused great loss of life with perhaps a smaller 'tail' of intangible damages contrasts with the Queensland event which was less damaging in terms of the loss of life but which appears to have a quite protracted 'tail' of impact particularly in mental illness. Between these two events, intangible costs were estimated by DAE to be between 1.3 and 1.5 times tangible (direct plus indirect costs). Each of these sets of damages estimates is essentially derived from a combination of stated preference[13] and resource costing. In addition, there is a fairly recent UK study (EA, 2010) that provides estimates of intangible damages from a set of stated preference surveys, and interestingly the level of intangible damages per person affected is much lower than the Australian estimates. These surveys elicit estimates of individuals' willingness to pay to avoid the impacts of flooding.

A limitation in these various estimates is that they are all derived from high impact low probability events, perhaps because by their nature these events attract significant research and policy interest. Similar information is not available for the more frequent lower impact events.

Estimation of intangibles across a wide spread of event probabilities would require some form of stated preference survey of potentially impacted households and businesses. As already discussed, that form of data collection is subject to notable limitations, can be controversial and is also expensive and time consuming.[14]

Given its quality and relevance, the cost benefit analysis will utilise the intangible to damages ratio of 1.2:1 from the two recent Australian events noted above – two of the worst natural disasters in Australia in the last 40 years or so. Tangible damages in this context are taken to comprise residential direct and indirect damages only, i.e. not commercial damages.

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[13] The stated preference element is embedded in the (monetary) valuation of life which is estimated by reference to the amounts people would be willing to pay for a small reduction in the risk of premature death.

[14] In the long term, initiatives to collect impact data for wider range of events in terms of probability and impact would be useful.

6.7.2.2 *Estimating Baseline Intangible Damages*

A simplistic approach would apply a uniform uplift factor for intangibles to the damages at each overfloor height interval in the stage-damage curves. This approach has the obvious weakness that an intangible to tangible damages ratio that has been derived from large impact events might not be relevant to smaller events.

Of relevance in this respect, BTRE (2002, P 87) presented data from Katherine in the Northern Territory showing direct and indirect damages for flood events ranging between 5% AEP and the Probable Maximum Flood (PMF). (see Table 6-13).

Table 6-13 Direct and indirect costs – Katherine NT

AEP	Actual residential cost	Actual business cost	Total actual cost	Indirect cost	Indirect uplift factor	Uplift factor as proportion of 1% AEP uplift
	$m	$m	$m	$m		
5%	$0.035	$0.000	$0.035	$0.035	0.0	0.0
2%	$5.000	$0.052	$5.052	$0.943	0.19	0.60
1%	$14.000	$0.432	$14.432	$14.497	0.30	1.00
PMF	$6.000	$0.407	$6.407	$7.282	1.14	3.80

Source: Derived from BTRE (2002)

To the extent that indirect costs are a measure of the disruption generated by flood events, the data from Katherine provides an albeit imperfect basis for estimating an intangibles uplift factor according to event probability.

Clearly, indirect costs are insignificant for small events but for the largest event the intangibles uplift factor is nearly four times that for a 1% AEP. Using the relative uplift values in the right hand column, with a 1.2:1 intangibles ratio at 1% AEP, the intangibles uplift factor at 2% AEP would be 0.72 (60% of 1.2) and at the probable maximum flood the intangibles uplift factor would be 4.56 (3.8 times 1.2) as in Table 6-14.

Table 6-14 Proposed intangibles uplift factors according to event probability

AEP	Intangibles uplift factor as % of 1% AEP uplift factor	Proposed intangibles uplift factor
5%	0%	0.00
2%	60%	0.72
1%	100%	1.20
PMF	380%	4.56

6.7.2.3 Sensitivity Testing of Intangible Damages Estimates

The intangibles factor proposed above for the 1% AEP event appears high given that that is calculated by reference to residential tangible damages[15]. An appropriate analytical response where there is uncertainty about an important variable is to sensitivity test the results of the cost benefit analysis for alternative values of that variable. Because the proposed intangibles uplift factor appears high, it would be appropriate to test the results of the CBA for a lower bound uplift factor. The UK intangible damages estimate of $200 million for the 2010-11 Queensland event implies an uplift factor of only 3.5% (that is, intangibles cost of $200 million relative to total tangible costs of $5.722 billion). That would be in effect a zero lower bound for intangible damages. The sensitivity assessment instead adopts a lower bound in which the uplift factor only applies to events of 1% AEP or larger. In this sensitivity test, no uplift factor is applied for more frequent events. In addition, the uplift factor does not vary from 1.2 for events larger than 1% AEP as shown in Table 6-15. This approach would be consistent with the likelihood that smaller events do not produce large intangible costs and with the lack of data about the intangible impacts of very large events.

Table 6-15 Proposed intangibles uplift factors according to event probability – lower bound sensitivity

AEP	Proposed intangibles uplift factor
5%	0.0
2%	0.0
1%	1.20
PMF	1.20

6.7.2.4 Estimating Intangible Damages for Mitigation Strategies

Embedding the intangibles to tangibles ratio in the stage damage curves allows fully specified costs (subject to the limitations outlined earlier) to be estimated for the current land use and flood mitigation strategies.

This approach is recommended for the study area but might not be totally appropriate for other parts of Queensland which have different (more strongly export oriented) economies. In those regions more consideration would need to be given to the national economic consequences of the loss of coal, agricultural and tourism output.

6.7.2.5 Loss of Business Value Added in Related Sectors

The question of whether the business disruption caused by natural disasters has longer and broader economic consequences in developed economies is not totally resolved, but the literature appears to suggest that the economic consequences are relatively short lived. Kousky (2012, p 18 et seq) cites a number of comparative studies:

[15] The tangible damage estimates in DAE (2016) also contain relatively small amounts for commercial and agricultural damages, and emergency services costs. Excluding those items from tangible damages for the purposes of estimating the intangible damages uplift factor would not change the recommended uplift factor. The DAE tangible benefits estimate also contains an unstated element of public infrastructure cost which, if excluded, would tend to increase the intangibles uplift factor. Hence the recommended uplift factor could underestimate intangibles but on the other hand at 1.2 times tangibles the recommended uplift factor remains seemingly high.

- Albala-Bertrand (1993) found that 'natural disasters do not impact GDP [gross domestic product] and may have a slight positive impact on GDP growth';
- An unpublished study (Caselli and Malhotra 2004) produced findings that suggest that natural disasters have no subsequent growth effect;
- Cundado and Ferreira (2011) found that floods do not have significant effects on growth in developed countries.

In a leading paper on this issue, Hallegatte (undated) concludes from the experience of Hurricane Katrina in the US that indirect losses (in terms of value added lost and not replaced elsewhere) are relevant only for events having direct losses of $US50 billion. At direct losses of $US 100 billion, indirect losses would be $US 50 billion. By comparison the 2011 events in Queensland have been estimated to have caused tangible losses of $5.7 billion.

Therefore there appears to be no strong reason for making allowance for upstream and downstream effects in estimating indirect or intangible losses[16].

6.7.3 Environmental Costs

Research so far has not isolated studies that would support estimates of environmental damage from flooding expressed in dollar terms. The issue is complicated by the range of potential impacts, by the fact that flooding, though modified by human intervention, is a natural process and also by the environmental risks that some mitigation measures present. As such, intangible costs for environmental damage are not included in total estimates.

6.8 Flood Damage Estimates

6.8.1 Tangible Damages

6.8.1.1 Overview

This section presents the tangible, intangible and total flood damage estimates, including average annual damage (AAD) estimates for the study area using the methodology described in Section 6.7. Flood damage estimates are provided for residential and non-residential properties, as well as transport and other infrastructure, utilities, public buildings and community assets. For property types for which it has not been possible to estimate damages in dollars (e.g. railway infrastructure, rural/agricultural properties and mining leases), only estimates of the number of properties inundated and the area of inundation are provided.

For property flood damages, estimates of potential and actual direct, indirect and total damages are provided for each of the 11 design flood events investigated in this study. The distribution of properties contributing to the total damage across all postcodes in the study area is given in Section 6.8.1.2. The distribution of properties contributing to the total damage across the 25 Seqwater

[16] This conclusion might not be as relevant to Queensland regions dependent more on export of commodities. Penning-Rowsell et al (2013 section 5.7.1) identify three circumstances in which production losses are unlikely to recovered elsewhere: 'where the economic sub-sector is highly concentrated so there is little capacity to make up the reduced sales at the flooded site; where the economic sub-sector is highly specialized so that there are few, if any, equivalent goods for that produced or sold at the site; and/or where the process that leads to the finished goods is long (e.g. products from pharmaceutical research, built-to order plant'). Queensland's coal sector and parts of its agricultural sector would exhibit the first two criteria to some degree.

reporting regions is given in Appendix B. Seqwater has requested these region damage estimates for use in studies associated with their Wivenhoe Dam upgrade planning investigations and economic evaluations.

6.8.1.2 Property Damage

6.8.1.2.1 Residential Damage

Table 6-16 shows the distribution of estimated potential and actual residential direct flood damages for each LGA as well as the whole study area for each of the modelled flood events. Table 6-16 also shows the distribution of estimated potential and actual residential direct AAD's for each LGA as well as the whole study area. Figure 6-52 shows the variation of estimated potential and actual residential direct flood damages in the study area for each of the modelled flood events.

Table 6-17 shows the distribution of estimated direct, indirect and total residential flood damages for each LGA as well as the whole study area for each of the modelled design flood events. Table 6-17 also shows the distribution of estimated direct, indirect and total residential flood AAD's for each LGA as well as the whole study area. Figure 6-53 shows the variation of estimated total residential damages for each LGA and the whole study area.

The results show that the majority of residential damage costs would occur in the BCC and ICC areas. The residential damage costs in the SRC and LVRC areas would be relatively low. The total residential (direct plus indirect) damages estimate for the study area for the 1 in 100 AEP event is some $1,343 million.

Residential damage of $1,145 million have also been estimated for the January 2011 flood event.

Table 6-16 Potential and actual direct flood damage estimates for residential properties ($ millions)

AEP (1 in x)	BCC		ICC		LVRC		SRC		Total	
	Pot.	Act.	Pot.	Act.	Pot.	Act.	Pot.	Act.	Pot.	Act.
2	$0.08	$0.03	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.08	$0.03
5	$0.14	$0.06	$0.48	$0.22	$0.01	$0.01	$0.23	$0.09	$0.86	$0.37
10	$1.00	$0.41	$8.41	$3.86	$0.55	$0.25	$1.32	$0.55	$11.28	$5.06
20	$13.34	$5.77	$35.73	$17.96	$1.70	$0.78	$5.91	$2.48	$56.68	$26.98
50	$149.8	$69.32	$299.4	$165.4	$3.24	$1.45	$10.80	$4.88	$463.3	$241.0
100	$1,254	$696.8	$749.6	$450.9	$5.39	$2.45	$36.50	$17.97	$2,045	$1,168
200	$2,578	$1,555	$1,343	$840.2	$8.93	$4.21	$125.5	$75.37	$4,055	$2,475
500	$4,407	$2,796	$1,961	$1,260	$12.49	$6.39	$179.9	$114.8	$6,560	$4,177
2,000	$7,434	$4,828	$2,831	$1,876	$18.50	$9.68	$241.9	$158.3	$10,525	$6,872
10,000	$13,226	$8,813	$4,135	$2,773	$25.20	$13.29	$349.5	$229.9	$17,735	$11,829
100,000	$27,079	$18,434	$7,379	$5,050	$56.43	$32.10	$753.1	$513.0	$35,267	$24,029
AAD	**$44.8**	**$27.0**	**$27.6**	**$16.6**	**$0.31**	**$0.14**	**$2.13**	**$1.18**	**$74.8**	**$44.9**

BCC – Brisbane City Council; ICC – Ipswich City Council; LVRC – Lockyer Valley Regional Council; SRC – Somerset Regional Council

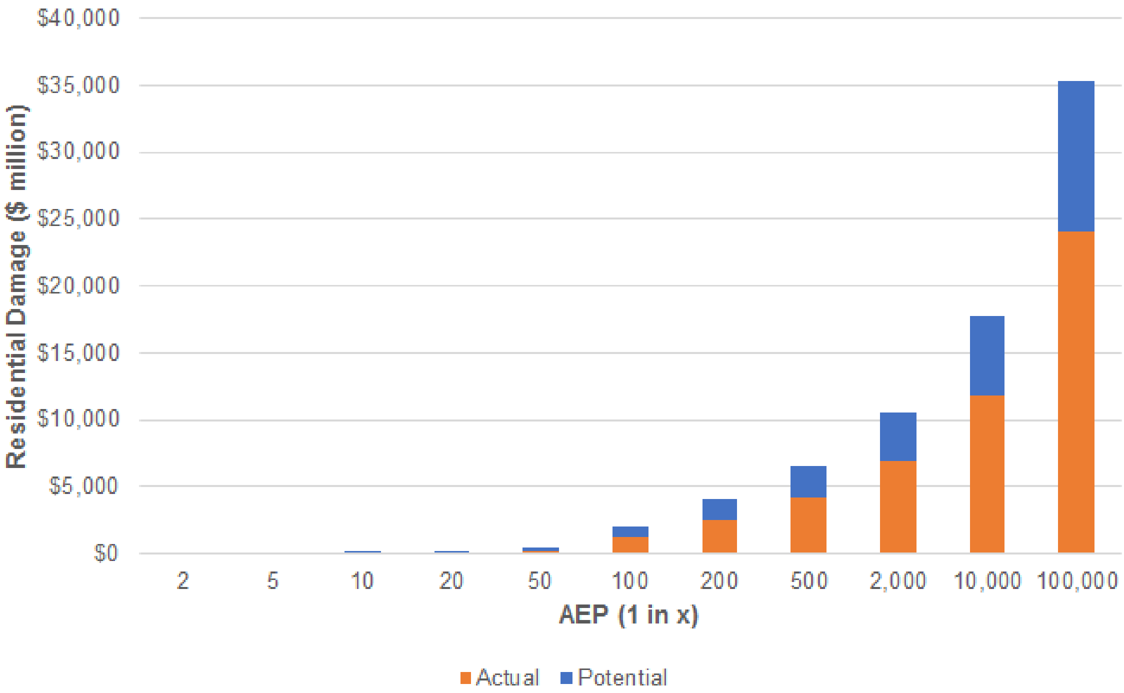


Figure 6-52 Variation of potential and actual residential damage estimates with AEP

Table 6-17 Direct and indirect flood damage estimates for residential properties ($ millions)

AEP (1 in x)	BCC			ICC			LVRC			SRC			Total		
	Dir.	Ind.	Total	Dir.	Ind.	Total	Dir.	Ind.	Total	Dir.	Ind.	Total	Dir.	Ind.	Total
2	$0.03	$0.00	$0.04	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.03	$0.00	$0.04
5	$0.06	$0.01	$0.06	$0.22	$0.03	$0.25	$0.01	$0.00	$0.01	$0.09	$0.01	$0.10	$0.37	$0.06	$0.42
10	$0.41	$0.06	$0.47	$3.86	$0.58	$4.44	$0.25	$0.04	$0.28	$0.55	$0.08	$0.63	$5.06	$0.76	$5.82
20	$5.77	$0.86	$6.63	$17.96	$2.69	$20.65	$0.78	$0.12	$0.89	$2.48	$0.37	$2.85	$26.98	$4.05	$31.03
50	$69.32	$10.40	$79.71	$165.4	$24.81	$190.2	$1.45	$0.22	$1.67	$4.88	$0.73	$5.61	$241.0	$36.15	$277.2
100	$696.8	$104.5	$801.3	$450.9	$67.63	$518.5	$2.45	$0.37	$2.82	$17.97	$2.70	$20.67	$1,168	$175.2	$1,343
200	$1,555	$233.3	$1,788	$840.2	$126.0	$966.3	$4.21	$0.63	$4.84	$75.37	$11.31	$86.68	$2,475	$371.3	$2,846
500	$2,796	$419.4	$3,215	$1,260	$189.0	$1,449	$6.39	$0.96	$7.35	$114.8	$17.22	$132.0	$4,177	$626.6	$4,804
2,000	$4,828	$724.1	$5,552	$1,876	$281.4	$2,157	$9.68	$1.45	$11.13	$158.3	$23.75	$182.1	$6,872	$1,031	$7,902
10,000	$8,813	$1,322	$10,135	$2,773	$415.9	$3,189	$13.29	$1.99	$15.28	$229.9	$34.48	$264.4	$11,829	$1,774	$13,604
100,000	$18,434	$2,765	$21,199	$5,050	$757.5	$5,807	$32.10	$4.81	$36.91	$513.0	$76.94	$589.9	$24,029	$3,604	$27,633
AAD	**$27.0**	**$4.05**	**$31.0**	**$16.6**	**$2.49**	**$19.1**	**$0.14**	**$0.02**	**$0.16**	**$1.18**	**$0.18**	**$1.36**	**$44.9**	**$6.74**	**$51.7**

BCC – Brisbane City Council; ICC – Ipswich City Council; LVRC – Lockyer Valley Regional Council; SRC – Somerset Regional Council

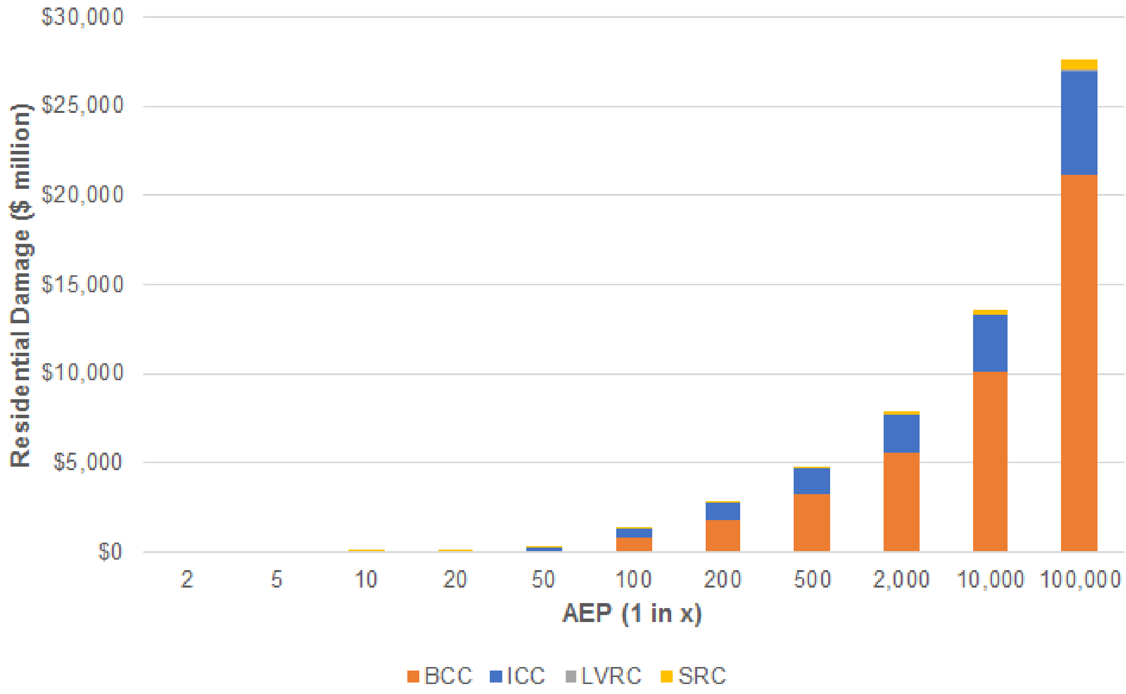


Figure 6-53 Variation of combined direct and indirect residential damage estimates with AEP

6.8.1.2.2 Non-Residential Damage

Table 6-18 shows the distribution of estimated potential and actual non-residential direct flood damages for each LGA as well as the whole study area for each of the AEP floods modelled. Table 6-18 also shows the distribution of estimated potential and actual non-residential direct AAD's for each LGA as well as the whole study area. Figure 6-54 shows the variation of estimated potential and actual non-residential direct flood damages in the study area for each of the modelled flood events.

Table 6-19 shows the distribution of estimated direct, indirect and total non-residential flood damages for each LGA as well as the whole study area for each of the modelled flood events. Table 6-19 also shows the distribution of estimated direct, indirect and total non-residential flood AAD's for each LGA as well as the whole study area. Figure 6-55 shows the variation of estimated total non-residential damages for each LGA and the whole study area.

The results show that the majority of non-residential damage costs would occur in the BCC and ICC areas. The non-residential damage costs in the SRC and LVRC areas would be relatively low. The total non-residential (direct plus indirect) damages estimate for the study area for the 1 in 100 AEP event is some $2,162 million.

Non-residential damage of $1,916 million have also been estimated for the January 2011 flood event.

Table 6-18 Potential and actual direct flood damage estimates for non-residential properties ($ millions)

AEP (1 in x)	BCC		ICC		LVRC		SRC		Total	
	Pot.	Act.	Pot.	Act.	Pot.	Act.	Pot.	Act.	Pot.	Act.
2	$0.40	$0.32	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.40	$0.32
5	$1.52	$1.22	$0.83	$0.66	$0.00	$0.00	$0.00	$0.00	$2.35	$1.88
10	$3.42	$2.74	$4.48	$3.59	$0.16	$0.12	$0.00	$0.00	$8.06	$6.45
20	$29.71	$23.77	$15.58	$12.46	$0.21	$0.17	$0.00	$0.00	$45.49	$36.40
50	$227.6	$182.0	$122.4	$97.89	$0.24	$0.19	$0.00	$0.00	$350.2	$280.1
100	$1,405	$1,124	$338.0	$270.4	$0.61	$0.49	$0.03	$0.03	$1,744	$1,395
200	$2,623	$2,099	$556.2	$445.0	$0.83	$0.66	$4.43	$3.54	$3,185	$2,548
500	$4,411	$3,529	$846.4	$677.1	$1.34	$1.07	$10.94	$8.75	$5,270	$4,216
2,000	$7,539	$6,031	$1,216	$973.1	$1.64	$1.31	$37.14	$29.71	$8,794	$7,035
10,000	$12,865	$10,292	$1,737	$1,390	$1.82	$1.45	$62.83	$50.26	$14,667	$11,733
100,000	$25,147	$20,117	$3,034	$2,428	$2.01	$1.61	$93.51	$74.81	$28,277	$22,621
AAD	**$48.9**	**$39.1**	**$12.0**	**$9.56**	**$0.04**	**$0.03**	**$0.10**	**$0.08**	**$61.0**	**$48.8**

BCC – Brisbane City Council; ICC – Ipswich City Council; LVRC – Lockyer Valley Regional Council; SRC – Somerset Regional Council

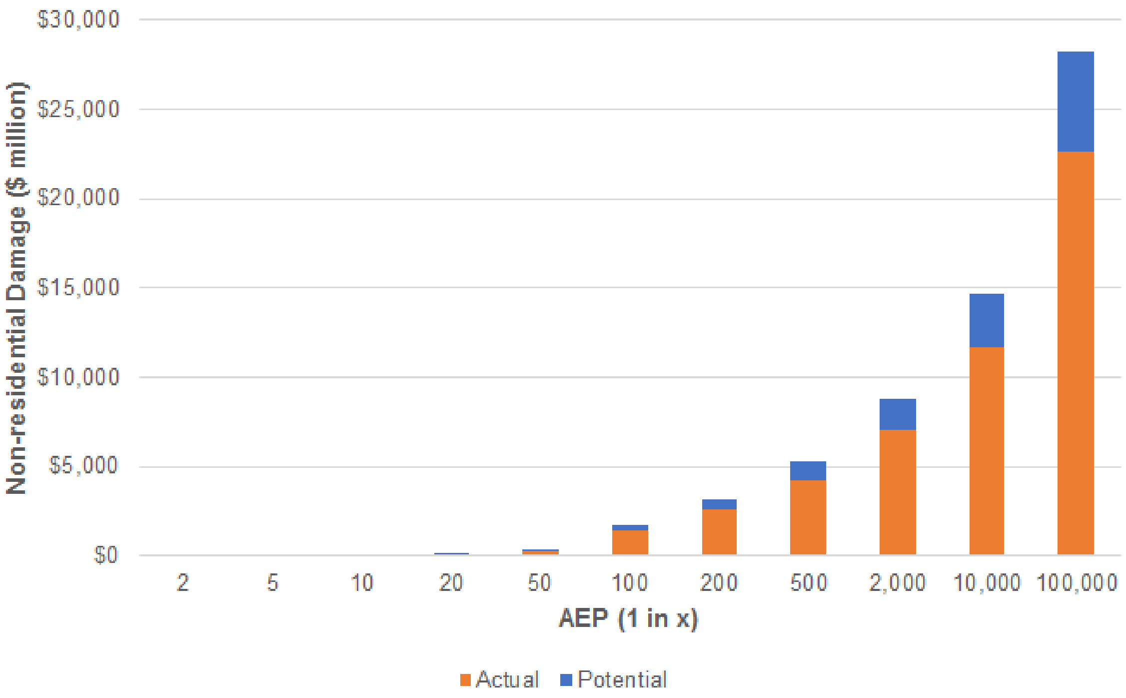


Figure 6-54 Variation of potential and actual non-residential damage estimates with AEP

Table 6-19 Direct and indirect flood damage estimates for non-residential properties ($ millions)

AEP (1 in x)	BCC			ICC			LVRC			SRC			Total		
	Dir.	Ind.	Total	Dir.	Ind.	Total	Dir.	Ind.	Total	Dir.	Ind.	Total	Dir.	Ind.	Total
2	$0.32	$0.18	$0.50	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.32	$0.18	$0.50
5	$1.22	$0.67	$1.89	$0.66	$0.36	$1.03	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$1.88	$1.03	$2.92
10	$2.74	$1.51	$4.25	$3.59	$1.97	$5.56	$0.12	$0.07	$0.19	$0.00	$0.00	$0.00	$6.45	$3.55	$10.00
20	$23.77	$13.07	$36.84	$12.46	$6.85	$19.31	$0.17	$0.09	$0.26	$0.00	$0.00	$0.00	$36.40	$20.02	$56.41
50	$182.0	$100.1	$282.2	$97.89	$53.84	$151.7	$0.19	$0.10	$0.30	$0.00	$0.00	$0.00	$280.1	$154.1	$434.2
100	$1,124	$618.2	$1,742	$270.4	$148.7	$419.2	$0.49	$0.27	$0.76	$0.03	$0.01	$0.04	$1,395	$767.2	$2,162
200	$2,099	$1,154	$3,253	$445.0	$244.7	$689.7	$0.66	$0.36	$1.02	$3.54	$1.95	$5.49	$2,548	$1,401	$3,949
500	$3,529	$1,941	$5,470	$677.1	$372.4	$1,050	$1.07	$0.59	$1.66	$8.75	$4.81	$13.56	$4,216	$2,319	$6,535
2,000	$6,031	$3,317	$9,348	$973.1	$535.2	$1,508	$1.31	$0.72	$2.03	$29.71	$16.34	$46.06	$7,035	$3,869	$10,904
10,000	$10,292	$5,661	$15,953	$1,390	$764.3	$2,154	$1.45	$0.80	$2.25	$50.26	$27.64	$77.91	$11,733	$6,453	$18,187
100,000	$20,117	$11,065	$31,182	$2,428	$1,335	$3,763	$1.61	$0.88	$2.49	$74.81	$41.14	$116.0	$22,621	$12,442	$35,063
AAD	**$39.1**	**$21.5**	**$60.6**	**$9.56**	**$5.26**	**$14.8**	**$0.03**	**$0.02**	**$0.05**	**$0.08**	**$0.04**	**$0.12**	**$48.8**	**$26.8**	**$75.6**

BCC – Brisbane City Council; ICC – Ipswich City Council; LVRC – Lockyer Valley Regional Council; SRC – Somerset Regional Council

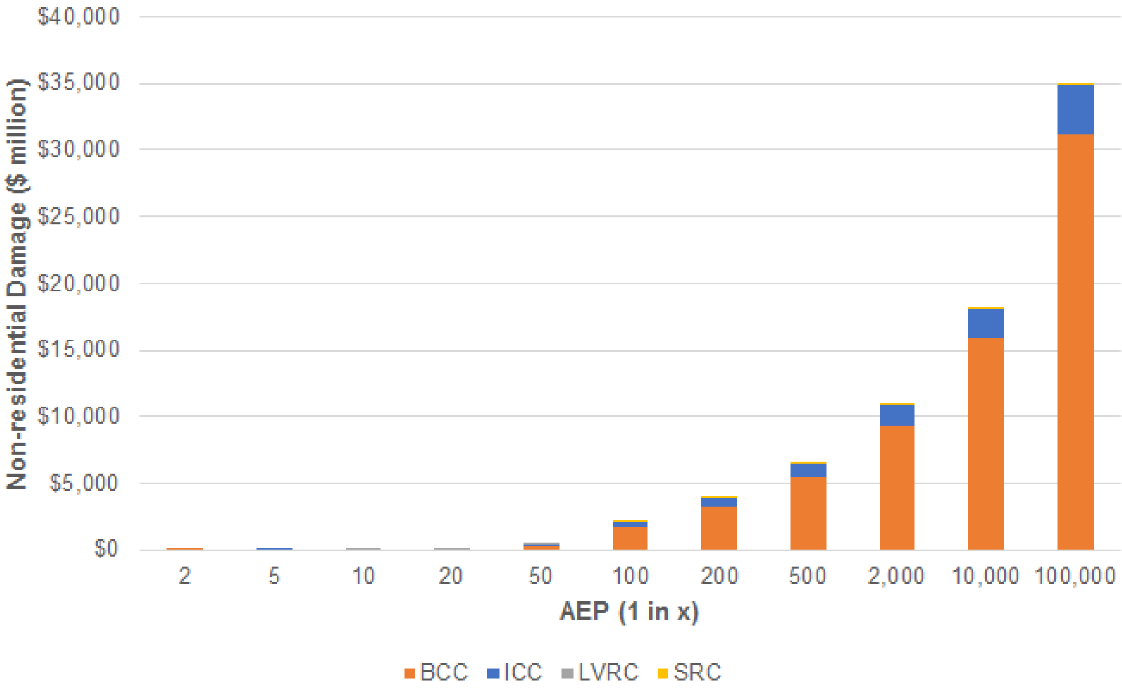


Figure 6-55 Variation of combined direct and indirect non-residential damage estimates with AEP

6.8.1.3 Other Damage

Only limited information is available to estimate flood damage to transport infrastructure, public buildings and assets and public utilities. The available information is limited to NDRRA and some BCC repair cost estimates provided for the January 2011 flood. There is no information to estimate flood damage to rural/agricultural properties and the mining industry.

NDRRA estimates have been used as the basis for the estimation of flood damage to transport infrastructure, public utility, public and community buildings and assets as described in Section 6.7. BCC estimates were used as a sanity check for the flood damage estimates made in this study for non-property damage, noting that BCC is only one of several local and state government organisations that incurred flood damage costs due the January 2011 flood.

BCC provided January 2011 flood damage estimates for council assets such as roads and roads related infrastructure, other transport infrastructure, council buildings and facilities; river structures, parks and environment, stormwater infrastructure and other miscellaneous assets. BCC reported the January 2011 damage costs to their infrastructure and assets to be of the order of $334 million, itemised approximately as follows:

- Roads and roads related infrastructure (footpaths, traffic signals, parking meters, fences, public lighting, etc.) - $72 million;
- Other transport infrastructure (bikeways, bus shelters) - $2 million;
- Council buildings and facilities (cemeteries, libraries, ward offices, bus depots, community sites, pools, etc.) - $13 million;

- River structures (bridges, sea and river walls, wharves and jetties, retaining walls, ferry terminals, boardwalks, boat ramps, etc.) - $94 million;
- River walk replacement - $75 million;
- Stormwater infrastructure, including de-silting and scour protection (pipes, culverts, gullies, stormwater quality improvement devices, etc.) - $21 million;
- Parks and environment - $16 million; and
- Miscellaneous (disaster operations, clean-up, etc.) - $41 million.

The above BCC damage estimates were reported to be incomplete, suggesting that the total damage was higher than the reported value. In addition, the damage estimates provided include damage caused by factors/variables other than river flooding e.g. creek flooding. The reported costs include repair/construction costs of many assets with improved standards of flood resilience. Therefore, these assets are likely to experience lower damages for equivalent future flood events.

6.8.1.3.1 Transport Infrastructure Damage

Figure 6-56 shows the variation of major and minor road lengths inundated and estimated flood damage repair costs with AEP. The estimates of total road damage costs vary from $2.93 million for the 1 in 2 AEP design flood to $3.36 billion for the 1 in 100,000 AEP design flood. Major roads are TMR controlled roads and minor roads are council controlled roads.

Figure 6-57 show the variation of rail line lengths inundated with AEP. There are no data available to estimate flood damage repair costs for rail.

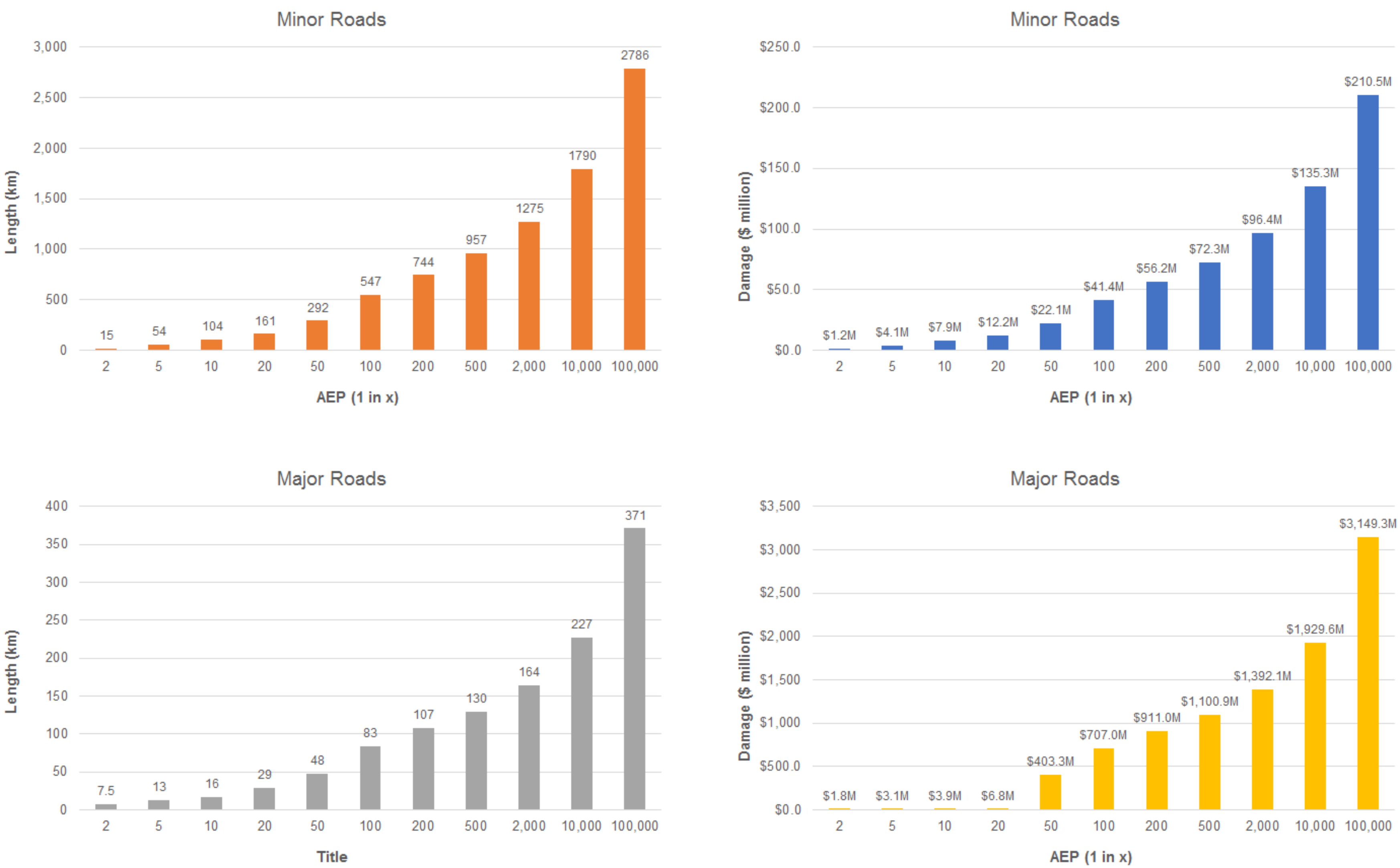


Figure 6-56 Variation of major and minor road lengths inundated and estimated flood damage repair costs with AEP

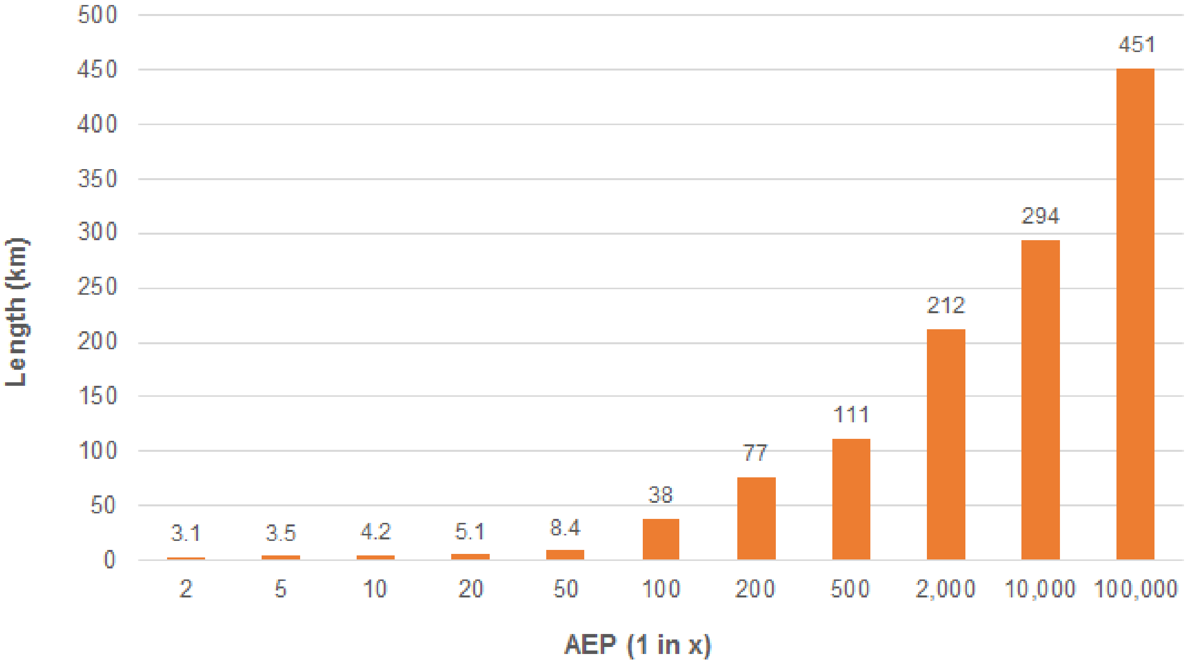


Figure 6-57 Variation of rail line lengths inundated with AEP

6.8.1.3.2 Public and Community Buildings and Assets Damage

Figure 6-58 shows the number of emergency service, health service and educational institutional buildings impacted with AEP as described below:

- Emergency Services Facilities shown include Police Stations, Ambulance Stations, Fire Stations and SES Facilities;
- Health Service Facilities shown include Public Hospitals, Private Hospitals, Dental Hospitals and Health Centres; and
- Educational institutions shown include Schools, Universities and Colleges.

There are no data available to estimate flood damage costs for any of these buildings.

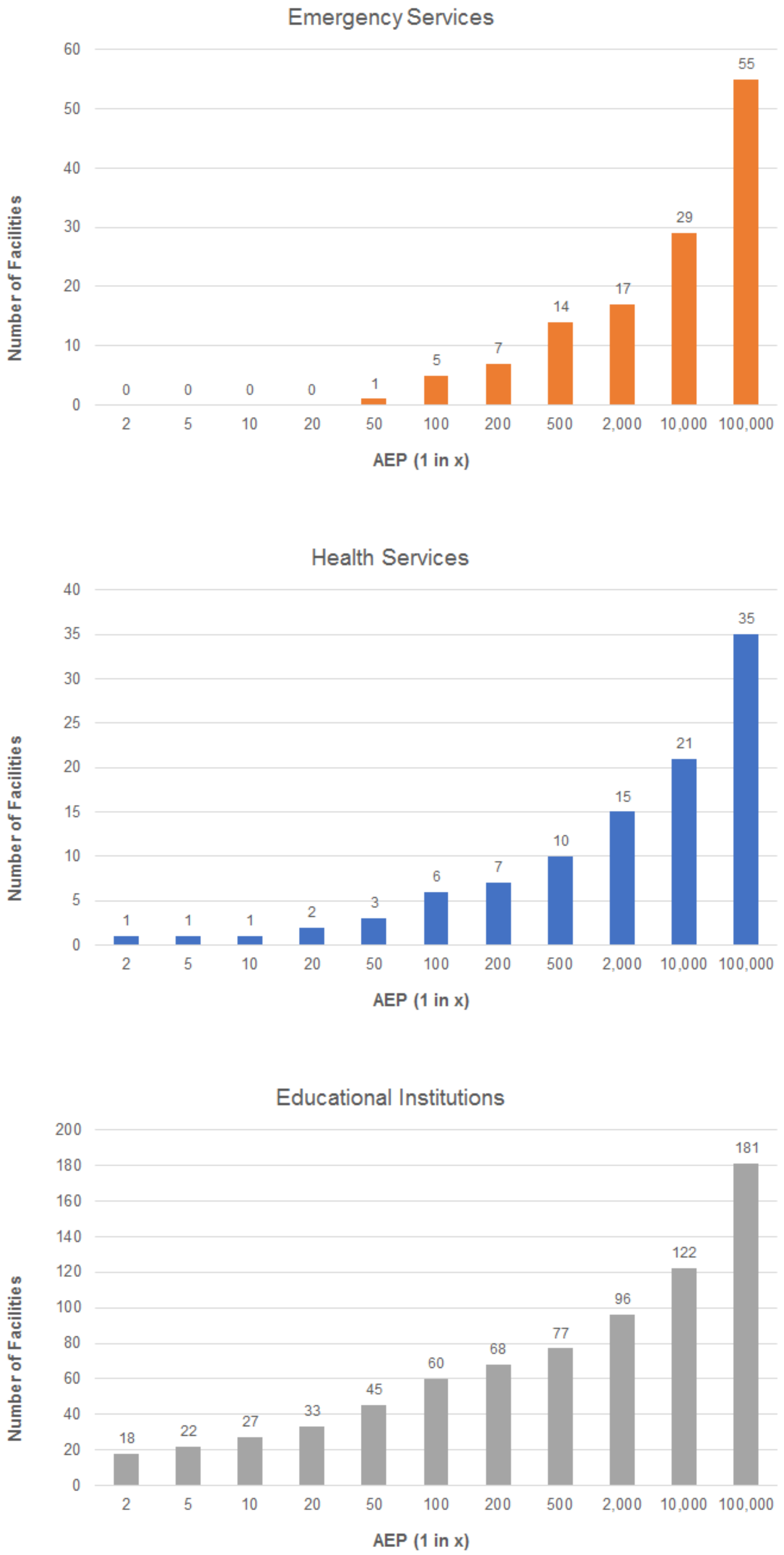


Figure 6-58 Variation of emergency services, health services and educational institutions impacted with AEP

6.8.1.3.3 Public Utilities Damage

Figure 6-59 shows the variation of the number of waste water treatment plants and sewer pump stations impacted and estimated indicative flood damage repair costs with AEP. Figure 6-60 shows the variation of the number of water pump stations, power plants and electricity sub-stations impacted and estimated indicative flood damage repair costs to water pump stations with AEP.

6.8.1.3.4 Rural/Agricultural Damage

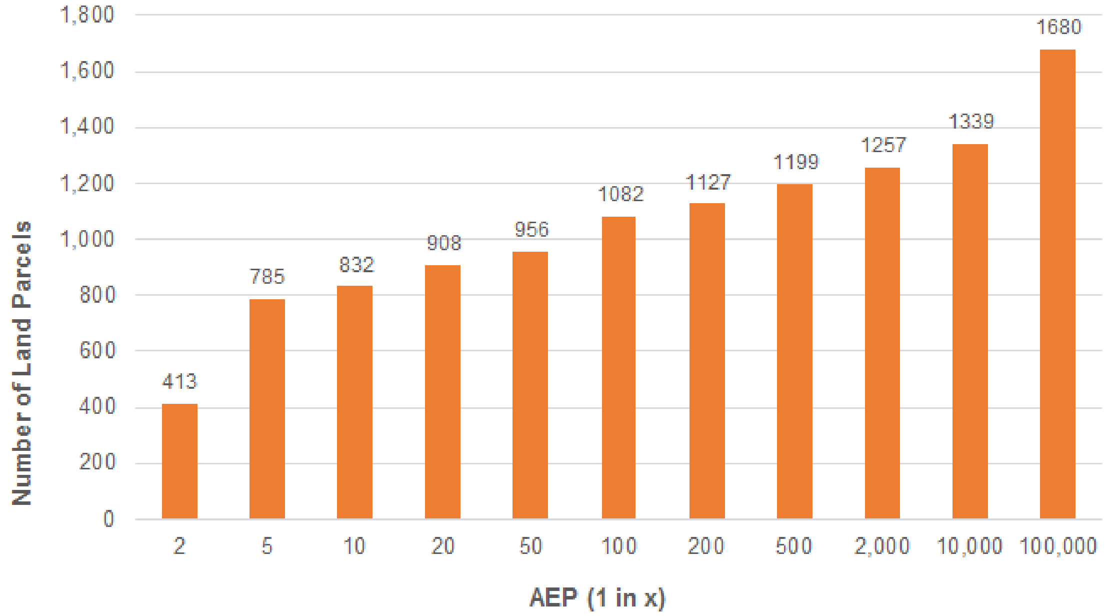
Figure 6-61 shows the variation of number of rural/agricultural land parcels impacted and land area inundated with AEP.

6.8.1.3.5 Mining Damage

Figure 6-62 shows the variation of number mining leases impacted and total lease area inundated with AEP.

Figure 6-59 Variation of the number of waste water treatment plants and sewer pump stations impacted and estimated flood damage repair costs with AEP

Figure 6-60 Variation of the number of water pump stations, power plants and electricity sub-stations impacted and estimated flood damage repair costs to water pump stations with AEP



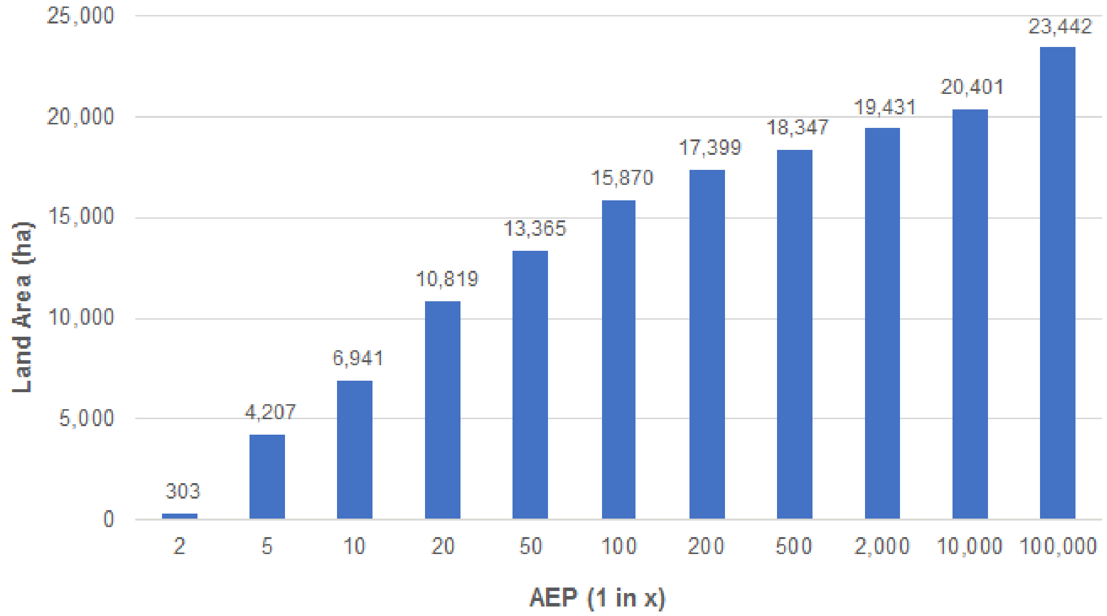
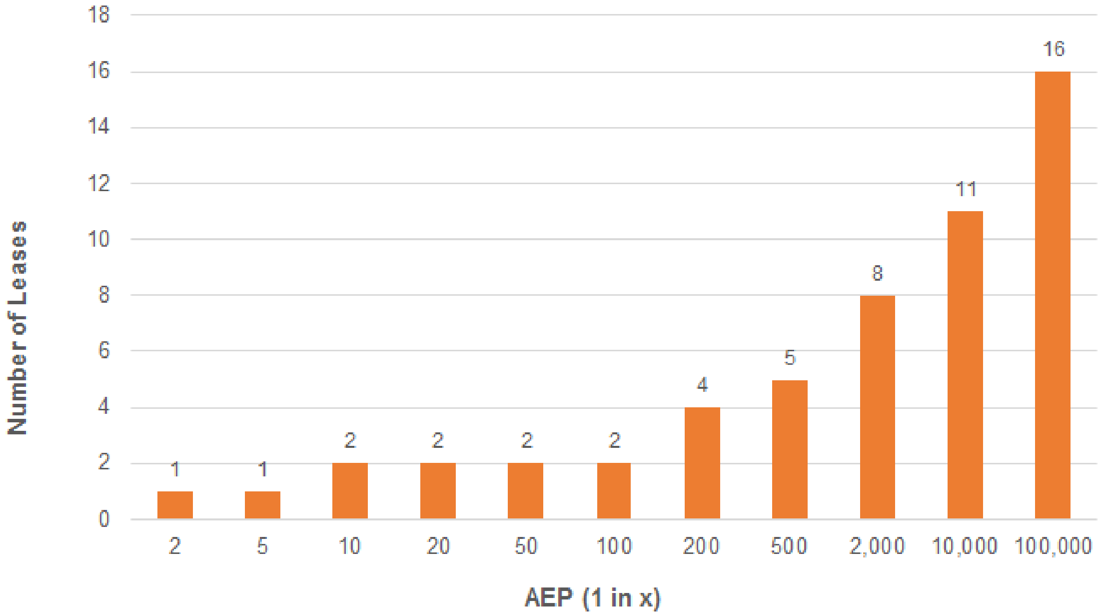


Figure 6-61 Variation of number of rural/agricultural land parcels impacted and land area inundated with AEP



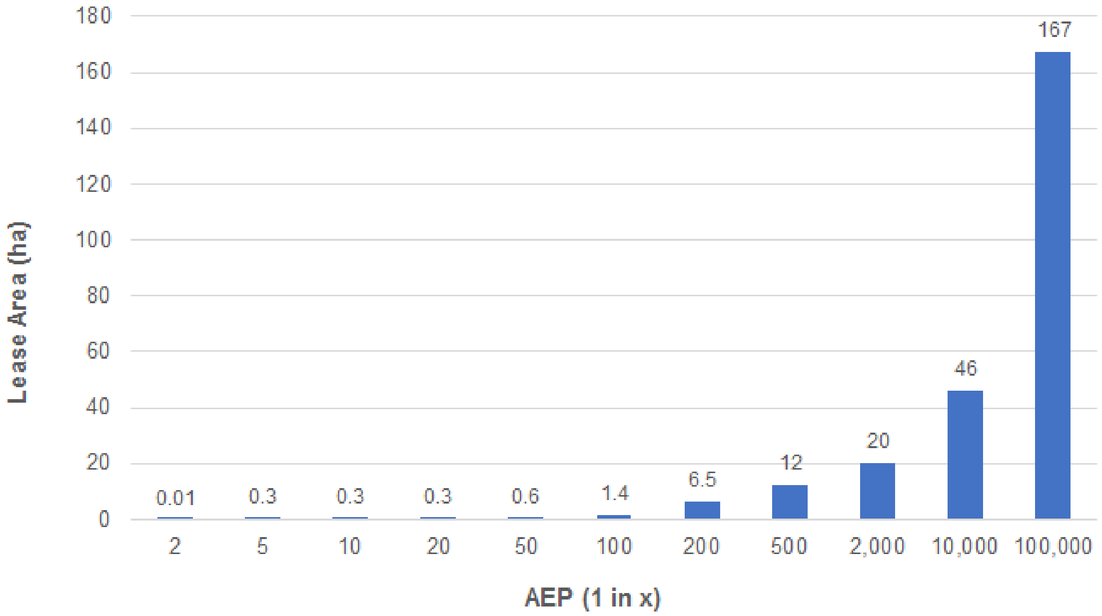


Figure 6-62 Variation of number of mining leases impacted and lease area inundated with AEP

6.8.1.4 Total Tangible Damages

Table 6-20 and Figure 6-63 show the distribution of estimated total tangible flood damages for each flood damage category for each of the modelled design floods. Table 6-20 also shows the distribution of estimated tangible damage AAD’s for each damage category as well as the whole study area. Figure 6-64 shows the percentage contribution made to the total tangible damage by the different damage categories.

Table 6-21 and Figure 6-65 show the distribution of estimated total tangible flood damages for each LGA as well as the whole study area for each of the modelled flood events. Table 6-21 also shows the distribution of estimated tangible damage AAD’s for each LGA as well as the whole study area. Figure 6-66 and Figure 6-67 show the percentage contribution made to the total tangible damages by the different AEP’s and LGA’s respectively. Table 6-22 shows the distribution of residential and non-residential tangible flood damages by potential hydraulic risk category, with categories as defined in Section 4 Current Flood Risk.

The estimated total tangible AAD for the study areas is $186.8 million. The contributions to this total from residential and non-residential properties are $51.7 million (28%) and $75.6 million (40%), respectively. The estimated contribution from other damages types is approximately $59.5 million (32%). By comparison, the AAD for the Hawkesbury-Nepean floodplain is about $70 million (2011 dollars) (Molino Stewart, 2012).

Flood damage in the BCC area contributes approximately 64.1% of the total tangible damage AAD. Contributions from ICC, LVRC and SRC areas are approximately 25.9%, 5.8% and 4.2%, respectively.

Floods between the 1 in 100 AEP and 1 in 500 AEP design flood events contribute 38% of the AAD values. Design floods up to, and including, the 1 in 100 AEP also contribute 38% of the AAD, while design floods larger than 1 in 500 AEP contribute only 24% of the AAD.

In terms of potential hydraulic risk categories, the majority (91%) of tangible flood damages are due to properties located in the highest 3 risk categories (HR1 to HR3), with approximately half of that located in the second highest risk category (HR2). Properties located in the lower 2 risk categories (HR4 and HR5) only contribute 9% of the tangible flood damages. The distribution of damages across the potential hydraulic risk categories are similar for both residential and non-residential properties.

Table 6-20 Distribution of total tangible damages and AAD by damage category ($ millions)

AEP (1 in x)	Residential	Non-Residential	Transport	Other infrastructure	Utilities	Clean Up	Total
2	$0.04	$0.50	$2.93	$2.35	$0.00	$0.23	$6.05
5	$0.42	$2.92	$7.21	$5.77	$0.03	$0.65	$17.01
10	$5.82	$10.00	$11.75	$9.40	$0.44	$1.50	$38.91
20	$31.03	$56.41	$18.98	$15.18	$2.33	$4.96	$128.9
50	$277.2	$434.2	$425.4	$340.3	$20.79	$59.92	$1,558
100	$1,343	$2,162	$748.4	$598.7	$100.7	$198.1	$5,151
200	$2,846	$3,949	$967.2	$773.8	$213.5	$350.0	$9,100
500	$4,804	$6,535	$1,173	$938.5	$360.3	$552.4	$14,363
2,000	$7,902	$10,904	$1,488	$1,191	$592.7	$883.1	$22,962
10,000	$13,604	$18,187	$2,065	$1,652	$1,020	$1,461	$37,988
100,000	$27,633	$35,063	$3,360	$2,688	$2,073	$2,833	$73,649
AAD	**$51.7**	**$75.6**	**$27.0**	**$21.6**	**$3.88**	**$7.19**	**$186.8**

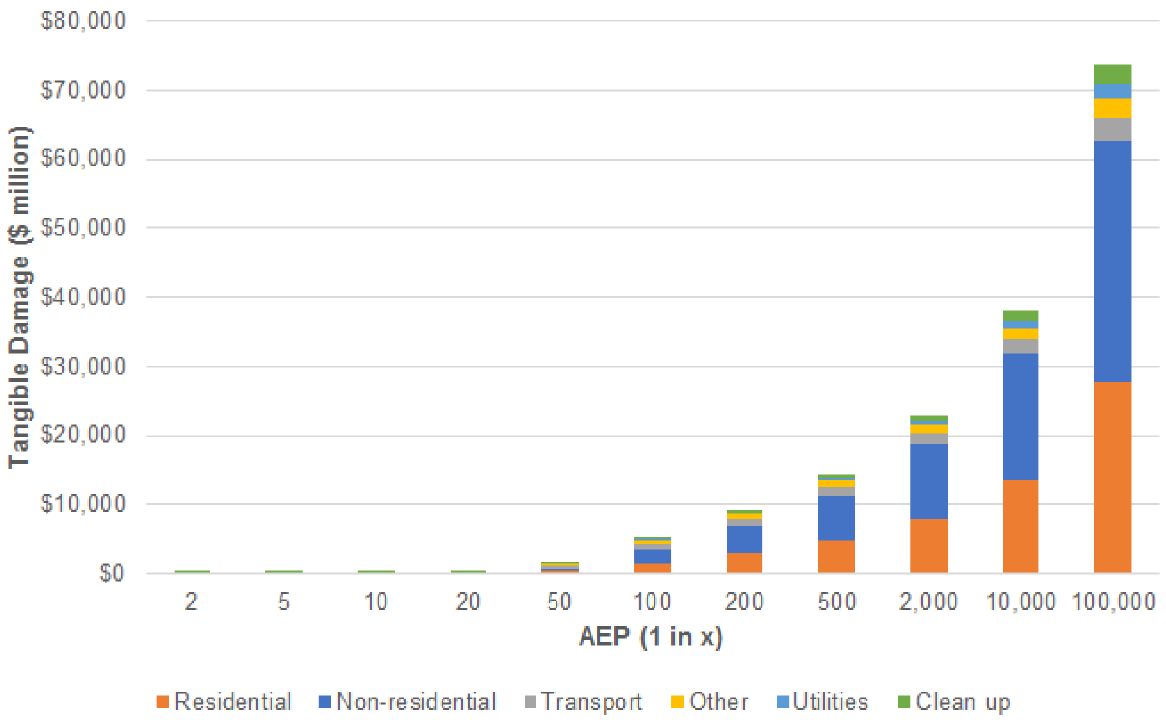


Figure 6-63 Variation of tangible damage estimates with AEP for different damage categories

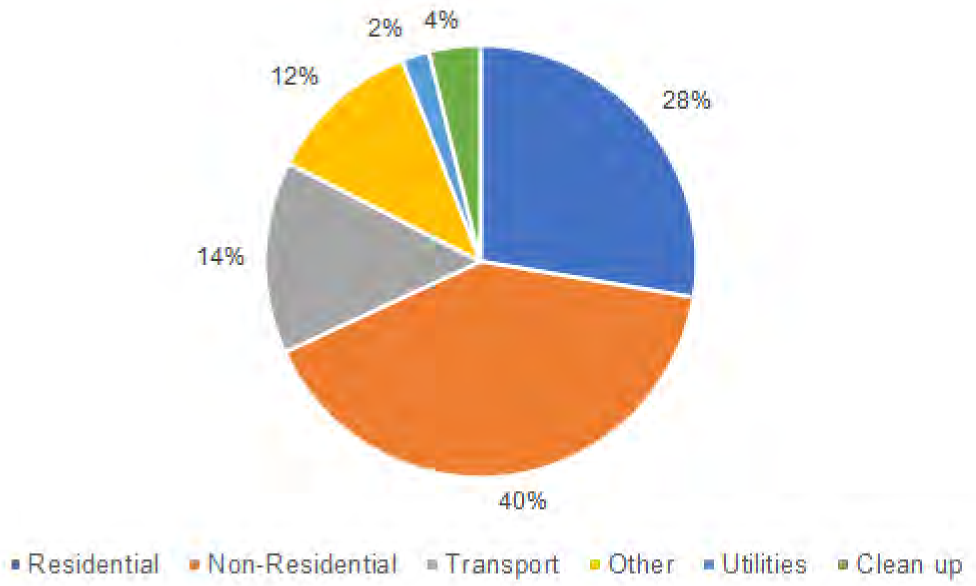


Figure 6-64 Percentage contribution to tangible damage AAD by different damage categories

Table 6-21 Distribution of total tangible damages and AAD by LGA ($ millions)

AEP (1 in x)	BCC	ICC	LVRC	SRC	Total
2	$5.04	$0.41	$0.26	$0.34	$6.05
5	$7.26	$3.44	$3.98	$2.33	$17.01
10	$11.29	$15.55	$6.43	$5.64	$38.91
20	$55.99	$50.13	$11.61	$11.15	$128.9
50	$697.1	$527.8	$193.8	$139.2	$1,558
100	$3,307	$1,393	$273.3	$178.2	$5,151
200	$6,186	$2,292	$358.1	$263.8	$9,100
500	$10,285	$3,343	$408.2	$327.0	$14,363
2,000	$17,290	$4,760	$490.0	$421.0	$22,962
10,000	$30,078	$6,827	$537.0	$546.4	$37,988
100,000	$60,040	$11,948	$708.6	$952.6	$73,649
AAD	**$119.7**	**$48.4**	**$10.8**	**$7.96**	**$186.8**

BCC – Brisbane City Council; ICC – Ipswich City Council; LVRC – Lockyer Valley Regional Council; SRC – Somerset Regional Council

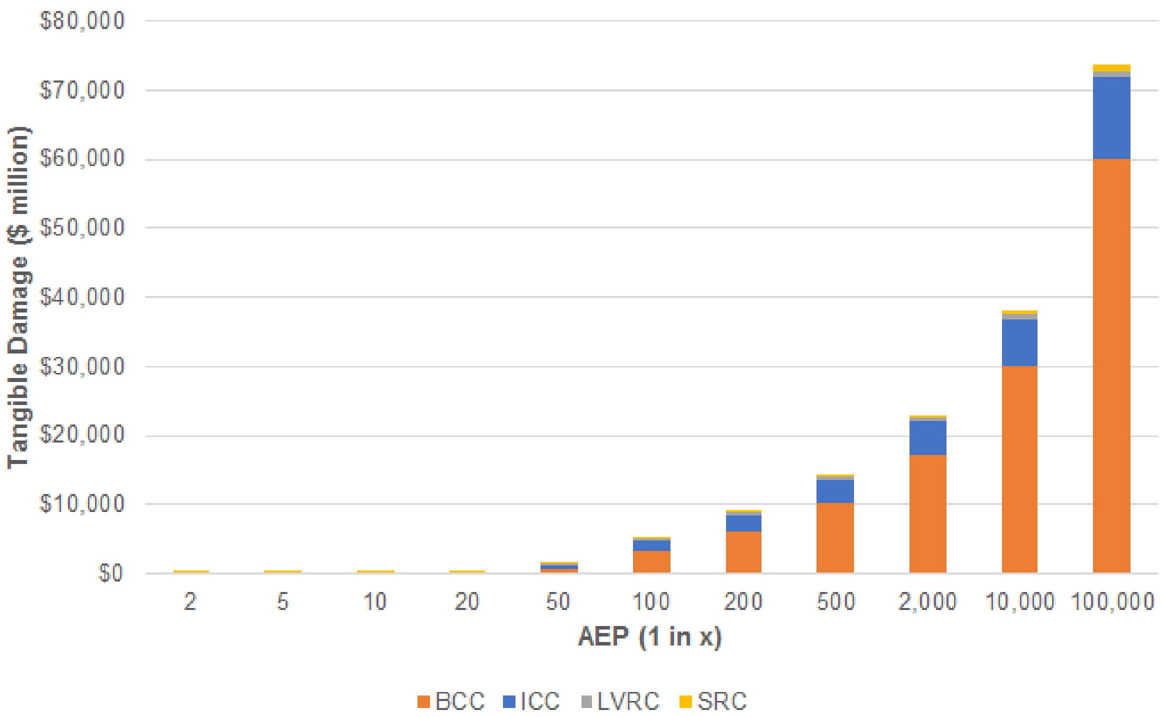


Figure 6-65 Variation of tangible damage estimates with AEP for different LGA's

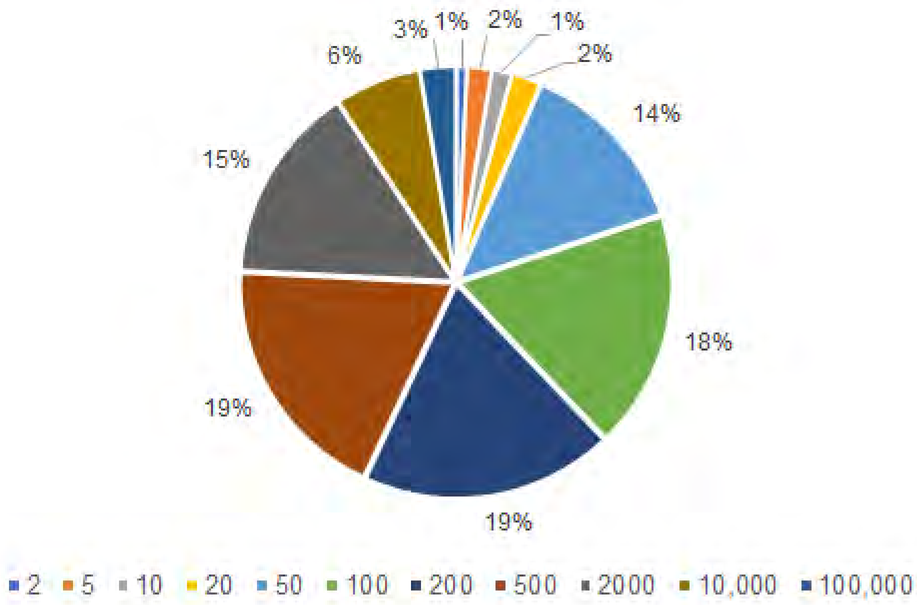


Figure 6-66 Percentage contribution to tangible damage AAD by different AEP's

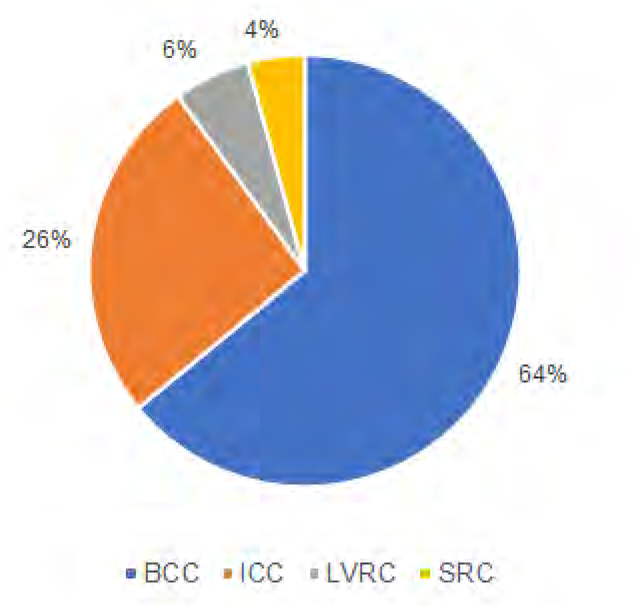


Figure 6-67 Percentage contribution to tangible damage AAD by different LGA's

Table 6-22 Distribution of total tangible damages and AAD by potential hydraulic risk category ($ millions)

AEP (1 in x)	Residential						Non-Residential						Total
	HR1	HR2	HR3	HR4	HR5	Total	HR1	HR2	HR3	HR4	HR5	Total	
2	$0.03	$0.01	$0.00	$0.00	$0.00	$0.04	$0.27	$0.23	$0.00	$0.00	$0.00	$0.50	$0.53
5	$0.32	$0.09	$0.01	$0.00	$0.00	$0.42	$2.14	$0.78	$0.00	$0.00	$0.00	$2.92	$3.34
10	$5.18	$0.36	$0.27	$0.00	$0.01	$5.82	$9.21	$0.79	$0.00	$0.00	$0.00	$10.00	$15.82
20	$26.00	$3.98	$0.91	$0.04	$0.09	$31.03	$47.23	$8.33	$0.86	$0.00	$0.00	$56.41	$87.44
50	$124.7	$144.9	$6.53	$0.92	$0.14	$277.2	$219.9	$205.4	$8.86	$0.01	$0.03	$434.2	$711.4
100	$177.2	$932.1	$230.4	$3.06	$0.49	$1,343	$337.4	$1,627	$192.7	$4.82	$0.53	$2,162	$3,505
200	$189.0	$1,406	$1,227	$22.48	$1.46	$2,846	$371.3	$2,387	$1,165	$24.97	$1.08	$3,949	$6,795
500	$192.3	$1,612	$2,670	$323.8	$5.14	$4,804	$388.9	$2,908	$2,947	$285.8	$4.85	$6,535	$11,339
2,000	$195.2	$1,680	$3,773	$2,122	$131.9	$7,902	$411.0	$3,299	$4,864	$2,227	$103.1	$10,904	$18,807
10,000	$197.4	$1,700	$4,089	$4,024	$3,594	$13,604	$436.3	$3,560	$6,216	$4,820	$3,155	$18,187	$31,790
100,000	$199.7	$1,715	$4,172	$4,359	$17,188	$27,633	$462.6	$3,724	$7,277	$6,879	$16,720	$35,063	$62,697
AAD	**$6.76**	**$21.4**	**$17.6**	**$4.06**	**$1.81**	**$51.7**	**$12.9**	**$37.2**	**$19.4**	**$4.39**	**$1.64**	**$75.6**	**$127.3**

HR1 to HR5, potential hydraulic risk category from highest (HR1) to lowest (HR5), as defined in Section 4 Current Flood Risk.

6.8.1.5 Sensitivity Assessment

To assess the significance of some of the data limitations, simplifications and assumptions made in the flood damage assessment, the sensitivity of the estimated AAD to the following six scenarios was investigated, with results noted:

- Scenario 1 – the adopted A/P ratios (to convert potential damage to actual damage) are too low: the adopted A/P ratios (see Section 6.7.1.2.1) were increased by 25% to assess the impact and contribution of higher A/P ratios to the total damage estimates. This scenario represents a case in which owners of residential and commercial properties are less able to implement flood damage reduction measures at their properties. Increasing the A/P ratio by 25% for residential and non-residential properties would increase the tangible damage AAD by approximately 18%.
- Scenario 2 – the adopted building floor levels are too high: the adopted floor levels were reduced uniformly by 0.15 m to assess the impact and contribution of lower floor levels to the total damage estimates. This scenario represents a case in which floor levels estimated for properties in the study area have a positive bias. Reducing all building floor levels by 0.15 m would increase the tangible damage AAD by approximately 4.7%.
- Scenario 3 – the adopted building floor levels are too low: the adopted floor levels were increased uniformly by 0.15 m to assess the impact and contribution of higher floor levels to the total damage estimates. This scenario represents a case in which floor levels estimated for properties in the study area have a negative bias. Increasing all building floor levels by 0.15 m would reduce the tangible damage AAD by approximately 4.2%.
- Scenario 4 – the adopted residential flood stage-damage curves produce damage values that are too high: the internal and external damage estimates at residential properties were reduced by 20% to assess the impact and contribution of lower residential damage to the total damage estimates. This scenario represents a case in which properties in the lower socio-economic parts of the study area would have lower damages. Reducing the internal and external damage at residential properties by 20% would reduce the tangible damage AAD by approximately 3.3%.
- Scenario 5 – the adopted damage cost for public and community owned buildings and assets are too high: the damage estimate for public and community owned buildings and assets was reduced by 50% to assess the impact and contribution of damage to these buildings and assets to the total damage estimates. This scenario represents a case in which the public and community owned buildings and assets damages are overestimated. Reducing the ‘other infrastructure’ damage costs by 50% would reduce the tangible damage AAD by approximately 5.7%.
- Scenario 6 – the adopted damage cost for public and community owned buildings and assets are too low: the damage estimate for public and community owned buildings and assets was increased by 50% to assess the impact and contribution of damage to these buildings and assets to the total damage estimates. This scenario represents a case in which the public and community owned buildings and assets damages are underestimated. Increasing the ‘other infrastructure’ damage costs by 50% would increase the tangible damage AAD by approximately 5.8%.

Table 6-23 compares the predicted flood damage estimates in this study, including the AAD’s, with damage estimates for the six sensitivity assessment scenarios.

In summary, the estimated tangible damage AAD is not very sensitive to the parameters investigated, except for the A/P ratio. It should be noted, however, that a 25% increase in the A/P ratio for non-residential properties would mean that the actual damages for these properties is equal to potential damages (i.e. A/P ratio equal to 1), suggesting that it would provide an upper limit estimate of the sensitivity of the adopted A/P value on the AAD.

Table 6-23 Comparison of predicted flood damage estimates ($ millions) with different sensitivity assessment scenarios

AEP (1 in x)	Base Case (current conditions)	Scenario 1 (increased A/P ratio)	Scenario 2 (reduced floor levels)	Scenario 3 (increased floor levels)	Scenario 4 (reduced property damages)	Scenario 5 (reduced other infrastructure costs)	Scenario 6 (increased other infrastructure costs)
2	$6.05	$6.19	$6.85	$5.61	$6.04	$4.88	$7.22
5	$17.01	$17.88	$18.26	$16.07	$16.96	$14.12	$19.89
10	$38.91	$43.14	$44.04	$35.65	$38.18	$34.21	$43.61
20	$128.9	$152.2	$148.4	$113.9	$124.9	$121.3	$136.5
50	$1,558	$1,748	$1,649	$1,471	$1,523	$1,388	$1,728
100	$5,151	$6,089	$5,409	$4,904	$4,987	$4,852	$5,451
200	$9,100	$10,922	$9,461	$8,759	$8,760	$8,713	$9,487
500	$14,363	$17,405	$14,819	$13,921	$13,804	$13,894	$14,832
2,000	$22,962	$28,006	$23,489	$22,451	$22,058	$22,366	$23,557
10,000	$37,988	$46,519	$38,678	$37,311	$36,450	$37,162	$38,814
100,000	$73,649	$90,489	$74,519	$72,783	$70,571	$72,306	$74,993
AAD	**$186.8**	**$220.9**	**$195.5**	**$179.0**	**$180.7**	**$176.1**	**$197.6**

6.8.2 Intangible Damages

Intangible damages have been estimated based on the methodology and uplift factors outlined in Section 6.7.2.2. That is, damages are calculated by applying an uplift factor to the combined direct and indirect residential damages. A sensitivity assessment for intangible damage has been undertaken using the reduced uplift factors given in Section 6.7.2.3.

The intangible AAD for the study area is estimated at $101.8 million. Table 6-24 shows the variation in intangible damage estimates with AEP and the intangible AAD. The results show that the intangible damages are quite sensitive to the adopted uplift factors. However, for reasons discussed in Section 6.7.2.3, the sensitivity results given in Table 6-25 are considered to provide a lower bound for the intangible damages.

Table 6-24 Variation in intangible damage estimates with AEP ($ millions)

AEP (1 in x)	Intangible Damage	Adopted uplift factor
2	$0.00	0
5	$0.00	0
10	$0.00	0
20	$0.00	0
50	$194.0	0.7
100	$1,612	1.2
200	$4,839	1.7
500	$11,049	2.3
2,000	$24,497	3.1
10,000	$51,694	3.8
100,000	$127,113	4.6
AAD	**$101.8**	

Table 6-25 Sensitivity of intangible damage estimates to lower uplift factors ($ millions)

AEP (1 in x)	Intangible Damage	Adopted uplift factor
2	$0.00	0
5	$0.00	0
10	$0.00	0
20	$0.00	0
50	$0.00	0
100	$1,612	1.2
200	$3,416	1.2
500	$5,764	1.2
2,000	$9,483	1.2
10,000	$16,324	1.2
100,000	$33,160	1.2
AAD	**$53.2**	

6.8.3 Total Damages

Table 6-26 shows the estimated variation in total flood damages with AEP and the total AAD for the study area. Based on the results of this study, the estimated total AAD for the study area is $288.7 million, made up $186.8 million (65%) in tangible damages and $101.8 million (35%) in intangible damages. The results also show that the total flood damage costs for a 1 in 100 AEP design flood event would be approximately $6.8 billion. Of this, approximately $5.2 billion (76%) would be in tangible damages and the remaining $1.6 billion (24%) would be intangible damages.

Table 6-26 Variation in total flood damage estimates with AEP ($ millions)

AEP (1 in x)	Tangible	Intangible	Total
2	$6.05	$0.00	$6.05
5	$17.01	$0.00	$17.01
10	$38.91	$0.00	$38.91
20	$128.9	$0.00	$128.9
50	$1,558	$194.0	$1,752
100	$5,151	$1,612	$6,763
200	$9,100	$4,839	$13,938
500	$14,363	$11,049	$25,412
2,000	$22,962	$24,497	$47,459
10,000	$37,988	$51,694	$89,682
100,000	$73,649	$127,113	$200,763
AAD	**$186.8**	**$101.8**	**$288.7**

6.8.4 Comparison with Previous Study Damage Estimates

6.8.4.1 Wivenhoe and Somerset Dams Optimisation Study

To assess potential benefits and costs of different dam operation options, WSDOS (DEWS, 2014) estimated flood damages and impacts associated with Brisbane River flooding in the Phase 3 (SFMP) study area to compare a range of options against the current operational strategy (base case). Only tangible flood damages were estimated in the WSDOS study.

WSDOS flood damage estimates were made using the best available data at that time. However, the WSDOS report states that the flood damage estimates made in the study should be considered as indicative only because there are significant uncertainties in the damage and impact estimates that have been made due to approximations and assumptions made in the methodology and limitations associated with the available data.

For current floodplain conditions and current dam operation strategy, WSDOS estimated that the total tangible average annual damage (AAD) in the Phase 3 (SFMP) area is $159.3 million (adjusted to 2017 dollars). These damage estimates assume that actual damages to residential and non-residential are the same as potential damages (i.e. A/P ratio is equal to 1).

The AAD estimated in this study is $186.8 million, which is 17% higher than the WSDOS estimate.

Figure 6-68 and Table 6-27 show a comparison between the AAD estimates for this study and the equivalent estimates from the WSDOS (DEWS, 2014). The WSDOS residential damage estimate ($79.1 million) and its contribution to the AAD (50%) are significantly higher than the residential estimate ($51.4 million) and its contribution to the AAD (28%) in this study.

Comparison of flood damage estimates between different studies have to be undertaken with caution. The adopted stage-damage curves are only one component of flood damage estimation that differs between this study and WSDOS. The differences in other input parameters used (e.g. floor levels, land use, property type, property area) also would have a significant influence on the differences in estimated flood damages. The available data on WSDOS flood damage estimation is insufficient to undertake an accurate assessment. Nevertheless, there are a number of potential reasons for WSDOS estimating significantly higher residential damages including the assumption that actual damage is equal to potential damage and simplifications that were made to estimate floor levels of houses. For example, in the absence of floor level data, WSDOS assumed that all lowset houses had a floor level 0.1 m above ground level. This assumption would result in an overestimation of the depth of flooding above floor level and therefore the flood damage estimate. Similarly, WSDOS non-residential damages are based on the original ANUFLOOD curves which were found in this study to underestimate flood damage.

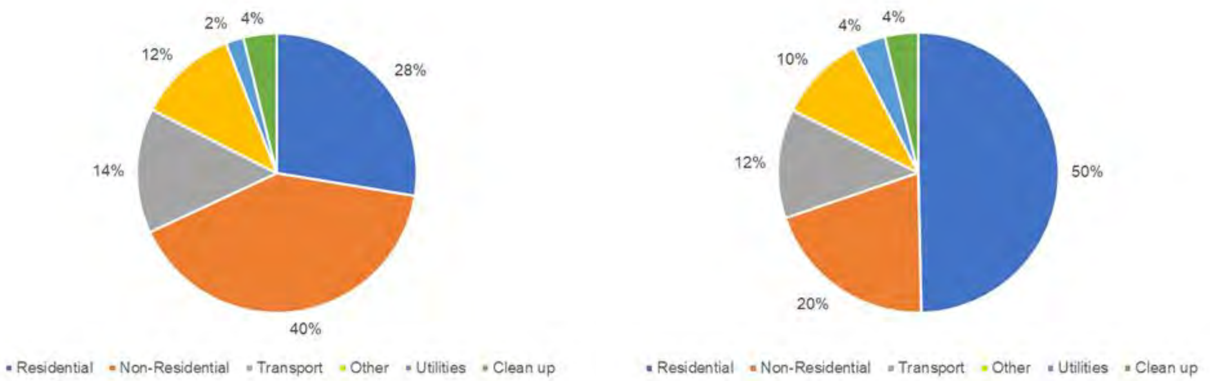


Figure 6-68 Percentage contributions to tangible damage AAD in this Phase 3 (SFMP) (left) and WSDOS (source: DEWS, 2014) (right)

Table 6-27 Comparison of tangible AAD costs between WSDOS and Phase 3 (SFMP) estimates

Category	WSDOS (DEWS, 2014)	Phase 3 (SFMP) (this study)
Residential	$79.1m	$51.7m
Non-residential	$32.0m	$75.6m
Transport infrastructure	$20.1m	$27.0m
Other infrastructure	$16.1m	$21.6m
Utilities	$5.90m	$3.88m
Clean-up and rehabilitation	$6.10m	$7.19m
Tangible AAD	**$159.3m**	**$186.8m**

6.8.4.2 Brisbane Valley Flood Damage Minimisation Study

The scope of the BVFDMS flood damages estimation was limited to only the estimation of potential direct flood damages to residential and non-residential properties affected by Brisbane River flooding in Brisbane, Ipswich and Somerset LGA's. The BVFDMS did not estimate flood damage to public utilities and infrastructure. Indirect flood damages were also not estimated.

The BVFDMS estimated flood damages for up to 10 different Brisbane River flood discharges at the Port Office ranging from 1,000 m^3/s to 12,000 m^3/s. These damage estimates were made using the stage-damage curves developed by WRM Water & Environment for Maroochy Shire Council (2006a), approximate flood extents estimated using results from a 1-dimensional hydraulic model, limited property data that was available at that time, and a number of simplifying assumptions regarding ground and floor levels, land use, property types and sizes, etc due to lack of reliable data. The BVFDMS did not estimate AAD values.

The BVFDMS study (undertaken for 2006 development conditions) estimated that, for a peak flood discharge of 10,000 m^3/s at the Port Office, the total potential direct flood damage (in 2006 dollars) would be approximately $1,307.3 million in Brisbane, $429.8 million in Ipswich, and $34.3 million in Somerset, giving a combined total potential damages estimate of $1,771.4 million, which is equivalent to about $2,330 million in 2017 dollars (when accounting for the CPI increase). The recent Phase 2 (Flood Study) predicted that a peak flood discharge of 10,000 m^3/s at the Port Office is approximately equivalent to the 1 in 100 AEP design flood event. For the 1 in 100 AEP design flood event, the Phase 3 (SFMP) study estimates the total potential direct flood damage in Brisbane, Ipswich and Somerset LGA's for residential and non-residential properties to be some $3,742 million (2017 dollars), which is about $1,412 million higher than the BVFDMS estimate. The Phase 3 (SFMP) study has been undertaken with data significantly more accurate than the BVFDMS. However, one of key potential reasons for the Phase 3 (SFMP) study estimating higher flood damages is the use of updated stage-damage curves that predict higher damage values.

The BVFDMS study estimated that, for a peak flood discharge of 10,000 m^3/s at the Port Office, about 17,900 buildings (14,760 residential and 3,140 non-residential) would be inundated above ground level in Brisbane, Ipswich and Somerset LGA's. For the 1 in 100 AEP design flood event, the Phase 3 (SFMP) (undertaken for the 2017 development conditions) estimates that 17,003 buildings (12,058 residential and 4,945 non-residential) would be inundated above ground level in Brisbane, Ipswich and Somerset LGA's. The difference between the two studies is likely due to the use of more accurate property and ground level data in this study.

Any comparison of the BVFDMS and Phase 3 (SFMP) results should be made with caution because they have been undertaken with different levels of rigour and accuracy with regards to input data. For example, the BVFDMS values are likely to include large outbuildings which were not removed from its building database. It is recalled that approximately 49,030 outbuildings in the study area were removed from the 'raw' database before it was used for flood damage estimation in the Phase 3 (SFMP). Further, it is likely that some change in the property numbers have also occurred due to in-fill development that has taken place in the study area since 2006.

6.8.4.3 A Comprehensive Evaluation of the Proposed Wivenhoe Dam on the Brisbane River (Grigg, 1977)

In the CEPWDBR study (Grigg, 1977), flood damages were estimated for Brisbane River flooding (including some creek flooding) for mid-1974 costs and mid-1974 development conditions in the floodplain. Damage estimates were made for flooding without the Wivenhoe Dam and for several Wivenhoe Dam design options (in conjunction with proposed floodplain management measures including development controls). In the absence of the dam, the tangible AAD was estimated at $6.18

million dollars (equivalent to about $51.3 million in 2017 dollars when adjusted for CPI increase). For the various dam design and flood mitigation options considered in the study, the post-dam tangible AAD estimates reduced to between $0.90 million and $3.40 million (equivalent to between about $7.5 million and $28.2 million in 2017 dollars). It appears that these damage estimates are only for the areas within the 1974 boundaries of Brisbane and Ipswich City Councils, and do not include damages for some areas modelled in the Phase 2 (Flood Study) and assessed in this Phase 3 (SFMP).

The CEPWDBR adopted flood stage-damage curves that were specifically developed for the study based on a comprehensive survey of flood damage to properties in the study area in the immediate aftermath of the1974 flood. Further, the relationship between the peak flood discharge and AEP used for the estimation of AAD's was based on flood study results available at that time and is quite different to the relationship derived in the Phase 2 (Flood Study). The predicted flood extent for a particular peak flood level at the City Gauge, between the CEPWDBR and the Phase 2 (Flood Study) is also significantly different. This is probably due to the differences in the study areas and the CEPWDBR study flood extent estimates excludes areas that are normally covered by water (i.e. waterways). The number and mix of property types and sizes have also changed significantly since 1974. For example, the average size of a residential property in Queensland has more than doubled since 1974 (DNRM, 2002). For these reasons, it is not considered meaningful to compare estimates of flood damages between CEPWDBR and the Phase 2 (Flood Study).

An attempt was made to compare the floodprone areas and the number of flood affected properties in the common study area predicted for different peak flood levels at the City Gauge.

Figure 6-69 shows a comparison of the predicted floodprone areas (excluding the areas 'normally inundated by water' assumed to be the waterway area) by the Phase 2 (Flood Study) and Grigg (1977) studies. For this comparison, it has been assumed that the waterway area remains unchanged for all gauge heights.

Figure 6-69 shows a comparison of the number of flood affected buildings predicted in the two studies for the 1974 Brisbane and Ipswich City Council areas. The CEPWDBR study estimated that, for a peak flood level of 4.5 mAHD at the City Gauge, about 8,860 buildings (6,610 residential and 2,250 non-residential) would be affected and damaged. It appears that these building numbers are for properties inundated above ground level. The Phase 2 (Flood Study) predicted a peak flood level of 4.5 mAHD at the City Gauge for the 1 in 100 AEP design flood event. For the 1 in 100 AEP design flood event, this study (for the 2017 development conditions) has estimated that a total of 15,455 buildings (11,010 residential and 4,445 non-residential) would be inundated above ground level and 10,969 buildings (7,567 residential and 3,402 non-residential) would be inundated above floor level in the 1974 extents of Brisbane and Ipswich City Council area. This difference in the number of inundated buildings reflects the development in the common study area since 1974, as well as the use of potentially more accurate topographical and floor level data used in this study.

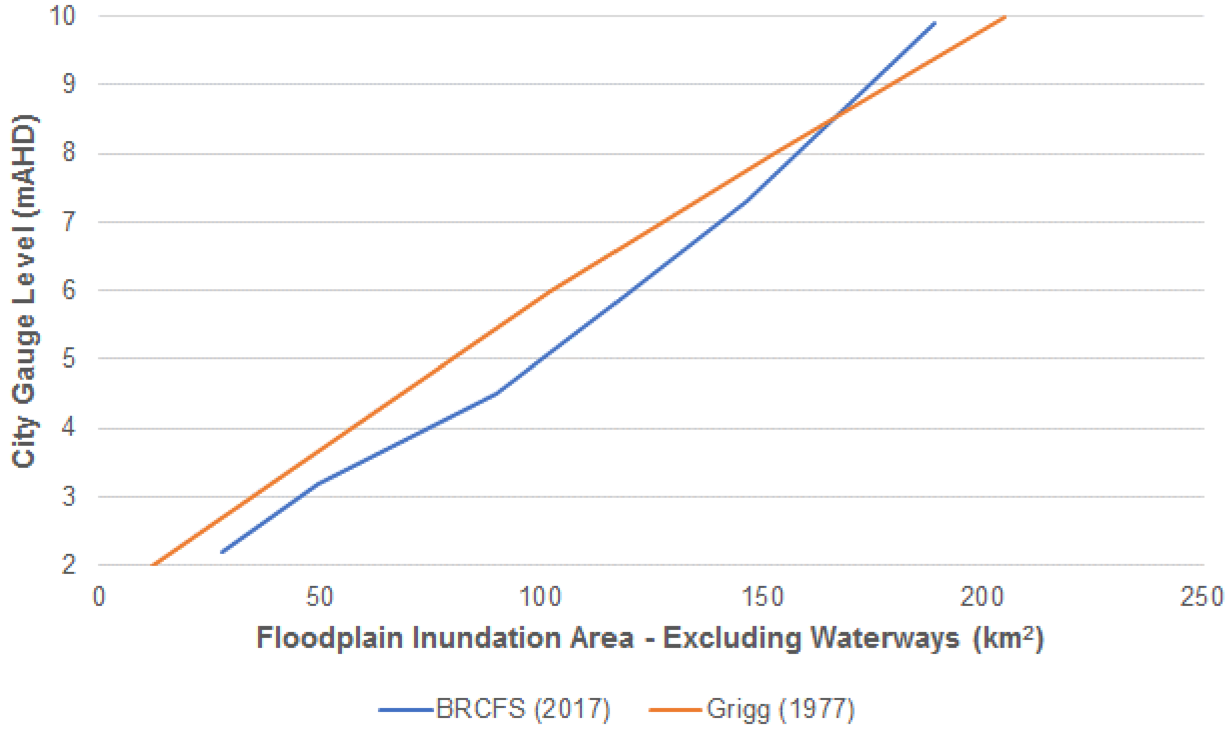


Figure 6-69 Comparison of floodplain inundation areas (excluding waterway areas) predicted by the Phase 2 (Flood Study) and Grigg (1977) studies

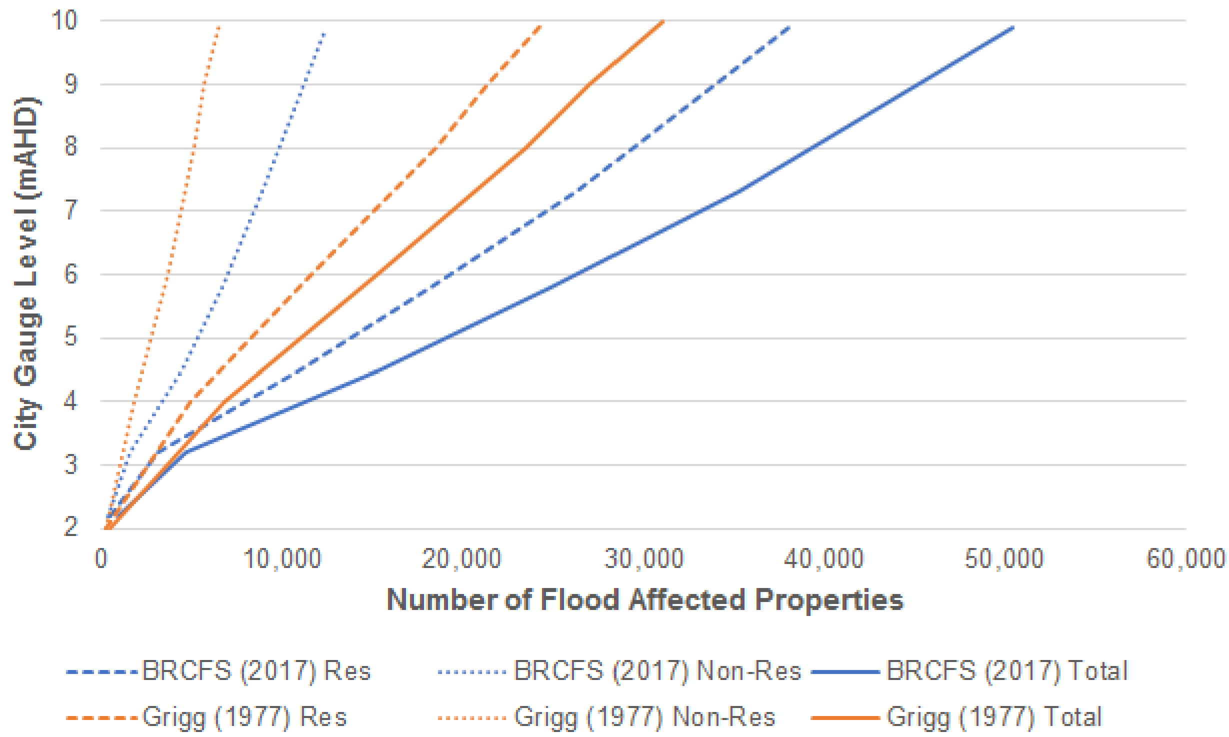


Figure 6-70 Comparison of the number of flood affected buildings predicted by the Phase 2 (Flood Study) and Grigg (1977) studies

6.9 Future Damages

6.9.1 Overview

An assessment was undertaken to estimate potential increases in flood damage to existing properties due to changes in flood behaviour associated with future development and climate change. Note, this assessment does not include potential increases in flood damage associated with new properties in the floodplain (associated with increased development density or new developments).

6.9.1.1 Future Development

Increased development in the floodplain can potentially affect flood damage to existing properties as a result of changing hydraulic behaviour by:

(1) Impacting the flow of water through the floodplain by blocking or constraining flowpaths (i.e. an impact on flood conveyance);

(2) Reducing the available volume of the floodplain by filling (i.e. an impact on flood storage); and

(3) Increasing runoff due to an increase in impermeable surfaces.

Testing of future development scenarios across the study area (including land within the four local government areas) has been undertaken to understand how future development may change flood behaviour within the lower Brisbane River study area due to (1) and (2). The assessment has not included the hydrologic impacts of development within the study area such as the increased runoff that might be expected from an increase in impermeable surfaces (3), or changes in the catchment area upstream of the study area. Outcomes of the assessment were used to highlight the sensitivity of flood damage to existing properties to changes in the floodplain due to future development. This provides the basis for regional-scale flood risk management of future development (in Section 9 Land Use Planning).

It is important to note that the future development scenario analysis is not intended to be predictive or provide an accurate forecast of future conditions. It also does not reflect Council policies regarding filling within the 1 in 100 AEP extent. Rather, it has been undertaken principally for exploratory purposes and to understand the floodplain's sensitivity to changes in development.

Two future development scenarios have been considered in this study, where flood damages have been assessed: DS1 (Modify Roughness) and DS2 (Modify Roughness and Topography), as further described in Section 5 Future Flood Risk.

6.9.1.2 Climate Change

Climate change can also potentially affect flood damage to existing properties as a result of changing hydraulic behaviour due to increases in rainfall and sea levels. Any future changes to Wivenhoe Dam or its operations were not considered in the sensitivity assessment.

IPCC (2013) provides a basis for projections for future climate conditions across the globe. More refined research and analysis has been carried out by institutions such as CSIRO, Bureau of

Meteorology, Engineers Australia and various universities in Australia that provide relevant future conditions for Australia relevant to the Phase 3 (SFMP).

Three climate change scenarios were investigated for the Phase 3 (SFMP), and simulated across the seven AEPs as used for estimating flood damages. The three climate change scenarios are presented in Table 6-28, and are further described in Section 5 Future Flood Risk.

Table 6-28 Climate Change Scenarios

Scenario (model reference)	Conditions Description	Rainfall	Sea Level Rise
CC2	RCP 8.5 conditions at 2050	10% increase	0.3m
CC4	RCP 8.5 conditions at 2090	20% increase	0.8m
CC5	RCP 4.5 conditions at 2090	10% increase	0.63m

6.9.2 Impact on Number of Existing Properties Inundated

Table 6-29 compares the number of existing properties inundated above ground level and above floor level under current conditions and under potential future development and climate change conditions assessed in this study for the full range of modelled flood events. It is important to note that the estimates in Table 6-29 do not include any new properties in the floodplain associated with the actual future development including increased development density. The assessment of future development has been limited to off-site impacts associated with changes to hydraulic behaviour as a result of the new development. For this reason, the number of impacted properties would be an under-estimate of actual conditions should the development proceed as assumed.

Also, no data is available on properties outside the current 1 in 100,000 AEP design flood extent. Therefore, for future development and climate change scenarios that extend beyond the current 1 in 100,000 AEP design flood extent, the estimates of the number of inundated properties would be underestimated.

The results show that the change in the number of existing floodprone properties under the two particular potential future development scenarios assessed in this investigation is not significant. However, the increase in the number of existing floodprone properties under future climate change conditions is significant.

Table 6-29 Comparison of the predicted number of properties flooded above ground level and above floor level under current and future development and climate change scenarios

AEP (1 in x)	Current Conditions		Future Development Conditions				Climate Change Conditions					
			DS1		DS2		CC2		CC4		CC5	
	AGL	AFL	AGL	AFL	AGL	AFL	AGL	AFL	AGL	AFL	AGL	AFL
2	29	10	28	10	17	6	170	43	1,363	361	736	205
5	85	23	87	24	75	24	320	87	1,901	504	1,040	276
10	500	152	514	171	297	101	1,122	402	3,179	1,026	2,003	622
20	1,646	653	1,660	665	865	314	2,873	1,126	6,297	2,453	4,153	1,463
50	6,608	3,355	6,670	3,404	2,710	1,260	11,386	6,004	20,145	11,360	13,078	6,603
100	20,144	12,395	20,235	12,457	21,772	13,702	31,835	21,462	43,536	30,679	33,273	22,167
200	32,071	22,101	32,121	22,177	33,604	23,493	41,637	29,726	52,095	38,241	43,430	30,611
500	45,432	33,012	45,353	33,048	46,392	33,999	56,097	42,628	67,827	53,506	57,672	43,584
2,000	64,286	50,490	64,250	50,484	64,853	51,116	74,950	61,184	84,927	72,363	75,722	61,935
10,000	93,462	81,642	93,481	81,656	94,309	82,391	102,928	91,421	110,969	99,882	103,267	91,775
100,000	155,122	144,630	155,375	145,083	155,810	145,515	162,071	153,541	164,754	158,060	162,120	153,672

AGL – above ground level; AFL – above floor level;

6.9.3 Impact on Existing Residential and Non-Residential Property Damage

Table 6-30 and Table 6-31 show the estimated total tangible damage contribution to the AAD's, as well as total tangible flood damages for the full range of modelled design flood events, under current conditions and under potential future development and climate change conditions assessed in this study. Figure 6-71 shows the variation in current and future total residential and non-residential flood damages under current and potential future development and climate change conditions with AEP.

The results show that the change in total residential and non-residential flood damage to existing properties is not significant under potential future development scenarios. However, the increase in total residential and non-residential flood damage to existing properties under future climate change conditions is quite significant. For the reason given earlier, for future climate change scenarios that extend beyond the current 1 in 100,000 AEP design flood extent, the estimates of flood damage and AAD would be underestimated.

Table 6-30 Comparison of predicted residential and non-residential tangible flood damage to existing properties ($ millions) under future development scenario

AEP (1 in x)	Current Conditions			Future Development Conditions					
				DS1			DS2		
	Res.	Non-Res.	Total	Res.	Non-Res.	Total	Res.	Non-Res.	Total
2	$0.04	$0.50	$0.53	$0.03	$0.50	$0.53	$0.03	$0.05	$0.08
5	$0.42	$2.92	$3.34	$0.41	$2.93	$3.34	$0.41	$2.22	$2.63
10	$5.82	$10.00	$15.82	$6.19	$10.74	$16.94	$3.80	$11.37	$15.17
20	$31.03	$56.41	$87.44	$31.94	$58.55	$90.49	$12.00	$16.23	$28.23
50	$277.2	$434.2	$711.4	$283.2	$440.6	$723.8	$90.81	$169.9	$260.7
100	$1,343	$2,162	$3,505	$1,356	$2,171	$3,527	$1,541	$2,345	$3,886
200	$2,846	$3,949	$6,795	$2,863	$3,953	$6,816	$3,089	$4,165	$7,254
500	$4,804	$6,535	$11,339	$4,822	$6,535	$11,357	$5,000	$6,734	$11,734
2,000	$7,902	$10,904	$18,807	$7,917	$10,872	$18,788	$8,032	$10,993	$19,026
10,000	$13,604	$18,187	$31,790	$13,642	$18,150	$31,792	$13,773	$18,299	$32,072
100,000	$27,633	$35,063	$62,697	$27,763	$35,352	$63,115	$27,872	$35,513	$63,384
AAD	**$51.7**	**$75.6**	**$127.3**	**$52.1**	**$75.9**	**$128.0**	**$50.1**	**$71.3**	**$121.4**

Table 6-31 Comparison of predicted residential and non-residential tangible flood damage to existing properties ($ millions) under climate change scenario

AEP (1 in x)	Climate Change Conditions								
	CC2			CC4			CC5		
	Res.	Non-Res.	Total	Res.	Non-Res.	Total	Res.	Non-Res.	Total
2	$0.69	$3.14	$3.82	$13.51	$23.72	$37.23	$5.72	$15.08	$20.80
5	$1.91	$7.88	$9.79	$20.31	$34.65	$54.95	$8.26	$22.79	$31.05
10	$16.32	$26.30	$42.62	$50.35	$70.96	$121.3	$25.27	$42.04	$67.31
20	$62.12	$110.8	$172.9	$148.8	$260.4	$409.2	$78.67	$130.5	$209.2
50	$553.1	$831.5	$1,385	$1,150	$1,859	$3,009	$600.1	$919.2	$1,519
100	$2,735	$3,919	$6,654	$4,265	$5,963	$10,228	$2,798	$4,029	$6,827
200	$4,144	$5,643	$9,787	$5,603	$7,795	$13,398	$4,210	$5,791	$10,002
500	$6,470	$8,933	$15,403	$8,300	$11,611	$19,911	$6,551	$9,120	$15,670
2,000	$9,732	$13,318	$23,050	$11,684	$15,871	$27,554	$9,789	$13,477	$23,266
10,000	$15,636	$20,732	$36,368	$17,427	$22,903	$40,331	$15,679	$20,838	$36,517
100,000	$30,026	$38,155	$68,181	$31,735	$40,710	$72,445	$30,053	$38,176	$68,229
AAD	**$81.5**	**$117.4**	**$198.9**	**$132.1**	**$193.9**	**$325.9**	**$88.0**	**$130.9**	**$218.9**

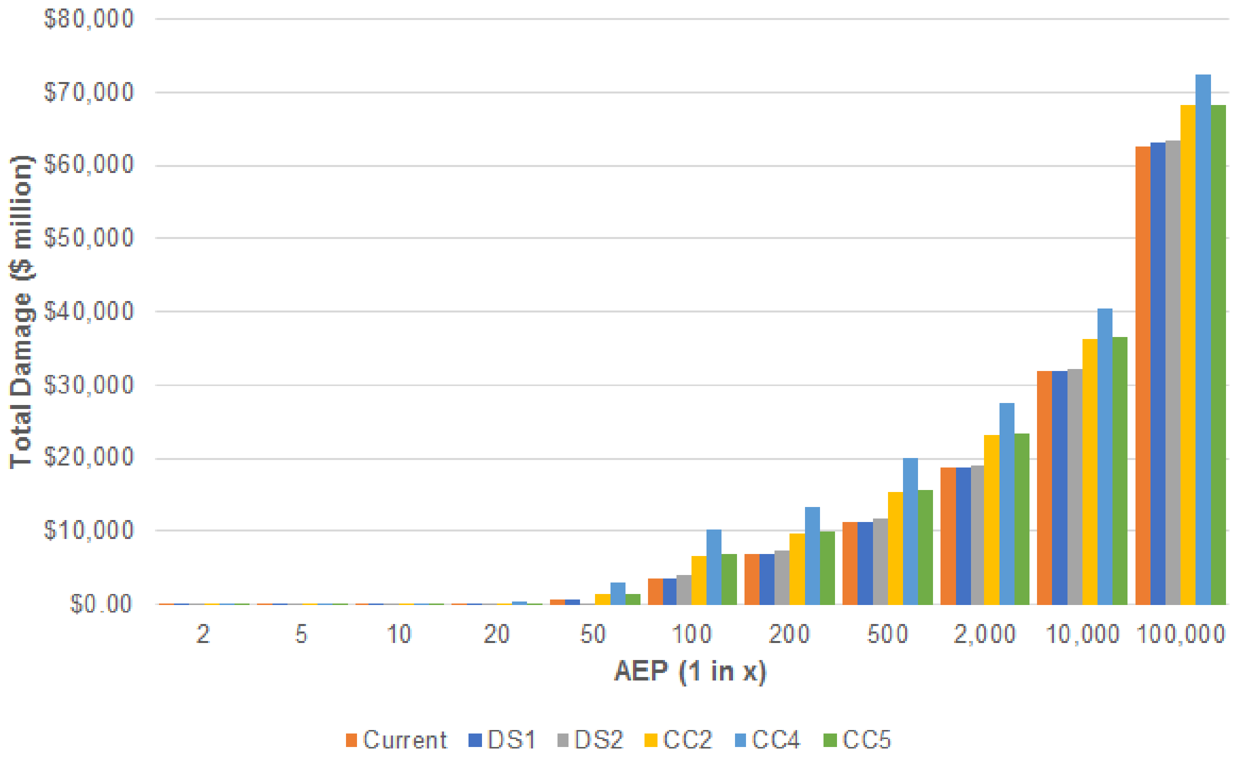


Figure 6-71 Variation of current and future total residential and non-residential flood damage to existing property under current and potential future development and climate change conditions

6.9.4 Impact on AAD

Table 6-32 shows the estimated total tangible AAD's, as well as total tangible flood damages for the full range of modelled flood events, under current conditions and under potential future development and climate change conditions assessed in this study. For the purposes of this comparative assessment, the AAD estimates for potential future conditions assume that non-property damages and intangible damage remain the same as for the equivalent current development conditions.

The results show that the change in total flood damages and the AAD for existing properties under the two particular potential future development scenarios investigated in this study is not significant. The increase in flood damages and the AAD under future climate change conditions, however, is quite significant. For the reason given earlier, for future climate change scenarios that extend beyond the current 1 in 100,000 AEP design flood extent, the estimates of flood damage and AAD would be underestimated.

Table 6-32 Comparison of predicted total flood damage to existing properties ($ millions) with future development and climate change scenarios

AEP (1 in x)	Current Conditions	Future Development Conditions		Climate Change Conditions		
		DS1	DS2	CC2	CC4	CC5
2	$6.05	$6.03	$5.37	$11.41	$53.56	$33.01
5	$17.01	$17.03	$16.12	$28.24	$86.96	$55.06
10	$38.91	$40.14	$36.95	$73.45	$169.5	$104.5
20	$128.9	$132.2	$62.18	$228.9	$497.9	$273.4
50	$1,558	$1,578	$962.7	$2,512	$4,552	$2,686
100	$5,151	$5,176	$5,606	$8,935	$13,107	$9,151
200	$9,100	$9,127	$9,634	$12,575	$16,825	$12,876
500	$14,363	$14,385	$14,830	$19,057	$24,400	$19,472
2,000	$22,962	$22,946	$23,221	$27,969	$33,302	$28,337
10,000	$37,988	$38,007	$38,340	$43,316	$48,179	$43,540
100,000	$73,649	$74,110	$74,423	$79,884	$84,745	$79,957
AAD	**$186.8**	**$187.8**	**$178.6**	**$276.1**	**$430.2**	**$301.8**

6.10 Conclusions and Recommendations

6.10.1 Conclusions

The assessment of flood damages for this Phase 3 (SFMP) has adopted best practice wherever possible, and has collected new relevant data, to provide a robust estimate of potential economic impacts associated with flooding in the Brisbane River catchment. The data collected for this study is of national significance, and can be utilised for future flood management assessments in South East Queensland and nationally.

There are approximately 130,090 buildings located within the Phase 3 (SFMP) study area that would experience above floor flooding during a 1 in 100,000 AEP design flood event. This number reduces to about 12,190 for a 1 in 100 AEP design flood event, and 150 for a 1 in 10 AEP design flood event.

The potential flood damages in the Brisbane River Catchment study area are very high compared to other known studies in Australia. The AAD for tangible damages is $186.8 million, and sets a new upper benchmark for Australian floodplains. By comparison, the tangible damage AAD for the Hawkesbury-Nepean River floodplain on the fringe of Sydney, NSW, is only $78 million (adjusted for 2017 dollars).

Future climate change has the potential to increase the flood exposure of properties within the Brisbane River Catchment study area, and therefore increase the potential property damage cost. The actual increase in damage would depend on the climate conditions and the resulting flood behaviour impacts, however, for the climate change scenarios considered for the Phase 3 (SFMP), the damage would increase by about $90 - $240 million per year on average.

Despite the limitations and uncertainties that have been identified, this report presents the most robust and comprehensive study of this type and scale ever undertaken in Australia for flood damage estimation.

6.10.2 Recommendations

Based on the findings of this study, the following recommendations are made to improve future flood damage estimation in the Phase 3 (SFMP) study area:

- There are gaps and inconsistencies in some of the data in the property information database (land use, building type, building size, building footprint, building material, building age, floor level, ground level, etc.) used in this study. It is recommended that the gaps identified be filled and the inconsistencies identified be rectified where they are in areas impacted by potential flood mitigation options under consideration.
- This project provided an opportunity to create new stage-damage curves for properties in the Brisbane River catchment. Within the limitations of time and budget, the property mix included in the property damage survey captured most property types, but not in large numbers, and not from diverse geographic and socio-economic areas. Drawing conclusions from small datasets is sub-optimal, but a recognised constraint of the Phase 3 (SFMP). Additional property surveys would be necessary to improve the flood stage-damage curves derived in this study, particularly for under-represented property types and sizes.
- A number of post-flood surveys have been undertaken by QRA in the aftermath of recent floods in Queensland (e.g. after the January 2011 flood in Brisbane, the February 2012 flood in Roma and the January 2013 flood in Bundaberg). It appears that these surveys had been designed to gather data for flood damage exposure assessment and disaster management purposes rather than for the estimation of the monetary values of flood damage or derivation of stage-damage curves. Therefore, these surveys have not collected data that would be useful for flood damage estimation such as accurate depth of flooding and actual flood damage at the surveyed properties. It is recommended that any future post-flood surveys include the collection of information that would assist improved flood damage estimation. The additional information collected should include, if possible: the type, style and approximate size of the buildings; the depth of flooding above ground and floor levels; and estimates of flood damage (building, contents and external damages separated if possible).

- Information available on flood damage to public and community infrastructure, utilities, buildings and other facilities is limited. It is recommended that a process be put in place, if possible, to collect, collate and compile a database of flood damage to these public and community owned assets in the aftermath of future flood events, recording as much detail as possible regarding the damage.
- Flood damage for very large commercial and industrial properties, as well rural/agricultural properties and mining leases would vary significantly from property to property and it would not be possible to accurately estimate flood damages to these properties with generic stage-damage curves. Flood damage for these types of properties should always be assessed individually on a case by case basis. It is recommended that a survey via a detailed questionnaire be considered to assess potential damage for key properties in the study area that belong to this category, if reliable estimates of flood damage to these types of properties are required.
- Estimating damage costs for road infrastructure is challenging as the extent of repairs can vary for different sized events based on hydraulic behaviour, including flood velocity. In recognition of this, the road transport infrastructure flood damage cost estimates made in this study for flood events up to 1 in 50 AEP, are smaller than the estimates adopted for rarer events (based on January 2011 repair costs) on a per km basis. It is recommended that further input from TMR is sought on expected road damage repair costs across a wide range of flood events, rather than just large events, to validate assumptions made in this study.
- Flood damage estimates made in this study are for the current (2017) level of development in the Phase 3 (SFMP) study area. Over the coming years, the number of buildings in the study area as well as the mix of buildings (e.g. single dwellings on lots being replaced by multi-unit buildings), are likely to change. It is recommended that the flood damage estimates made in this study be periodically reviewed (say, every 10 years), even in the absence of an update to the Phase 2 (Flood Study).
- The evidence presented here suggests that the intangible costs of natural disasters can be very large for more extreme events. More research would be desirable including preparation of data collection methodologies able to be deployed after not only large flood events but smaller events also, so that impact data can be assembled across a range of event probabilities. Surveys should be capable of application in urban South East Queensland, regional and rural settings.

A program of research should be considered to establish the consequential effects of large flood events on business output focusing on economic (rather than financial) losses. This research could focus on 'services' economies (particularly South East Queensland) and on export oriented regions including mining, agriculture and tourism.

6.11 Limitations

The flood damage assessment results presented in this report are based on the best available data and information at the time of preparing the report. The data and information used have been obtained from a range of sources and with varying levels of reliability. Notwithstanding the above, due to data limitations, a number of simplifications and assumptions have been made in this study for the estimation of flood damages. Therefore, as with any flood damages assessment, there is a degree of uncertainty in the estimated flood damages.

The flood damage estimates in this report for transport infrastructure, public utilities, public and community buildings and assets should be considered as indicative only and their reliability has not been tested. Hence, the non-property flood damage estimates presented in this report should be accepted with some caution.

The flood damage estimates in this report do not include damage to rural/agricultural and mining properties, and the environment (e.g. erosion, bank slumping and scour damage to waterways, damage to flora and fauna). Some of the costs associated with indirect flood impacts such as the interruption of water supplies, power and essential services, as well as traffic delays, interruption of ferry services, bridge closures, disruption to river navigation due to debris, etc. are also not included due to lack of available data. Flood damage to stormwater infrastructure also has not been included due to lack of data.

Despite the limitations and uncertainties that have been identified, this report presents the most robust and comprehensive study of this type and scale ever undertaken in Australia for flood damage estimation. The data collected for this study is of national significance, and would be of considerable value for future flood management studies in South East Queensland and nationally.

7 Landscape Management

7.1 Integrated Catchment Planning Approach

Integrated Catchment Management (ICM) is a well recognised practice that aims to improve and integrate the management of land, water and related biological resources in order to achieve the sustainable and balanced use of these resources (AWA 2017). Integrated Catchment Planning (ICP) is a term used to in the context of this report to describe the more holistic planning and strategic development of ICM objectives rather than any on-ground works. ICP recognises that land, water and biodiversity are all part of an interconnected environment that spans the total catchment. ICM and ICP acknowledge the intrinsic values of our environment and that healthy catchments underpin regional economies and provide social and recreational benefits for the community (Council of Mayors 2015; DELWP 2016).

ICP has a strong focus on collaboration between stakeholders, agencies and the community in the planning and decision making process. This helps to facilitate a coordinated approach and strategies that will be readily adopted to enable the best outcomes.

In 2016, the Queensland Audit Office (QAO) undertook a review of the effectiveness of flood resilience activities since the 2011 floods, focussing specifically on the Bremer, Lockyer, Mid and Upper Brisbane River catchments. The findings recognised that a coordinated strategic approach that manages risk and integrates and prioritises efforts and resources at a whole of catchment scale (i.e. beyond LGA boundaries) is required and is currently missing. It also recognised that the absence of such an approach is a missed opportunity to undertake ICP, integrating flood risk mitigation with other elements of catchment management including water quality, biodiversity and recreational activities (QAO, 2016). It did, however, note that the Brisbane River Catchment Flood Studies represents a significant step forward in identifying and assessing flood risk at a whole of catchment scale. The Resilient Rivers Initiative (SEQ Council of Mayors 2015) was also noted by the QAO to be improving coordination, however, the absence of an overarching strategic vision by the State and local governments for ICP and building flood resilience remains a barrier for effective coordination at the whole-of-catchment scale. A key recommendation of QAO (2016) was that DILGP develop strategies and plans in consultation with three of the four councils within the Brisbane River Catchment Flood Studies area (ICC, SRC and LVRC) and relevant entities to effectively identify, assess, prioritise and manage catchment scale flood risks using an ICP approach.

The Phase 3 (SFMP) aims to ensure that any proposed flood management actions and initiatives are complementary with other ICP programs, such as those in the Catchment Action Plans (CAPs) (developed as part of the Resilient Rivers Initiative), and consider wherever possible the principles and objectives of ICP, recognising that flood risk management is an element of ICP.

By way of example, in the 2013 Australia Day floods, high sediment loads upstream of the offtake weir for the Mount Crosby Water Treatment Plant (WTP) caused the WTP to shut down, reducing potable water supply to just hours. Although a rare event, the consequences are potentially catastrophic, and show the interconnected relationship between flooding, water quality and water supply. Since this time, revegetation works have been undertaken at Sapling Pocket at Pine Mountain to assist in slowing flows and reducing sediment loads, improving water quality and ecological values, as well as protecting the water supply offtake at Mt Crosby weir (Clarke 2017).

The works are a good example of how ICP can achieve multiple outcomes and can provide environmental, social and economic benefits to the community.

By undertaking a collaborative whole of systems approach that underpins the nature of ICP, these benefits are magnified. For example, investigating the impact of management measures on a total catchment scale enables more effective prioritisation of works and best 'bang for buck' solutions to be implemented. This may mean revegetating in the upper catchment to reduce flooding impacts downstream in an entirely different LGA.

The impacts of flooding are recognised to cost communities billions of dollars in direct and indirect costs, however the indirect costs are rarely quantified (Croke *et al.*, 2016; QAO, 2016). A key component of ICP is strategic revegetation to reduce the effects of flooding and impacts to downstream water quality and associated environmental, social and economic values of waterways. Revegetation works help to slow flows and erosive velocities, promote recharge of groundwater aquifers, and keep soil and nutrients on the land, which is important for agriculture and rural economies, protects waterway ecosystem health, and protects economic values (e.g. Port of Brisbane, aquaculture, tourism) and recreational (e.g. fishing, swimming, boating) values of waterways. It also provides habitat and improved ecological health of a catchment.

A scientific review of literature by DEHP (2012) on the role of natural assets to reduce flood impacts provided the following best available advice from the synthesis of information:

- *There is a clear link between vegetation clearing and an increase in rainfall runoff;*
- *Vegetation is not likely to noticeably affect extreme flood events but has the potential to reduce local runoff and small-scale floods;*
- *Local studies to understand the catchment context are essential to determining the best locations for vegetation to mitigate flooding; and*
- *Floodplains (through re-engagement) can provide a cost effective alternative or supplement to structural mitigation approaches with additional ecosystems service and ecological benefits.*

In particular DEHP (2012) cites the following best available advice from literature reviewed on the effectiveness on riparian vegetation for mitigating flood impacts:

- *There is a clear link between riparian vegetation, reduced flood velocity, changed downstream flood peak and increased upstream flooding. The increased localised flooding spreads the flood flow, removing systemic energy and reducing flood-velocity damage;*
- *A whole of catchment approach is important to effectively plan for riparian rehabilitation. In highly modified catchments, riparian vegetation is only part of a flood security approach; and*
- *Riparian vegetation can help reduce downstream flood peaks, but may cause increased localised flooding upstream. Land use planning can ensure appropriate land uses occur in areas once again prone to flooding due to riparian vegetation.*

Further to the DEHP (2012) review, detailed studies have been undertaken in the Brisbane River catchment as part of the Big Flood Australian Research Council (ARC) project (ARC 2016). Results of this study and research by Croke *et al.* (2017) studying the local characteristics of the Lockyer Creek catchment identified a framework for identifying and prioritising the placement of riparian vegetation for future flood risk mitigation and sediment management programs. The research highlighted the importance of understanding local hydrologic and geomorphic processes and macrochannel characteristics in prioritising where riparian revegetation may be most effective.

A recent project in North Yorkshire (*Slowing the Flow at Pickering*) demonstrating the effectiveness of ICP in reducing flood risk is presented by Nisbet *et al.* (2015; 2016). In response to the 2007 floods in England and Wales, which were described as causing the biggest civil emergency in British history (Pitt 2008), a comprehensive review of the lessons learnt called for the Department for Environment, Food and Rural Affairs (Defra), the Environment Agency and Natural England to work with partners to deliver flood risk management involving greater integration with natural processes. In response, Defra funded a pilot project (*Slowing the Flow at Pickering*) with the aim to demonstrate how the integrated application of a range of land management interventions can help to reduce flood risk at the catchment scale in addition to providing wider multiple benefits for the community. Modelling predicts that the measures implemented will deliver the primary objective of protecting the town of Pickering from a 25% chance of flooding in any one year to less than a 4% chance (Nisbet *et al.* 2015).

A subsequent flood event on Boxing Day 2015 tested the actual effectiveness of the measures implemented. Analysis of the Boxing Day event (Nisbet 2016) suggest the measures reduced the peak flow by around 15-20% (2 m^3/s), with around half of the reduction due to the upstream land management measures and half due to the main flood storage area. Furthermore, the assessment concludes with a relatively high degree of certainty that the project measures prevented flooding to a small number of residential properties and the museum on the Beck Isle area of the town.

Riparian revegetation used exclusively may not provide extensive flood mitigation benefits (with literature generally limiting the impacts to small floods), however, if undertaken with other ICP components at a catchment scale (packaged with extensive full floodplain revegetation, floodplain reengagement and increasing infiltration losses among other things) these measures may achieve flood mitigation benefits, such as those noted in the *Slowing the Flow at Pickering* case study (Nisbet *et al.* 2015).

It is acknowledged that further research and modelling of ICP options is required, particularly in local catchments, and that these types of solutions will need to be combined with more traditional structural options to provide a holistic and integrated approach to flood risk management.

7.2 Potential Impacts of Landscape Management on Hydrology and Flooding

The following section provides a summary of the potential hydraulic/flooding impacts of landscape management solutions (as an element of ICP), in addition to outlining the other benefits (e.g. environmental / social / economic) that they provide. The solutions have been categorised into five key themes that encompass landscape management strategies that have been put forward by stakeholders for the Brisbane River catchment, including:

- Riparian and / or floodplain revegetation;
- Restoring catchment vegetation;

- Re-engaging floodplains;
- Land management practices; and
- Water sensitive urban design.

These types of strategies may be implemented either individually or in combination, with a combination most likely to provide the best outcome, in the same way that a suite of structural options may be employed to manage risk across the floodplain.

7.2.1 Riparian and / or Floodplain Revegetation

Riparian vegetation increases the channel roughness / resistance to flows, slowing flow velocities and spreading flows. Review of literature by DEHP (2012) indicates a clear linkage between riparian vegetation, reduced flood velocity, changed downstream flood peak and increased upstream flooding. Similarly, revegetation in the wider floodplain will slow and attenuate floodwater that has escaped the main channel. The increased localised flooding spreads the flood flow, removing systemic energy and reducing velocity-related damage. These benefits may also assist to provide some resilience to expected future increase in the intensity of rainfall as a result of climate change. Attenuation and delay of flood peaks can also provide additional time for issuing flood warnings, thus improving public safety. However, consideration must be given to potential increases in flow velocities in newly engaged areas, and increases in flood duration due to attenuation which may have implications for coincidence of flooding with other sources.

The local variables that control the hydraulic effect of riparian revegetation on stream roughness and hydrograph stage height, as identified by Rutherford *et al.* (2007) are reproduced in Table 7-1. Rutherford also notes that the resistance of vegetation will fluctuate with flow depth (as plants become submerged resistance decreases), stem density (increases turbulence and resistance), and stem flexibility (resistance declines as stems bend with flow).

Table 7-1 Variables Controlling the Effect of Vegetation on Stream Roughness and Stage (Source: Rutherford *et al.* 2007)

Variable	Effects on Hydraulics	Direction of Change
Cross sectional area of channel	The bigger the channel, the smaller the relative effect of the vegetation	Bigger cross section = smaller blockage
Position of vegetation on the boundary	The lower in the cross section, the greater the effect	The lower the vegetation on the bank = higher the stage
Density of vegetation across the channel	Greater density of vegetation provides greater resistance	Greater the density = higher the stage
Density of vegetation along the stream	Generally, the greater the density of vegetation along the banks, the greater the flow resistance	Greater planting density along banks = higher stage
Length of bank vegetated	The backwater will extend from the upstream end of a clump of vegetation	Longer vegetated zone = longer flood effect
Slope of the channel	Everything else being equal, the lower the slope, the greater the relative effect of vegetation on roughness	Greater slope = less roughness effect

In general, it is recognised that riparian vegetation will be more effective at reducing small floods, and in highly modified catchments it is only part of a flood security approach (DEHP, 2012).

Other benefits of riparian revegetation include stream bank stabilisation, reduced erosion and sedimentation, improved water quality and waterway health, protection of water supply sources and increased biodiversity.

Riparian revegetation will assist to improve in-stream ecosystem health through reducing erosion and filtering pollutants (sediment and nutrients) prior to entering waterways, as well as through shading, assisting in the control of aquatic weeds. Fallen branches (that form shelter for fish) and reduced in stream velocities from riparian revegetation can also improve fish passage along these areas. Protecting waterway health can also protect important social and economic values of receiving waters (e.g. fishing, tourism, aquaculture). The Mid Brisbane River CAP (RRI, 2016b) highlights the importance of riparian revegetation in the catchment to reduce erosion potential and protect significant recreational values of the catchment and also downstream users of Moreton Bay (improving waterway health and amenity).

Riparian revegetation and bank stabilisation in the Mid Brisbane and Lockyer catchments also helps to improve / protect water quality for a significant regional water supply intake catchment (supplying Mount Crosby West Bank WTW). Furthermore, managing sediment generation at source is demonstrated to be more cost effective than managing the issues at Water Treatment Plants.

As noted previously, a whole of catchment approach is necessary for effective planning of riparian revegetation works, to both assess the potential for coincident peaks (causing a potential worsening in downstream flooding) and assess the best 'bang for buck' solutions on a whole of catchment scale. Studies by Croke *et al.* (2017) also highlight the importance of understanding local catchment geomorphic processes in prioritising effective placement of riparian vegetation to alleviate flooding.

7.2.2 Restoring Catchment Vegetation

Van Dijk *et al.* (2009) identifies the key mechanisms by which vegetation is thought to influence rainfall induced flood generation to be through changes in interception loss (direct evaporation of rainfall intercepted by the canopy), soil infiltration capacity, and retention of infiltrated water. Deep rooted trees are recognised to absorb more water from the soil than crops and grasses, with the capacity of forests to store rainfall commonly referred to as the 'sponge' effect (DEHP, 2012).

Restoring catchment vegetation can also assist to slow flows, reducing flood hazard to farm infrastructure and people (flash flooding). Slowing flows and promoting soil infiltration and groundwater recharge may also potentially delay and reduce flood peaks.

Review of literature by DEHP (2012) concludes that although vegetation has the potential to affect local runoff and small-scale floods, the capacity for vegetation to mitigate extreme events is not clear and may be less effective. Vegetation enhances deposition and faster growth rates such that it may play an important role in larger events once established, however further research (particularly in similar climate / catchment conditions) is required to confirm this. It is further recognised that local studies providing a good understanding of catchment conditions influencing runoff (including geomorphology) are required to determine the best locations for vegetation interventions to mitigate flooding.

Restoring catchment vegetation can have multiple benefits in addition to flood mitigation, including greater biodiversity through improving existing and/or creating new habitats and fauna movement corridors. Planting of deep rooted trees can also help to address rising water tables and salinity issues, which can adversely impact on crop production. Revegetation to slow flows and promote infiltration and groundwater aquifer recharge can also provide improved resilience in times of drought for farmers and the environment relying on these water sources. Additionally, slowing flows reduces erosion and therefore provides water quality and waterway health benefits (from reducing sediment and nutrient loads to waterways).

Furthermore, restoring catchment vegetation can provide climate regulation (through carbon sequestration) and also improve landscape amenity, providing improved opportunities for passive and active recreation.

7.2.3 Re-Engaging Floodplains

Floodplains include low lying grounds adjacent to rivers that become naturally inundated and provide temporary storage of flood waters during large rainfall events. Re-engaging floodplains refers to the removal / modification of human interventions, such as levees, to reconnect floodplains to the river and restore their capacity to provide natural flood storage. This would only be appropriate in areas where re-engaging the floodplain causes no significant risk to infrastructure or agricultural practices.

A comprehensive literature review of floodplain wetlands and their impact on flood mitigation by Bullock and Acreman (2003) concludes that floodplains generally reduce or delay floods. Review of studies into floodplain storage by DEHP (2012) indicate that floodplains can provide a cost effective alternative or supplement to structural mitigation options with additional ecosystem service and ecological benefits. These additional benefits include supporting biodiversity, fisheries, climate regulation through carbon sequestration, regulating erosion and reducing the amount of sediment reaching watercourses (protecting receiving water quality and instream habitats as well as social and recreational values of healthy waterways), drinking water treatment and tourism. However, there was recognition that floodplain wetlands need to be appropriately sized in relation to local flooding expectations and limitations to flood storage capacity need to be understood. For example, literature values cited by DEHP (2012) in relation to floodplain storage areas required to attenuate peak flow rates during the Brisbane River 2011 floods indicate very large areas would be required to mitigate floods of this magnitude.

Re-engaging the floodplain will promote recharge of groundwater, slow flows and potentially reduce / delay flood peaks. Delays in flood peaks would need to be cognisant of coincident timing of flood peaks from other sources/catchments.

7.2.4 Land Management Practices

Land management practices such as strategic vegetation areas to promote recharge and agricultural practices can impact on flooding through their effects on increasing infiltration and reducing surface runoff (as described already above). Measures such as cross floodplain structures that increase floodplain roughness, slowing flows and reducing the risk of scour also help to reduce the impacts of flood damage to crops (Walker *et al.* 2014). Bank stabilisation through methods such as battering and revegetation can assist to protect the integrity of levees (reducing risk of failure that can cause floodplain scour and impact on crops), and can prevent uncontrolled channel widening and loss of farmland in future floods. These practices promote the same hydrological processes as catchment reforestation (Section 7.2.2) but can be implemented within rural / agricultural land uses, as opposed to more broadscale revegetation programs.

Land management practices such as ground cover can help to improve soil condition and increase infiltration. Studies by McIvor *et al.* (1995) indicated 40% groundcover could reduce runoff significantly for small storms and intensity (<50 mm and <15 mm/hr), however, cover had little effect on runoff in large storms and higher intensity (>100mm and intensity >45mm/hr).

Literature reviewed by DEHP (2012) also indicated that bushfires can affect catchment hydrology, generating soil repellence and leading to increased runoff, but this was found to vary with burn severity and rainfall intensity.

Overall DEHP (2012) indicates that impacts on runoff at a catchment scale from land management practices are generally unclear, and change would need to be substantial across the catchment to have a meaningful impact.

Land management practices are also recognised to provide other ecosystem benefits. As previously noted, strategic revegetation can provide improved biodiversity / habitat, increased recharge of groundwater aquifers (providing resilience of farm irrigation to drought), salinity / water table management, climate regulation through carbon sequestration, erosion regulation through bank stabilisation - in turn reducing the amount of sediment reaching watercourses (protecting receiving water quality and instream habitats as well as social and recreational values of healthy waterways), drinking water treatment and tourism.

Other land management practices relating to grazing and agriculture such as cross floodplain structures (e.g. vetiver) and ground/crop cover assist to reduce erosion, promote groundwater aquifer recharge and filter sediment, nutrients and other pollutants prior to entering waterways / groundwater (protecting waterway health, water supply sources and recreational values). These management measures also assist in keeping fertile soils on farms to protect significant agricultural lands and associated economic benefits. These types of land management practices can help to ensure sustainable agricultural / horticultural land use practices.

7.2.5 Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) refers to the integrated planning and design of the urban water cycle, incorporating stormwater, groundwater, water supply and wastewater management, urban design and environmental protection (BMT WBM, 2009).

Principles of WSUD encourage detention (rather than rapid conveyance), infiltration and reuse of stormwater and restoring / preserving the natural hydrological regime of catchments. Broad scale detention measures must be managed to ensure the change in timing does not inadvertently correspond with other catchment inflows and impact downstream reaches, and so preference is generally given to WSUD solutions that increase infiltration. WSUD measures have been recognised to reduce the frequency of runoff events for small rainfall events, which is important for maintaining the ecological health waterways. Other key benefits from the adoption of WSUD include the protection of surface and groundwater quality (through treatment of sediment, nutrient and other pollutants), protection of ecological processes and ecosystem health, enhancement of visual amenity, potable water cost savings and resilience to climate change (e.g. avoiding water restrictions) through the use of alternative water supply sources (e.g. rainwater/stormwater/wastewater), protection of social and economic values of our waterways (tourism, fishing, aquaculture) and improved microclimate (reducing the impacts of the urban heat island effect).

Li *et al.* (2017) recently undertook a literature review of modelling and monitoring studies on the performance of WSUD measures which indicated that implementation of such measures can reduce surface runoff and peak discharge, increase hydrograph lag times and base flow magnitude, and decrease storm recession rate. Treatment measures were predicted to restore natural hydrologic regimes (i.e. pre-development) more closely for small storm events than for large storm events. The study focused on small, urban catchments which are not scalable to the Brisbane River catchment. However, it did identify the need for further catchment-scale studies to better quantify the effects of stormwater management measures on flow regimes.

7.3 Hydraulic Modelling Sensitivity Tests

7.3.1 Model Changes

It is not possible to simulate the impacts of specific landscape management activities on flood behaviour unless it is supported by evidence of how these activities would change key hydrological parameters within the catchment hydrology model. Changes to the Brisbane River catchment hydrology model was beyond the scope of the Phase 3 (SFMP) and, further, any significant changes to catchment hydrology would also require consideration of potential implications for dam operations. Notwithstanding, the Phase 3 (SFMP) has explored theoretical impacts of landscape management through a sensitivity assessment of hypothetical flow attenuation.

Sensitivity testing has been undertaken on the Brisbane River detailed hydraulic model by reducing peak catchment inflows by 5% to 10%, but maintaining the same runoff volume (i.e. simply increasing catchment detention). These reduction values are nominal only and do not correlate to any specific landscape management scenarios. Review of literature quantifying the performance of landscape management activities however suggests peak flow reductions generally of up to between 4% and 15%, justifying the assessment of these scenarios (Acreman *et al.*, 2003; Liu *et al.*, 2004; Bronstert & Kundzewicz, 2006; BMT WBM, 2011; Sharpe, 2012; Nisbet *et al.*, 2015). A scientific review of literature by DEHP (2012) on the role of natural assets to reduce flood impacts also indicates that greater peak flow reductions would be expected for local runoff and small scale floods compared to larger flood events. The sensitivity testing involved reducing peak inflows from sub-catchments downstream of Wivenhoe Dam including:

- Lockyer Creek;
- Laidley Creek (Lockyer Creek tributary);
- Buaraba Creek (Lockyer Creek tributary);
- Bremer River;
- Warrill Creek (Bremer River tributary); and

- Purga Creek (Bremer River tributary).

Whilst there is also opportunity for landscape management activities in the upper Brisbane and Stanley Rivers, flow from these catchments are regulated by Wivenhoe and Somerset Dams, and so for the purposes of the sensitivity tests, inflows from Wivenhoe Dam remained unchanged.

An example of the adjusted inflow hydrograph for a 5% and 10% reduction in flow in the Bremer River is shown in Figure 7-1. Results of the sensitivity assessment are described in the sections below.

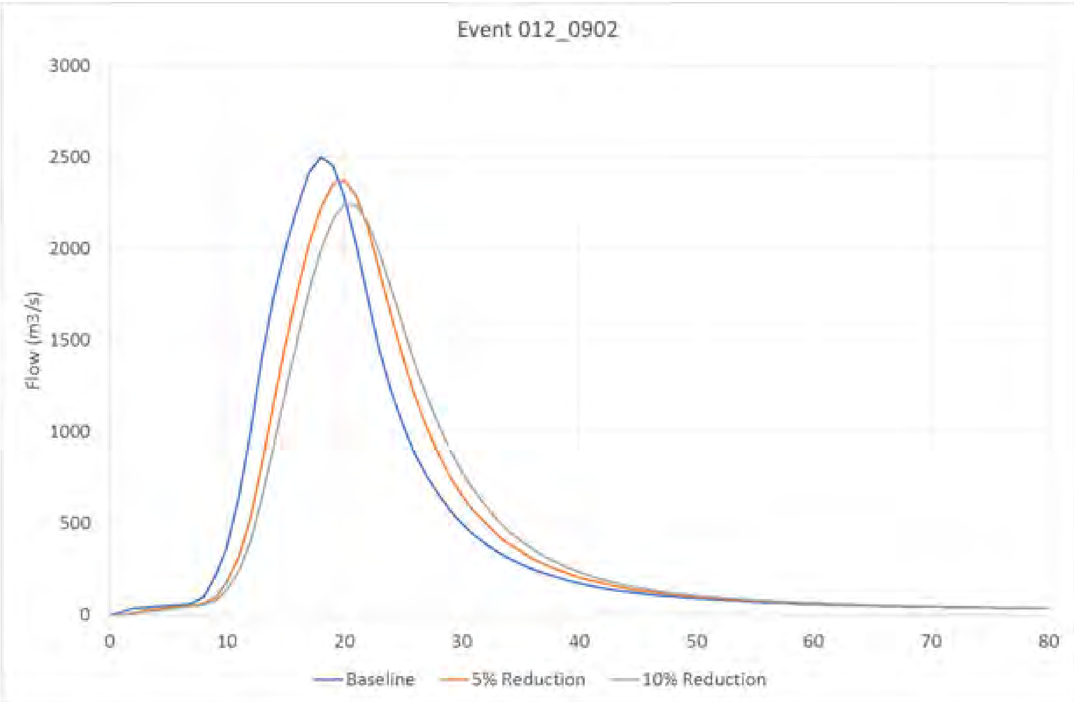


Figure 7-1 Example of Inflow Change on the Bremer River

As discussed above, landscape management would have a greater potential to modify flood catchment hydrology, and thus flood behaviour, in smaller flood events than larger flood events (DEHP, 2012). Interpretation of the results discussed in the section below therefore needs to be cognisant of the fact that one suite of landscape management activities would not have the same percentage of flow reduction across all AEPs assessed (with percentage reducing as the flood increases). To this point, results have only been presented for flood events up to the 1 in 100 AEP flood; larger floods are less likely to be affected by landscape management activities.

7.3.2 Modelling Results (5% and 10% Peak Flow Reductions)

The results of the 5% and 10% reductions in peak inflows, as outlined in Section 7.3.1, are presented concurrently for a range of AEPs, from a 1 in 5 AEP to 1 in 100 AEP on the following pages.

The results for the 1 in 5 AEP are presented in Figure 7-2 and Figure 7-3 for a 5% and 10% reduction, respectively. Notable reductions in peak flood level are observed in the Bremer River of up to 0.52 metres for a 5% reduction and 0.67 metres for a 10% reduction, and in the Brisbane River immediately downstream of the Bremer junction of up to 0.29 metres for a 5% reduction and 0.32 metres for a 10% reduction. Minor flood level reductions were also observed in the lower Locker Creek floodplain. Small increases in peak flood level (< 0.2m) were observed in some sections of the Brisbane River between Wivenhoe and the Bremer River – this would be the result of the attenuation of peak flow from the Lockyer Creek coincident more with the peak flow from Wivenhoe Dam.

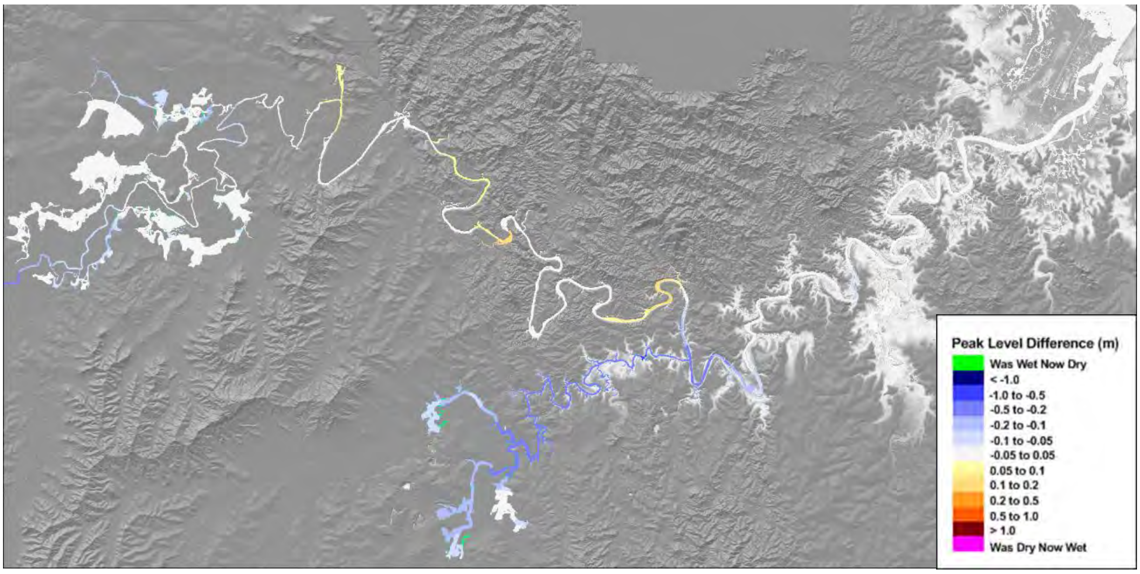


Figure 7-2 Peak Level Difference for 5% Peak Flow Reduction - 1:5 AEP

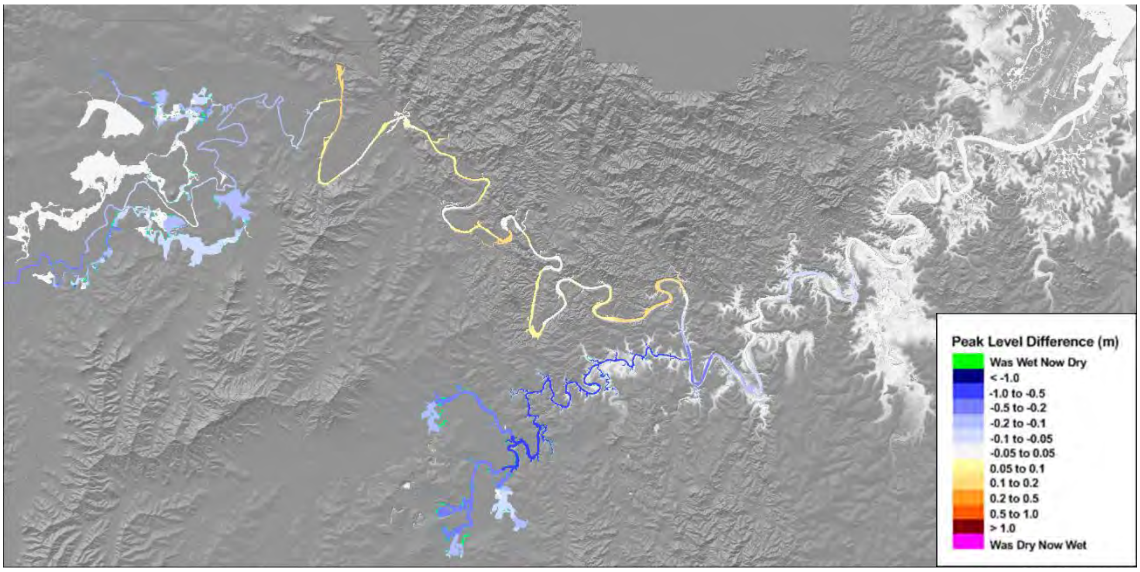


Figure 7-3 Peak Level Difference for 10% Peak Flow Reduction - 1:5 AEP

The results for the 1 in 10 AEP are presented in Figure 7-4 and Figure 7-5 for a 5% and 10% reduction, respectively. Similar to the 1 in 5 AEP, reductions in peak flood level are observed in the Bremer River of up to 0.55 metres for a 5% reduction and 0.91 metres for a 10% reduction, and in the Brisbane River immediately downstream of the Bremer junction of up to 0.13 metres for a 5% reduction and 0.22 metres for a 10% reduction. Minor flood level reductions were also observed in the lower Locker Creek floodplain. For the 1 in 10 AEP, there were no notable areas of increases in peak flood level, from the ensemble of events simulated.

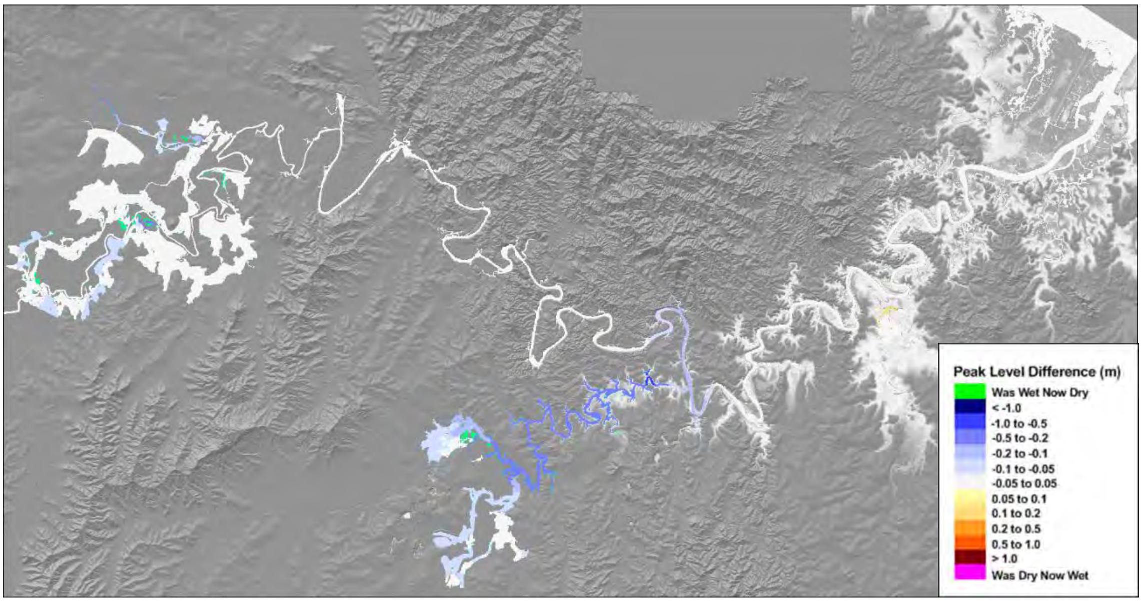


Figure 7-4 Peak Level Difference for 5% Peak Flow Reduction - 1:10 AEP

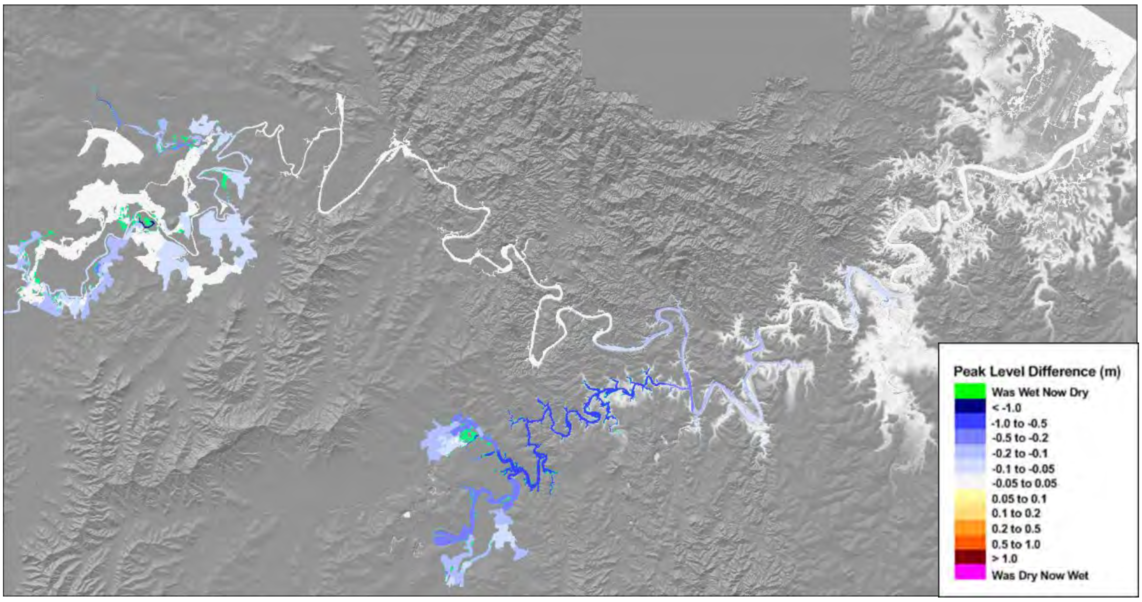


Figure 7-5 Peak Level Difference for 10% Peak Flow Reduction - 1:10 AEP

The results for the 1 in 20 AEP are presented in Figure 7-6 and Figure 7-7 for a 5% and 10% reduction, respectively. Similar to the 1 in 5 AEP and 1 in 10 AEP, reductions in peak flood level are observed in the Bremer River of up to 0.37 metres for a 5% reduction and 0.70 metres for a 10% reduction, and in the Brisbane River downstream of the Bremer junction of up to 0.08 metres for a 5% reduction and 0.18 metres for a 10% reduction. Reductions in the Brisbane River extend further downstream that the previous smaller events. Reductions in the lower Locker Creek floodplain are relatively minor for this flood, while there are some areas immediately downstream of Wivenhoe Dam where flood levels increase (by < 0.2m) due to more coincident flood peaks from the Lockyer and Wivenhoe Dam.

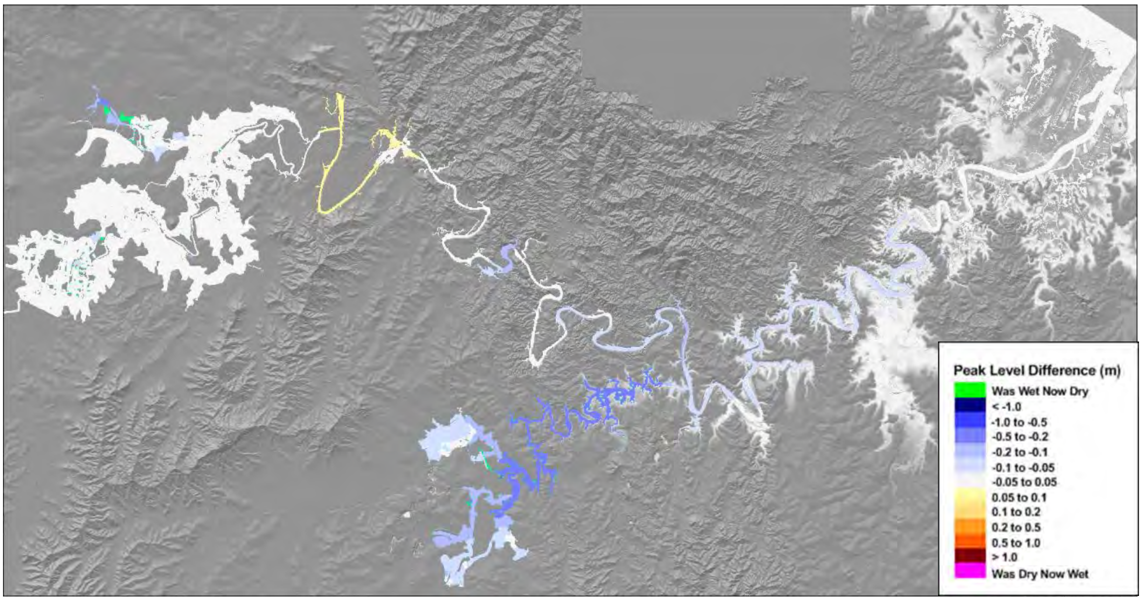


Figure 7-6 Peak Level Difference for 5% Peak Flow Reduction - 1:20 AEP

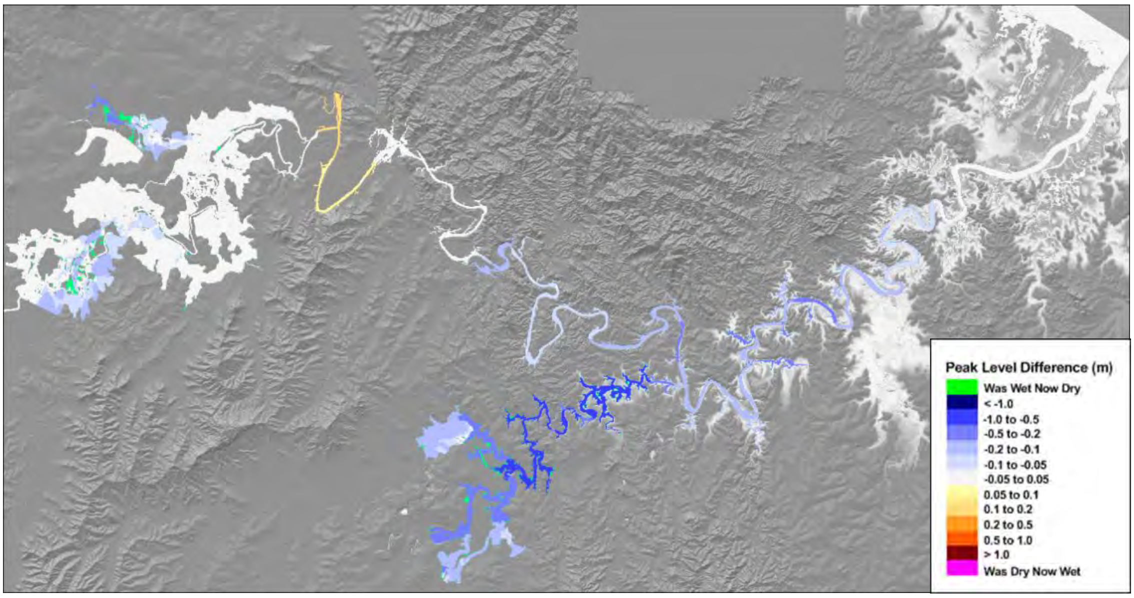


Figure 7-7 Peak Level Difference for 10% Peak Flow Reduction - 1:20 AEP

The results for the 1 in 50 AEP are presented in Figure 7-8 and Figure 7-9 for a 5% and 10% reduction, respectively. Reductions in peak flood level are observed across much of the Brisbane River Catchment Flood Studies area, with reductions in the Bremer River of up to 0.14 metres for a 5% reduction and 0.37 metres for a 10% reduction, in the Brisbane River downstream of the Bremer junction of up to 0.07 metres for a 5% reduction and 0.13 metres for a 10% reduction, and in the lower Lockyer Creek of up to 0.09 metres for a 5% reduction and 0.30 metres for a 10% reduction. Similar to the 1 in 10 AEP flood, the particular ensemble simulations used for this flood do not result in worsening of flood levels downstream of Wivenhoe due to more coincident peaks. As outlined in Section 7.3.1, landscape management works may be less effective in larger floods and a 10% reduction in peak flow may not be achievable.

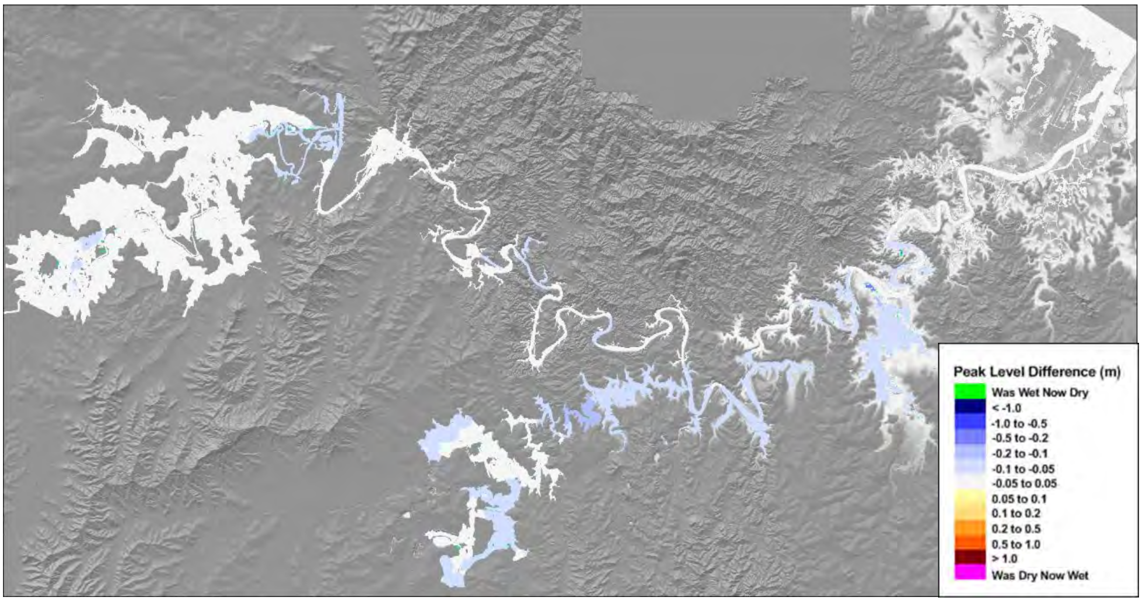


Figure 7-8 Peak Level Difference for 5% Peak Flow Reduction - 1:50 AEP

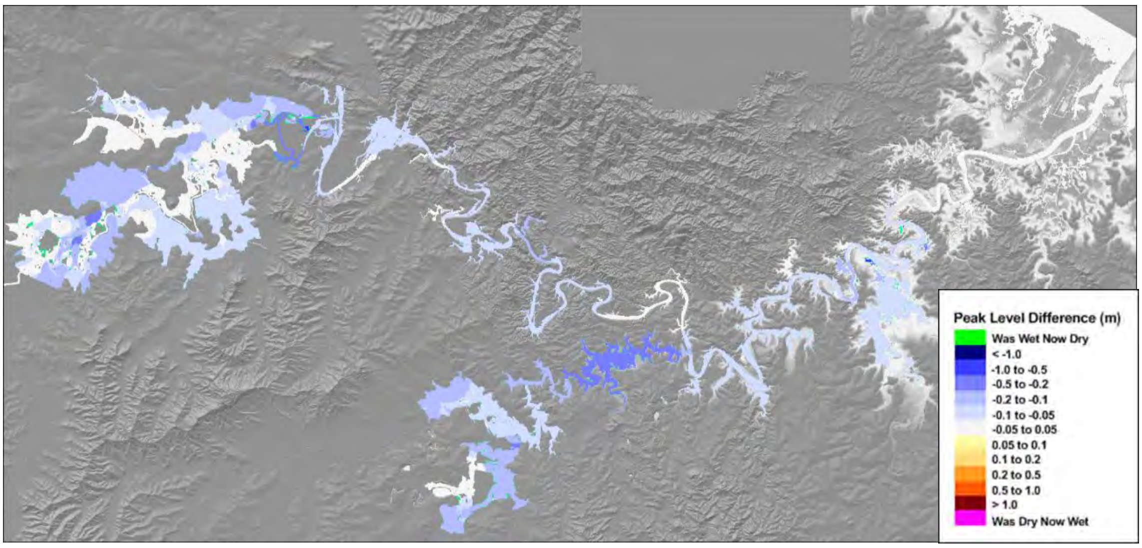


Figure 7-9 Peak Level Difference for 10% Peak Flow Reduction - 1:50 AEP

The results for the 1 in 100 AEP are presented in Figure 7-10 and Figure 7-11 for a 5% and 10% reduction, respectively. Reductions in peak flood level are observed in the Bremer River and Lockyer Creek floodplains, with reductions in the Bremer River of up to 0.33 metres for a 5% reduction and 0.55 metres for a 10% reduction, and in the lower Lockyer Creek of up to 0.21 metres for a 5% reduction and 0.40 metres for a 10% reduction. For the 1 in 100 AEP ensemble simulations, the lag of flow from the Bremer River is more coincident with flows down the Brisbane River (from Wivenhoe and the Lockyer) resulting in increased flood levels in the Brisbane River downstream of the Bremer River junction of up to 0.2 metres for both a 5% and 10% reduction. As outlined in Section 7.3.1, may be less effective in larger floods and a 10% reduction in peak flow may not be achievable.

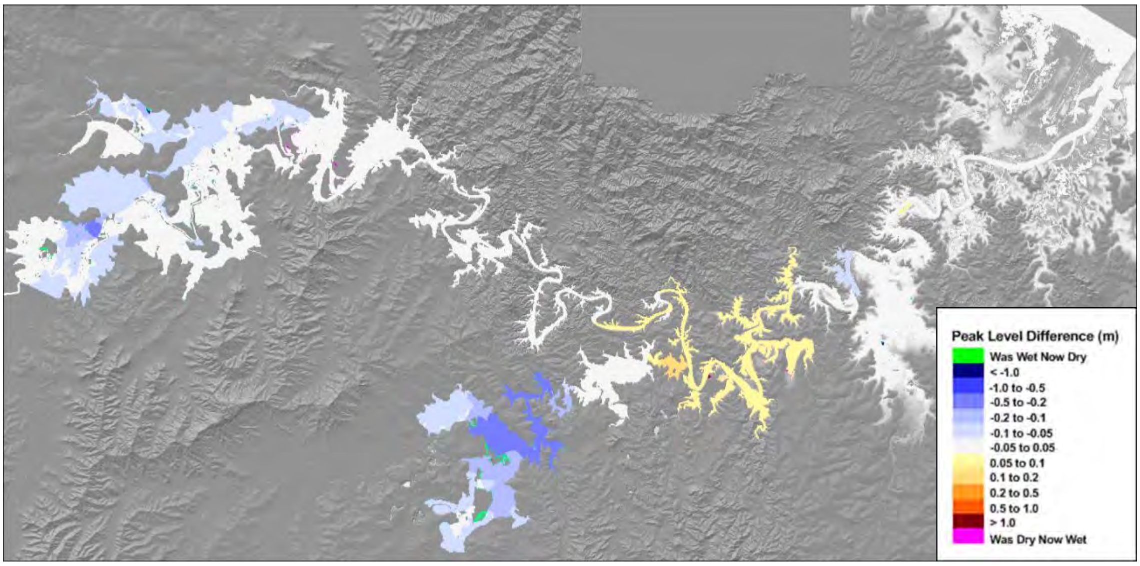


Figure 7-10 Peak Level Difference for 5% Peak Flow Reduction - 1:100 AEP

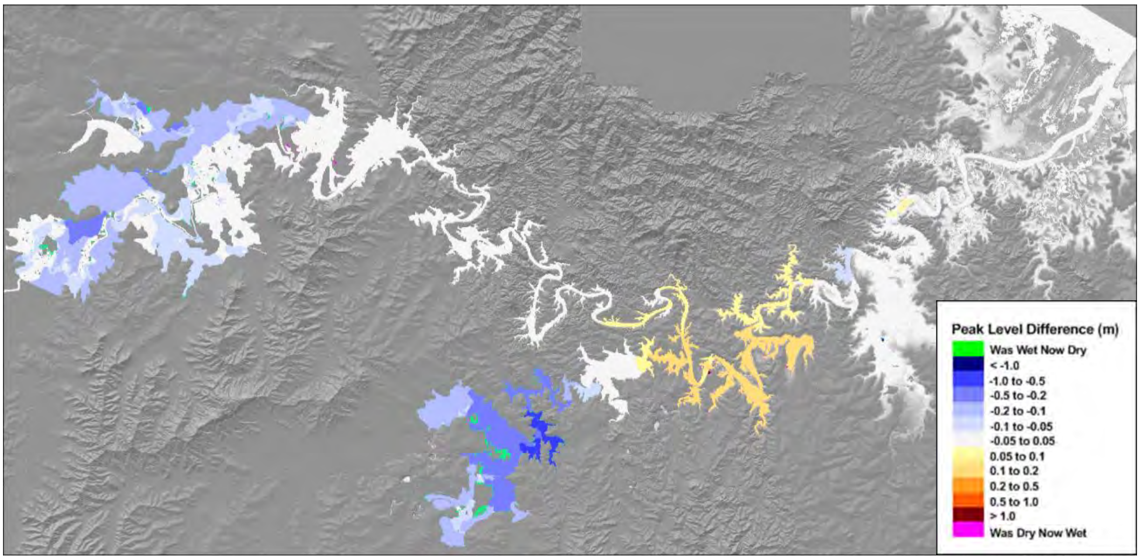


Figure 7-11 Peak Level Difference for 10% Peak Flow Reduction - 1:100 AEP

A summary of the impacts on flood levels at Ipswich CBD and Brisbane CBD is provided in Table 7-2.

Table 7-2 Summary of 5% and 10% peak flow reductions on flood levels at Ipswich and Brisbane CBD

AEP	5% reduction in peak flow		10% reduction in peak flow	
	WL reduction at Ipswich CBD	WL reduction at Brisbane CBD	WL reduction at Ipswich CBD	WL reduction at Brisbane CBD
1 in 5	320 mm	< 50 mm	630 mm	< 50 mm
1 in 10	340 mm	< 50 mm	790 mm	< 50 mm
1 in 20	250 mm	< 50 mm	510 mm	60 mm
1 in 50	50 mm	< 50 mm	120 mm	< 50 mm
1 in 100	140 mm	< 50 mm (incr.)	250 mm	< 50 mm (incr.)
1 in 200	170 mm	50 mm	360 mm	< 50 mm
1 in 500	140 mm	130 mm (incr.)	230 mm	150 mm (incr.)
1 in 2,000	60 mm	< 50 mm (incr.)	70 mm	< 50 mm (incr.)
1 in 10,000	110 mm (incr.)	< 50 mm (incr.)	110 mm (incr.)	100 mm (incr.)
1 in 100,000	60 mm (incr.)	< 50 mm (incr.)	<50 mm (incr.)	< 50 mm (incr.)

7.3.3 Discussion of Modelling Results

The results indicate that a reduction in peak inflows from the catchment has the potential to have an impact on flood levels within the Phase 3 (SFMP) study area. The magnitude of the change is larger for a 10% inflow reduction compared to a 5% inflow reduction, as expected. Flood level reductions were observed in the Bremer River as a result of reduced inflows from the Bremer River catchments across the full range of AEPs. The reduction in flood levels was not proportional to the size of the flood, with larger reductions observed for smaller floods. It is noted that as a landscape management measure, revegetation of riparian corridor and / or floodplain may increase the frequency and extent of debris blockage, increasing flood levels upstream of structures. Debris blockage is not included in either the existing design events, or the landscape management sensitivity tests.

The lower Lockyer Creek floodplain did not exhibit the same degree of response as the Bremer River. Flood levels along the Bremer River and the Brisbane River downstream of Wivenhoe Dam are particularly sensitive to catchment inflows given the topography of the floodplain (i.e. it is an incised valley with limited overbank floodplain area – higher or lower inflows translate to relatively significant changes in flood levels through the main channel sections). By comparison, the lower Lockyer Creek is less sensitive to catchment inflows as the floodplain is more extensive and can store and detain more flood flows.

The simulations carried out for this sensitivity test were the 60 simulations carried out as part of the Phase 2 (Flood Study) to reflect design AEP conditions. For some of the simulations modelled, a reduced but delayed inflow from the catchment resulted in a higher flood level due to the inflow being more coincident with the peak inflow from other sources, primarily the release of water from Wivenhoe Dam. However, as noted in Section 7.3.1, to date there has been insufficient research to quantify how landscape management activities mitigate and delay peak inflows in larger flood events such as the 1 in 100 AEP. Further research is required to better understand the relationship between broad scale landscape management activities and hydrologic and hydraulic parameters, particularly in larger flood events and in more similar climate / catchment conditions. The findings of this research should then be incorporated into the hydrologic and hydraulic modelling (including consideration of dam operations) to quantify the benefit of landscape management activities on flood behaviour in the lower Brisbane River. This would seek to further increase the value of a regional approach to ICP and floodplain management.

7.4 ICP Workshop

To assist in exploring an ICP approach to flood risk management, a workshop was convened on 12th May 2017 with local councils and other key stakeholders (Healthy Land and Water, Seqwater) to ensure current / planned landscape management works (as an element of ICP) were captured and considered in this study where possible. A key outcome of the workshop was identification of two landscape management scenarios to be assessed as part of the Phase 3 (SFMP). These scenarios focused largely on the impacts of revegetation / landscape restoration works throughout the catchment, and included:

Scenario 1: Targeted catchment revegetation. This scenario included large scale revegetation works and other large scale landscape management works nominated by stakeholders that are currently underway, planned for or under investigation (e.g. in Catchment Action Plans, results of the Big Flood studies).

Scenario 2: Restoration of Pre-European Conditions. This scenario assumes full catchment revegetation. It was noted that this is not a realistic scenario, but rather provides a comparative benchmark for the best possible outcome for catchment revegetation and an indication of whether the benefits are worthwhile.

During the workshop, it was noted that the Brisbane River Catchment Phase 2 (Flood Study) hydraulic model was limited in its ability to assess specific ICP outcomes as it is reliant on defined inflows from the catchment at the upstream model boundaries. It was further noted that re-running the catchment hydrology model to redefine catchment inflows based on modified hydrologic parameters was outside the set scope of the study analysis.

Scenarios considered for the Phase 3 (SFMP) involved large scale restoration works at a catchment-wide scale. Works of this scale would be required to have a meaningful impact on catchment hydrology.

7.5 Recommendations

Landscape management options explored as part of this Phase 3 (SFMP) form part of a broader approach of ICP, which should underpin future decision making regarding land management across the catchment, and not just in the context of flood mitigation and floodplain management.

To advance the principles of landscape management and ensure alignment with broader ICP values, the following steps are recommended:

- Co-ordinate and share landscape management information within a consistent regional framework.

- Co-ordinate, conduct and share landscape management research, in particular the relationship between broad-scale revegetation and catchment hydrology in the local catchment and climate.
- Undertake further local geomorphological studies as required to identify key catchment processes and issues, and assess current conditions and pressures, to help effectively prioritise locations for landscape management actions. As stated by ARC (2016), "*Consistently defining floodplain types, spill out zones, locations of high stream power and aligning management actions with the right erosion process will take SEQ a long way to better flood hazard management and downstream water quality protection*".
- Based on the outcomes of the research, undertake hydrologic and hydraulic modelling to assess landscape management actions in the upper catchment, including potential implications for the operation of dams in the catchment.
- Include potential landscape management actions within flood assessments for waterways within the upper catchment areas.
- Undertake catchment and receiving water quality modelling to quantify other (non-flood) benefits for waterways associated with potential landscape management actions.

8 Structural Options Assessment

8.1 Options Assessment Framework

8.1.1 Overview

Within this study, 'structural measures' are defined as those which modify flood behaviour. Other measures with a structural element which do not modify flood behaviour (e.g. modification to properties) are discussed elsewhere in the study (see Evidence Report on property-specific measures). Structural options generally include heavily engineered works, such as dams, levees, detention basin and flood gates.

Various structural options for address flooding in the lower Brisbane River have been suggested over the years, notably since the river experienced significant and devastating flooding in early 2011 and again in 2013.

The simple framework for assessing structural options for the Phase 3 (SFMP) is shown in Figure 8-1.

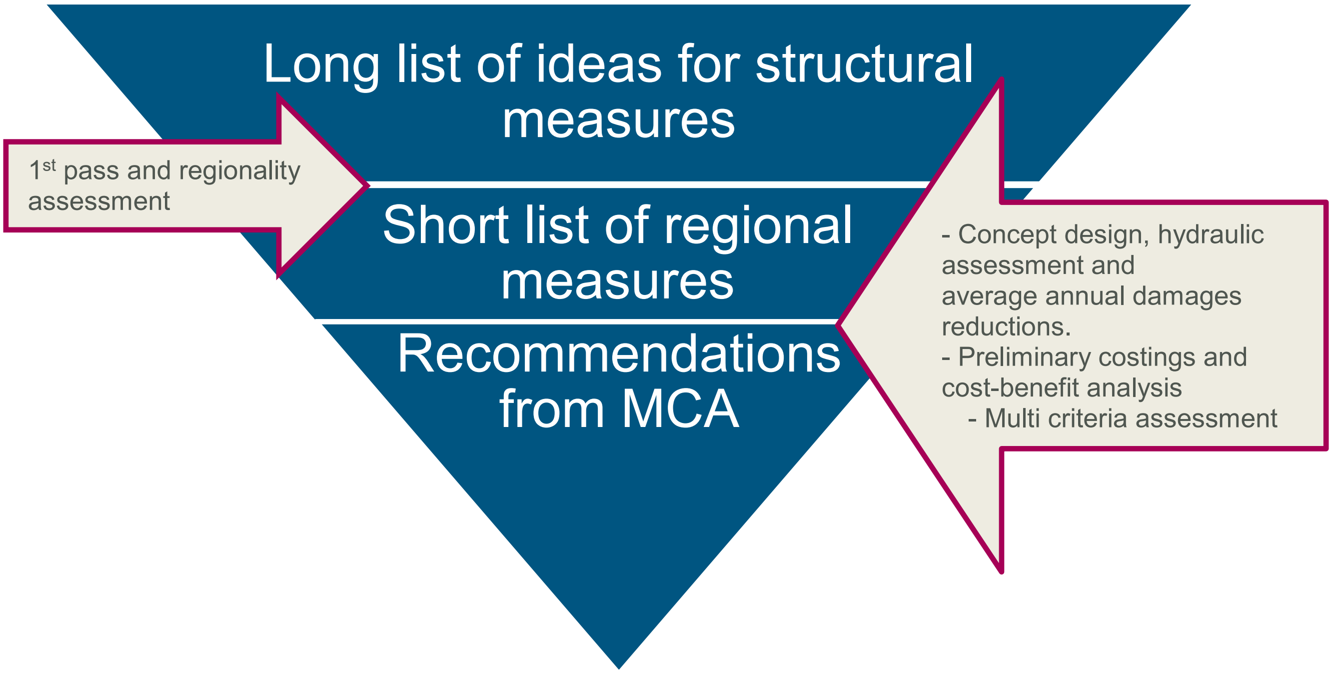


Figure 8-1 Framework for structural options assessment

The framework commenced with the generation of a long list of ideas for structural options or measures that will have a tangible impact on flooding in the Brisbane River. The initial long list was refined through a first pass evaluation, including consideration of regional benefits. Once a short-list was agreed, these options were evaluated through hydraulic modelling and damages assessment, a cost-benefit analysis, and finally a more extensive multi-criteria assessment.

Options that performed well in the multi-criteria assessment (with a higher overall score compared to other options, and better than 'no change' conditions, or with significant intangible benefits) are recommended for further investigation and / or implementation.

8.1.2 First Pass and Regional Assessment

A preliminary assessment of potential structural options was carried out by consulting with stakeholders as part of a Phase 3 (SFMP) workshop, with an initial long list of options grouped into those that were expected to be effective and with potentially few limitations; those that were expected to be somewhat effective, but may have more challenging limitations; and those that were not expected to be effective and/or would be very challenging to implement.

The Phase 3 (SFMP) is a regional-scale strategic planning tool and structural options to be included in the plan were therefore selected on the basis of having a regional focus. For the purposes of the Phase 3 (SFMP), the definition of 'regional' was established by the project Steering Committee as:

- regional scale impacts; and/or
- cross-Council boundary implementation or impacts; and/or
- significant local benefits; and/or
- large implementation footprint; and/or
- significant cost.

Additional 'local' options will be investigated as part of the Phase 4 (LFMPs).

A summary of the application of the first pass and regionality assessments is provided in Section 8.2.

8.1.3 Hydraulic Modelling and Damage Reduction Assessment

Preferred options from the first pass and regional assessment were assessed to quantify their potential hydraulic benefits and impacts. Flooding characteristics can be complicated, with a range of factors determining peak flood levels along the river. For this reason, structural options considered as part of the Phase 3 (SFMP) have been assessed using the Phase 2 (Flood Study) hydraulic model for the full range of AEP events (noting that each AEP scenario is made up of several individual events to form an ensemble).

The results of the hydraulic modelling then feed into the flood damages assessment (refer to Section 6 Flood Damages Assessment[17]), whereby a reduction in flood damages is considered the benefits of the option. Damages were quantified in terms of average annual damages. Benefits therefore were quantified in terms of reduction in average annual damages (or simply annual average benefits).

[17] It is noted that the flood damages assessment (Section 6) was updated subsequent to this structural options assessment (Section 8) to reflect revisions to the property database survey and the structural options assessment is therefore based on slightly different estimates of average annual damages. These differences are minor and are considered unlikely to affect the findings and recommendations of this assessment.

8.1.4 Benefit – Cost Analysis

8.1.4.1 Baseline Analysis

Structural options generally involve hard engineering, which comes at a significant cost. Concept designs have been developed for short-listed options, and preliminary costs estimated.

These costs have been compared with the potential benefits from flood damage reduction (including property, indirect and intangible damages) through a formal benefit-cost analysis. This has considered a 100 year period, and a 7% discount rate (based on Queensland Treasury guidance), although sensitivity to other discount rates has also been presented.

Options with a high benefit/cost ratio generally represent those options that have a more tangible economic justification for proceeding, with values > 0.5 typically signalling justification for more detailed option assessment and preliminary design. Options with a low benefit-cost ratio may have a low economic argument but may still be considered if it has very strong merit on other grounds – as discussed in Section 8.1.5.

8.1.4.2 Sensitivity with Wivenhoe Dam Upgrade Included

Studies are currently underway to investigate options for upgrading existing flood mitigation storages within the Brisbane River catchment (see Section 8.1.8.2), which may provide some reduction in flood risk. Within the Phase 3 (SFMP), sensitivity testing was carried out on the benefit/cost analysis of structural options, to determine what impact, if any, this may have on the economic viability of options considered in the Phase 3 (SFMP).

To do this, Seqwater provide discharge relationships for current conditions and the 4.0m Wivenhoe Dam upgrade option, at Savages Crossing, Moggill and Ipswich. Only the 4.0m raising option has been tested as this would provide the largest possible reduction in flood risk, and is therefore the most conservative scenario for testing.

Only Savages Crossing and Moggill were used in this assessment as the influence in the Bremer River was very limited for the range of structural options that required sensitivity testing. The relationships for the 4 metre dam raising option show that post flows would be about 80% of pre flows for the range of about 6,000 to 15,000 m^3/s (i.e. about 1 in 50 AEP to about 1 in 500 AEP).

Adjusted relationships between discharge and AEP at Savages Crossing and Moggill were constructed and are presented in Figure 8-2. Taking an average of the Savages Crossing and Moggill results, it can be seen that a current 1 in 50 AEP event will become a 1 in 64 AEP event with the upgrade; a current 1 in 100 AEP event will become a 1 in 180 AEP event; a current 1 in 200 AEP event will become a 1 in 370 AEP event, and a current 1 in 500 AEP event will become a 1 in 790 AEP event. Events smaller than a 1 in 50 AEP and larger than a 1 in 500 AEP remain the about the same.

The majority of damages within the Brisbane River catchment occur for floods between a 1 in 50 AEP and 1 in 2,000 AEP (refer to Section 6 Flood Damages Assessment). For floods smaller than a 1 in 50 AEP, the 4 metre dam raising is unlikely to have an impact on flood behaviour (as indicated by the relationship provided by Seqwater), while floods larger than the 1 in 2000 AEP are particularly rare and do not have much influence on total damage when considered on an average annual basis.

The sensitivity testing involved recalculating the 'base case' and structural option damages estimates with the Wivenhoe Dam upgrade included. For the base case condition, the current AAD (including intangible damages) of $287.8 million (refer to Section 6 Flood Damages Assessment) will reduce to $212.7 million (~26% reduction) with the upgrade. This adjusted base case was then used for sensitivity assessment of other structural options.

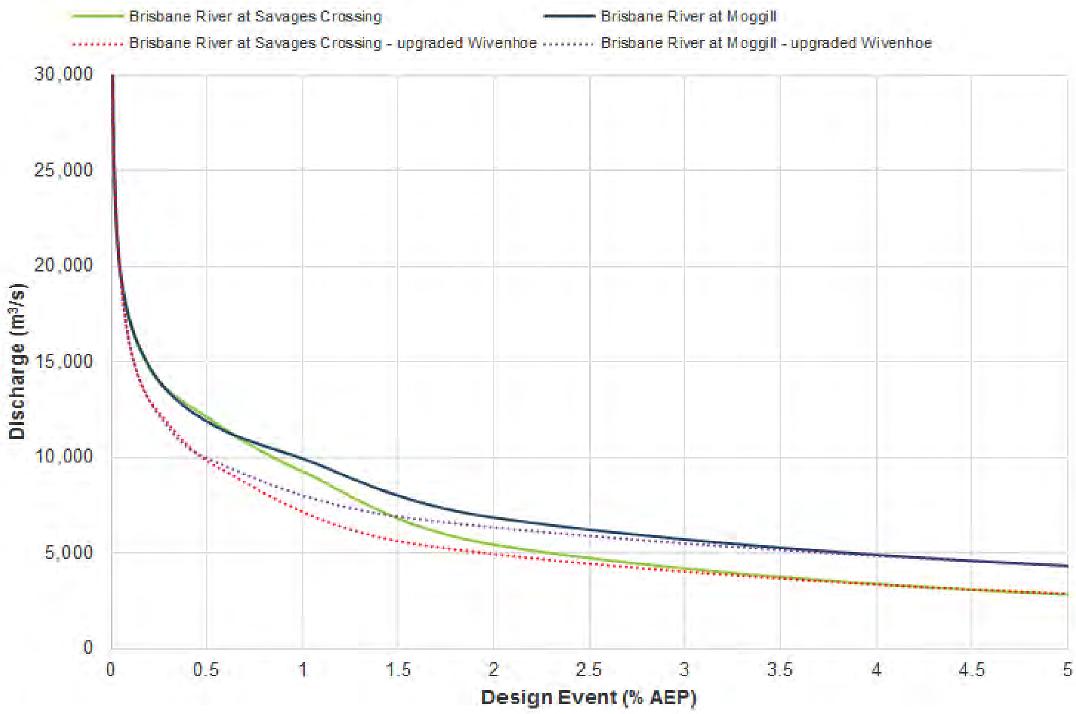


Figure 8-2 Adjusted Discharge / AEP relationship for Wivenhoe Dam 4m raising option

8.1.5 Multi Criteria Assessment

A multi-criteria assessment (MCA) has been used to help compare and assess the various short-listed structural options considered for the Phase 3 (SFMP). The MCA targets a range of criteria, many of which are intangible. The MCA framework has been developed in consultation with stakeholder and is described further in Section 8.3.

The MCA may also be used as a consistent framework when considering other non-structural measures for managing flood risk, such as Disaster Management and Community Awareness actions.

8.1.6 Recommendations for Further Consideration

Based on the outcomes of the MCA a suite of options has been recommended for further consideration by the stakeholders. These options are considered to have positive regional benefits, are deemed to be socially and environmentally practical, and can be economically justified within the context of floodplain management for the broader Brisbane River catchment.

8.1.7 Feasible Alternatives Assessment Consideration

The Minister's Guidelines and Rules under the Planning Act 2016 (DILGP, 2017) outlines the requirements for local government preparing a report assessing feasible alternatives for reducing a material risk of serious harm to persons or property on premises from natural events or processes (as stated in Section 30(4)(e) of the Planning Act 2016), where the local government does not wish a proposed planning change to be an adverse planning change under Section 30(2) of the Act.

The Feasible Alternatives Assessment Report (FAAR) must include:

a) the site description for all premises potentially affected by the proposed planning change;

b) the anticipated risk to premises associated with natural events or processes to be undertaken in accordance with AS/NZS ISO 31000:2009 Risk Management, detailing the impact for the whole premises, not just the part of the premises at risk;

c) any existing uses on the premises;

d) the current intended outcomes of the planning scheme for the premises;

e) details of the proposed planning change and the resultant intended outcomes under the planning scheme for the premises;

f) a statement about the proposed planning change's consistency with the SPP and State Interest Guidelines with regard to natural hazards, risk and resilience; and

g) feasible alternatives to the proposed planning change that have been identified and investigated in accordance with the SPP and associated State Interest Guidelines, any relevant Australian Standard, contemporary best practice guidance or other specifications, and the results of those investigations.

When investigating and assessing alternatives to making proposed planning changes, local governments are required to consider all options for avoiding or mitigating the risk to persons or property on the premises from natural events or processes. For alternatives determined to be not feasible there must be:

a) an unacceptable remaining or residual risk of serious harm to persons or property on the premises;

b) environmental or social disadvantage;

c) an unacceptable economic cost to State, local government, community or individual;

d) technical impracticability; or

e) other unusual or unique circumstances.

The risk-based framework to evaluate flood risk across the Brisbane River catchment study area provides a tool for local governments to use when preparing the FAAR. Structural options assessed as part of the Phase 3 (SFMP) may be used as alternatives within the FAAR. This report therefore considers each structural option in light of the criteria above that govern non-feasible alternatives to planning changes.

8.1.8 Options Identified and Considered in the Phase 3 (SFMP)

Options considered as part of the Phase 3 (SFMP) draw upon the suggestions of stakeholders, some of which have originated from community members and interest groups. The options considered are discussed in detail in Section 8.2.

Structural options need to be considered regionally, as changes to flood behaviour may reduce flood risk in one area, but may increase risk elsewhere. Some structural options capture flood volume in upstream storages, releasing the volume at a slower rate than would otherwise occur (i.e. detention dams/basins). However changes to the timing of a flood peak from one part of the catchment may exacerbate flooding if the delayed peak subsequently coincides with the peak from another part of the catchment. Meanwhile, the storage of water in the upper catchment will also inundate other upstream parts of the floodplain on a more regular basis.

8.1.8.1 Landscape Management

Landscape management is an important component of Integrated Catchment Planning (ICP). Landscape management is not a 'structural option' as it does not involve the construction of infrastructure. However, the potential benefits and impacts of landscape management can be assessed in a similar way to structural options on the basis that changes in catchment hydrology will have an impact on flood hydraulics within the floodplain.

For this reason, landscape management options are considered alongside the other options assessed in this report. The landscape management options are presented and discussed in Section 8.8.

8.1.8.2 Changes to Existing and Future Storages such as Wivenhoe Dam

Existing water storages in the Brisbane River catchment have a flood mitigation benefit, as discussed in Section 2.2.1. Following the 2011 floods and subsequent Queensland Floods Commission of Inquiry, the Wivenhoe Somerset Dam Optimisation Study (WSDOS) was completed in 2013-2014 by the then Department of Energy and Water Supply (DEWS, now Department of Natural Resources, Mines and Energy, DNRME), Seqwater, and other stakeholders to investigate potential alternative operations of the existing infrastructure in order to improve flood mitigation benefits and water supply security for South East Queensland. The WSDOS investigations (DEWS, 2014b) found:

- that when considering the necessary trade-offs between flood mitigation, water supply security, dam safety and disruption to the community, it is not possible to optimise the outcomes for all the key considerations for every flood;
- the dams cannot eliminate flood inundation during moderate and major floods;
- predicted flows at critical downstream locations are a better indicator of likely downstream flood damages and impacts than outflows from Wivenhoe Dam;
- flooding downstream of the dams is a complex interaction of downstream tributary inflows (particularly Bremer River and Lockyer Creek), other inflows to the Brisbane River and releases from Wivenhoe Dam;

- optimising the operations of Wivenhoe and Somerset dams requires recognition that every flood will be different and that operational strategies need to provide good outcomes across a wide range of possible floods not just for one particular flood;
- increasing the available flood storage (by either reducing the full supply level/volume or raising the Dam Safety Strategy trigger level) can decrease peak downstream flows in major floods and larger moderate floods;
- within the level of accuracy of the net present cost assessments for all the options, permanent reductions in the full supply level/volume of Wivenhoe Dam cannot be justified. While reducing the full supply level of Wivenhoe Dam significantly reduces flood damages and impacts, when water supply costs are considered, there is likely to be no overall benefit to the community as a whole. Separate assessment of new infrastructure for increasing flood storage may be warranted to determine if there is a net benefit.

Following the completion of WSDOS, further studies were led by DEWS, with contributions from Seqwater and other agencies, for prefeasibility investigations into flood mitigation storage infrastructure (PIFMSI) (DEWS, 2014a). The study investigated scenarios for potential new dam options (for either flood mitigation or as alternative water supply to combine with water supply operation changes at Wivenhoe Dam) and upgrades to Wivenhoe Dam.

While the feasibility of upgrading Wivenhoe Dam to increase flood mitigation is yet to be confirmed, the PIFMSI study identified, indicatively, that options involving upgrading Wivenhoe Dam to increase flood mitigation benefits ranked among the best of the scenarios that were considered. The study noted that all scenarios would require the necessary dam safety upgrades and modifications to existing dams to be able to pass the Probable Maximum Flood (PMF). The study noted there will need to be detailed risk assessments and consideration of flood emergency response and planning control measures for communities immediately downstream of Wivenhoe Dam. A key recommendation was that a further feasibility assessment is required to complete value engineering assessments and better quantify the costs, benefits and risks before a preferred scenario could be identified.

Seqwater and the Queensland State Government are currently progressing further feasibility level planning of options for upgrading of Wivenhoe Dam. The feasibility study will aim to identify preferred dam upgrade concepts for Wivenhoe Dam and Somerset Dam to provide flood capacity to pass the PMF. For Wivenhoe Dam, there are a large number of options to be considered including increasing the spillway capacity in combination with raising, or not raising, the dam wall. The study will also identify whether the preferred upgrade concept for Wivenhoe Dam could feasibly increase the flood mitigation benefit. The findings from this investigation are due in 2018-2019 and will build upon the outcomes from this Phase 3 (SFMP) and the preceding Phase 2 (Flood Study).

Whilst the feasibility study continues, specific options involving changes to Wivenhoe Dam have not been considered as part of this Phase 3 (SFMP). Notwithstanding, Seqwater and DEWS (now DNRME) have been integral to the preparation of the Phase 3 (SFMP) and have provided information from the PIFMSI assessments to inform indicative potential for flood mitigation benefits on flood behaviour in the Brisbane River. The information included the potential flood mitigation benefit of notionally raising Wivenhoe Dam by 4.0m and with assumed operating parameters, in concert with other options developed as part of the Phase 3 (SFMP) to evaluate the sensitivity of the benefits of these other options if the upgrade works were to proceed.

The sensitivity assessment that includes potential future changes to Wivenhoe Dam storage and operations presented in this Phase 3 (SFMP) must be recognised as indicative only as it is subject to significant limitations and assumptions that will be the subject of separate investigations. Furthermore it is important to recognise that irrespective of any upgrade of Wivenhoe Dam, the potential for levels to exceed Major flood level at Moggill will remain as significant floods can occur from downstream catchments such as Lockyer Creek, Bremer River, and other local creeks.

8.1.8.3 Relocation of Residents

A flood management suggestion was submitted by a member of the public to DILGP to relocate residents from areas of significant flood risk within the Brisbane suburbs of Sherwood, Graceville, Chelmer and Oxley to alternative land at Pinjarra Hills. The land identified at Pinjarra Hills is currently owned by the University of Queensland for its Veterinary Science campus. An initial investigation into this proposal identified that the land at Pinjarra Hills is also located within the Brisbane River floodplain and therefore is still at risk of flooding, although the exposure to flooding is less than that of Sherwood, Graceville, Chelmer and Oxley.

This option has not been addressed in the Phase 3 (SFMP) as the State does not support compulsory relocation of residents. However, principles inherent in this suggestion have been investigated by the Phase 3 (SFMP) through the following means:

- Land use planning: a key component of the Phase 3 (SFMP) is risk-based land use planning, with the aim of future development occurring in locations appropriate to the level of flood risk. The Phase 3 (SFMP) advocates the establishment of a regional framework to support a more consistent and coordinated risk-based planning approach across the floodplain, building on the comprehensive flood behaviour information provided by the Phase 2 (Flood Study).
- Whilst voluntary house purchase / buy back schemes are currently implemented by Local Government for some areas at risk of flooding, the Phase 3 (SFMP) does provide a regional assessment of properties currently located in high hazard areas for further consideration by councils.

8.1.8.4 New Flood Detention Basins in Ipswich

During consultation on the SEQ Regional Plan, DILGP received a community suggestion that identified five potential locations in Ipswich for small flood detention basins. The Phase 3 (SFMP) is a regional scale plan, which is seeking to identify mitigation options with potential to provide regional benefits, and/or significant local benefits. As such, the Phase 3 (SFMP) has not assessed this local option, as the volume of water that would need to be detained in order to achieve regional benefits, or significant local impacts, significantly exceeds the current suggestion. However, the Phase 3 (SFMP) has assessed the potential for large-scale flood detention basins to form part of the mitigation strategy, and one such basin is located on Warrill Creek in the Ipswich region (refer Section 8.6.2).

Details of the suggested option for flood detention basins in Ipswich have been provided to Ipswich City Council for consideration in their subsequent Phase 4 (LFMP).

8.2 Options Identification and First Pass Assessment

8.2.1 Types of Structural Measures

There are many types of structural measures that can modify flood behaviour for the purposes of mitigating flood risk to communities or valued infrastructure. Key measures that are typically targeted for flood mitigation works in Australia and abroad are outlined in Table 8-1, along with the main advantages and disadvantages of each, and other considerations for floodplain management.

8.2.2 Sourcing of Potential Options

Potential structural options for managing existing and future flood risk across the Brisbane River floodplain were sourced from the following:

- Queensland Flood Commission of Inquiry submissions – a list of nearly 300 options submitted to the Inquiry by the public and stakeholders, as consolidated in Table 8-2;
- The Prefeasibility Investigation into Flood Mitigation Storage Infrastructure (PIFMSI) report (DEWS, 2014a), with specific reference to selected options relevant to the Brisbane River Phase 3 (SFMP) study area;
- Previously identified and/or assessed options from each of the councils;
- Participants at the Phase 3 (SFMP) Workshop (held on 9 March 2017), which included representatives from all project stakeholders; and
- Phase 3 (SFMP) project team members, who have a detailed appreciation of the hydraulic behaviour and sensitivity of flooding within the Brisbane River. Project team options were included after the first pass stakeholder review of options.

More than 40 potential options were identified from these sources to generate an initial ‘long-list’, which were grouped under the following categories:

- Permanent levee with flood gate;
- Permanent levee (without flood gate);
- Flood gate only;
- Temporary levee;
- Channel modification (e.g. re-alignment, straightening etc);
- Pipe and / or pump measure;
- Dam;
- Dredging; and
- Landscape management measures (e.g. revegetation, detention basins etc).

Table 8-1 Overview of types of flood mitigation measures

Type	Advantages	Disadvantages	Constraints / Considerations
Riparian revegetation	Bank stability / erosion protection	Reduction in conveyance causing increase in flood levels in the river / upstream for smaller events	Suitable locations / negotiations with private landowners
	Improved habitat / buffer zones	Potential increase in flows bypassing the channel, causing an increase in flood levels downstream (e.g. Lockyer, upper Warrill, Brisbane at Lowood, Fernvale bends)	Requires catchment assessment to ensure no worsening due to changes in tributary timing.
	Reduction in conveyance potentially lowering flood levels and velocities in the river / downstream (if no bypassing, see Disadvantages)		
Flood mitigation dams	Storage of large volume of flood waters which can be control released after the event has passed	Substantial costs	Suitable locations, land availability and land take
	Possibility of multi-uses (e.g. water supply, recreation)	In some events the volume of the floodwaters will exceed dam capacity	To be maximised flood mitigation opportunities, other uses should be avoided.
		Removal of habitat and substantial environmental modification	
		Lack of downstream community awareness of residual risk	
Flood detention basins	Can attenuate flood peaks through temporary storage of small volumes of flood water	To have an impact on larger floods, substantial areas of land required	Suitable locations and land availability
	Possibility of multi-use at both local and regional scale (i.e. parks, playgrounds, carparks, rural) to maximise land use	Provide minimal attenuation when overtopping occurs	Generally most effective in local context (not regional)
Levees	Can be used to exclude areas of the floodplain up to design event	May interrupt water flow into areas such as wetlands - ecological disruption	Suitable locations and land availability

Type	Advantages	Disadvantages	Constraints / Considerations
	Comparatively small construction footprint	Requires maintenance - crest level, grass cover and spillways	May be geotechnical constraints in narrow land parcels
		Increase flood levels upstream / in the river / downstream	Design considerations (overtopping locations, risk of failure)
		Visual amenity	ICC report: Overview of levees for the provision of regional flood mitigation in Ipswich (Parsons Brinckerhoff, 2012)
		Lack of awareness of residual risk (overtopping / failure)	
		Can increase erosion and sedimentation	
Use of existing embankments as levees / storage	As per levees	Lack of awareness of residual risk	Suitable locations
Temporary flood levees	As per levees	As not specifically designed as levees, likely to be increased maintenance costs and/or reduced effective crest heights	Typically local (not regional) benefits
Bypass floodways	Improved flow conveyance	Can transfer problems downstream	Suitable locations, land take requirements
	Redirection of floodwaters away from urban areas	Can cause erosion and stability issues e.g. Lockyer Creek	
Use of infrastructure for conveyance	As per floodways	As per floodways	Suitable locations
			May require modifications to evacuation planning
Channel modification / bank reprofiling	Improved flow conveyance	Can transfer problems downstream	
	Bank stabilisation	High maintenance costs	
		Possible destruction of habitat	
		Potential for increased erosion directly upstream	

Type	Advantages	Disadvantages	Constraints / Considerations
Dredging	Improved flow conveyance	Ongoing maintenance and disposal costs	Equipment constraints in narrow channels
		Sedimentation / deterioration of water quality	
		Sedimentation / loss of habitat / physical impacts on aquatic ecology	
		Environmental impacts associated with the disposal of dredge spoil	
Flood gates	Redirection of floodwaters away from urban areas	Increased upstream flooding	Suitable locations
		Deterioration of water quality including water stagnation and sedimentation upstream	
Backflow prevention devices	Prevention of backflow via drainage network / creeks	Cumulative impact on flood levels in the river / downstream	Suitable locations
		Increased local flooding	Typically local (not regional) benefits

Table 8-2 Structural options suggested during QFCoI

Mitigation measure type	Location where suggested
Flood gates on suburban creeks	Oxley Creek
	Pamphlet Bridge
Dams	Wivenhoe Dam operations / upgrades (as per DEWS report)
	Raise Wivenhoe Dam (as per DEWS report)
	New dam near Linville (as per DEWS report)
	New dam on Lower Warrill Creek near Willowbank (as per DEWS report)
	New dam on Oxley Creek in Greenbank Military Training area
	Expansion of Lake Atkinson
Channel bypass	Canal from the Brisbane River to the Logan River
	Overflow for Somerset Dam
	Develop a combined canal/river route using the Warrego River as a conveyance to the Murray
	Escape channel/spillway from Wivenhoe to another reservoir or to Moreton Bay
Pumping and pipes	Divert flood water from the Bremer River, Lockyer Creek & Brisbane River catchments using a pump and pipeline complex from the intersection of Lockyer Creek and the Brisbane River
	Pipe water to NSW for trading
	Transfer of water from Wivenhoe using tunnel/channel options
Levee banks	Ipswich CBD and Marsden Parade (as per ICC report)
	Mary Street and Martin Street, Ipswich (as per ICC report)
	Old Railway Workshops, North Ipswich (as per ICC report)
	Chubb Street, One Mile (as per ICC report)
	River Park, Fig Tree Pocket area, Madalay Street
	Brisbane River/Oxley Creek banks in Indooroopilly-Canoe reaches
Channel modification	Straighten waterways (Brisbane River)
	Concrete line creeks and drainage paths
	Redirect mouth of Oxley Creek
Dredging	Dredge Brisbane River
	Dredge mouth of Oxley Creek
Detention basins	Deebing Creek - cascading basins/small flood storage dams
	Build flood water storage tanks on the Bremer and Brisbane Rivers

8.2.3 Regional Assessment

The Phase 3 (SFMP) is focussed on the regional assessment and management of flood risk across the catchment. As such, only those options that are considered 'regional' have been assessed as part of this project. For the purposes of the Phase 3 (SFMP), the definition of 'regional' was established by the project Steering Committee as:

- regional scale impacts; and/or
- cross-Council boundary implementation or impacts; and/or
- significant local benefits; and/or
- large implementation footprint; and/or
- significant cost.

While it is possible that additional local options could provide significant benefits, future Phase 4 (LFMPs) provide the opportunity for investigating these further.

8.2.4 First Pass Stakeholder Review

The initial list of possible structural flood mitigation and management options was reviewed by stakeholders as part of a Phase 3 (SFMP) workshop (held on 9 March 2017). At this workshop, participants provided a relative scoring of the different options using a 'traffic light' assessment based on their views and knowledge of feasibility and impact. Options were grouped into those that were expected to be effective and with potentially few limitations ('green'); those that were expected to be somewhat effective, but may have more challenging limitations ('orange'); and those that were not expected to be effective and/or would be very challenging to implement ('red').

Results of the stakeholder assessment are presented in Appendix H, while a summary of the options, in approximate ranked order of initial preference, are listed in Table 8-3, along with the outcomes of the regional criteria assessment. Relative scores were based on the number of 'green' (1), 'orange' (0) and 'red' (-1) points allocated to each option by workshop participants.

Generally, landscape options were considered as 'no regrets' options due to the multiple environmental and water quality benefits, however, the value to flood management needs further investigation. Levees were generally considered favourably, but it was noted that most only have local benefits. Major infrastructure works associated with new storages or flow diversions require significant assessment to justify benefits and ascertain economic sensibility.

Table 8-3 Stakeholder review of long list of structural options

Option Type	Option Location	Key comments from stakeholders	Relative Score
Landscape (various)	Upper catchment generally	Good for ICP, may be less effective in extreme events	9
Landscape (levee removal)	Upper catchment generally	Rural levees only, multiple benefits but would need to test value for flooding	7
Temporary flood barrier	Hotspots	As long as not raising flood levels elsewhere	6
Temporary flood barrier	South Bank / South Brisbane	Regionally significant and potentially affordable	5
Levee	Fernvale	Good local benefits	4
Landscape (upstream detention basins)	Lockyer	Replenish floodplain with silt	3
Dam	Linville	After Wivenhoe investigations	1
Levee / temp levee	Brisbane CBD	Regionally significant, but visual impact	1
Dam modifications	Wivenhoe	Control flows entering Brisbane River	1
Flow diversion	England Creek overflow from Wivenhoe	Previously considered	1
Flood mitigation dam	Lower Warrill Creek / Willowbank	Investigated previously. Share costs with Inland Rail infrastructure	1
Levee	Fig Tree Pocket	Local benefits	1
Floodgate	Ipswich CBD / Marsden Parade	Local business benefits	0
Levee	Mary / Martin St, Ipswich	Local benefits	0
Dam	Oxley Creek / Greenbank Military area	Oxley Creek benefits only	0
Dam	Laidley	Minor benefits to Brisbane River	0
Channel modifications	Oxley Creek mouth reorientation	Community request Geomorphic impacts	0
Floodgate	Breakfast Creek	Local flooding issues	0
Channel modifications	In-stream channel management	Needs further investigation Geomorphic impacts	-1
Landscape (detention basins)	Deebing Creek	Not of significant scale	-1
Floodgate	Norman Creek	Loss of flood storage; size and $	-1
Levee	Old railway workshops, North Ipswich	No comment	-1
Flow Diversion	Overflow for Somerset Dam	Volume and timing difficulties	-2

Option Type	Option Location	Key comments from stakeholders	Relative Score
Dam	Upper Brisbane River, O'Shea Crossing	Considered by PIFMSI	-2
Dam	Expand Lake Atkinson	No comment	-2
Levee	Chubb Street, One Mile	No comment	-2
Flow diversion	Secondary outlet to Wivenhoe	Potentially part of dam assessment	-3
Dredging	Tidal reaches of Brisbane River	Not sustainable	-3
Dam	Bremer River	Limited benefit; tested previously	-3
Floodgate	Oxley Creek / Pamphlet Bridge	Loss of flood storage for Brisbane R. Protection of Rocklea Markets	-4
Detention basins	Storage tanks on Bremer and Brisbane Rivers	Water supply storages too	-4
Channel modifications	Straighten waterway reaches	Environmental impacts Geomorphic impacts	-6
Flow diversion	Divert flows to Logan River	Fail feasibility and economics	-7
Flow diversion	Divert flows to Warrego River	Cost and effectiveness	-7
Flow diversion	Divert flows to NSW for trading	Ineffective for flood relief	-9
Channel modifications	Concrete line creeks and drains	Not sustainable; community backlash Geomorphic impacts	-9
Flow diversion	Pumping from Wivenhoe	Questionable	-10

From the list above, a number of well supported regional options were chosen for further detailed analysis, including modelling and multi criteria assessment, as outlined in Table 8-4. This was primarily based on the relative score from the stakeholders, together with direction from the QRA. As outlined in Section 8.1.8.2, a separate study is currently underway to investigate options for upgrading existing flood mitigation storages within the Brisbane River catchment including Wivenhoe and Somerset Dams. That study is not anticipated for completion within the timeframe of this Phase 3 (SFMP) and so these options have not been able to be included in this assessment or reported here, however the intent is that the relevant outcomes of this Phase 3 (SFMP) (and subsequent Phase 4 (LFMPs)) will be considered and incorporated into those ongoing investigations.

Table 8-4 Short-listed options from stakeholder review at workshop

Short-listed Option	Reason included
Landscape management options	Potential for reducing catchment inflows and additional environmental and water quality benefits. Two options considered covering different approaches and extents within the catchment
South Brisbane temporary levee	Protection of regionally significant amenity area
Brisbane CBD temporary levee	Protection of regionally significant economic area
Willowbank dry flood mitigation dam on Warrill Creek	Potential for significantly reducing inflows to the Bremer River and Brisbane River. Re-examined with latest hydraulic modelling and economic assessment framework
Floodgate at Marsden Parade, Ipswich CBD	Protection for regionally significant uses

8.2.5 Short-Listing to Determine Modelling Scenarios for Assessment

In addition to the short-list of options taken from the stakeholder review described above in Table 8-4, the following options were considered appropriate for further technical analysis, including hydraulic modelling and multi criteria assessment. A listing of the options not included in the short-listing is provided in Appendix I, including the main reasons for exclusion.

Table 8-5 Additional options short-listed for assessment

Short-listed Option	Reason included
Levee protecting Amberley RAAF base	The RAAF base is a critical infrastructure item that is of national significance. Two variations of a levee around the base were considered for investigation.
Suite of protection levees on small storage areas along the sides of the Bremer River in built-up areas	To assess the significance of these storage areas to the overall flood behaviour. Testing for levees at 1 in 50 AEP and 1 in 100 AEP levels.
Suite of protection levees on small storage areas along the sides of the Brisbane River in built-up areas	To assess the significance of these storage areas to the overall flood behaviour. Testing for levees at 1 in 50 AEP and 1 in 100 AEP levels.
On-line dam on Brisbane River near Kholo for flood mitigation purposes only	To help detain flooding before reaching urban areas, with a focus on detention of Lockyer Creek flows and overflows from Wivenhoe Dam
Levee protecting the Mt Crosby West Bank Water Treatment Works	The WTW is a critical infrastructure item that provides water to the Brisbane population. Requested by Seqwater.
Levee at Fernvale	Additional option requested by Somerset Regional Council.
Floodgate / levee on Woogaroo Creek, Goodna	Additional option requested by Ipswich City Council, with structure at mouth of Woogaroo Creek.
Floodgate / levee at Goodna CBD	Additional option requested by Ipswich City Council, with structures targeting Goodna CBD only.

Short-listed Option	Reason included
Floodgate / levee on Oxley Creek	Additional option requested by Brisbane City Council, although protection extends to the regionally significant Rocklea markets and industrial area. Two variations of protection were considered targeting different flood AEPs.
Floodgates / levees on Oxley Creek, Norman Creek and Breakfast Creek	Additional option requested by Brisbane City Council.
A suite of the most feasible options combined	To ensure that the benefits of options are not eroded when considered cumulatively.
Dredging of the tidal reaches	For comparative purposes only.
Realignment of Oxley Creek mouth	Additional option requested by Brisbane City Council.

Based on the above assessment outcomes, a summary of the short-listed options for further assessment is presented in Table 8-6.

A total of 24 options were assessed as part of the Phase 3 (SFMP) and documented in the subsequent sections of this chapter.

Table 8-6 Short-listed options Summary

Option type	Location	Section Reference
Permanent levee / floodgate	Fernvale	Section 8.4.2
	Amberley RAAF base (x2)	Section 8.4.3
	Goodna, Woogaroo Creek	Section 8.4.4
	Goodna, CBD	Section 8.4.5
	Oxley Creek, Pamphlet Bridge	Section 8.4.6
	Oxley Creek, Railway line	Section 8.4.8
	Marsden Parade, Ipswich CBD	Section 8.4.6
	Bremer River side storages (x2)	Section 8.4.9.3
	Brisbane River side storages (x2)	Section 8.4.9.2
Temporary levees	South Brisbane	Section 8.5.2
	Brisbane CBD	Section 8.5.3
Flood mitigation dams	Warrill Creek at Willowbank	Section 8.6.2
	Brisbane River at Kholo	Section 8.6.3
Combined options	Oxley, Norman and Breakfast Creeks	Section 8.7.2
	Selection of most feasible options (x2)	Sections 8.7.3, 8.7.4
Landscape management	Lockyer and Bremer subcatchments (x2)	Section 8.8
Other	Mt Crosby West Bank WTW	Section 8.9.2
	Dredging in tidal reaches	Section 8.9.3
	Realignment of Oxley Creek mouth	Section 8.9.4

8.3 Detailed Multi-Criteria Framework

8.3.1 Overview

Selection of preferred flood mitigation options requires consideration of a wide range of tangible and intangible benefits and costs. One method of doing this is through a multi-criteria analysis (MCA). An MCA involves the evaluation of one or more options against a range of considerations and objectives. For an MCA to be effective there needs to be:

(1) Clear method for scoring the option(s) against each criterion; and

(2) Clear weighting between the criteria.

Guideline 7.6 which supports implementation of Handbook 7 (AIDR, 2017) provides information on assessing options for treating existing flood risk, while an example assessment matrix covering potential relevant criteria is presented in Table 9.3 of Handbook 7 (AIDR, 2017).

8.3.2 Criteria Adopted and Scoring

Using the example criteria from Table 9.3 in Handbook 7 (AIDR, 2017) as a starting point, stakeholders were asked to provide input to relevant criteria and associated targeted issues. Stakeholders were also asked to provide input to the proposed scoring system of options for each criterion / targeted issue.

Feedback was received from stakeholders and collated to develop an agreed criteria list, target issues and associated scoring table (refer Table 8-7). As per AIDR (2017), scores are provided on a sliding scale between 1 and 5, with 1 being the lowest score and 5 being the highest score. Continuing existing practice (i.e. ‘no change’) would typically be scored mid-way or 2.5 with no net benefit or cost to the community (refer AIDR, 2017).

It is noted that, for the purposes of this study, the MCA is a high level assessment to identify which options should proceed to a pre-feasibility (and potentially feasibility) assessment, and which options should be abandoned as unfeasible or unsupported. The scoring of each element is therefore based on a preliminary, not detailed, assessment, together with stakeholder feedback. For those options to be progressed, a more rigorous assessment of each element will be required as part of subsequent investigations.

8.3.3 Relative Weighting between Criteria

As recognised in all MCAs, different criteria can be weighted differently depending on the importance of the criteria / issues to the relevant stakeholders. Using direct feedback from the Phase 3 (SFMP) stakeholders, weightings were defined for the key criteria, along with the relative weightings of each target issue criterion. The result is an overall weighting of each issue across all criteria.

A summary of the weightings of criteria and targeted issues is provided in Table 8-8.

Table 8-7 Multi-criteria, targeted issues and scoring scale

Criteria Category	Targeted Issue	Scoring Scale (1 to 5)		
		1	2.5	5
Safety of people	**Reduce hydraulic risk rating (now and future)**	Number of properties with increased risk	No reduction in risk	Number of properties with reduced risk
	Improve time for evacuation (now and future)	Time for evacuation reduced	No effect to current evacuation time	Increased time for evacuation
Social	**Targets vulnerable community members or areas**	Predominantly benefits areas of high average household income	Benefits a mix of high and low average household income	Predominantly benefits areas of low average household income
	Social health benefits	Negative effect on social health - more dwellings affected	No net change in social health - current flood behaviour	Anticipated social health benefits because of less dwellings affected
	Improves community flood resilience (now and future)	Measure will provide less certainty around when and where flooding will occur, and appropriate community response	No net change to existing community understanding and resilience of flood risk	Improved understanding of flood risk and appropriate actions when inundation is likely to occur
	Recreation and amenity	Decrease in diversity of open space areas	No net change	Increase in sport and recreation opportunities
	Connection and collaboration	Increased separation of community from watercourse (out of sight out of mind)	No net change	Measure encourages community to positively engage with watercourse via creation of riverside parks, education centres etc
Economic	**Reduce damages and costs to residential property (now and future)**	Net damage likely to increase following measure	No net change in flood damages	Decreases in flood damages following measure
	Reduce damages and costs to business and industry (now and future)	Net damage likely to increase following measure	No net change in flood damages	Decreases in flood damages following measure
	Option likely to be cost beneficial (now and future)	Costs of option likely to outweigh benefits	Near neutral cost benefit ratio	Benefits of measure likely to outweigh associated costs
Feasibility	**Physical / technical (now and future)**	Low feasibility (complex, expensive and many unknown issues)	Likely to be feasible subject to further investigations	High degree of feasibility and certainty around outcomes

Criteria Category	Targeted Issue	Scoring Scale (1 to 5)		
	Legal / approval risk	Requires approval and residual risk that approval not obtained	Requires approval but generally approval granted assuming requirements are met	No or minimal approval required
	Potential for additional funding sources	Minimal chance of external funding	Moderate chance of external funding	High chance of external funding
Attitude	**Decision makers**	Assumed / likely low level of political will for measure (or measure likely to be opposed)	Assumed / likely to be politically neutral	Assumed / likely high level of political will to implement measure
	Community	Majority of community likely to oppose measure	Community neutral on measure	High community expectations that measure will go ahead
Key infrastructure and transport	**Improve availability and function (now and future)**	Measure will negatively impact on key infrastructure or proposed key infrastructure	No net change (effect) on key infrastructure (existing and planned)	Improvements to key infrastructure (existing and planned) through reduced flood risk
	Protection of regional water supply quality and security - catchment protection (quality and yield)	Significant loss in ability to store/extract water	No net change to water security	Increased catchment storage or management practices leading to significant improvements to water security
Environment and Natural Resource Management	**Species impacts**	Loss of species diversity or abundance	No net change in species	Species abundance and diversity improved
	Vegetation and habitat impacts	Loss of vegetation and habitat due to measure	No net change in vegetation cover and habitats	Increase in vegetation and improvements to habitats due to measure
	Ecosystem health and connectivity (fish passage/fauna movement)	Significant loss in ability to store/extract water	No net change to water security	Increased catchment storage or management practices leading to significant improvements to water security
	Reduction in landscape salinity / improved moisture retention and groundwater recharge	Reduction in ability to respond to future climate conditions	No change to existing climate resilience	Improvement in ability to withstand future climate conditions
	Reduction in erosive capacity / soil movement - channel stability / geomorphology	Increase in soil erosion from catchment and/or negative impact on geomorphic processes	No change to soil erosion from catchment and/or negative impact on geomorphic processes	Decrease in soil erosion from catchment and/or negative impact on geomorphic processes

Table 8-8 Relative Weightings of Criteria and Overall Targeted Issues

Criteria category	Criteria weighting (%)	Targeted issue	Weighting of issue within criteria (%)	Overall weighting of targeted issue (%)
Safety of people	**25**	Reduce hydraulic risk rating (now and future)	75	18.75
		Improve time for evacuation (now and future)	25	6.25
Social	**10**	Targets vulnerable community members or areas	25	2.5
		Social health benefits	15	1.5
		Improves community flood resilience (now and future)	30	3.0
		Recreation and amenity	15	1.5
		Connection and collaboration	15	1.5
Economic	**20**	Reduce damages and costs to residential property (now and future)	45	9.0
		Reduce damages and costs to business and industry (now and future)	25	5.0
		Option likely to be cost beneficial (now and future)	30	6.0
Feasibility	**15**	Physical / technical (now and future)	60	9.0
		Legal / approval risk	30	4.5
		Potential for additional funding sources	10	1.5
Attitude	**10**	Decision makers	50	5.0
		Community	50	5.0
Key infrastructure and transport	**10**	Improve availability and function (now and future)	50	5.0
		Protection of regional water supply quality and security - catchment protection (quality and yield)	50	5.0
Environment and Natural Resource Management	**10**	Species impacts	20	2.0
		Vegetation and habitat impacts	20	2.0
		Ecosystem health and connectivity (fish passage/fauna movement)	20	2.0
		Reduction in landscape salinity / improved moisture retention and groundwater recharge	20	2.0
		Reduction in erosive capacity / soil movement - channel stability / geomorphology	20	2.0
TOTAL	***100***			***100***

8.3.4 Scoring for Quantifiable Economic Criteria

The economic criteria used in the MCA allow the use of quantifiable metrics, as calculated through the assessment process described in this report. A guide used for scoring of these criteria is presented in Table 8-9.

Table 8-9 Quantifiable scales for economic criteria

Score	Reduction in damages and costs to properties	Likely to be cost beneficial
	Reduction in AAD = …..	Benefit / Cost ratio = …..
1.0	< -$1.0m (i.e. increase)	< 0.05
1.5	-$1.0 to -$0.2m (i.e. increase)	0.05 – 0.25
2.0	-$0.2 - $0 (i.e. increase)	0.25 – 0.50
2.5	$0 – $0.5m	0.50 – 0.75
3.0	$0.5 – 1.0m	0.75 – 1.0
3.5	$1.0 - $10m	1.0 – 1.5
4.0	$10 – $25m	1.5 – 2.0
4.5	$25 – $50m	2.0 – 3.0
5.0	>$50m	>3.0

With respect to reduction in damages and costs, the targeted issues in the MCA differentiate between residential and business damages and costs. For simplicity, the economic analysis has considered total damages (or benefits) to all property types, and includes both tangible and intangible damages/benefits. Where there is known to be a predominance of either residential, or business properties within the area impacted by the option, then the scale related mostly to that property type (with the other being essentially neutral – i.e. minimal impact). Where there is a mix of both residential and business properties, the same score was applied to both target issues in the MCA.

8.4 Permanent Levees and Flood Gates

8.4.1 Overview

The following levee and flood gate options were short-listed and have been evaluated:

Table 8-10 Permanent Levee and Floodgate Options Assessed

Location	Description / Immunity level	Report Section
Fernvale	1 in 100 AEP	Section 8.4.2
Amberley Air Base	1 in 50 or 1 in 100 AEP	Section 8.4.3
Goodna	Woogaroo Creek, 1 in 50 AEP	Section 8.4.4
Goodna	CBD, 1 in 100 AEP	Section 8.4.5
Ipswich CBD	Marsden Parade rail underpass	Section 8.4.6
Oxley Creek	Pamphlet Bridge, 1 in 50 AEP	Section 8.4.7
Oxley Creek	Railway, 1 in 100 AEP	Section 8.4.8

Levees and flood gates have different targeted AEP floods depending on specific conditions at each site, the targeted flood immunity, and technical feasibility. Generally, levees and flood gates have targeted flood immunity levels in the range of 1 in 50 AEP to 1 in 200 AEP as it balances benefits (i.e. the number of properties protected) with the size of the structure and is within the range of AEPs that most contribute to flood damages (refer to Section 6 Flood Damages Assessment).

As flood levels within the Brisbane River are very sensitive to changes in flow (due to the limited overbank floodplain storage areas), there are large peak level differences between AEPs, which make designing for higher AEPs less practical and more costly.

8.4.2 Fernvale

8.4.2.1 General Description of Option and Assessment

The option consists of raising an existing unsurfaced access road to act as a levee, preventing an overland flow path from the Brisbane River joining Ferny Gully. The unnamed access road joins the Brisbane Valley Highway (A17) approximately 300 metres northwest of the Fernvale State School and provides access to a local mine site. The road is located approximately 100 metres from the nearest property. There are two small water bodies either side of the road, which appear to be connected by several small culverts of an unknown size.

The Phase 2 (Flood Study) indicates the flow path develops between a 1 in 50 and 1 in 100 AEP flood event. In the case of a 1 in 100 AEP flood event, flood water overtops the banks of the Brisbane River and travels in a south-easterly direction, inundating approximately 50 properties in Fernvale township.

This option proposed a levee with a crest level at the 1 in 100 AEP flood (plus freeboard). Floods smaller than this do not create an overland flowpath and thus are not targeted. The 1 in 200 AEP flood is approximately two metres higher than the 1 in 100 AEP flood. While it is possible to build a higher levee, the costs would increase significantly. Moreover, backwater inundation from the Brisbane River into Ferny Gully during a 1 in 200 AEP flood would still inundate properties in Fernvale, thus negating many of the benefits achieved by the proposed levee. For these reasons, the 1 in 100 AEP flood was chosen as the proposed design standard.

8.4.2.2 Concept Design

To achieve the desired immunity (1 in 100 AEP) with a freeboard allowance (0.5m), a levee would require a crest level no lower than 43.50 m AHD. This would involve raising a 480m long section of the access road by an average of 1.70m.

The proposed levee would not impact the small water bodies either side of the road. However, a new transverse drainage structure would be required under the levee. To prevent flood water from back-flooding through the transverse drainage structure, a backflow prevention device would need to be constructed on the northern side of the crossing.

The extent of the levee and the indicative location of the transverse crossing can be seen in Figure 8-3.

8.4.2.3 Indicative Cost

The indicative costing of the proposed Fernvale levee is provided in Table 8-11 and has been based on the following assumptions:

- The levee height is based on results from the Phase 2 (Flood Study) and, therefore, the costing does not take into account the potential increase in water level as a result of the option;
- All of the access road and land required for raising would need to be purchased to offset loss of existing use and to ensure access for maintenance, including during flood events;
- The existing road surface and topsoil is not contaminated and therefore requires no treatment;
- Only limited traffic management would be required and no financial compensation would be provided to any stakeholders/landowners (i.e. mine owner);
- The levee would be built with imported materials;
- The dimensions of the levee would be 8m wide at the crest and 1 in 3 batters; and
- The transverse drainage structure would be a single flap-gated 900mm RCP.

Table 8-11 Indicative Costs for Fernvale levee (2017 dollars)

Description	Cost ($)
Traffic and Environmental Management Plans	239,600
Transverse structures and floodgates	93,700
Earth Works	806,500
Road Works	203,100
Total Direct Job Cost	**$ 1,342,900**
Indirect Job Costs – On-Site Costs (31%)	416,300
Design Costs (9%)	158,300
Indirect Costs - Offsite Costs (3%)	57,500
Contractors Margin and Profit (9%)	177,700
Applications (5%)	107,600
Contingencies (40%)	904,100
Total Cost Estimate (Excluding Operating Expenses)	**$ 3,165,500**
Annual Operating Expenses (assume 2% of capex)	$ 63,300

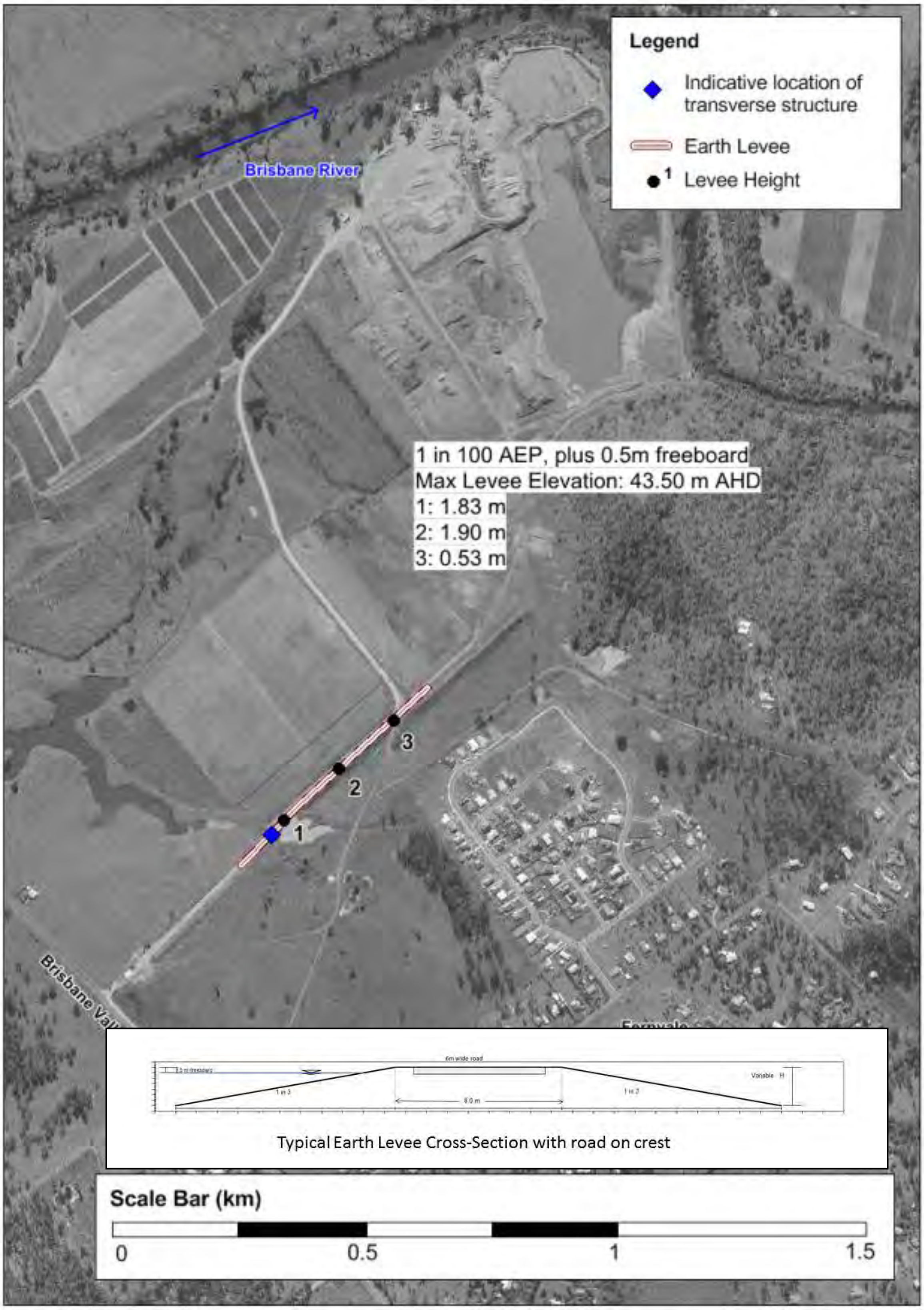


Figure 8-3 Location of Fernvale Levee

8.4.2.4 Hydraulic Impacts

Potential impacts of the proposed Fernvale levee on the hydraulic behaviour of flooding within the Brisbane River were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

The proposed Fernvale levee prevents overland flow between the Brisbane River and Ferny Gully during the 1 in 100 AEP event, and thus prevents inundation of about 51 residential properties within this overland flowpath. These properties are within the current HR3 Potential Hydraulic Risk area. Although the overland flow is prevented, backwater flooding within Ferny Gully still occurs due to elevated flood levels in the Brisbane River, which would impact a number of properties within Fernvale (refer Figure 8-4).

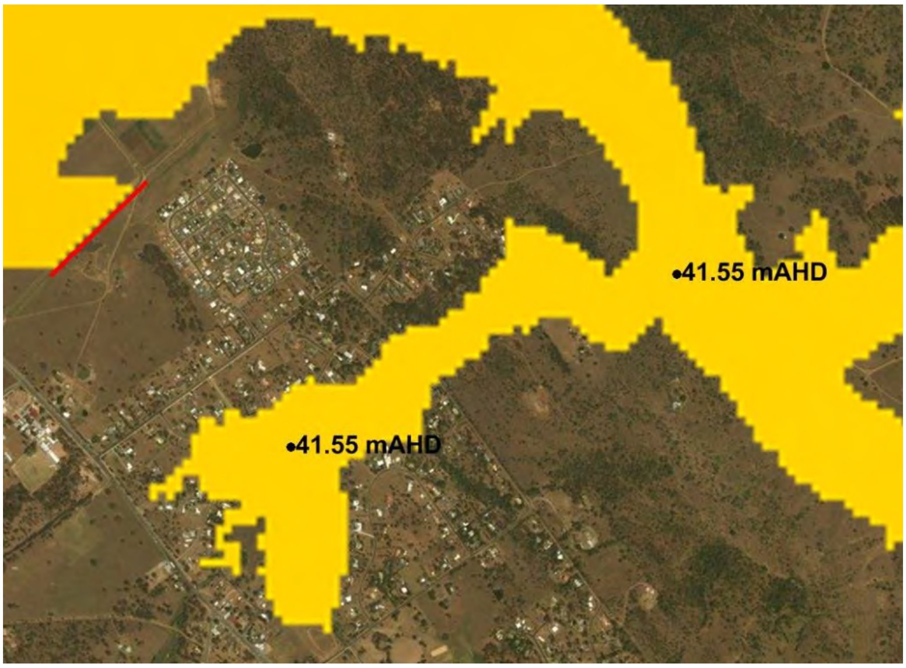


Figure 8-4 Fernvale Levee 1 in 100 AEP flood extents

Hydraulic modelling of the 1 in 100 AEP flood indicates that the peak flood afflux generated by the proposed levee structure is less than 50mm, being the smallest threshold for gradation mapping in this regional assessment (refer Figure 8-5).

Hydraulic modelling was also carried out for other AEPs. A summary of the impacts of the proposed Fernvale levee on properties for the different AEP floods is given in Table 8-12.

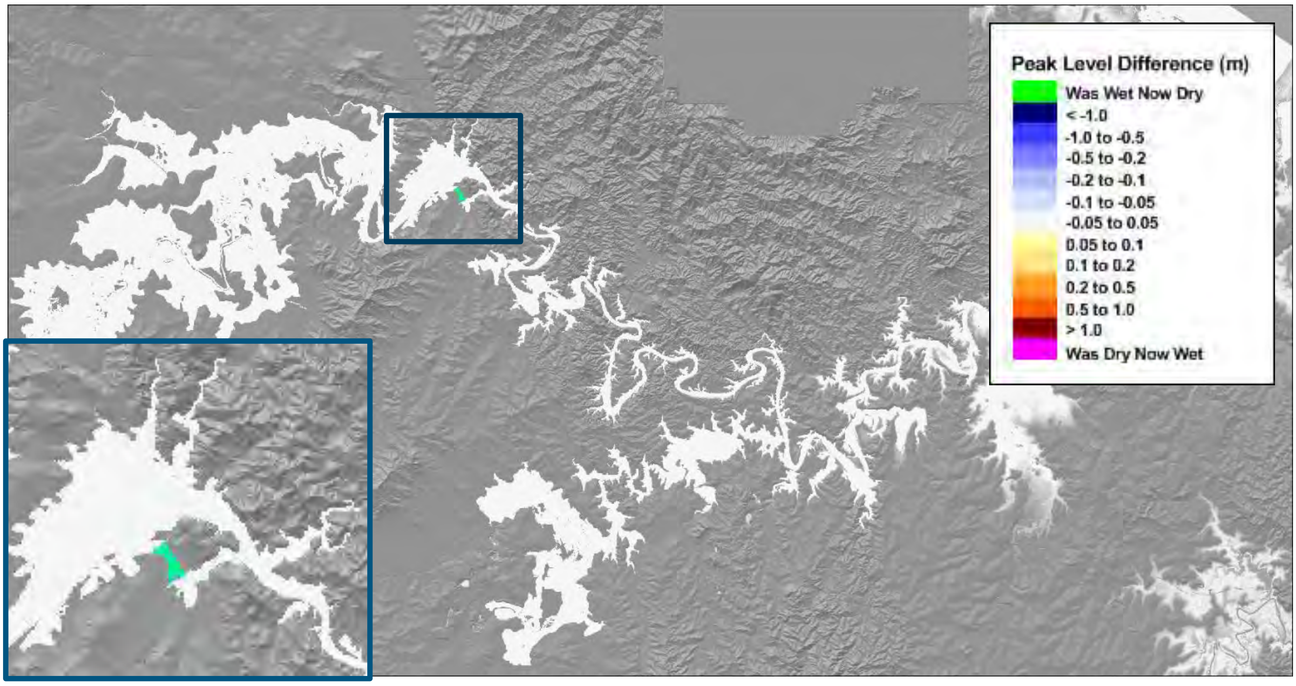


Figure 8-5 Fernvale Levee water level impacts 1 in 100 AEP

Table 8-12 Summary of Fernvale levee impacts on properties

AEP	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	n/a	n/a	n/a	0	0	0	0
1 in 5	n/a	n/a	n/a	0	0	0	0
1 in 10	n/a	n/a	n/a	0	0	0	0
1 in 20	n/a	n/a	n/a	0	0	0	0
1 in 50	n/a	n/a	n/a	0	0	0	0
1 in 100	< 50mm	< 50mm	< 50mm	11	51	0	4
1 in 200	< 50mm*	< 50mm*	< 50mm*	0	2	0	0
1 in 500	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.

[2] Building no longer affected by flooding.

[3] Building is flooded to a greater degree, either above or below habitable floor level.

[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.

For events larger than the 1 in 100 AEP (plus 500mm freeboard), the levee will be overtopped and the overland flowpath re-engaged, resulting in similar flood conditions as in current conditions and therefore there is no material benefit from the levee. The presence of the levee (albeit overtopped) in larger events does not have a notable impact on flood levels within the river (that is, afflux is less than 50mm).

For floods smaller than the 1 in 100 AEP, the overland flowpath in the vicinity of the levee is not activated. Therefore, smaller flood events are not affected by this option.

Overall, it is concluded that the Fernvale levee would have positive benefits in terms of reduced inundation extents for events in the order of a 1 in 100 AEP , and would not generate any notable negative impacts in adjacent areas. Benefits and impacts for floods larger than the 1 in 100 AEP and smaller than the 1 in 100 AEP are considered negligible.

8.4.2.5 Benefit / Cost Analysis

The Fernvale levee, with a capital cost of $3.2m and an annual maintenance cost of $63,000, will generate a net annual average benefit of $40,000, leading to a benefit/cost ratio of 0.12 when adopting a discount rate of 7% over a 100 year period. The benefit of the levee is restricted to about 50 properties, and essentially for flood events in the order of a 1 in 100 AEP only. A summary of the benefit / cost analysis for the Fernvale levee option is presented in Table 8-13.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-13, to provide an indication of the influence of assumptions on the analysis. If benefits were limited to reductions in tangible damages, the annual average benefit would reduce to just $10,000 per year, giving a net benefit/cost ratio of 0.04. Potential upgrades to Wivenhoe Dam could reduce the impact of flooding at Fernvale, resulting in the annual average benefit of the levee option reducing to $30,000 per year, with to a benefit/cost ratio of 0.10. Sensitivity was also undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 0.19, while for a higher discount rate of 10%, the benefit/cost ration reduces to 0.09.

Table 8-13 Benefit/cost analysis summary for Fernvale levee option

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case (1)	288.7	288.6	0.04	**0.12**
Sensitivity 1: No intangibles	186.8	186.8	0.01	**0.04**
Sensitivity 2: with Wivenhoe up.	213.2	213.1	0.03	**0.10**
Sensitivity 3: 4% discount rate				**0.19**
Sensitivity 4: 10% discount rate				**0.09**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

8.4.2.6 Multi-Criteria Review

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.4.2.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	62 properties benefit directly from the reduced inundation extents in the 1 in 100 AEP flood, with 120 properties currently flooded above floor level for this flood in the Fernvale suburb. These properties are currently within HR3 Potential Hydraulic Risk area. The potential hydraulic risk would largely remain the same except that the small area of HR2 within the overland flowpath (mostly open space area) would become HR3. Events larger than the 1 in 100 AEP would still impact these properties. As the number of properties benefiting are very small compared to the total number of properties within the floodplain, the score for this criteria remains neutral.	2.5
Improve time for evacuation (now and future)	Approximately 290 properties would benefit through maintenance of a passable local access road (Schmidt Road) during the 1 in 100 AEP event. Without this access, these properties would be isolated. Note, floods larger than the 1 in 100 AEP event would overtop the levee and inundate the access road. However, the works would result in more warning time before access was cut compared to current conditions. Flood immunity of regional evacuation routes (i.e. the State controlled roads as identified in Section 4 Current Flood Risk) will not be improved by this option. As the evacuation benefit is very limited, the score for this criteria remains neutral.	2.5

8.4.2.6.2 Social

Targets vulnerable community members or areas	The population benefiting from this option is considered to be more vulnerable than average, particularly due to physical and flood awareness characteristics, as detailed in Section 4 Current Flood Risk.	4.0
Social health benefits	The reduction in the number of residential properties inundated would lead to some social health benefits, although the extent of this would be small as the benefit footprint is limited and is only relevant to events in the order of the 1 in 100 AEP.	3.0
Improves community flood resilience (now and future)	The construction of a flood levee in Fernvale may have some positive benefits for community awareness, as it highlights to residents the potential for flooding. Many of the properties	3.0

	affected by loss of access on Schmidt Road are newly built, and therefore residents may not have a good appreciation of flood susceptibility. However, the community may alternatively get a false sense of security because of the levee, and disregard the potential for the levee to be overtopped. Overall, it is considered to be a slight benefit to the community. No significant critical infrastructure has been identified as benefitting from this option.	
Recreation and amenity	There would be no significant change to recreation and amenity as a result of this option.	2.5
Connection and collaboration	This option would not impact the community's connectedness to the river and watercourses.	2.5

8.4.2.6.3 Economic

Reduce damages and costs to residential property (now and future)	The net average annual benefit from this option is $40,000 due to the small number of properties impacted and the limited hydraulic benefits. As per the scale presented in Table 8-9, this small benefit produces a neutral score.	2.5
Reduce damages and costs to business and industry (now and future)	There are no impacts to business or industry	2.5
Option likely to be cost beneficial (now and future)	Low BCR of 0.12	1.5

8.4.2.6.4 Feasibility

Physical / technical (now and future)	The design and construction of the levee at Fernvale would be relatively straightforward. There is an existing road which would serve as the base for the levee structure.	3.0
Legal / approval risk	Land is in a road reserve, with Rural Zone to the north-west and Emerging Community Zone and General Residential Zone to the south and south-east. This would be an Impact Assessable Development Application under Schedule 10 of the Planning Regulation 2017, with SRC as the Assessment Manager and	4.0

	referral to SARA[18]. It could alternatively be a Local Government or Ministerial infrastructure designation development[19]. Approval for this development would be likely, noting that it will require comprehensive engineering documentation. These is also a statutory requirement for public notification where submitters have appeal rights.	
Potential for additional funding sources	This option may qualify for external funding on the basis of reducing risk in vulnerable rural communities.	3.0

8.4.2.6.5 Attitude

Decision makers	There appears to be general support for this option at local government level as decision maker for this structure (see above).	4.0
Community	Results from the community survey (refer to Section 11 Community Awareness and Resilience) showed a neutral response to levees [scoring 2.8 out of 5] in the Somerset council area. It is assumed the local community that benefits from this option would likely be very supportive of the works. As there are no significant off-site impacts and costs are relatively affordable, it is also assumed that the broader community would likely be more supportive.	4.5

8.4.2.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	This option will improve access along Schmidt Road in events in the order of the 1 in 100 AEP. Schmidt Road is the only access road servicing a residential precinct in Fernvale of approximately 290 properties.	3.0
Protection of regional water supply quality and security – catchment protection (quality and yield)	This option would have no impact on regional water quality or quantity.	2.5

[18] To be assessed under State Development Assessment Provisions, State Code 19 Category 3 levees (assessed by Council), and Schedule 10 of Water Regulation 2016 Code for assessment of development for construction or modification of particular levees (assessed by SARA). Documentation would likely need to include: vulnerability and tolerability assessment report; report identifying benefits and impacts to people and property; levee operations and maintenance manual; update to SRC's Local Disaster Management Plan to reflect any changes in emergency response; safety and stability of the structure; and community safety for failure or overtopping.
[19] This assessment pathway would require further discussions with relevant Authorities to determine if it would be a more efficient process than the typical assessment pathway.

8.4.2.6.7 Environment and Natural Resource Management

Species impacts	There would be no impact to species richness or diversity.	2.5
Vegetation and habitat impacts	This option would have no impact on vegetation and habitats. The location of the levee, on an existing road, means that there would be no net loss of habitat due to construction.	2.5
Ecosystem health connectivity (fish passage/fauna movement)	This option would have no impact on the ecosystem health connectivity through fish and fauna passage.	2.5
Reduction in landscape salinity / improved moisture retention and groundwater recharge	There would be no impact to the landscape salinity or moisture, as this option does not encourage local ponding or water storage.	2.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	Even though some overland flow would be prevented, there would be no material change to sediment generation from the floodplain, while the change in flood behaviour at the design level would not be sufficient to result in a geomorphic response in the main river channel.	2.5

8.4.2.7 Assessment of Option Against Multiple Criteria

As outlined in Section 8.10.2, the Fernvale levee has an overall multi-criteria assessment result of 0.32, where a value of 0.0 represents a net 'no change' condition across the various criteria. The levee is ranked 9th out of the 16 options considered in the MCA (refer Table 8-64).

The lowest scoring criterion for this option was the cost beneficial criterion (value of 1.5), while the best was the expected community attitude/response (value of 4.5). There are no specific factors that would automatically rule out this option from further consideration. Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.4.2.8 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The proposed Fernvale levee will address flooding for events in the order of a 1 in 100 AEP flood. Larger events will still impact on the local population at risk in Fernvale with no residual mitigation by the levee.

environmental or social disadvantage	The Fernvale levee will not create environmental or social disadvantage.
an unacceptable economic cost to State, local government, community or individual	The cost of the Fernvale levee is not insignificant given the limited numbers of beneficiaries and the infrequent context in which the levee would be operational.
technical impracticability	The Fernvale levee would be technically practical.
other unusual or unique circumstances	There are no obvious other unusual or unique circumstances that would preclude the feasibility of this option.

8.4.3 Amberley Air Base

8.4.3.1 General Description of Option and Assessment

Amberley RAAF base is considered critical infrastructure. Continuous functioning of the air base during a flood event is highly desirable for assistance with flood response and recovery efforts, as well as maintaining national defence and counter-terrorism services. Under existing conditions, these services are compromised by flood susceptibility of the air base and the local road network that services the air base (notably the Cunningham Highway across the Warrill Creek and Purga Creek floodplains). Results from the Phase 2 (Flood Study) suggest that the RAAF Amberley Air Base will start to be inundated between a 1 in 5 AEP and 1 in 10 AEP flood event. The air base is surrounded on three sides by floodplain and, as a result, there are multiple points of ingress into the air base that are inundated in a regional flood event.

This option consists of raising an existing private road that circles the RAAF Amberley Air Base to act as a levee to prevent flood inundation of the base (and especially the runway and associated flight instrumentation infrastructure) from the Bremer River and Warrill Creek. The existing private road is crossed by at least 15 separated transverse drainage structures, which serve to drain the airbase from local flood events. The total catchment draining from the airbase is 8.1km^2. The majority of the runoff is directed to five transverse drainage structures beneath the existing road.

While a levee that is as high as possible would be ideal, it is recognised that such a levee will have detrimental impacts on downstream residential properties in Ipswich. Also, a high levee around the air base would be of limited value during a flood event if the connecting road network was not improved to provide a commensurate level of flood immunity.

An iterative process was followed in determining an appropriate design standard for the proposed Amberley RAAF levee. This involved exploring the impacts of a levee with crest elevation of 1 in 50 AEP and 1 in 100 AEP, and also exploring the benefits of accompanying landform changes in the floodplain to help offset impacts. The difference in flood levels between 1 in 50 AEP and 1 in 100 AEP at Amberley is approximately 0.85 metres, while the difference between 1 in 100 AEP and 1 in 200 AEP flood levels is approximately 1.15m.

The impact of the Amberley RAAF levee was also explored in concert with other options, including a potential flood mitigation dam on Warrill Creek, as discussed further in Section 8.7.3.

8.4.3.2 Concept Design

For initial concept design purposes, a 1 in 100 AEP levee was chosen, although a 1 in 50 AEP levee was also assessed and costed, as discussed herein.

Excluding freeboard allowance[20], a 1 in 100 AEP levee would require a crest level no lower than 27.14 m AHD adjacent to the Bremer River and 27.35 m AHD adjacent to Warrill Creek. This would involve raising a 9.2km long section of road by an average of 3.5m. The proposed levee would cross the existing transverse drainage crossings and each one would need to be re-constructed with a backflow prevention device. The extent of the levee and the indicative location of the transverse drainage crossings is shown in Figure 8-6. In a large regional flood event, downstream flooding will prevent local runoff to drain from the air base. As a result, low lying portions of the airbase could become inundated from local flooding rather than from regional flooding. To prevent inundation of the RAAF Amberley Air Base from coincident local runoff, pumping stations would be required.

The concept design includes the construction and operation of two pump stations at two natural low points. For concept design and costing purposes, it was assumed that the pumps would require a capacity to drain flows for a 1 in 20 AEP, 24 hour rainfall event. This was selected to determine the pump capacity as it was deemed a reasonably feasible scenario for coincidence of this event with flooding in the Bremer River and Warrill Creek significant enough to prevent local drainage. If this option is to be pursued in the future, detailed assessment would need to consider the coincident probabilities of flooding in order to more accurately size and cost the pumps.

8.4.3.3 Indicative Cost

The indicative costing of the option is presented in Table 8-14 and has been based on the following assumptions:

- The levee height is based on the Phase 2 (Flood Study) and, therefore, does not take into account the potential increase in water level as a result of the option;
- No land purchase will be required;
- No financial compensation would be provided to the Department of Defence for potential costs accrued for changes to base security features (i.e. check points, cameras, fences);
- Traffic and Environmental Management is a major factor for construction works at the base and major controls will need to be in place;
- The existing road surface and topsoil is not contaminated and, therefore, requires no treatment;
- The levee would be built with imported materials;
- The dimensions of the levee would be 8m wide at the crest and 1 in 3 batters;

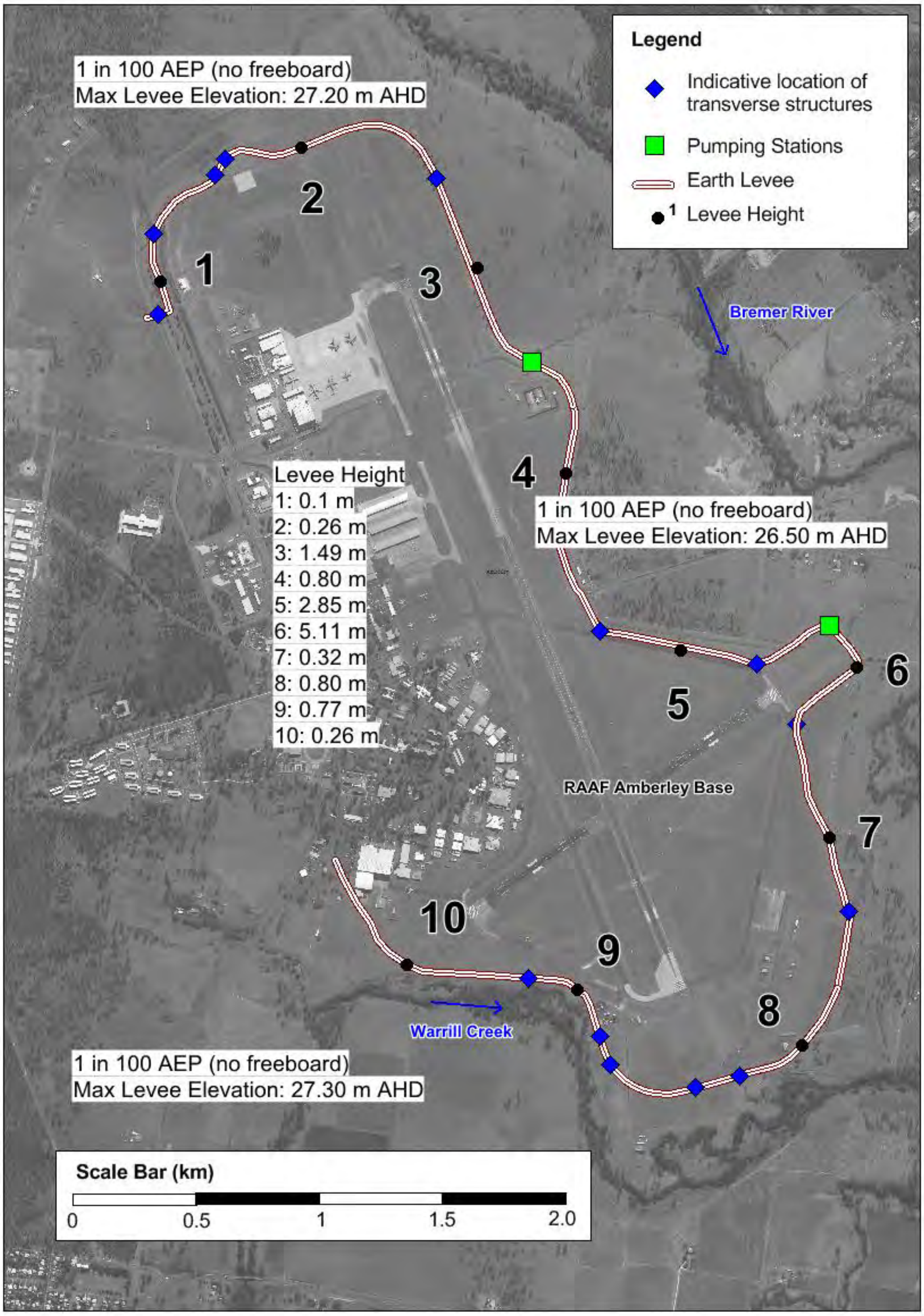
[20] Freeboard was excluded in this initial hydraulic assessment for ease of analysis. Freeboard provisions for one-off items of critical infrastructure such as Amberley Air Base need to be assessed on a merits basis. Should this option be pursued further, consideration needs to be given to the appropriateness of freeboard, balancing the level of protection it offers the air base against the additional potential impacts it will create on downstream properties.

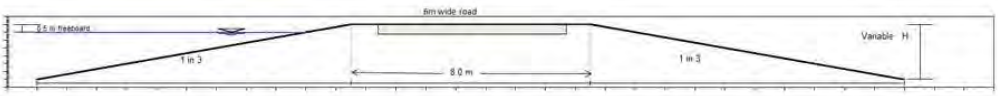
- Existing transverse drainage structures will all need to be replaced and fitted with flood gates; and
- Merging of the local catchments behind the levee is possible through local drains to reduce the number of pump stations.

Table 8-14 Indicative Cost for 1 in 100 AEP Amberley RAAF levee (2017 costs)

Description	Cost ($)
Traffic and Environmental Management Plans	1,062,500
Transverse structures and floodgates	1,621,200
Earth Works	12,093,100
Road Works	7,549,700
Pumping stations	9,800,000
Total Direct Job Cost	**$32,126,600**
Indirect Job Costs – On-Site Costs (31%)	9,959,200
Design Costs (9%)	3,787,700
Indirect Costs - Offsite Costs (3%)	1,376,200
Contractors Margin and Profit (9%)	4,252,500
Applications (5%)	2,575,100
Contingencies (excluding pumps) (40%)	17,710,900
Contingencies for pumping stations (40%)	3,920,000
Total Cost Estimate (Excluding Operating Expenses)	**$77,222,400**
Annual Operating Expenses (assume 2% of capex)	$ 1,514,200

A cost comparison has also been carried out for a 1 in 50 AEP levee. The majority of costs for a smaller levee would be comparable to the 1 in 100 AEP levee, including the size of the pump stations. The main difference would be the cost of the earthworks, as a lower levee (approximately 0.85 metres lower) would require less fill for construction. The Total Cost Estimate (excluding Operating Expenses) of a 1 in 50 AEP levee at Amberley RAAF Air Base would be approximately **$70,406,100** (91% of the 1 in 100 AEP levee cost).





Typical Earth Levee Cross-Section with road on crest

Figure 8-6 Location of Amberley Airbase Levee (1 in 100 AEP, no freeboard)

8.4.3.4 Hydraulic Impacts

8.4.3.4.1 1 in 100 AEP Levee

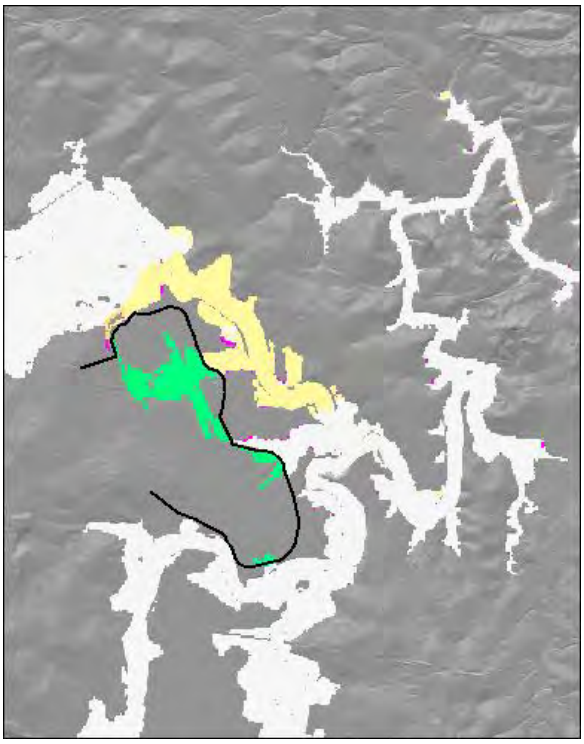
Potential impacts of the proposed Amberley RAAF levee on the hydraulic behaviour of flooding were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

The proposed Amberley RAAF levee constricts the Bremer River floodplain and reduces flood storage area for floodwaters from both the Bremer River and Warrill Creek. The impacts of the 1 in 100 AEP levee on flood levels in the vicinity of Amberley RAAF Air Base and downstream suburbs of Ipswich are presented in Figure 8-7 for the range of flood events from the 1 in 20 AEP to 1 in 200 AEP.

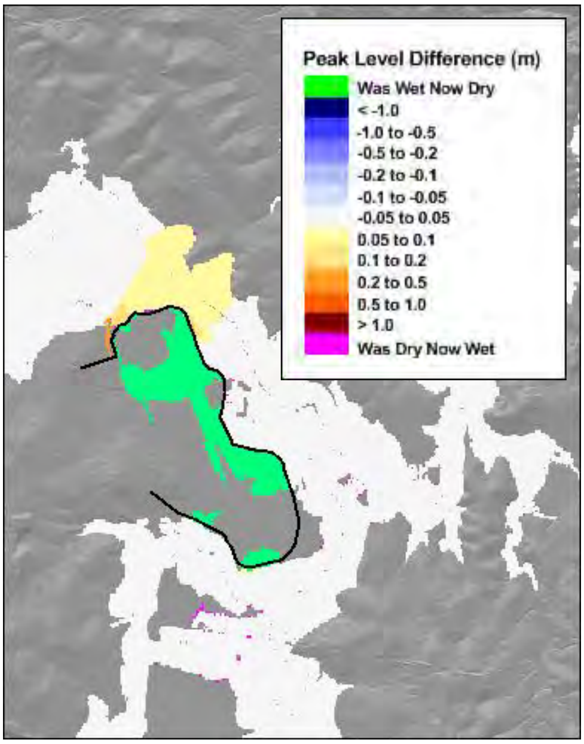
For floods smaller than the 1 in 20 AEP, impacts of the levee are minimal. For the 1 in 20 AEP and the 1 in 50 AEP flood, impacts are generally less than approximately 50mm and are confined to the area in the immediate vicinity of the levee, on the Bremer River. In a 1 in 100 AEP flood, Amberley RAAF Air Base currently provides significant flood storage. With the levee in place, flood levels adjacent to and downstream of the levee are increased, by up to just over 100mm, due to the reduction in floodplain storage. This increase in flood levels will have a detrimental effect on approximately 1,800 properties downstream of the air base. This includes about 1,400 residential and about 300 commercial properties that are currently located in HR1, HR2 and HR3 Potential Hydraulic Risk Areas. Also, there are 15 items of critical infrastructure in the Bremer River floodplain that would experience an increase in flooding as a consequence of the levee, including one piece of critical energy infrastructure.

In the 1 in 200 AEP event, the levee is overtopped and the air base is re-engaged as a flood storage area. Consequently, the impacts of the levee on the 1 in 200 AEP event are localised and generally minor, although a small reduction in flood levels within the Deebing Creek area is picked up by a relatively large number of properties (~700). For floods larger than the 1 in 200 AEP event, there are no material impacts due to the levee.

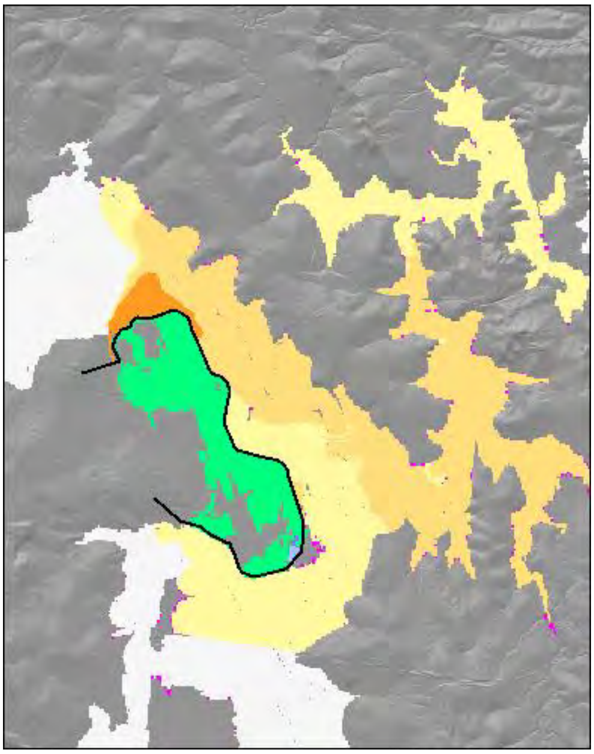
A summary of the impacts of the proposed Amberley RAAF levee on properties for the different AEP floods is given in Table 8-15. Note that maximum afflux presented in Table 8-15 is the maximum afflux in the adjacent waterway. It does not include highly localised impacts immediately adjacent to the levee.



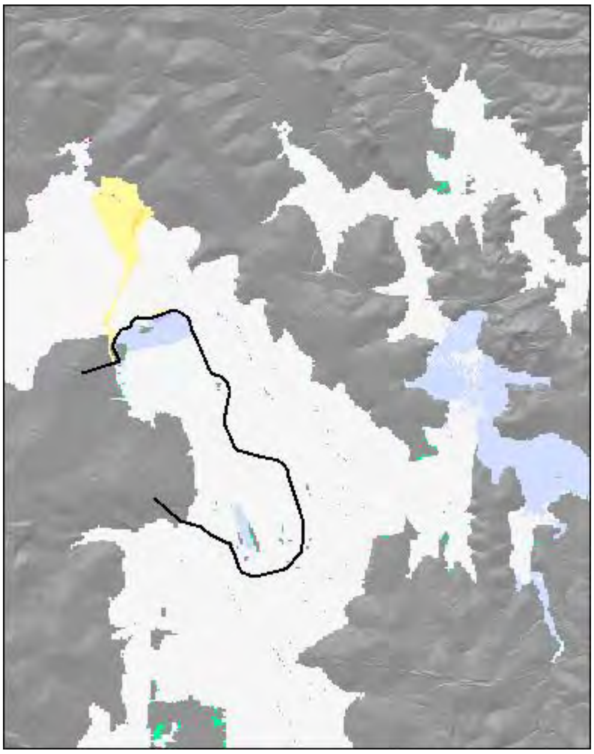
1 in 20 AEP



1 in 50 AEP



1 in 100 AEP



1 in 200 AEP

Figure 8-7 Amberley 1 in 100 AEP levee (no freeboard): Impacts 1 in 20 AEP to 1 in 200 AEP

Table 8-15 Summary of Amberley 1 in 100 AEP levee impacts on properties

AEP	Maximum afflux in river / creek centreline	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 5	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10	< 50mm*	< 50mm*	< 50mm*	0	0	0	2
1 in 20	< 50mm	< 50mm	< 50mm	1	28	35	9
1 in 50	**60mm**	< 50mm	< 50mm	0	37	146	52
1 in 100	**110mm**	**60mm**	< 50mm	0	87	1740	58
1 in 200	**110mm**	< 50mm	< 50mm	686	60	1	21
1 in 500	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.

[2] Building no longer affected by flooding.

[3] Building is flooded to a greater degree, either above or below habitable floor level.

[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.

8.4.3.4.2 1 in 100 AEP Levee with Floodplain Modification

As presented in Section 8.4.3.4.1, the 1 in 100 AEP levee will potentially have significant detrimental impacts on properties around Amberley RAAF Air Base as well as properties downstream of the air base, notably at One Mile and Yamanto. As an iterative step for assessment, the 1 in 100 AEP levee was assessed in combination with modification to the floodplain, lowering ground levels within the section of floodplain constricted by the levee. The aim of these modifications was to restore the conveyance of the Bremer River by increasing the floodplain area.

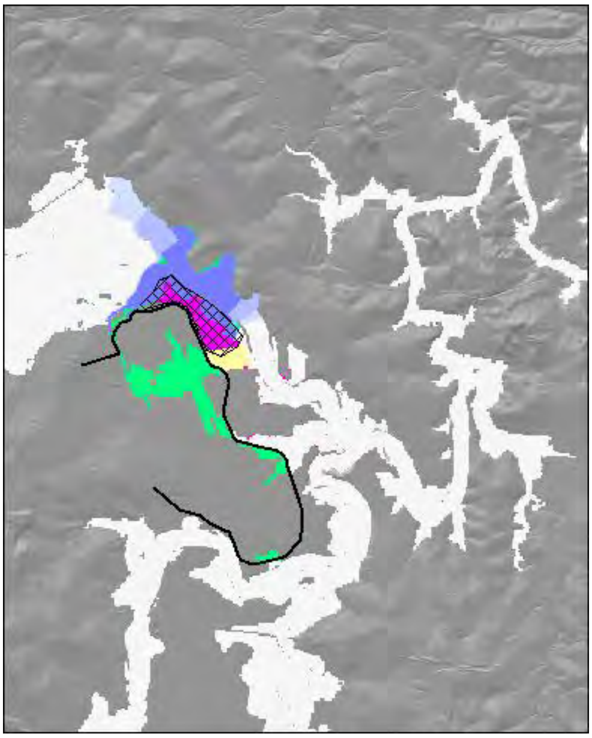
The results of the hydraulic modelling that included the floodplain modification (in addition to the 1 in 100 AEP levee) are presented in Figure 8-8, covering a range of events from the 1 in 20 AEP flood up to the 1 in 200 AEP flood. The results show that the zone of influence of the proposed floodplain landform change is limited to the immediate vicinity of the changed area, as well as a small area immediately upstream. In essence, the modification to the floodplain has remedied any potential afflux created upstream of the levee due to the constriction of the floodplain, but does not materially mitigate the increase in flood levels downstream which is due to the reduction in floodplain storage.

A summary of the impacts of the proposed 1 in 100 AEP levee with floodplain modification on properties for the different AEP floods if given in Table 8-16. Comparing this table with Table 8-15 it can be seen that the floodplain modification reduces the number of properties affected downstream by about 200, but still with some 1,600 properties affected at the 1 in 100 AEP flood level. Also, the small downstream benefit at the 1 in 200 AEP level is extended to about 1,000 properties, instead of about 700 for the condition without floodplain modification.

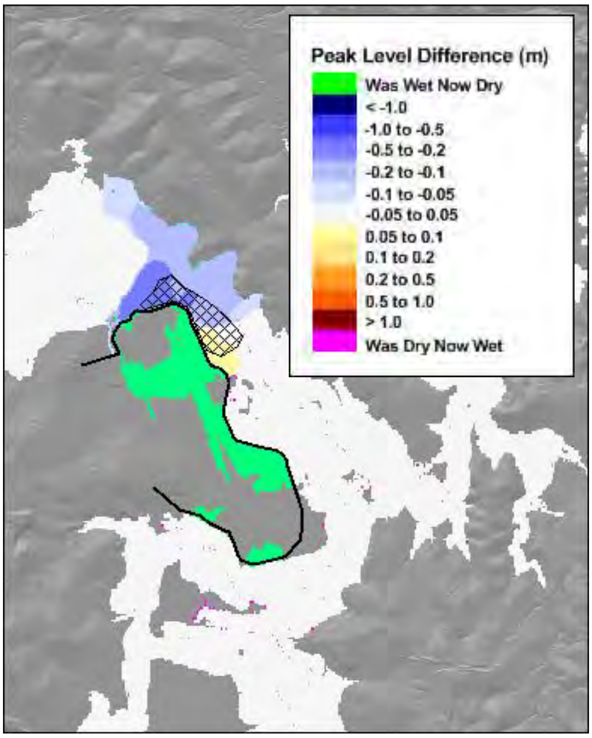
Table 8-16 Summary of Amberley 1 in 100 AEP levee plus floodplain modifications impacts on properties

AEP	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Number of properties where flooding is reduced	Number of properties where flooding is eliminated	Number of properties where flooding is increased	Number of properties where flooding is created
1 in 2	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 5	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10	< 50mm*	< 50mm*	< 50mm*	0	0	2	2
1 in 20	< 50mm	< 50mm	< 50mm	1	27	9	9
1 in 50	< 50mm	< 50mm	< 50mm	0	37	69	40
1 in 100	**90mm**	**50mm**	< 50mm	0	81	1563	50
1 in 200	< 50mm	< 50mm	< 50mm	1001	65	31	15
1 in 500	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0

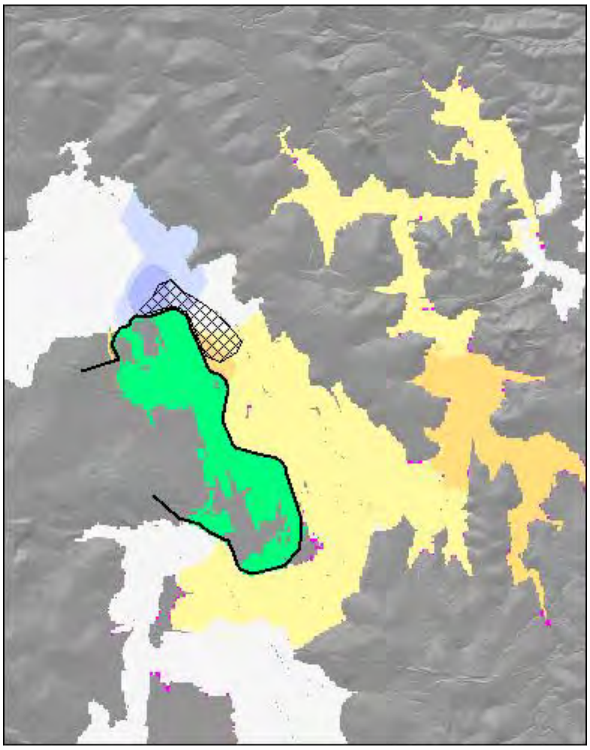
** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*



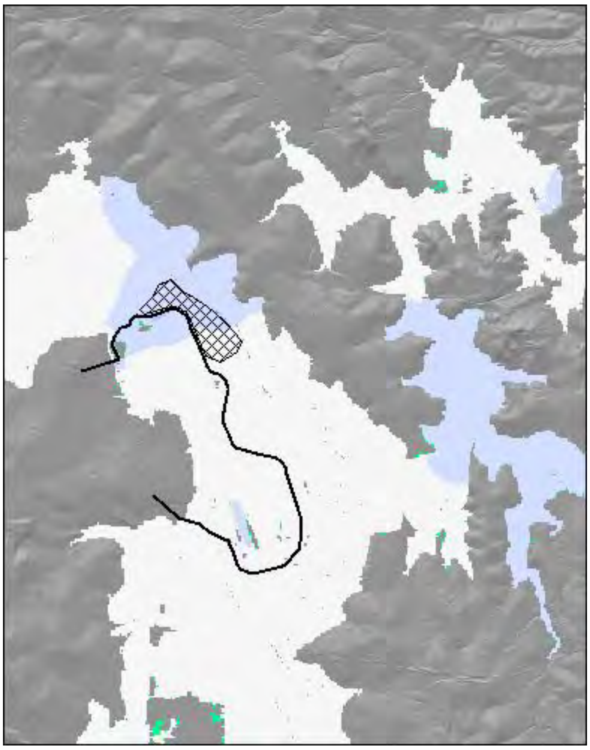
1 in 20 AEP



1 in 50 AEP



1 in 100 AEP with floodplain modification



1 in 200 AEP with floodplain modification

Figure 8-8 Amberley 1 in 100 AEP levee (no freeboard) with floodplain modification: Impacts 1 in 20 AEP to 1 in 200 AEP

8.4.3.4.3 1 in 50 AEP Levee

As discussed above, the 1 in 100 AEP levee will potentially have significant detrimental impacts on downstream properties. As a result, hydraulic assessment was undertaken adopting a levee height no higher than the 1 in 50 AEP flood level. As indicated in Section 8.4.3.3, there is only a marginal cost reduction associated with a lower levee compared to the 1 in 100 AEP levee.

Impacts of the 1 in 50 AEP levee on floods that are equal to or less than 1 in 50 AEP are the same as the impacts for the 1 in 100 AEP levee, and therefore are represented by the plots presented in Figure 8-7. The impacts on the 1 in 100 AEP and 1 in 200 AEP events are presented in Figure 8-9.

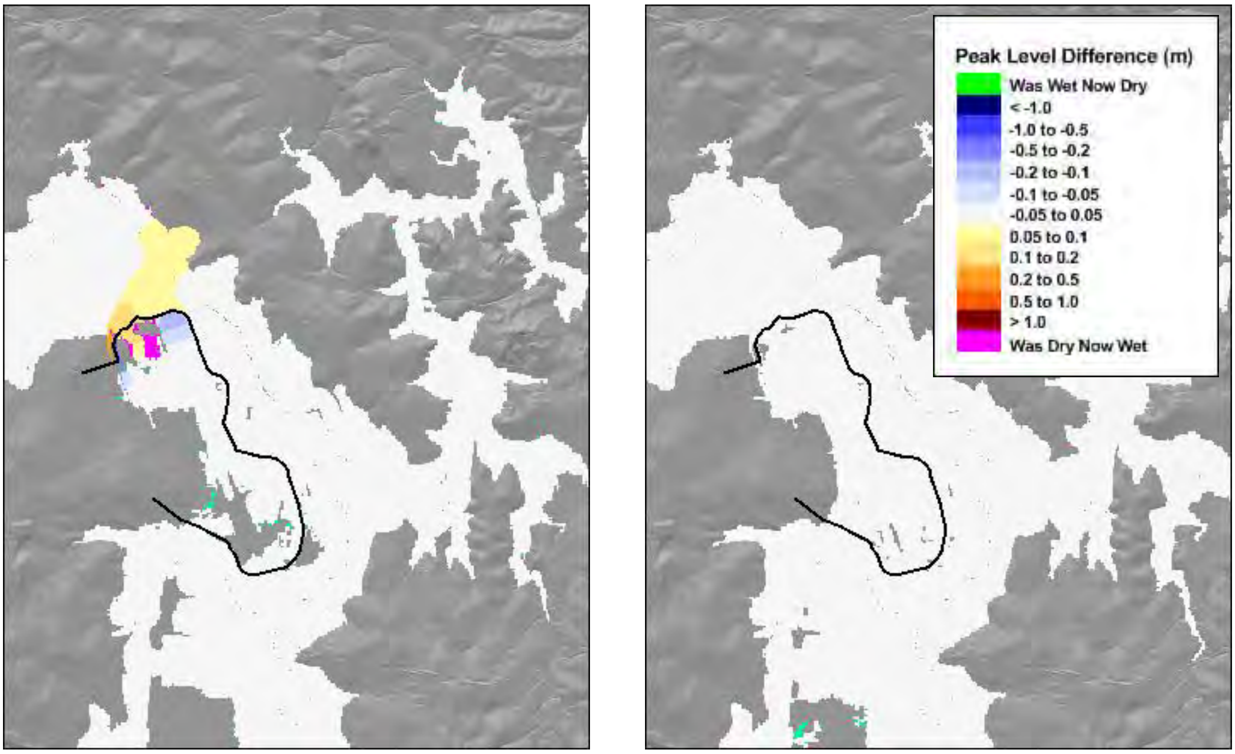
The analysis shows there is a relatively minimal impact on flood levels for the 1 in 100 AEP or 1 in 200 AEP events, though there remains some impact in the 1 in 50 AEP event.

A summary of the impacts of the proposed Amberley Air Base levee on properties for the different AEP floods is given in Table 8-17.

Table 8-17 Summary of Amberley 1 in 50 AEP levee impacts on properties

AEP	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Number of properties where flooding is reduced	Number of properties where flooding is eliminated	Number of properties where flooding is increased	Number of properties where flooding is created
1 in 2	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 5	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10	< 50mm*	< 50mm*	< 50mm*	0	0	0	2
1 in 20	**60mm**	< 50mm	< 50mm	1	28	35	9
1 in 50	**60mm**	< 50mm	< 50mm	0	37	146	52
1 in 100	**60mm**	< 50mm	< 50mm	8	52	0	2
1 in 200	< 50mm	< 50mm	< 50mm	0	39	0	3
1 in 500	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*



1 in 100 AEP

1 in 200 AEP

Figure 8-9 Amberley 1 in 50 AEP levee (no freeboard): Impacts 1 in 100 AEP and 1 in 200 AEP

8.4.3.5 Benefit / Cost Analysis

It is difficult to undertake a rigorous benefit/cost analysis on this option, as the significant intangible benefits associated with maintaining serviceability of the air base during flood events cannot be quantified, and cannot be inferred from a simple uplift of a commensurate tangible benefit.

From an economic perspective, however, it is worth noting that without any accompanying works or actions that would mitigate the increase in flood levels downstream, notably around One Mile / Yamanto, the potential increase in tangible damage as measured by an increase in AAD is $20,000 per annum for a 1 in 50 AEP levee, and $410,000 per annum for a 1 in 100 AEP levee.

Although the intangible benefits of a serviceable and functional air base are difficult to determine, the benefit/cost approach has been used to back-calculate what monetary benefit is needed in order to result in a net positive value, that is, a b/c ratio > 1.0. Based on the costs of the structure and the increase in AAD to downstream properties, the benefit needed to support a net positive value is a present value of $90 million (assuming 7% discount rate). This is equivalent to an annual average benefit of about $8 million over a period of 100 years.

A sensitivity of benefit / cost results to a potential Wivenhoe Dam upgrade option (as discussed in Section 8.1.4.2) was not carried out as the benefits of such works would be very limited in the vicinity of Amberley RAAF Air Base (pers. comm., Seqwater).

8.4.3.6 Multi-Criteria Review

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.4.3.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	The current HR1 and HR2 areas located behind the proposed levee would become HR3 areas. Existing HR3 areas in the vicinity are largely defined by the 1 in 500 AEP flood, which will not change as a result of the levee. The main benefit of the levee relates to serviceability of the air base during and immediately after a flood event. There are no residential properties that would benefit from the levee. In contrast, the levee (in isolation to other works) will increase flood levels downstream, which will increase the number of flooded properties around One Mile / Yamanto and increase inundation depths for properties that would already be inundated. Properties affected are mostly located in HR1 to HR3 areas. A 1 in 100 AEP levee would create a maximum 110mm afflux at One Mile, whereas a 1 in 50 AEP levee would create a maximum 60mm afflux. The positive benefits behind the levee are offset by the negative benefits downstream of the levee giving a net neutral score.	2.5
Improve time for evacuation (now and future)	The proposed levee at Amberley RAAF air base would not change evacuation time for any local residents. It is expected, however, that the merits of a levee at the air base would only be realised if it was built in concert with improving the flood immunity of major roads servicing the air base. Flood immunity of regional evacuation routes (i.e. the State controlled roads as identified in Section 4 Current Flood Risk) will not be improved by this option alone. Raising the Cunningham Highway (State controlled road with currently a 1 in 20 AEP immunity – refer Section 4 Current Flood Risk) was not investigated as part of this option in the Phase 3 (SFMP), however, it should form the basis of further investigations if this option is to be pursued further.	2.5

8.4.3.6.2 Social

Targets vulnerable community members or areas	As the proposed levee is targeting the protection of an item of critical infrastructure, any benefits to vulnerable communities and populations would be indirect, on the basis that improved serviceability of the RAAF air base would result in improved disaster management and emergency response during and immediately after a major flood event. The consequences of the levee are increased flood levels in the One Mile / Yamanto area (if not mitigated through other works). Section 4 Current Flood Risk indicates that One Mile and Yamanto are areas of more vulnerable people. Thus, this option could be counter-productive if downstream impacts are not offset. The impacts of a 1 in 50 AEP levee would be significantly less than a 1 in 100 AEP levee.	1.5
Social health benefits	Indirect social health benefits may result from improved serviceability of the air base, however, direct social health disbenefits would also occur in One Mile / Yamanto as a result of this option. Again, note that the impacts of a 1 in 50 AEP levee would be significantly less than a 1 in 100 AEP levee.	1.5
Improves community flood resilience (now and future)	The levee on the RAAF air base would be 'out of mind and out of sight' from the general community. It is unlikely that the levee would directly improve community flood resilience, and indeed, would potentially reduce resilience through higher flood levels in the One Mile / Yamanto area. The 1 in 100 AEP levee would increase flooding at 15 elements of critical infrastructure within the Bremer River floodplain, including one critical energy infrastructure item.	1.5
Recreation and amenity	There would be no change to recreation and amenity as a result of this option.	2.5
Connection and collaboration	There would be no impact on the community's connectedness to the river and watercourses.	2.5

8.4.3.6.3 Economic

Reduce damages and costs to residential property (now and future)	In the absence of other works that may mitigate increased flood levels downstream of the levee, this option would result in an increase in damages and costs to approximately 1,400 residential properties. The increase would be significantly less for a 1 in 50	1.5

	AEP levee (180 residential properties) compared to a 1 in 100 AEP levee.	
Reduce damages and costs to business and industry (now and future)	There are approximately 300 businesses that would potentially be detrimentally affected, through increased water levels from a 1 in 100 AEP levee. The 1 in 50 AEP levee in contrast would affect less than 20 businesses.	2.0
Option likely to be cost beneficial (now and future)	It is difficult to determine whether this option is cost beneficial given the intangible nature of benefits from having a more serviceable and accessible RAAF air base during and after a major flood event. For the purposes of this preliminary assessment, it is assumed that the intangible benefits would be sufficient to support the investment in this infrastructure and therefore the score for this criteria is neutral.	2.5

8.4.3.6.4 Feasibility

Physical / technical (now and future)	The design and construction of the levee at Amberley would be relatively straightforward. There is an existing road which would serve as the base for the levee structure.	3.0
Legal / approval risk	Zoning of the Amberley airbase is in the Amberley Area Zone and the Amberley Airbase and Aviation Precinct. Land immediately surrounding the site includes land in the Rural Living zone. The levee would be an Impact Assessable Development Application under Schedule 10 of the Planning Regulation 2017, with IRC as the Assessment Manager and referral to SARA[21]. It could alternatively be dealt with by a local or Ministerial infrastructure designation development[22]. Pumping stations in the Amberley Area zone are likely to be accepted development (not requiring approval) but this will need to be reviewed further if locations changed. Approval for this development would be likely, noting that it will require comprehensive engineering documentation. There is also a statutory requirement for public notification where submitters have appeal rights.	3.0

[21] To be assessed under State Development Assessment Provisions, State Code 19 Category 3 levees (assessed by Council), and Schedule 10 of Water Regulation 2016 Code for assessment of development for construction or modification of particular levees (assessed by SARA). Documentation would likely need to include: vulnerability and tolerability assessment report; report identifying benefits and impacts to people and property; levee operations and maintenance manual; update to Ipswich City Council's Local Disaster Management Plan to reflect any changes in emergency response; safety and stability of the structure; and community safety for failure or overtopping.

[22] This assessment pathway would require further discussions with relevant Authorities to determine if it would be a more efficient process than the typical assessment pathway.

	Land owners consent and/or an application to undertake works in a road reserve will also be required.	
Potential for additional funding sources	Given the works would be on Defence land and would benefit the ADF, the levee would most likely be funded through the Federal Government. To maximise the benefits of the works, improvements to the flood immunity of Cunningham Highway would also be required, which is under the jurisdiction of Queensland Department of Transport and Main Roads (DTMR). Co-funding between state and federal government is therefore expected for this option, and would be considered on a merits basis.	3.0

8.4.3.6.5 Attitude

Decision makers	Substantial co-ordination and co-operation between State and Federal governments would be required for this option to progress. The 1 in 50 AEP levee has less impact on downstream properties than the 1 in 100 AEP levee, and as such, may have a higher degree of support from decision makers.	3.0
Community	Results from the community survey (refer Section 11 Community Awareness and Resilience) showed residents of ICC had no particular preference for or against the use of levees. With no direct impacts, and only indirect benefits, this option may be difficult to garner community support. The potential for worsening of flooding on private residential properties would detract from the merits of the option. The 1 in 50 AEP levee would have less community opposition than the 1 in 100 AEP levee given the substantially smaller downstream impacts.	1.5

8.4.3.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	This option targets improvement to the functionality of the Amberley RAAF air base, which is an important transport centre for Defence, and would likely be critical during a natural hazard event, such as a flood, for mobilising and co-ordinating logistical support. For this option to be beneficial, it would also need matching improvements in the road network to and from the air base so that goods and personnel can be transported to support operations during an event. As such, road network improvements	5.0

	would also be expected (although not directly assessed or costed as part of this option).	
Protection of regional water supply quality and security – catchment protection (quality and yield)	This option would have no impact on regional water quality or quantity.	2.5

8.4.3.6.7 Environment and Natural Resource Management

Species impacts	There would be no impact to species richness or diversity.	2.5
Vegetation and habitat impacts	There would be no impact on vegetation and habitats. The location of the levee, on an existing road, means that there would be no net loss of habitat due to construction.	2.5
Ecosystem health connectivity (fish passage/fauna movement)	This option would have no impact on ecosystem health connectivity through fish and fauna passage.	2.5
Reduction in landscape salinity / improved moisture retention and groundwater recharge	There would be no impact to the landscape salinity or moisture, as this option does not encourage local ponding or water storage.	2.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	The levee may increase flood velocities in the vicinity of the levee as floodwaters are diverted away from the air base. There may be a minor potential for increased erosion of the riverbanks and overbank flowpaths under this scenario, but in general, impacts on catchment erosivity would be minor to negligible (giving a net neutral score).	2.5

8.4.3.7 Assessment of Option Against Multiple Criteria

As outlined in Section 8.10.2, the Amberley Air Base levee has an overall multi-criteria assessment result of -0.01, where a value of 0.0 represents a net 'no change' condition across the various criteria. Thus, with a negative score it has been determined that the option would have a net overall detrimental impact when weighed against the various criteria.

The air base levee option is ranked 12th out of the 16 options considered in the MCA (refer Table 8-64). Without any other ancillary mitigative works, the air base levee would exacerbate flooding at downstream properties, which has impacted heavily on the MCA scoring.

The lowest scoring criteria for this option were related to social values and residential damages (value of 1.5), while the best was the improvement to key infrastructure (value of 5.0) being the improved functionality of Amberley RAAF base during times of flood. There are no specific factors that would automatically rule out this option from further consideration. When combined with other options (notably the Warrill Creek dry flood mitigation dam), warrants more detailed investigations. Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.4.3.8 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The proposed Amberley RAAF levee will not address existing flooding outside of the air base land. Indeed unless other mitigation measures are put in place, there is the potential for the levee to worsen flooding in neighbouring residential areas.
environmental or social disadvantage	The Amberley RAAF levee will not create environmental disadvantage. Without mitigation, there is potential for the levee to exacerbate social disadvantage in areas where flooding is worsened.
an unacceptable economic cost to State, local government, community or individual	The Amberley levee would attract a very high cost and would benefit ADF. Ancillary and complementary works may have broader community benefits, however, these have not been scoped or costed as part of this Phase 3 (SFMP).
technical impracticability	The Amberley RAAF levee would be technically practical.
other unusual or unique circumstances	This option would have indirect community benefits (through improved serviceability of the RAAF air base) but direct disbenefits through increased flood levels in downstream locations. The disbenefits may be mitigated or offset through other works, not considered under this option. A combination of the RAAF levee and a flood mitigation dam on Warrill Creek is explored in Section 8.7.3

8.4.4 Woogaroo Creek, Goodna (1 in 50 AEP)

8.4.4.1 General Description of Option and Assessment

Woogaroo Creek drains a large catchment containing the suburb of Goodna, in Ipswich council area. In 2011, backwater from the Brisbane River inundated the lower reaches and floodplain of Woogaroo Creek, causing significant damage to residential and business areas. Flood waters during 2011 peaked in Woogaroo Creek at about 16.2m AHD (BMT WBM, 2017), with depths of flooding within and around Goodna reaching several metres deep.

Selected design flood results generated in the Phase 2 (Flood Study) are shown in .

Table 8-18 Flood levels at Woogaroo Creek (from BMT WBM, 2017)

Design Event	Peak level (AHD) at Woogaroo Creek
1 in 20 AEP	8.4m
1 in 50 AEP	12.6m
1 in 100 AEP	16.5m

The option consists of constructing a barrier across the mouth of Woogaroo Creek and installing flood gates, to prevent the backwater inundation of Goodna from Brisbane River flooding. The 1 in 50 AEP flood is fully contained within the banks at the mouth of Woogaroo Creek, providing an opportunity to prevent backwater inundation via a simple in-channel structure. The 1 in 100 AEP flood, which is almost four metres higher than the 1 in 50 AEP flood, would overtop the banks of the Brisbane River over extensive areas upstream and downstream of Woogaroo Creek.

To prevent backwater inundation into Woogaroo Creek during the 1 in 100 AEP flood would require a high levee (up to 4 metres) along the southern bank of the Brisbane River over a distance of approximately 1.5 kilometres. Given the impractical nature of such a structure, this option explores the benefits, costs and impacts of a 1 in 50 AEP structure, limited essentially to an in-channel floodgate and levee structure.

8.4.4.2 Concept Design

To achieve the desired flood immunity (1 in 50 AEP) with a freeboard (0.5m), a levee structure would require a crest level no lower than 13.10 m AHD. The barrier would consist of an earth levee on either bank of the creek (200m in length), which would tie into high ground within Richardson Park and the adjacent Wolston Park Golf Club. The average height of the levee would be 2.7m and the batters would need to be 1 in 2 due to space constraints. The location of the levee and flood gates can be seen in Figure 8-10. An example of a similar (but smaller than proposed) sluice gate is presented in Figure 8-11, while a concept drawing of a similar flood gate structure in flood, and during normal times, is shown in Figure 8-12.

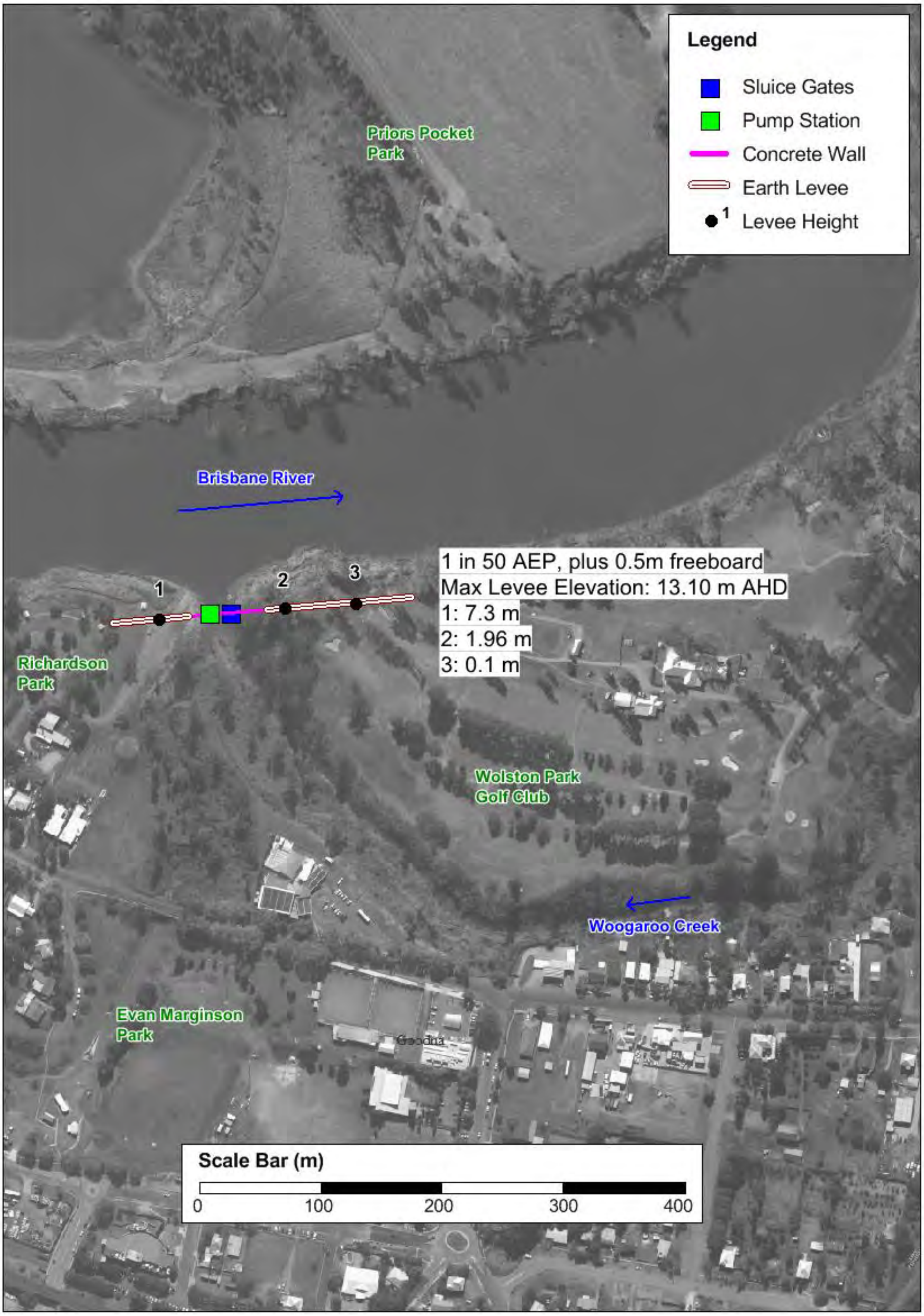


Figure 8-10 Location of Woogaroo Creek levee and sluice gates

Figure 8-11 Example of sluiced flood gate, Halstead, UK (source: cc-by-sa/2.0 - © Nigel Cox - geograph.org.uk/p/1457081)

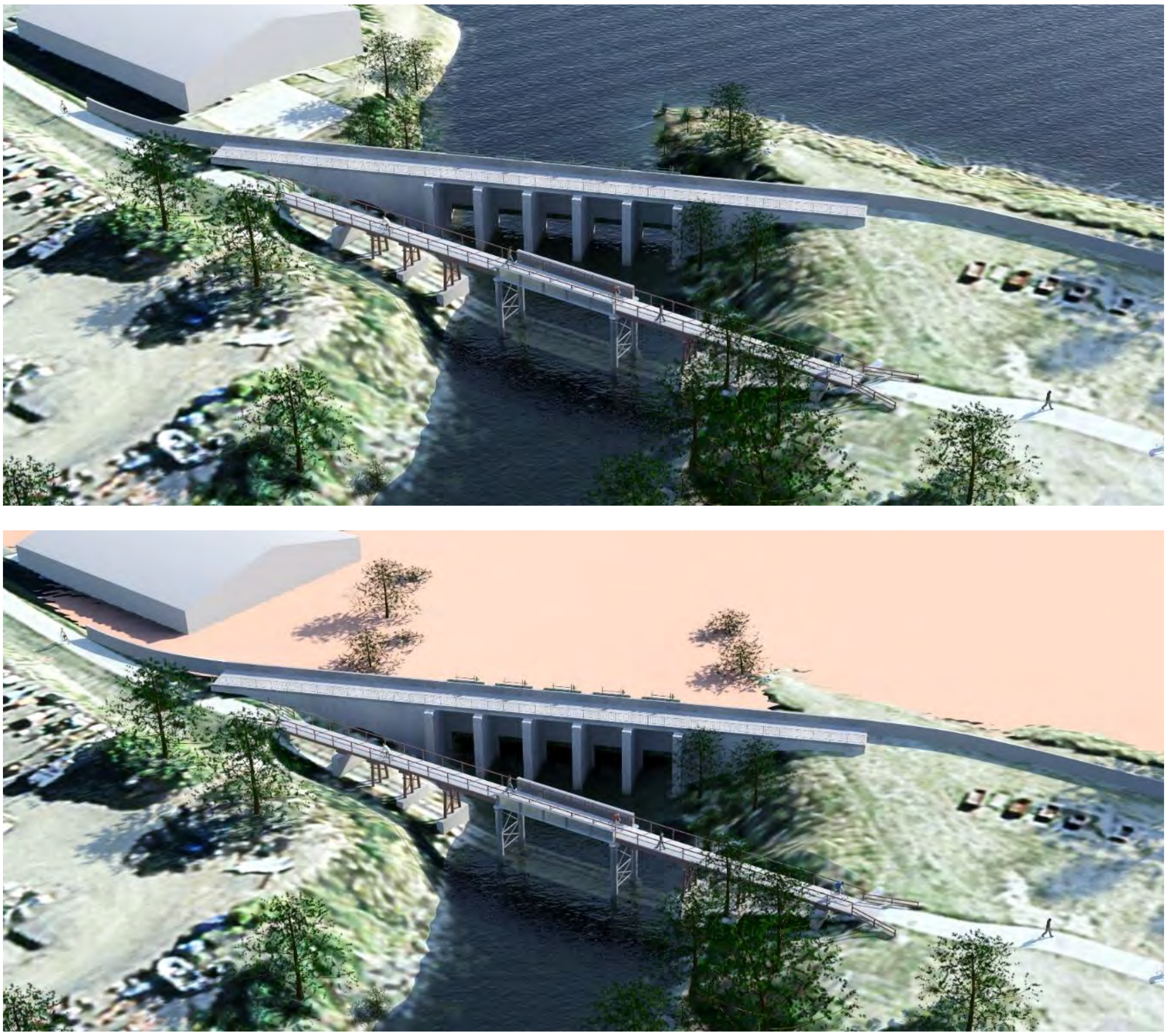


Figure 8-12 Example of sluice flood gate – concept plan, Saltwater Ck, Queensland (source: DILGP, Saltwater Creek study)

A concrete wall situated across Woogaroo Creek would include the flood gates (likely to be sluice gates) and be approximately 50m long. The height of the wall depends on the elevation of the creek bed. However, it is assumed that it would likely be approximately 14m high. With an active channel width of 22m at the location of the barrier, four large flood gates (5.9m wide and 3.6m high) would be required to convey the Woogaroo Creek flow.

When closed, the flood gates would restrict Brisbane River floods from backing up into Woogaroo Creek. However, closed gates would also prevent the local catchment from discharging into the Brisbane River. Woogaroo Creek has a catchment of $67km^2$ and is likely to generate significant volumes of runoff from coincident local flood events. With the gates closed, the volume of floodwater generated from the local catchment would inundate the floodplain. The volume associated with a 1 in 5 AEP, 24 hour duration local flood event would be sufficient to generate similar flood extents as the 1 in 50 AEP Brisbane River flood.

To prevent local flood inundation, pumping stations would be required to drain the runoff from the Woogaroo Creek catchment. The pumps would require a capacity to drain the flow for a 1 in 5 AEP, 24 hour duration flood event. The 1 in 5 AEP flood event was selected to determine the pump capacity, as the potential volume for a 1 in 5 AEP local flood event is the equivalent volume as the 1 in 50 AEP Brisbane River flood event. The 24 hour storm duration was selected for the pump analysis, as it was deemed a feasible duration for water levels in the Brisbane River to remain high enough to prevent free drainage.

If this option is to be pursued in the future, detailed assessment would need to consider the coincident probabilities of flooding in order to more accurately size and cost the pumps.

8.4.4.3 Indicative Cost

The indicative costing of the proposed Woogaroo Creek levee and sluice gate structure is provided in Table 8-19 and has been based on the following assumptions:

- The levee height is based on the Brisbane River Catchment Phase 2 (Flood Study) (BMT WBM, 2017) and, therefore, does not take into account the potential increase in water level as a result of the option;
- No land purchase will be required;
- The existing topsoil is not contaminated and, therefore, requires no treatment;
- The levee would be built with imported materials;
- The dimensions of the levee would be 3m wide at the crest and 1 in 2 batters;
- The construction will have access to Noel Kelly Drive;
- Site setup would be situated in the playing fields west of Woogaroo Creek;
- The pumps are capable of a pumping out a 1 in 5 AEP local event and the pumping station will require a capacity of 80 m^3/s; and
- The cost of the sluice gate was estimated based on a similar size gate costed for the Bundaberg Flood Protection Study (DILGP, 2016).

Table 8-19 Indicative Cost for Woogaroo Creek levee and sluice gate (2017 costs)

Description	Cost ($)
Traffic and Environmental Management Plans	980,800
Temporary works	2,044,800
Civil / Structures	3,224,700
Earth Works	409,800
Other	1,600,000
Pumping stations	78,400,000
Total Direct Job Cost	**$86,660,100**
Indirect Job Costs – On-Site Costs (31%)	26,864,600
Design Costs (9%)	10,217,200
Indirect Costs - Offsite Costs (3%)	3,712,300
Contractors Margin and Profit (9%)	11,470,900
Applications (5%)	6,946,300
Contingencies (excluding pumps) (40%)	26,988,500
Contingencies for pumping stations (40%)	31,360,000
Total Cost Estimate (Excluding Operating Expenses)	**$204,219,900**
Annual Operating Expenses (assume 2% of capex)	$ 4,084,400

8.4.4.4 Hydraulic Impacts

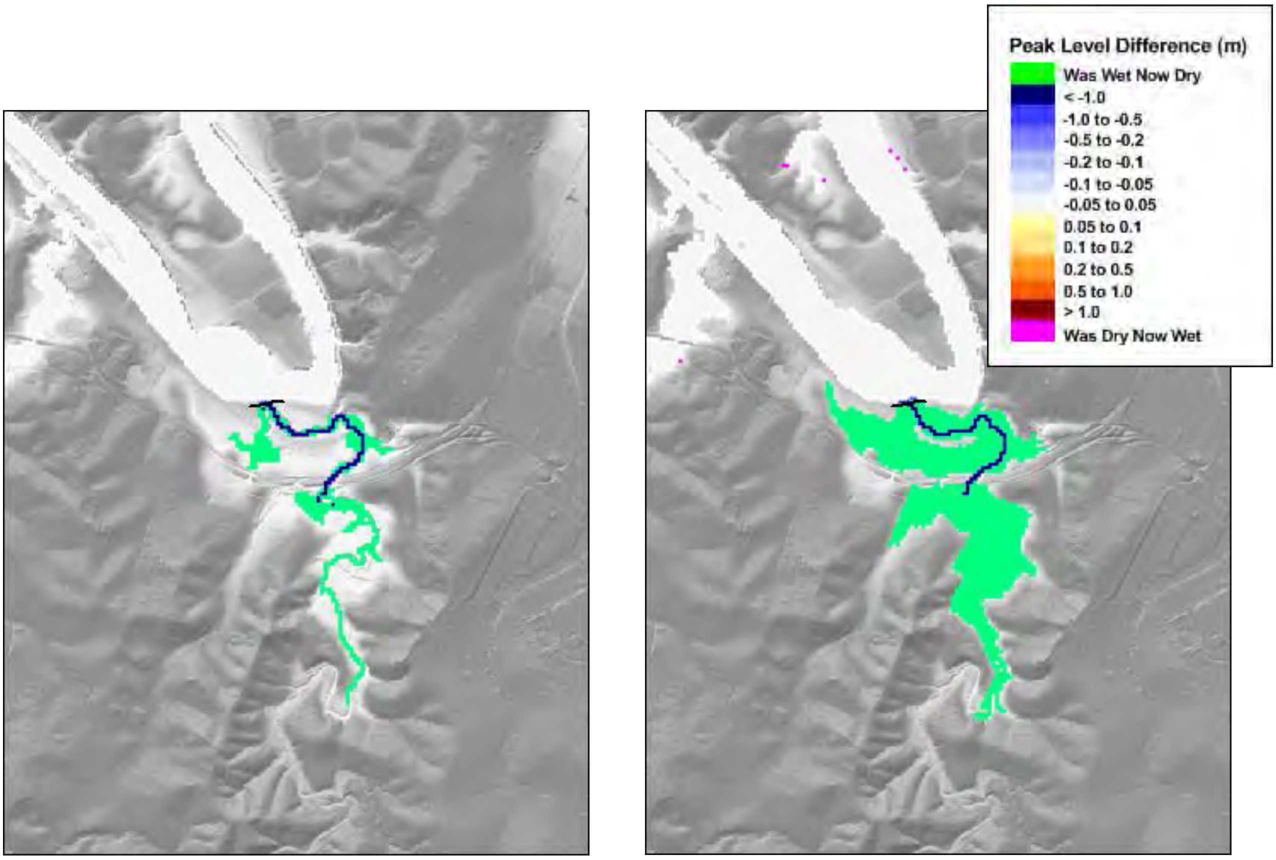
Potential impacts of the proposed Woogaroo Creek levee and sluice gate on the hydraulic behaviour were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

Woogaroo Creek is a backwater zone of the Brisbane River during large floods in the Brisbane River. For events up to and including the 1 in 50 AEP flood, excluding backwater into Woogaroo Creek (that is, essentially a loss in flood storage area) does not have a notable impact on flood behaviour in the Brisbane River. Impact plots are shown in Figure 6-11 (no impact is recorded for events less than 1 in 20 AEP and therefore have not been shown).

For the 1 in 100 AEP or larger events, the levee and sluice gate structure would be overtopped as Brisbane River flood levels exceed the crest level of the structure. Consequently, there is no impact on flood behaviour in the Brisbane River for floods that are 1 in 100 AEP or larger.

While there is no impact in Brisbane River flood levels downstream of the structure, it will provide protection to properties and assets upstream for events up to and including the 1 in 50 AEP event, providing that pumping stations are operational to remove the ponding of runoff from local catchment flows behind the structure.

A summary of the impacts for the different AEP floods if given in Table 8-20.



1 in 20 AEP 1 in 50 AEP

Figure 8-13 Impact of Woogaroo Creek levee and sluice gate for 1 in 20 and 1 in 50 AEPs

Table 8-20 Summary of Woogaroo Creek levee and sluice gate impacts on properties

AEP	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 5	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 20	< 50mm	< 50mm	< 50mm	1	10	1	3
1 in 50	< 50mm	< 50mm	< 50mm	0	278	145	68
1 in 100	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 200	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 500	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*
[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.
[2] Building no longer affected by flooding.
[3] Building is flooded to a greater degree, either above or below habitable floor level.
[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.

Benefits of the Woogaroo Creek levee and sluice gates would extend to about 280 properties, most of which are residential. These properties are currently located within HR1 and HR2 Potential Hydraulic Risk areas, and as such, are a priority for regional floodplain management.

8.4.4.5 Benefit / Cost Analysis

A summary of the benefit / cost analysis for the Woogaroo Creek 1 in 50 AEP flood gate option is presented in Table 8-21.

The flood gate (and pumping stations etc), with a capital cost of $204m and an annual maintenance cost of over $4m, will generate a net annual average benefit of $900,000, leading to a benefit/cost ratio of 0.05 when adopting a discount rate of 7% over a 100 year period.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-21. If benefits were limited to reductions in tangible damages, the annual average benefit would reduce to $600,000 per year, giving a net benefit/cost ratio reduces to 0.03. Potential upgrades to Wivenhoe Dam could have an adverse impact in this location, resulting in marginal increase in the benefits of this option, $1.0m per year, although the benefit/cost ratio would still be approximately 0.05. Sensitivity was also undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 0.07, while for a higher discount rate of 10%, the benefit/cost ration reduces to 0.03.

Table 8-21 Benefit/cost analysis summary for Woogaroo Creek 1 in 50 floodgate option

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case [1]	288.7	287.8	0.9	**0.05**
Sensitivity 1: No intangibles	186.8	186.3	0.6	**0.03**
Sensitivity 2: with Wivenhoe up.	213.2	212.2	1.0	**0.05**
Sensitivity 3: 4% discount rate				**0.07**
Sensitivity 4: 10% discount rate				**0.03**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

8.4.4.6 Multi-Criteria Review

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.4.4.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	Approximately 280 properties currently located within HR1 and HR2 Potential Hydraulic Risk areas benefit directly. Being in HR1 and HR2 areas, these properties would represent a priority for regional floodplain management. Events larger than the 1 in 50 AEP would still impact all these properties with a damage profile the same as existing conditions. The potential hydraulic risk would largely remain the same except that the area of HR1 within the Woogaroo Creek floodplain would change to HR2 (as HR2 in this vicinity is controlled by the 1 in 100 AEP event). HR2 is still considered to represent high flood risk.	3.0
Improve time for evacuation (now and future)	Approximately 280 properties would have more time to respond to a larger event that would potentially overtop the levee and sluice gate structure. However, once the structure is overtopped, the valley will fill quickly with Brisbane River floodwater (potentially much faster than the general rise of the Brisbane River flood level), which may increase the risk to those who have not heeded warnings to evacuate. Fortunately, due to the incised nature of Woogaroo Creek valley, travel time to reach flood-free land would be short (subject to traffic and weather conditions). Flood immunity of regional evacuation routes (i.e. the State controlled roads as identified in Section 4 Current Flood Risk) will not be improved by this option.	3.0

8.4.4.6.2 Social

Targets vulnerable community members or areas	The population within and around Goodna that would benefit from this option is considered to be more vulnerable than average, across all vulnerability indices, as detailed in Section 4 Current Flood Risk.	4.0
Social health benefits	The reduction in the number of residential properties inundated for floods up to and including the 1 in 50 AEP event would lead to some social health benefits, although this would be limited to the benefit footprint and only up to a 1 in 50 AEP flood.	3.0
Improves community flood resilience (now and future)	The construction of a flood levee and sluice gate in Woogaroo Creek may have some positive benefits for community awareness, as it highlights to residents the potential for flooding. However, it introduces significant residual risk, especially as the design immunity is relatively low. As the structure is located	2.5

	remote from the community, there is the potential for it to be forgotten thus providing limited benefit for resilience. Alternatively, the community may have an expectation that it will protect them and therefore not consider other measures, or pro-active responses. As the design level of the structure is lower than the level of the flood experienced in 2011, community confidence in the structure may also be limited. No critical infrastructure items would benefit from this option.	
Recreation and amenity	There would be little change to recreation and amenity as a result of this option assuming that public access to the levee and structure would be restricted for safety and security reasons.	2.5
Connection and collaboration	This option would potentially detract from the community's connectedness to the river and watercourses as it involves constructing a very large artificial structure across the natural waterway.	1.5

8.4.4.6.3 Economic

Reduce damages and costs to residential property (now and future)	About 240 residential properties will benefit from this option. Benefits extend up to the 1 in 50 AEP flood only, as in larger floods, the structure will be overtopped and inundation of Woogaroo Creek floodplain will be as per existing. The total average annual benefit of the proposed structure (for all property types) amounts to approximately $900,000 per year, including allowance for intangible benefits.	3.0
Reduce damages and costs to business and industry (now and future)	There are a small number of commercial properties within the Woogaroo Creek floodplain that would benefit from this option (~20), with protection limited to floods up to and including the 1 in 50 AEP event.	2.5
Option likely to be cost beneficial (now and future)	The Woogaroo Creek structure is very expensive, for a relatively small net economic benefit. The b/c ratio therefore is very low, as outlined in Table 8-21.	1.5

8.4.4.6.4 Feasibility

Physical / technical (now and future)	The design and construction of the levee and sluice gates at the mouth of Woogaroo Creek would be relatively straightforward. Further information on geotechnical conditions will be essential to confirm design requirements and technical feasibility.	3.0

Legal / approval risk	The proposed structures will be located within the Woogaroo Creek waterway (mapped as a 'major waterway') and on either side. This waterway forms the boundary between the Brisbane City local government area (on the eastern side) and the Ipswich City local government area (on the western side). The land either side of the waterway is described as follows: • Western/Ipswich City side – contains Richardson Park which is in the Recreation Zone under the Ipswich planning scheme • Eastern/Brisbane side – contains Wolston Park Golf Club which is in the Community Facilities Zone (CF1 – Major Health Care) and on the local heritage register. This site is also part of a State heritage listing associated with the Wolston Park hospital complex. The structures will likely require development applications assessable by Ipswich City Council, Brisbane City Council and SARA. These applications are for building works and operational works that are Waterway Barrier Works and works within the erosion prone area of the Coastal Management District (as this part of Woogaroo Creek is a tidal waterway), and works in a Queensland heritage place. Any applications will require comprehensive engineering documentation, and technical assessments to address impacts on heritage, fishways, ecological processes (including matters of state ecological significance) and coastal processes to address development requirements outlined in the Ipswich planning scheme, Brisbane City Plan and State codes. For waterway barrier works, justification will need to be provided by way of demonstrated need, and also identifying the unviability of alternatives which do not involve constructing or raising waterway barrier works. In relation to heritage, further investigations will need to be undertaken to confirm the location of the works and areas of archaeological interest relating to the site of an early graveyard that is understood to be located within the Wolston Park Golf Course (as per heritage register listing, Criterion C). Land owners consent from all parties will be required to support the applications.	3.0

Potential for additional funding sources	The benefit-cost assessment indicates that there is very low return on investment for such a structure through reduction of damages over time. As such, it would be difficult to formulate a business case that would receive positive support from potential funding bodies.	1.5

8.4.4.6.5 Attitude

Decision makers	With a low economic return on this option, it is unlikely to receive widespread support for implementation.	1.5
Community	Results from the community survey (refer to Section 11 Community Awareness and Resilience) showed residents of ICC had no particular preference for or against the use of levees. While there are a small number of community members that would benefit from this option, they would only be protected for floods up to the 1 in 50 AEP. With a high cost and limited benefits, it is expected that this option would not have much community support.	1.0

8.4.4.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	This option will improve local access on roads within the Woogaroo Creek floodplain for floods up to the 1 in 50 AEP event. This includes providing road access for some 570 residential properties within the floodplain, which may assist in evacuation during a flood event. This option would have no impact on the susceptibility of the rail network or Ipswich Motorway in this vicinity as they are only impacted by floods larger than the design immunity of 1 in 50 AEP.	3.0
Protection of regional water supply quality and security – catchment protection (quality and yield)	This option would have no impacts on regional water quality or quantity.	2.5

8.4.4.6.7 Environment and Natural Resource Management

Species impacts	There would be no significant impact to species richness or diversity. The structure would impede aquatic species movement during times of flood, however this would be for relatively short periods of time. Nonetheless, there may be some impact on	2.0

	species that rely on floods for movement through the river environment.	
Vegetation and habitat impacts	There would be no significant impact on terrestrial vegetation and habitats. The location of the levee and relatively small footprint, means that there would be little to no net loss of valued habitat due to construction. The restriction of flow during times of flood, however, may have an impact on aquatic habitats that rely on floods, including upstream wetlands.	2.0
Ecosystem health connectivity (fish passage/fauna movement)	There would be no significant impact on ecosystem health connectivity through fish and fauna passage with the exception of fish passage during times of flood. It is recognised that waterways provide a natural corridor for some species. The structure proposed is unlikely to have a significant detrimental effect on species movement in the long term. Pondage of local flood waters behind the levee has the potential to form anoxic in-stream conditions through the decay or organic matter washed into waterways during the flood event. On the basis that ponded water is pumped into the Brisbane River, this would not be of concern, however, if pumping was to be insufficient and allow extended ponding of floodwaters, anoxia within the water may degrade the ecosystem health with the potential for lasting impacts.	2.5
Reduction in landscape salinity / improved moisture retention and groundwater recharge	There would be no impact to the landscape salinity or moisture, as this option does not encourage local ponding or water storage.	2.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	There would be no impact to the erosive capacity of the catchment or channel stability providing that higher velocities in and around the structure itself are managed through bed and bank protection works.	2.5

8.4.4.7 Assessment of Option Against Multiple Criteria

As outlined in Section 8.10.2, the Woogaroo Creek levee and sluice gates has an overall multi-criteria assessment result of 0.07, where a value of 0.0 represents a net 'no change' condition across the various criteria. The levee is ranked 10th out of the 16 options considered in the MCA (refer Table 8-64).

The lowest scoring criterion for this option was the community attitude criterion (value of 1.0), while the best related to safety of people and reduced residential damages (value of 3.0). Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.4.4.8 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The proposed Woogaroo Creek levee and sluice gates will address flooding for events up to the 1 in 50 AEP flood only. Larger events will still impact on the local population at risk in Goodna with no residual mitigation by the levee.
environmental or social disadvantage	The Woogaroo Creek levee and sluice gates should not create environmental or social disadvantage providing they are operated in accordance with design and do not allow extended periods of ponding of local flood waters.
an unacceptable economic cost to State, local government, community or individual	The Woogaroo Creek levee and sluice gates would require a very significant investment given the limited numbers of beneficiaries. This could be considered an unacceptable economic cost.
technical impracticability	The levee and sluice gates would be technically feasible but may have some construction challenges given the site constraints and unknown geotechnical conditions.
other unusual or unique circumstances	There are no obvious other unusual or unique circumstances that would preclude the feasibility of this option.

8.4.5 Goodna CBD (1 in 100 AEP)

8.4.5.1 General Description of Option and Assessment

The Goodna CBD experienced deep flood inundation during the 2011 event. Goodna CBD is located on a small enclave of the Woogaroo Creek floodplain and has very little catchment draining into it directly. There are approximately 30 business properties located within the Goodna CBD.

This option involves providing a defensive structure around the Goodna CBD in order to prevent backwater inundation of the properties within. During the 2011 flood, Brisbane River floodwaters overtopped the Ipswich Motorway, and flowed through the large road underpass of the motorway and adjacent railway line. The option therefore consists of constructing a flood barrier along a section of the Ipswich Motorway and installing very large floodgates in the underpass to prevent the inundation of Goodna CBD.

Results from the Phase 2 (Flood Study) indicate that the commercial and retail properties within the Goodna CBD will become inundated between a 1 in 50 and 1 in 100 AEP flood event, noting that there is almost 4 metres difference in flood level between these two events.

The 1 in 100 AEP was chosen as the design level for this event because smaller floods would not inundate the Goodna CBD, while larger floods would involve infrastructure that was excessively large, given that the 1 in 200 AEP flood is a further 2.2 metres higher than the 1 in 100 AEP flood..

8.4.5.2 Concept Design

To achieve the desired flood immunity (1 in 100 AEP), a barrier would need to have a crest level no lower than 16.5 m AHD. The barrier would consist of a concrete wall situated on a section of the Ipswich Motorway (350m in length), which would tie into high ground. The wall is required to prevent the Ipswich Motorway from being overtopped, which has a low point of 14.5m AHD (some 2 metres lower that the peak 1 in 100 AEP flood level). The average height of the wall would be 1.7m, with a maximum height of 2.6m.

Large floodgates would be required to span the Church Street underpass to prevent the flood water from inundating the CBD and still maintain this transport route during non-flood times. The Church Street underpass would likely require three separate floodgates, due to the width of the road and pedestrian access. The depth of water on Church Street during a 1 in 100 AEP flood would be up to approximately 7.3m, which precludes the use of temporary flood barriers, as discussed further in Section 8.5.

The location of the levee and floodgates can be seen in Figure 8-14, while an example of a similar floodgate using in the USA is shown in Figure 8-15.

A second flood gate would be required to cross Brisbane Road to prevent inundation of the CBD from a secondary flow path.

In addition to the flood barrier and floodgates, a small pumping station would be required to drain the local surface water when the floodgates were closed.

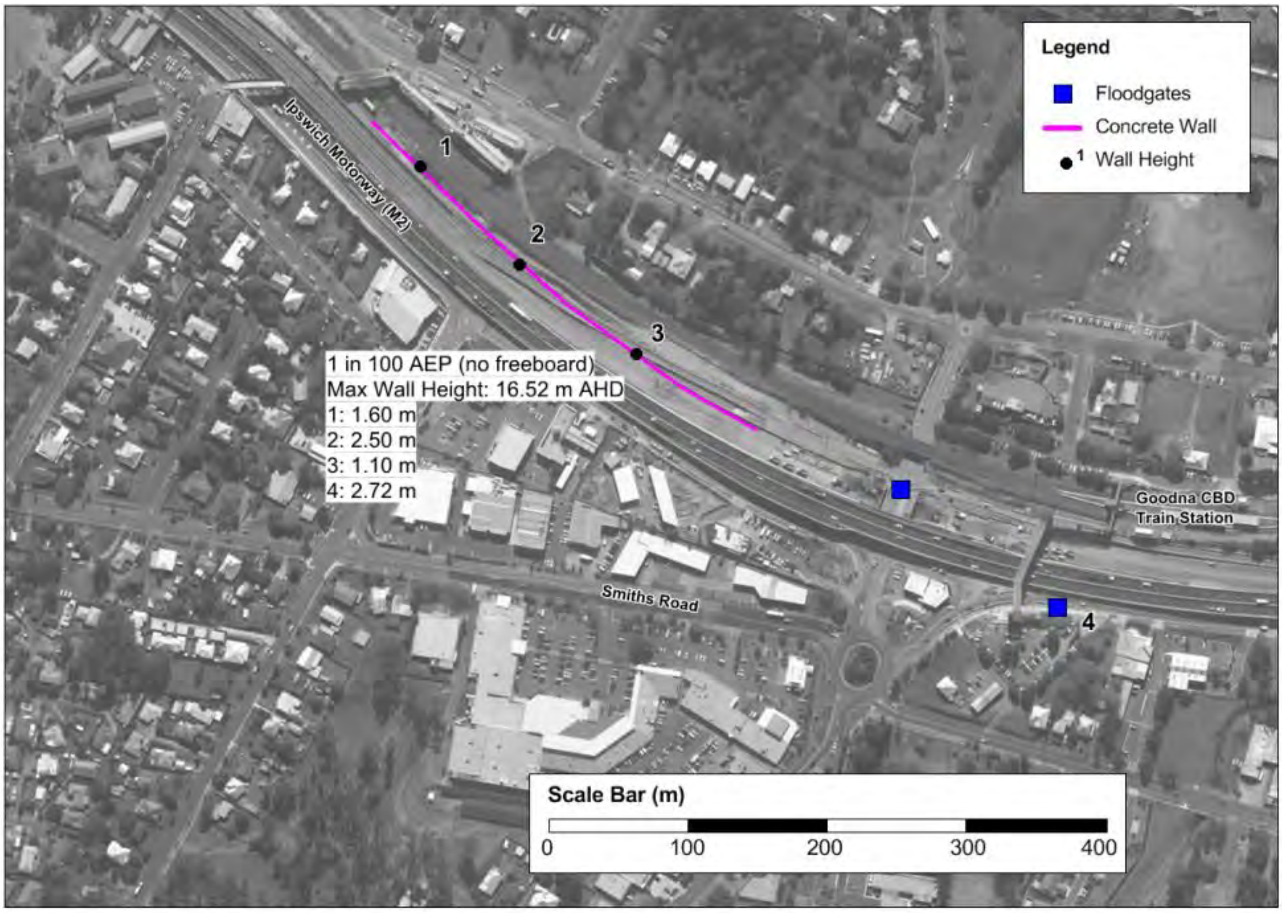


Figure 8-14 Location of Goodna CBD wall and floodgates

Figure 8-15 Floodgate preventing backwater inundation from the Meremac River, USA, 31/12/15 (photo by David Carson, post-dispatch.com)

8.4.5.3 Indicative Cost

The indicative costing of the proposed Goodna CBD levee and flood gates is provided in Table 8-22 and has been based on the following assumptions:

- The flood barrier height is based on the Phase 2 (Flood Study) and, therefore, does not take into account the potential increase in water level as a result of the option;
- No land purchase will be required;
- The Ipswich Motorway embankment is suitable for use as a flood defence, which would require confirmation and agreement from the Department of Transport and Main Roads;
- Pumping Station will require a capacity of 1 m^3/s;
- Back flow prevention devices will need to be added to the trunk drainage network beneath Church Street;
- The flood barrier would be located within the Ipswich Motorway corridor and require significant traffic management;
- Three flood gates (5.9m wide and 3.6m high) would be constructed across Church Street, with appropriate traffic safety measures in place between the gates;
- A single flood gate (5.9m wide and 3.6m high) would be constructed across Brisbane Road.

Table 8-22 Indicative Cost for Goodna CBD levee and flood gates (2017 costs)

Description	Cost ($)
Traffic and Environmental Management Plans	1,758,200
Civil / Structures	7,132,200
Earth Works	484,800
Other	1,600,000
Pumping stations	980,000
Total Direct Job Cost	**$11,955,300**
Indirect Job Costs – On-Site Costs (31%)	3,706,100
Design Costs (9%)	1,409,500
Indirect Costs - Offsite Costs (3%)	512,100
Contractors Margin and Profit (9%)	1,582,500
Applications (5%)	958,300
Contingencies (excluding pumps) (40%)	7,657,500
Contingencies for pumping stations (40%)	392,000
Total Cost Estimate (Excluding Operating Expenses)	**$28,173,300**
Annual Operating Expenses (assume 2% of capex)	$ 563,500

8.4.5.4 Hydraulic Impacts

Potential impacts of the proposed Goodna CBD levee and flood gates on the hydraulic behaviour of flooding within the Brisbane River were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

Woogaroo Creek, including the area around Goodna CBD, is a backwater zone of the Brisbane River during large floods in the Brisbane River. The Goodna CBD area becomes inundated when flood levels exceed a 1 in 50 AEP. The proposed Goodna CBD levee and flood gates would exclude this inundation for floods between the 1 in 50 AEP and 1 in 100 AEP. Floods in excess of the 1 in 100 AEP would overtop the proposed levee structure and would inundate Goodna CBD to levels comparable to existing conditions.

For floods up to the 1 in 50 AEP, there is no impact on Brisbane River hydraulics, as the Goodna CBD area would remain unaffected by flooding.

For the 1 in 100 AEP, the proposed works would isolate a small section of the Brisbane River floodplain, with a small loss of flood storage area. Impact plots for the 1 in 100 AEP flood show that up to approximately 29 business properties (plus eight residential properties) are protected by the works, while the peak flood afflux generated by the proposed levee and flood gates is less than 50mm, being the smallest threshold for gradation mapping in this regional assessment (see Figure 8-16). Businesses protected by the works are mostly within a current HR2 Potential Hydraulic Risk area.

For floods that exceed the 1 in 100 AEP, the proposed structure would not prevent backwater, and therefore would have no impact on flood storage within the Brisbane River floodplain. There are no mappable impacts on flood levels for floods in excess of 1 in 100 AEP, and as such, maps for larger floods have not been presented here.

A summary of the impacts of the proposed Goodna CBD levee and flood gates on properties for the different AEP floods if given in Table 8-23.

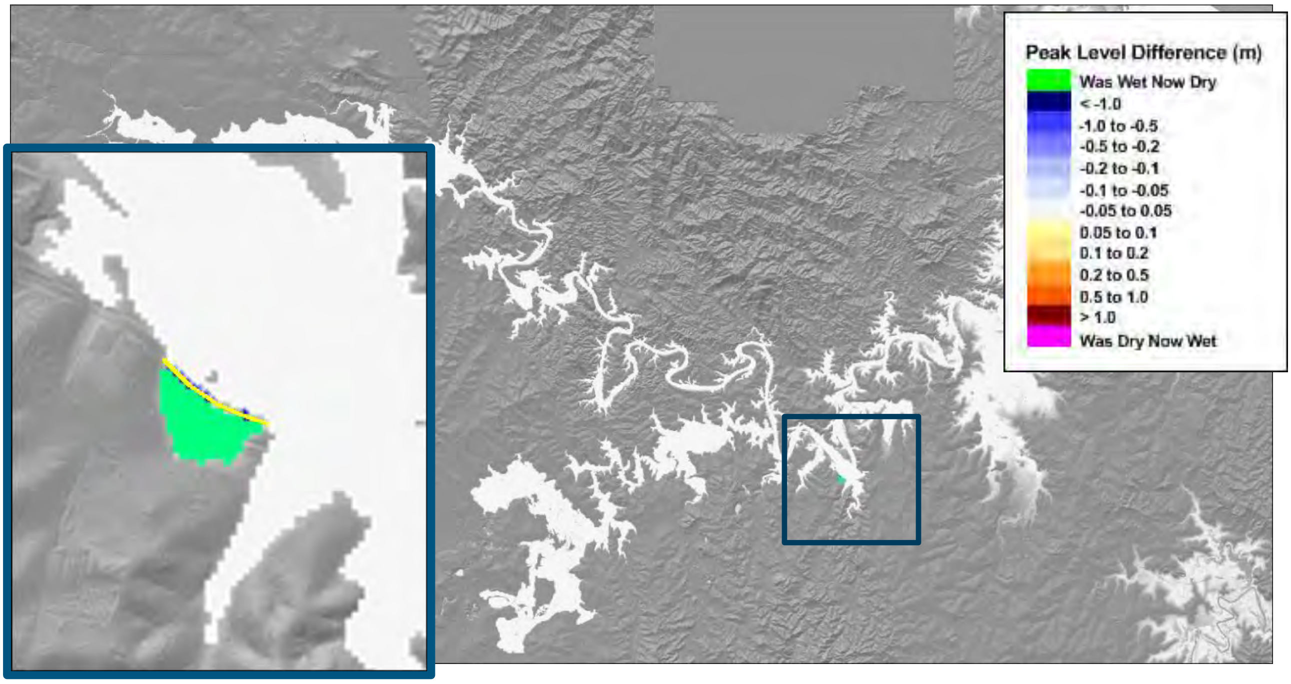


Figure 8-16 Impact of Goodna CBD levee and flood gates for 1 in 100 AEP

Table 8-23 Summary of Goodna CBD levee and flood gate impacts on properties

AEP	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	n/a	n/a	n/a	0	0	0	0
1 in 5	n/a	n/a	n/a	0	0	0	0
1 in 10	n/a	n/a	n/a	0	0	0	0
1 in 20	n/a	n/a	n/a	0	0	0	0
1 in 50	n/a	n/a	n/a	0	12	1	5
1 in 100	< 50mm	< 50mm	< 50mm	0	37	0	9
1 in 200	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 500	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.

[2] Building no longer affected by flooding.

[3] Building is flooded to a greater degree, either above or below habitable floor level.

[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.

8.4.5.5 *Benefit / Cost Analysis*

A summary of the benefit / cost analysis for the Goodna CBD levee option is presented in Table 8-24.

The Goodna CBD levee, with a capital cost of $28m and an annual maintenance cost of $560,000, will generate a net annual average benefit of $220,000, leading to a benefit/cost ratio of 0.08 when adopting a discount rate of 7% over a 100 year period. The benefit of the levee is essentially restricted to the ~30 commercial properties and several residential properties, and essentially for the 1 in 100 AEP event only.

Table 8-24 Benefit/cost analysis summary for Goodna CBD 1 in 100 AEP levee option

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case (1)	288.76	288.53	0.22	**0.08**
Sensitivity 1: No intangibles	186.9	186.7	0.23	**0.09**
Sensitivity 2: with Wivenhoe up.	213.3	213.1	0.20	**0.07**
Sensitivity 3: 4% discount rate				**0.13**
Sensitivity 4: 10% discount rate				**0.06**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-24. Potential upgrades to Wivenhoe Dam could reduce the impact of flooding at Goodna, which would reduce the annual average benefit of the levee to $200,000, leading to a benefit/cost ratio of 0.07. This option is insensitive to consideration of intangible damages, as the benefits are restricted to commercial properties only. As discussed in Section 6 Flood Damages Assessment, intangible damages are only applied to residential costs. Sensitivity was also undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 0.13, while for a higher discount rate of 10%, the benefit/cost ration reduces to 0.06.

8.4.5.6 *Multi-Criteria Review*

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.4.5.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	Approximately 37 business and residential properties (currently located in HR2 Potential Hydraulic Risk area) benefit directly from the reduction in flooding within the Goodna CBD in the 1 in 100 AEP flood only. Events larger than the 1 in 100 AEP would still impact these properties, while events up to the 1 in 50 AEP do not inundate these properties. The potential hydraulic risk within Goodna CBD would reduce from HR2 to HR3 with protection up to the 1 in 100 AEP flood. Hazard level for floods in excess of 1 in 100 AEP would be H5/H6,	2.5

	indicating severe hazard with potential for structural collapse due to excessive flood depths.	
Improve time for evacuation (now and future)	Approximately 37 properties would have more time to respond to a larger event that would potentially overtop the levee. As for the Woogaroo Creek structure, once it is overtopped, the CBD will fill very quickly, which may increase the risk to those who have not heeded warnings to evacuate. Flood immunity of a regional evacuation route (i.e. State controlled road as identified in Section 4 Current Flood Risk) may be improved by this option. The Ipswich Motorway is inundated at the 1 in 100 AEP flood level. This option has the potential to provide some benefit to the motorway, although further investigations would be required to ensure flooding at other locations of the motorway is also addressed.	3.0

8.4.5.6.2 Social

Targets vulnerable community members or areas	This option targets the business community in Goodna CBD. These businesses service a residential community that is considered more vulnerable than average across the catchment, but are not necessarily more vulnerable in their own right.	3.0
Social health benefits	The reduction in damage to businesses within Goodna CBD may marginally improve social health benefits as these businesses would be able to remain function for floods up to the 1 in 100 AEP event, which will benefit the local communities.	3.0
Improves community flood resilience (now and future)	The construction of the Goodna CBD levee and flood gates may have some positive benefits for community awareness, as it highlights to residents the potential for flooding. This would particularly be the case for the very large flood gates that the community would see during dry times as well as floods. However, it may also generate a false sense of security because of the flood gates, and disregard the potential for flooding bigger than the 1 in 100 AEP, and especially given the rapid onset of flooding once the defensive structures are overtopped. No critical infrastructure elements have been identified that would benefit from this option.	3.0
Recreation and amenity	There would be no impact on recreation and amenity as a result of this option.	2.5

Connection and collaboration	This option would impact on the community's connectedness to the river and watercourses.	2.5

8.4.5.6.3 Economic

Reduce damages and costs to residential property (now and future)	There are approximately 8 residential properties that would benefit from this option.	2.5
Reduce damages and costs to business and industry (now and future)	There are approximately 29 commercial properties that would benefit from this option. The average benefit amounts to approximately $220,000 per year, when assessed over the long term (covering both the business and residential benefits).	2.5
Option likely to be cost beneficial (now and future)	The b/c ratio of this option is very low due to the high capital and maintenance costs.	1.5

8.4.5.6.4 Feasibility

Physical / technical (now and future)	The design and construction would be relatively straightforward, albeit challenging to fit within the space-constrained urban development footprint. The size of the flood gates required to close the Church St underpass would be substantial. This measure would need to involve early consultation with the Department of Transport and Main Roads to ensure its technical viability for the safe and efficient operation of the Ipswich Motorway and also how this aligns with any future road upgrade requirements.	3.0
Legal / approval risk	There are a number of exemptions for approval requirements where DTMR are undertaking government supported transport infrastructure. It will need to be determined in consultation with DTMR whether they will be able to undertake the work and to understand if these exemptions apply for the installation of a flood barrier and floodgates. Consultation with DTMR will also be needed to ensure that the flood mitigation devices will not affect the safe and efficient operation of the Ipswich Motorway. If exemptions are not applicable and if DTMR are supportive of the works, an application for Building works (and possibly Operational Works) within a State Transport Corridor would be required.	3.5

	Without consultation with the Department of Main Roads and understanding how the design relates to the operation of the road, approval likelihood is difficult to determine. However, scoring is based on the structure being supported by DTMR given it is of a minor nature in terms of scale and likely impact on the operation of the motorway.	
Potential for additional funding sources	The benefit-cost assessment indicates that there is low return on investment based on the reduction of damages over time. As such, it would be difficult to formulate a business case that would receive positive support from potential funding bodies.	1.5

8.4.5.6.5 Attitude

Decision makers	With a low economic return on this option, it is unlikely to receive government support for implementation.	2.0
Community	Results from the community survey (refer to Section 11 Community Awareness and Resilience) showed residents of ICC had no particular preference for or against the use of levees. While there are a small number of businesses that would benefit from this option, the benefit is limited to flood events between a 1 in 50 AEP and 1 in 100 AEP. With a high cost and limited benefits, it is expected that this option would not have much community support outside the business community.	1.5

8.4.5.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	This option will have little impact on the availability and function of key transport and infrastructure, noting that a major transport link under the motorway would be closed during flooding (with or without this option).	2.5
Protection of regional water supply quality and security – catchment protection (quality and yield)	This option would have no impact on regional water quality or quantity.	2.5

8.4.5.6.7 Environment and Natural Resource Management

Species impacts	There would be no impact to species richness or diversity.	2.5

Vegetation and habitat impacts	There would be no impact on vegetation and habitats. The location of the levee and flood gates is entirely within an existing urban environment.	2.5
Ecosystem health connectivity (fish passage/fauna movement)	There would be no impact on ecosystem health connectivity through fish and fauna passage.	2.5
Reduction in landscape salinity / improved moisture retention and groundwater recharge	There would be no impact to the landscape salinity or moisture, as this option does not encourage local ponding or water storage.	2.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	There would be no impact on the erosive capacity of the catchment or the bank stability of waterways.	2.5

8.4.5.7 Assessment of Option Against Multiple Criteria

As outlined in Section 8.10.2, the Goodna CBD option has an overall multi-criteria assessment result of 0.01, where a value of 0.0 represents a net ‘no change’ condition across the various criteria. The levee is ranked 11th out of the 16 options considered in the MCA (refer Table 8-64).

The lowest scoring criteria for this option were the cost benefit, funding and community attitude criteria (value of 1.5), while the best related to legal / approval risk (value of 3.5) given works would likely be located within state-controlled lands. Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.4.5.8 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The proposed Goodna CBD levee and flood gates will mitigate flooding up to the 1 in 100 AEP flood only. Larger events will still impact on the local business population at risk in Goodna with no residual mitigation by the works.
environmental or social disadvantage	The Goodna CBD levee and flood gates will not create environmental or social disadvantage.

an unacceptable economic cost to State, local government, community or individual	The works would attract a very high cost given the limited numbers of business-related beneficiaries and the infrequent context in which the levee would be operational.
technical impracticability	The Goodna CBD levee and flood gates would be technically feasible but may have some construction challenges given the site constraints within the existing urban footprint.
other unusual or unique circumstances	There are no obvious other unusual or unique circumstances that would preclude the feasibility of this option.

8.4.6 Marsden Parade, Ipswich CBD

8.4.6.1 General Description of Option and Assessment

Ipswich CBD is susceptible to flooding, as demonstrated by the inundation experienced during the 2011 flood event (refer Figure 8-17). At the peak of the 2011 event, floodwaters overtopped the rail embankment and inundated properties to depths in excess of 2 to 3 metres in many locations.

Figure 8-17 Inundation of Ipswich CBD during peak of 2011 flood

The results from the Phase 2 (Flood Study) indicate that the Ipswich CBD becomes inundated because of flood ingress from the Bremer River through the Marsden Parade rail underpass (see

Figure 8-18). Flooding of properties within the Ipswich CBD begins to occur in the 1 in 10 AEP flood event. Overtopping of the rail embankment occurs at the 1 in 50 AEP flood, as experienced in 2011 (which was approximately a 1 in 80 AEP event at Ipswich).

This option consists of constructing a mobile barrier that can be positioned across the Marsden Parade underpass during times of flooding. The 1 in 50 AEP flood would overtop the entire rail embankment at this location. Therefore, the design level for this option is the 1 in 20 AEP, and would prevent the rail underpass becoming a flowpath for backwater inundation of the Ipswich CBD.

Figure 8-18 Marsden Parade Rail Underpass (source: Google streetview)

8.4.6.2 Concept Design

To achieve the desired flood immunity (1 in 20 AEP), a permanent concrete wall would need to be constructed north of the existing railway line, with a crest no lower than 16.02 m AHD. The wall would tie into natural high ground and would be approximately 50m long. The location of the barrier can be seen in Figure 8-20. An example of a similar flood gated structure in the USA is presented in Figure 8-19.

A single flood gate would be installed within the wall to allow for Marsden Parade to remain trafficable during non-flood times. The depth of water on Marsden Parade would be approximately 8.6 m, which precludes the use of temporary flood barriers, as discussed further in Section 8.5.

Marsden Parade forms an overland flowpath for locally generated runoff. Management of this runoff would need to be considered as part of detailed design. Also, as the existing rail embankment will form a pseudo levee for flood events up to the 1 in 20 AEP, the structural suitability of the embankment for this purpose would need to be verified.

Figure 8-19 Flood gate preventing backwater inundation from the Meremac River, USA, (photo by Laurie Skrivan, post-dispatch.com)

Figure 8-20 Flood gate barrier for Marsden Parade (Ipswich CBD)

8.4.6.3 Indicative Cost

The indicative cost of the Ipswich CBD flood gate is presented in Table 8-25 and has been based on the following assumptions:

- The levee height is based on the Phase 2 (Flood Study) and, therefore, does not take into account the potential increase in water level as a result of the option;
- No land purchase will be required;
- No compensation would be provided to local businesses for potential loss of revenue;
- Inclusion of small pumping station and one-way valve for local stormwater;
- Marsden Parade geometry would be altered to a single lane;
- The wall is built in front of railway and passive loading is agreed by Queensland Rail.

Table 8-25 Indicative Cost for Ipswich CBD flood gate (2017 costs)

Description	Cost ($)
Traffic and Environmental Management Plans	293,300
Civil / Structures	1,185,100
Road Works	695,400
Other	1,300,000
Total Direct Job Cost	**$3,473,800**
Indirect Job Costs – On-Site Costs (31%)	1,076,900
Design Costs (9%)	409,600
Indirect Costs - Offsite Costs (3%)	148,800
Contractors Margin and Profit (9%)	459,800
Applications (5%)	278,400
Contingencies (40%)	2,338,900
Pumping station and one-way valve provisional sum	300,000
Total Cost Estimate (Excluding Operating Expenses)	**$8,486,300**
Annual Operating Expenses (assume 2% of capex)	$ 169,700

8.4.6.4 Hydraulic Impacts

Potential impacts of the proposed Ipswich CBD flood gates on the hydraulic behaviour of flooding within the Brisbane River were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

The floodplain that contains the Ipswich CBD is essentially a backwater zone of the Bremer River. This would be impacted by floods within the Bremer River as well as floods in the Brisbane River that back-up into the Bremer River, and a combination of the two. The flood gate would prevent inundation for floods up to the 1 in 20 AEP. Flooding at 1 in 50 AEP or higher would overtop the existing rail embankment in the vicinity of Marsden Parade, negating any benefits associated with the proposed flood gate structure.

For floods up to the 1 in 20 AEP, the flood gate would prevent inundation of Ipswich CBD, and in doing so, would protect up to 24 commercial properties. Most of these commercial properties are located within an existing HR1 Potential Hydraulic Risk area, which is the highest level of flood risk. Impact plots for the 1 in 20 AEP flood show that exclusion of the Ipswich CBD from the flood storage area of the floodplain for this event would not generate a peak flood afflux in excess of 50mm, this being the smallest threshold for gradation mapping in this regional assessment (see Figure 8-21).

For 1 in 50 AEP floods or greater, the flood gate would not prevent backwater, and therefore would have no impact on flood storage within the floodplain. There are no mappable impacts on flood levels for floods of 1 in 50 AEP or larger, and as such, maps for these events have not been presented here.

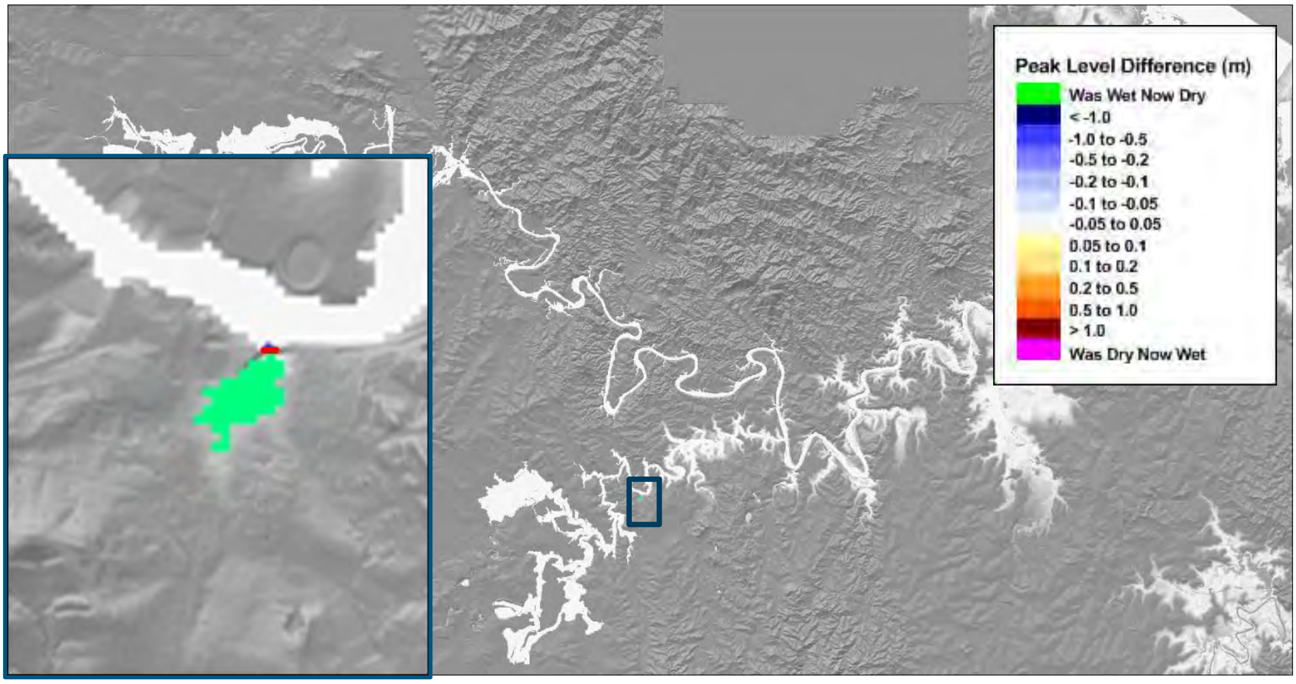


Figure 8-21 Impact of Ipswich CBD flood gate for 1 in 20 AEP

A summary of the impacts of the proposed Ipswich CBD flood gate on properties for the different AEP floods if given in Table 8-26.

Table 8-26 Summary of Ipswich CBD flood gate impacts on properties

AEP	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	n/a	n/a	n/a	0	0	0	0
1 in 5	n/a	n/a	n/a	0	1	0	0
1 in 10	n/a	n/a	n/a	0	5	0	0
1 in 20	< 50mm	< 50mm	< 50mm	1	24	1	3
1 in 50	< 50mm*	< 50mm	< 50mm	0	0	0	0
1 in 100	< 50mm*	< 50mm	< 50mm	0	0	0	0
1 in 200	< 50mm*	< 50mm	< 50mm	0	0	0	0
1 in 500	< 50mm*	< 50mm	< 50mm	0	0	0	0
1 in 2,000	< 50mm*	< 50mm	< 50mm	0	0	0	0
1 in 10,000	< 50mm*	< 50mm	< 50mm	0	0	0	0
1 in 100,000	< 50mm*	< 50mm	< 50mm	0	0	0	0

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.

[2] Building no longer affected by flooding.

[3] Building is flooded to a greater degree, either above or below habitable floor level.

[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.

8.4.6.5 Benefit / Cost Analysis

A summary of the benefit / cost analysis for the Ipswich CBD flood gate option is presented in Table 8-27.

The flood gate, with a capital cost of $8.5m and an annual maintenance cost of $170,000, will generate a net annual average benefit of $70,000, leading to a benefit/cost ratio of 0.92 when adopting a discount rate of 7% over a 100 year period. The benefit of the levee is very high when considering that it is realised by 24 commercial properties, and only for the 1 in 20 AEP. A 1 in 50 AEP flood overtops the railway line and would still inundate the commercial centre. The frequency of benefit is the basis for high net economic returns.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-27. Sensitivity was undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 1.41, while for a higher discount rate of 10%, the benefit/cost ration reduces to 0.67.

Sensitivity to intangible damages was carried out and demonstrated that the b/c ratio for this option was insensitive to intangible, as benefits associated with these works are only applicable up to the 1 in 20 AEP event. As outlined in Section 6 Flood Damages Assessment an uplift to account for intangible losses are not applied to damages incurred in a 1 in 20 AEP flood or smaller. Further, intangible damages have only be applied to residential damages (refer to Section 6 Flood Damages Assessment). A Wivenhoe Dam upgrade option (as discussed in Section 8.1.4.2) was also not carried out as the benefits of such works would be very limited in the vicinity of Ipswich CBD (pers. comm. Seqwater).

Table 8-27 Benefit/cost analysis summary for Ipswich CBD flood gate option

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case (1)	288.7	287.9	0.75	**0.92**
Sensitivity 1: No intangibles	186.8	186.1	0.75	**0.92**
Sensitivity 2: with Wivenhoe up.	n/a	n/a	n/a	**n/a**
Sensitivity 3: 4% discount rate				**1.41**
Sensitivity 4: 10% discount rate				**0.67**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

8.4.6.6 Multi-Criteria Review

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.4.6.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	24 commercial properties benefit directly from the exclusion of flooding within the Ipswich CBD for floods up to the 1 in 20 AEP. These properties are located within an existing HR1 Potential Hydraulic Risk area. Events that are 1 in 50 AEP or larger would still impact these properties as per existing conditions. The potential hydraulic risk within Ipswich CBD would not change and would remain HR1 / HR2, as the risk levels are dominated by the conditions in the 1 in 50 AEP and 1 in 100 AEP events.	2.5
Improve time for evacuation (now and future)	As discussed above, 24 commercial properties would benefit from protection up to the 1 in 20 AEP event. As such, these same properties would have more time to respond to a larger event that would potentially overtop rail embankment. It is expected that overtopping of the rail embankment would fill the Ipswich CBD floodplain quickly providing little response time for business owners. Flood immunity of regional evacuation routes (i.e. the State controlled roads as identified in Section 4 Current Flood Risk) will not be improved by this option.	3.0

8.4.6.6.2 Social

Targets vulnerable community members or areas	This option targets the business community in Ipswich CBD. These businesses service a residential community that is considered more vulnerable than average across the catchment, but are not necessarily more vulnerable in their own right.	3.0
Social health benefits	The reduction in damage to businesses within Ipswich CBD may marginally improve social health benefits as these businesses would be able to remain function for floods up to the 1 in 20 AEP event, which will benefit the local communities.	3.0
Improves community flood resilience (now and future)	The construction of the Ipswich CBD flood gate may have some positive benefits for community awareness, as it highlights to residents the potential for flooding. However it may also generate a false sense of security because of the flood gate, and disregard the potential for flooding of 1 in 50 AEP or larger, which would overtop the rail embankment, and especially given the rapid onset of flooding once it is overtopped. No items of critical infrastructure benefit from this option.	3.0
Recreation and amenity	There would be impact to recreation and amenity as a result of this option.	2.5
Connection and collaboration	There would be no impact on the community's connectedness to the river and watercourses.	2.5

8.4.6.6.3 Economic

Reduce damages and costs to residential property (now and future)	No residential properties would significantly benefit directly from this option.	2.5
Reduce damages and costs to business and industry (now and future)	There are 24 commercial properties within the Ipswich CBD that would benefit from temporary closure of Marsden Parade to prevent backwater inundation from the Bremer River. The average annual benefit sums to $750,000.	3.0
Option likely to be cost beneficial (now and future)	The b/c ratio of this option is relatively high due to proportionate cost and low maintenance demands, balanced against reasonable average annual returns.	3.0

8.4.6.6.4 Feasibility

Physical / technical (now and future)	The design and construction of the flood gate structure at Marsden Parade would be relatively straightforward. Works would be undertaken within existing vacant land on road and rail reserves.	3.5
Legal / approval risk	The proposed structure will be located within land zoned in the CBD Primary Commercial Zone under the Ipswich planning scheme. The structure will likely require Code Assessable development applications assessable by both Ipswich City Council and SARA. These applications are for building works and operational works with the SARA referrals involving land within 25m of a State transport corridor (railway line), and operational works for waterway barrier works (triggered by the mapping, unlikely in this case to require a detailed assessment). Given the structure's proximity to the railway line, consultation will be required with DTMR to clarify the technical assessment necessary (as there could be concerns associated with vibration during construction of the works). Approval for this development would be likely, notwithstanding the need for rigorous technical assessment on the impacts to rail. Any applications will require comprehensive engineering documentation, and technical reporting to address impacts and development requirements outlined in the Ipswich planning scheme and State codes. Land owners consent from relevant parties will be required to support the applications.	3.5
Potential for additional funding sources	The cost of this option is high given it is benefiting only 24 businesses, and is only applicable for flooding up to the 1 in 20 AEP. However the benefit-cost assessment indicates that there is a comparably good return on investment (b/c ratio almost parity) which should support funding submissions.	3.0

8.4.6.6.5 Attitude

Decision makers	With a good economic return on this option, it is likely to receive modest government support for implementation.	3.5

Community	Results from the community survey (refer to Section 11 Community Awareness and Resilience) showed residents of ICC had no particular preference for or against the use of levees. While there are a small number of businesses that would benefit from this option, the level of benefit is limited to flooding that is up to the 1 in 20 AEP only. With a modest cost and reasonable benefits, it is expected that this option would garner community support, but it may be limited as only businesses would benefit directly.	3.0

8.4.6.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	This option will have little impact on the availability and function of key transport and infrastructure, noting that an important transport link under the rail line would be closed during flooding (with or without this option).	2.5
Protection of regional water supply quality and security – catchment protection (quality and yield)	This option would have no impact on regional water quality or quantity.	2.5

8.4.6.6.7 Environment and Natural Resource Management

Species impacts	There would be no impact to species richness or diversity.	2.5
Vegetation and habitat impacts	There would be no impact on vegetation and habitats. The location of the levee, on an existing road, means that there would be no net loss of habitat due to construction.	2.5
Ecosystem health connectivity (fish passage/fauna movement)	There would be no impact on the ecosystem health connectivity through fish and fauna passage.	2.5
Reduction in landscape salinity / improved moisture retention and groundwater recharge	There would be no impact to the landscape salinity or moisture, as this option does not encourage local ponding or water storage.	2.5
Reduction in erosive capacity / soil movement – channel	There would be no impact on the erosive capacity of the catchment or the bank stability of waterways.	2.5

stability / geomorphology		

8.4.6.7 *Assessment of Option Against Multiple Criteria*

As outlined in Section 8.10.2, the Ipswich CBD flood gate option has an overall multi-criteria assessment result of 0.34, where a value of 0.0 represents a net 'no change' condition across the various criteria. The levee is ranked 8th out of the 16 options considered in the MCA (refer Table 8-64).

No criteria had a value of less than 2.5 (the 'no change' score), while the highest scoring criteria were related to feasibility and the attitude of decision makers (value of 3.5). Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.4.6.8 *Feasible Alternative Assessment*

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The proposed Ipswich CBD flood gate will address flooding in Ipswich CBD up to the 1 in 20 AEP only. Larger events will still impact on the local business population at risk in Ipswich CBD with no residual mitigation by the works.
environmental or social disadvantage	The Ipswich CBD flood gate will not create environmental or social disadvantage.
an unacceptable economic cost to State, local government, community or individual	The works would attract a high cost given the limited numbers of business-related beneficiaries.
technical impracticability	Design and construction of the flood gate would be technically feasible and practical.
other unusual or unique circumstances	There are no obvious other unusual or unique circumstances that would preclude the feasibility of this option other than the potential unsuitability of the existing rail embankment for detaining flood waters.

8.4.7 Oxley Creek, Pamphlet Bridge (1 in 50 AEP)

8.4.7.1 *General Description of Option and Assessment*

There are approximately 2,600 properties within the Oxley Creek floodplain that are inundated by the 1 in 50 AEP Brisbane River flood, increasing to approximately 3,200 properties for the 1 in 100

AEP. For some residential and commercial properties in this area, flooding commences at the 1 in 5 AEP level. A number of the properties inundated within the Oxley Creek floodplain are commercial and industrial enterprises including the regionally significant Rocklea markets.

Results from the Phase 2 (Flood Study) show that the flood level difference between the 1 in 50 AEP and 1 in 100 AEP is three metres. Options have been explored to address backwater inundation from the Brisbane River into Oxley Creek for flooding at both the 1 in 50 AEP and 1 in 100 AEP levels. This option involves backwater prevention to the 1 in 50 AEP level, while the next section of this chapter (Section 8.4.8) explores the potential and impacts for backwater prevention to the 1 in 100 AEP level. A third option looking at realigning the creek entrance is considered in Section 8.9.4.

8.4.7.2 Concept Design

Within the most downstream reach of Oxley Creek, backwater inundation to the 1 in 50 AEP level is wholly contained within the Oxley Creek channel. Thus, backwater prevention to this level can be achieved simply through an in-channel structure, such as flood gates (typically sluice gates).

To achieve the desired immunity (1 in 50 AEP) with a typical freeboard allowance of 0.5m, a barrier would need to have a crest level no lower than 7.20 m AHD. The flood barrier would consist of an earth levee on either bank of the creek (100m in length), which would tie into high ground (Graceville Rugby League Club to the north and St Joseph's College Gregory Terrace playing fields to the south). The average height of the levee would be 2.0m and the batters would need to be 1 in 3.

A concrete wall constructed across the creek would include the flood gates (likely to be sluice gates) and be approximately 50m long. The height of the wall depends on the elevation of the creek bed. However, it would likely be approximately 9m high. With an active channel width of 40m at the location of the barrier, seven sluice gates (5.9m wide and 3.6m high) would be installed to convey the normal Oxley Creek flow.

When closed, the sluice gates would prevent Brisbane River flood events from backing up into the Oxley Creek. However, the gates could also prevent the local catchment from discharging into the Brisbane River during coincident flood events. Oxley Creek has a catchment area of 230km^2 and is likely to generate significant volumes of runoff during coincident flood events. With the gates closed the volume of floodwater generated from the local catchment would inundate the floodplain. The volume associated with a 1 in 20 AEP, 24 hour duration local flood event would generate similar flood extents as the 1 in 20 AEP Brisbane River flood.

To prevent local flood inundation, pumping stations would be required to drain the runoff from the Oxley Creek catchment. The pumps would require a capacity to pump flows for a 1 in 5 AEP, 24 hour duration flood event. The 1 in 5 AEP event was selected to determine the pump capacity, as less frequent events would require a significantly large pump/cost, however may never occur in the lifetime of the scheme. The 24 hour storm duration was selected for the pump analysis, as it was deemed a feasible duration for water levels in the Brisbane River to remain high enough to prevent free drainage. Further stages of assessment of this option would need to consider the probabilities of coincident flooding to more accurately size and cost the pumps. A variation on the option without pumping stations was considered, however this was found to significantly reduce the benefits of the levee and sluice gate whilst still requiring significant capital investment and was not taken forward for further assessment.

The approximate location of the levee and sluice gates can be seen in Figure 8-22, while typical examples of similar structures were presented in Figure 8-11 and Figure 8-12.

8.4.7.3 Indicative Cost

The indicative costing of the 1 in 50 AEP Oxley Creek levee and sluice gate option is presented in Table 8-28 and has been based on the following assumptions:

- The levee height is based on the Phase 2 (Flood Study) and, therefore, does not take into account the potential increase in water level as a result of the option;
- No land purchase will be required;
- The existing topsoil is not contaminated and, therefore, requires no treatment;
- The levee would be built with imported materials;
- The dimensions of the levee would be 3m wide at the crest and 1 in 3 batters;
- The construction will have access to Vivian Street;
- Site setup would be next to St Joseph's College Gregory Terrace playing fields;
- The pumps are capable of discharging a 1 in 5 AEP local event and require a pumping station with a capacity of 140 m^3/s; and
- The cost of the sluice gate was based on cost estimates for a similar size structure in the Bundaberg Flood Protection Study (DILGP, 2016).

Table 8-28 Indicative Cost for 1 in 50 AEP Oxley Creek levee and sluice gates (2017 costs)

Description	Cost ($)
Traffic and Environmental Management Plans	422,500
Temporary works	2,669,600
Civil / Structures	3,110,900
Earth Works	97,800
Other	1,482,000
Pumping stations	137,200,000
Total Direct Job Cost	**$144,982,700**
Indirect Job Costs – On-Site Costs (31%)	44,944,600
Design Costs (9%)	17,093,500
Indirect Costs - Offsite Costs (3%)	6,210,600
Contractors Margin and Profit (9%)	19,190,800
Applications (5%)	11,621,100
Contingencies (excluding pumps) (40%)	42,737,300
Contingencies for pumping stations (40%)	54,880,000
Total Cost Estimate (Excluding Operating Expenses)	**$341,660,700**
Annual Operating Expenses (assume 2% of capex)	$ 6,833,200

Figure 8-22 Location of Oxley Creek levee and sluice gates

8.4.7.4 Hydraulic Impacts

Potential benefits and impacts of the proposed 1 in 50 AEP Oxley Creek levee and sluice gates on the hydraulic behaviour of flooding were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

The proposed 1 in 50 AEP Oxley Creek levee and sluice gates reduces flooding for a significant number of targeted properties, however it also reduces floodplain storage for floodwaters within the Brisbane River catchment. The Oxley Creek floodplain is the largest tributary storage area of the Brisbane River downstream of the Bremer River. As such, the temporary storage and detention of floodwaters within this area is important for the overall flood hydraulics of the Brisbane River. The impacts of the 1 in 50 AEP Oxley Creek levee and sluice gates on flood levels in the Brisbane River are presented in Figure 8-23 for the range of flood events from 1 in 5 AEP to 1 in 50 AEP. As the structure is overtopped for floods larger than 1 in 50 AEP, impacts are essentially as per existing conditions.

A summary of the impacts of the proposed 1 in 50 AEP Oxley Creek levee and sluice gates on properties for the different AEP floods is given in Table 8-29. Maximum afflux presented in Table 8-29 is considered to be the maximum afflux in the Brisbane River. It does not include highly localised impacts in storage areas such as parks.

Table 8-29 Summary of 1 in 50 AEP Oxley Creek levee and sluice gates impacts on properties

AEP	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 5	< 50mm	< 50mm	< 50mm	6	13	0	2
1 in 10	**60mm**	< 50mm	< 50mm	6	98	3	0
1 in 20	**60mm**	< 50mm	< 50mm	0	424	44	23
1 in 50	**120mm**	< 50mm	**70mm**	0	1603	1661	363
1 in 100	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 200	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 500	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.

[2] Building no longer affected by flooding.

[3] Building is flooded to a greater degree, either above or below habitable floor level.

[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.

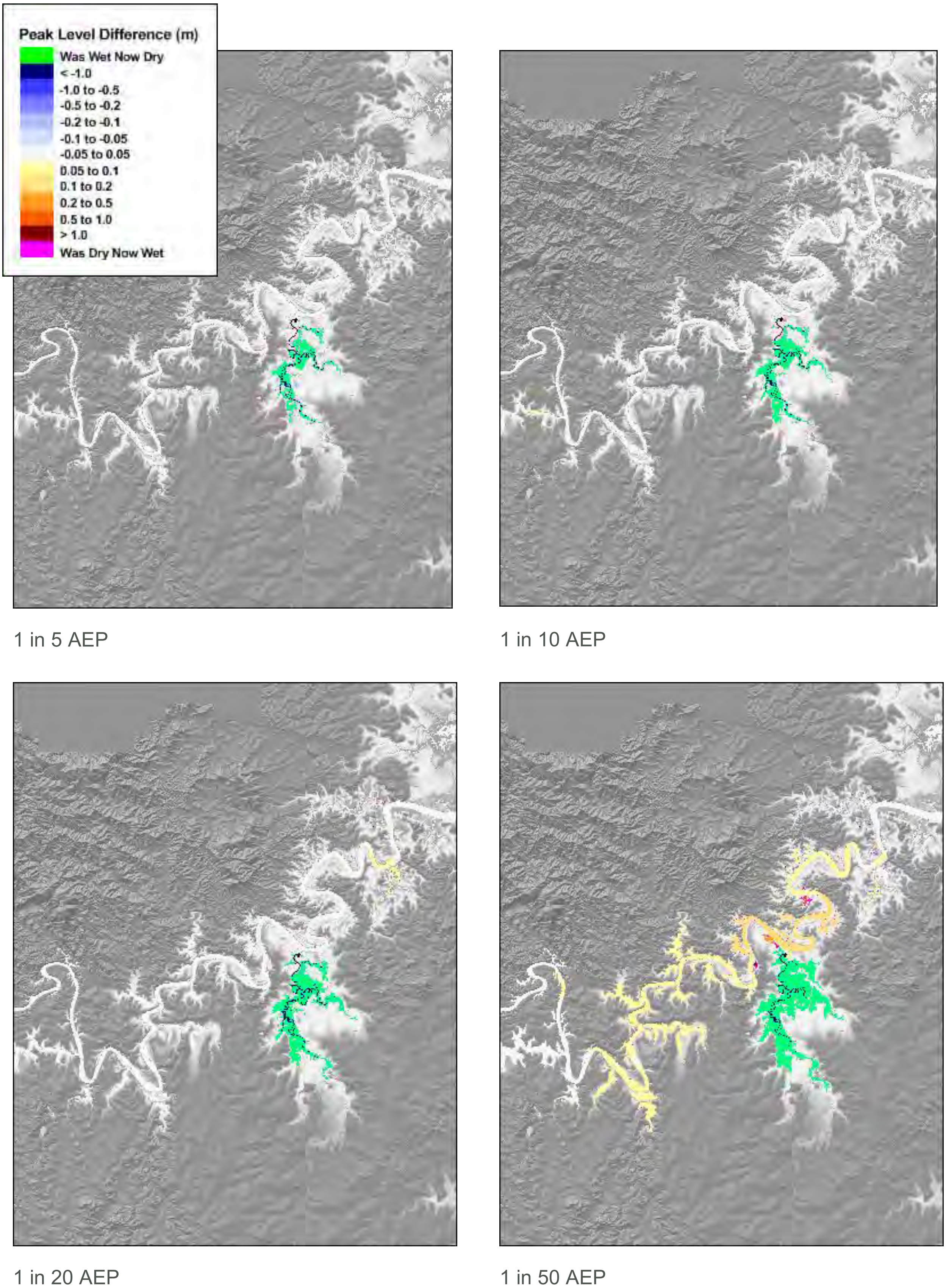


Figure 8-23 Oxley Creek 1 in 50 AEP levee and sluice gates: Impacts 1 in 5 to 1 in 50 AEP

From Table 8-29 it can be seen that benefits in the 1 in 5 AEP are realised for 19 properties, almost all of which are commercial properties. For the 1 in 10 AEP, benefits extend to more than 100 properties (including a small number of residential properties, ~23), while for the 1 in 20 AEP, more than 400 properties benefit from no flooding, almost half of which are residential.

The maximum benefit from this option is at the 1 in 50 AEP, with about 1,600 properties benefiting, half of which are residential and mostly located within HR2, but also some HR1 Potential Hydraulic Risk areas. HR1 and HR2 areas represent locations of highest flood risk across the region, and therefore are considered priority areas for management. The commercial properties benefiting are also located across a mix of HR1 and HR2 areas.

From Figure 8-23, however, it is seen that this option has significant downstream impacts for a 1 in 50 AEP event. Removal of the Oxley Creek flood storage area alters the flood behaviour in the Brisbane River for this sized event, resulting in increased flood levels downstream. The maximum afflux (increase in flood level) is 0.12 metres, while more than 2,000 properties (including >1,200 residential properties) would be detrimentally affected by higher flood levels under these circumstances. Properties that are impacted are mostly located within existing HR2 Potential Hydraulic Risk areas.

For floods larger than the 1 in 50 AEP, the sluice gate structure would be overtopped, and the Oxley Creek flood storage area re-engaged. Impacts behind the structure as well as downstream would be largely as per existing conditions for this size flood or larger.

8.4.7.5 Benefit / Cost Analysis

A summary of the benefit / cost analysis for the Oxley Creek 1 in 50 AEP sluice gate option is presented in Table 8-30.

The Oxley Creek structure, with a capital cost of $342m and an annual maintenance cost of almost $7m, will generate a net annual average benefit of over $10m, leading to a benefit/cost ratio of 0.31 when adopting a discount rate of 7% over a 100 year period. As outlined in Table 8-29, there are about 1,600 properties located behind the structure that would benefit from this option, however, there are a further 2,000 properties located on the downstream side of the structure and along the Brisbane River that would be detrimentally affected through higher flood level. The benefit / cost assessment indicates that the significant benefits gained by the protected properties far exceeds the marginal dis-benefits experienced by properties downstream. Notwithstanding, the impacts downstream are still considered unacceptable without mitigation.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-30. If benefits were limited to reductions in tangible damages, the annual average benefit of the works would reduce to $9.6 million, giving a net benefit/cost ratio of 0.30. Potential upgrades to Wivenhoe Dam could reduce the impact of flooding within the Oxley Creek floodplain, the annual average benefit of the structure would increase to over $11 million per annum, leading to a benefit/cost ratio of 0.34. Sensitivity was also undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 0.47, while for a higher discount rate of 10%, the benefit/cost ratio reduces to 0.23.

Table 8-30 Benefit/cost analysis summary for Oxley Creek 1 in 50 AEP flood gate option

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case (1)	288.7	278.6	10.1	**0.31**
Sensitivity 1: No intangibles	186.8	177.2	9.6	**0.30**
Sensitivity 2: with Wivenhoe up.	213.2	202.1	11.1	**0.34**
Sensitivity 3: 4% discount rate				**0.47**
Sensitivity 4: 10% discount rate				**0.23**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

8.4.7.6 Multi-Criteria Review

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.4.7.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	Approximately 1,600 properties (located within existing HR1 and HR2 Potential Hydraulic Risk areas) would benefit directly from preventing Brisbane River backwater into Oxley Creek for flooding up to the 1 in 50 AEP event. Benefits would only be achieved if local catchment runoff was also prevented from inundating these properties, which would require very large pumps (during events when local catchment runoff coincides with Brisbane River flooding). Events larger than the 1 in 50 AEP would overtop the structure and would impact Oxley Creek properties as per existing conditions. Removal of flood storage from within the Oxley Creek floodplain would increase flood levels in the Brisbane River. This would have the unacceptable impact of exacerbating flooding at the 1 in 50 AEP level for approximately 2,000 properties.	1.5
Improve time for evacuation (now and future)	Evacuation routes located behind the structure would benefit from flood immunity up to the 1 in 50 AEP flood. This includes the regional evacuation route (State controlled road) the Ipswich Motorway. Currently the motorway is susceptible to flooding at the 1 in 20 AEP (refer Section 4 Current Flood Risk). While there would be improved time for evacuation in areas adjacent to Oxley Creek behind the flood gate structure, the increase in flood levels along the Brisbane River would reduce available warning time for a large number of properties and affect local evacuation routes.	1.5

8.4.7.6.2 Social

Targets vulnerable community members or areas	The population benefiting from this option includes the suburbs of Inala and Oxley, which are considered to be more vulnerable than average, as detailed in Section 4 Current Flood Risk. Areas where flooding is exacerbated by this option include Sherwood, Graceville and Fairfield, some residents of which are also considered vulnerable.	2.5
Social health benefits	While there are some areas that benefit from this option, there are a higher number that are detrimentally affected. On balance, the social health benefits would be worse than existing conditions under this option.	2.0
Improves community flood resilience (now and future)	The option provides benefits to some residents, but at the expense of worsening conditions for others. The installation of the flood gate structure would not provide any significant regional community resilience, as there would be a tendency for the community to rely on infrastructure to manage flooding rather than taking effective measures themselves. On balance, and due to the widespread impacts, community resilience under this option would be lower than existing conditions. One emergency management facility and one critical energy infrastructure item would be protected behind the levee and sluice gates, however, the increased flooding downstream would exacerbate flood conditions for a critical telecommunications infrastructure item.	2.0
Recreation and amenity	This option would potentially restrict waterway access along Oxley Creek. The lower reaches of the waterway are used for recreational boating and there are a number of private jetties along the waterway banks. Passive watercraft, such as kayaks and canoes, may be used more extensively upstream of the structure. Depending on the design, the structure may provide pedestrian access across the creek at this location, which may improve local amenity.	1.5
Connection and collaboration	This option would potentially detract from the community's connectedness to the river and watercourses as it involves constructing a very large artificial structure across the natural waterway.	1.5

8.4.7.6.3 Economic

Reduce damages and costs to residential property (now and future)	There are a large number of residential properties located behind the flood gates that benefit from this option. There are also a large number of residential properties located downstream where flooding would be exacerbated. On balance, the economic benefits of the properties protected (for all property types) outweighs the economic dis-benefits of the properties impacted, leading to a net positive benefit of approximately $10 million per year.	3.5
Reduce damages and costs to business and industry (now and future)	As for the residential properties described above, the net benefit extends to commercial properties as well. There are a large number of commercial properties located within the Oxley Creek floodplain.	3.5
Option likely to be cost beneficial (now and future)	This option involves a very high cost, but relatively solid economic returns from reduced damages. Notwithstanding the benefits, the b/c ratio is still below the typical 0.5 threshold that defines a reasonable likelihood of project implementation depending on other benefits and impacts.	2.0

8.4.7.6.4 Feasibility

Physical / technical (now and future)	The design and construction of the 1 in 50 AEP Oxley Creek levee and sluice gates would be relatively straightforward. Further information on geotechnical conditions will be essential to confirm design requirements and technical feasibility.	3.0
Legal / approval risk	The proposed structures will be located within the Oxley Creek waterway and on land in the Open Space Zone (north of the proposed structure) and the Community Facilities Zone (south of the proposed structure). The proposed structures will likely require Code Assessable development applications assessable by both Brisbane City Council and SARA. These applications are for building works and operational works that are Waterway Barrier Works and works within the erosion prone area of the Coastal Management District. Approval for this development would be likely, based on that for waterway barrier works, there is likely to be demonstrated need for the development and alternatives which do not involve constructing or raising waterway barrier works are not viable. With regard to the pumping station, if it is located on land in the Community Facilities Zone it will be accepted development, with	3.5

	no approval necessary, however if a change in design requires it to be located on land in the Open Space Zone, the structure will require an Impact Assessable development application to Brisbane City Council. On this particular aspect, there would also be a statutory requirement for public notification where submitters have appeal rights. Any applications will require comprehensive engineering documentation, and technical reporting to address impacts on fishways, ecological processes and coastal processes to address development requirements outlined in the City Plan 2014 and State codes. Land owners consent from all parties will be required to support the applications.	
Potential for additional funding sources	The cost of this option is very high, with the majority of costs allocated to the pumping stations. The benefit-cost assessment indicates that there is a somewhat low return on investment for such a structure through reduction of damages over time. As such, it would be difficult to formulate a business case that would receive positive support from potential funding bodies.	1.5

8.4.7.6.5 Attitude

Decision makers	With a low economic return on this option and worsening of flood risk for properties downstream, it is unlikely to receive government support for implementation.	1.5
Community	Results from the community survey (refer to Section 11 Community Awareness and Resilience) showed residents of BCC had no particular preference for or against the use of levees. Although there are some 1,600 properties that would be protected by the structure, the impacts of the structure would exacerbate flood impacts for more than 2,000 properties at the 1 in 50 AEP flood level. Furthermore, as the structure is only designed to protect to the 1 in 50 AEP level, it would not be effective for flooding comparable to that experienced in 2011. With a high cost and limited benefits, it is expected that this option would not have much community support, and indeed may face significant community opposition to the use of funds.	1.0

8.4.7.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	This option will improve local access on roads within the Oxley Creek floodplain for floods up to the 1 in 50 AEP event. This includes providing road access for some 2,600 residential properties within the floodplain, which may assist in evacuation during a flood event. However, the impacts of this option will create higher flood levels elsewhere which will have a detrimental impact on the function of transport and infrastructure in neighbouring suburbs.	2.5
Protection of regional water supply quality and security – catchment protection (quality and yield)	This option would have no impact on regional water quality or quantity.	2.5

8.4.7.6.7 Environment and Natural Resource Management

Species impacts	There would be no significant impact to species richness or diversity. The structure would impede aquatic species movement during times of flood, however this would be for relatively short periods of time. Nonetheless, there may be some impact on species that rely on floods for movement through the river environment.	2.0
Vegetation and habitat impacts	There would be no significant impact on terrestrial vegetation and habitats. The location of the levee, means that there would be little to no net loss of valued habitat due to construction. The restriction of flow during times of flood, however, may have an impact on aquatic habitats that rely on floods, including upstream wetlands.	2.0
Ecosystem health connectivity (fish passage/fauna movement)	There would be no significant impact on ecosystem health connectivity through fish and fauna passage with the exception of fish passage during times of flood. It is recognised that waterways provide a natural corridor for some species. The structure proposed is unlikely to have a significant detrimental effect on species movement in the long term. Pondage of local flood waters behind the levee has the potential to form anoxic in-stream conditions through the decay or organic matter washed into waterways during the flood event. On the basis that ponded water is pumped into the Brisbane River, this would not be of concern, however, if pumping was to be insufficient and allow extended ponding of floodwaters, anoxia	2.5

	within the water may degrade the ecosystem health with the potential for lasting impacts. Ponding of local flood waters in industrial areas behind the levee will also potentially impact water quality, however this would be similar to the current situation in backwater conditions.	
Reduction in landscape salinity / improved moisture retention and groundwater recharge	There would be no impact to the landscape salinity or moisture, as this option does not encourage local ponding or water storage.	2.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	There would be no impact to the erosive capacity of the catchment or channel stability providing that higher velocities in and around the sluice gate structure itself are managed through bed and bank protection works.	2.5

8.4.7.7 Assessment of Option Against Multiple Criteria

As outlined in Section 8.10.2, the 1 in 50 AEP Oxley Creek levee and sluice gates option has an overall multi-criteria assessment result of -0.26, where a value of 0.0 represents a net ‘no change’ condition across the various criteria. Thus, with a negative score it has been determined that the option would have a net overall detrimental impact when weighed against the various criteria.

The levee is ranked 14th out of the 16 options considered in the MCA (refer Table 8-64).

The lowest scoring criterion for this option was the community attitude criterion (value of 1.0), while the best related to reduced residential and commercial damages and legal/approval risk (value of 3.5). Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.4.7.8 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The 1 in 50 AEP Oxley Creek levee and sluice gates will address flooding for events up to the 1 in 50 AEP flood only. Larger events will still impact on the local population at risk with no residual mitigation by the levee.
environmental or social disadvantage	The 1 in 50 AEP Oxley Creek levee and sluice gates should not create environmental or social disadvantage providing they are operated in accordance with design and do not allow extended periods of ponding of local flood waters.

an unacceptable economic cost to State, local government, community or individual	The 1 in 50 AEP Oxley Creek levee and sluice gates would attract a high very cost given the limited numbers of beneficiaries. This could be considered an unacceptable economic cost.
technical impracticability	The levee and sluice gates would be technically feasible but may have some construction challenges given the site constraints and unknown geotechnical conditions.
other unusual or unique circumstances	There are no obvious other unusual or unique circumstances that would preclude the feasibility of this option.

8.4.8 Oxley Creek, Rail Line (1 in 100 AEP)

8.4.8.1 General Description of Option and Assessment

As outlined in Section 8.4.7.1, there are approximately 3,200 properties within the Oxley Creek floodplain that are inundated by the 1 in 100 AEP Brisbane River flood, including many commercial and industrial properties. There are also many more properties located adjacent to the Brisbane River in the vicinity of Oxley Creek, but not within the Oxley Creek floodplain, including the suburbs of Tennyson, Graceville and Chelmer.

This option involves backwater prevention in the Oxley Creek floodplain to the 1 in 100 AEP level. It would be impractical to extend protection to flood-prone suburbs adjacent to the Brisbane River, and as such, the benefits of this option remain limited to those areas within the Oxley Creek floodplain proper.

The option consists of raising an existing railway line that crosses Oxley Creek and installing flood gates across Oxley Creek at the rail line crossing to prevent backwater inundation. Therefore, only properties that are upstream of the rail line crossing of Oxley Creek would be protected by this option. This includes properties within Sherwood, Corinda, Rocklea and Oxley. It is noted that a number of these become inundated between a 1 in 5 AEP and 1 in 10 AEP flood.

8.4.8.2 Concept Design

To achieve the desired immunity (1 in 100 AEP) with a freeboard (0.5m), a 1.55km long section of existing railway line will need to be raised to an elevation of 10.2 m AHD. The railway line would sit on an earth levee, which would tie into high ground (Tennyson to the north and Sherwood to the south). The average height of the levee would be 1.9m and the batters would need to be 1 in 3.

A concrete wall constructed across the creek would include the flood gates (likely to be sluice gates) and be approximately 50m long. The height of the wall depends on the elevation of the creek bed. However, it would likely be approximately 12m high. With an active channel width of 40m at the location of the barrier, seven sluice gates (5.9m wide and 3.6m high) would be installed to convey Oxley Creek flows.

When closed, the sluice gates would prevent Brisbane River flood events from backing up into the Oxley Creek. However, the gates could also prevent the local catchment from discharging into the

Brisbane River during coincident flood events. Oxley Creek has a catchment area of 230km^2 and is likely to generate significant volumes of runoff during coincident flood events. With the gates closed the volume of floodwater generated from the local catchment would inundate the floodplain. The volume associated with a 1 in 20 AEP, 24 hour duration local flood event would generate similar flood extents as the 1 in 20 AEP Brisbane River flood.

To prevent local flood inundation, pumping stations would be required to drain the runoff from the Oxley Creek catchment. The pumps would require a capacity to pump flows for a 1 in 5 AEP, 24 hour duration flood event. The 1 in 5 AEP event was selected to determine the pump capacity, as less frequent events would require a significantly large pump/cost, however may never occur in the lifetime of the scheme. The 24 hour storm duration was selected for the pump analysis, as it was deemed a feasible duration for water levels in the Brisbane River to remain high enough to prevent free drainage. Further stages of assessment of this option would need to consider the probabilities of coincident flooding to more accurately size and cost the pumps. A variation on the option without pumping stations was considered, however this was found to significantly reduce the benefits of the railway levee and sluice gate whilst still requiring significant capital investment and so was not taken forward for further assessment.

The location of the rail line embankment/levee and sluice gates can be seen in Figure 8-24, while typical examples of similar structures were presented in Figure 8-11 and Figure 8-12.

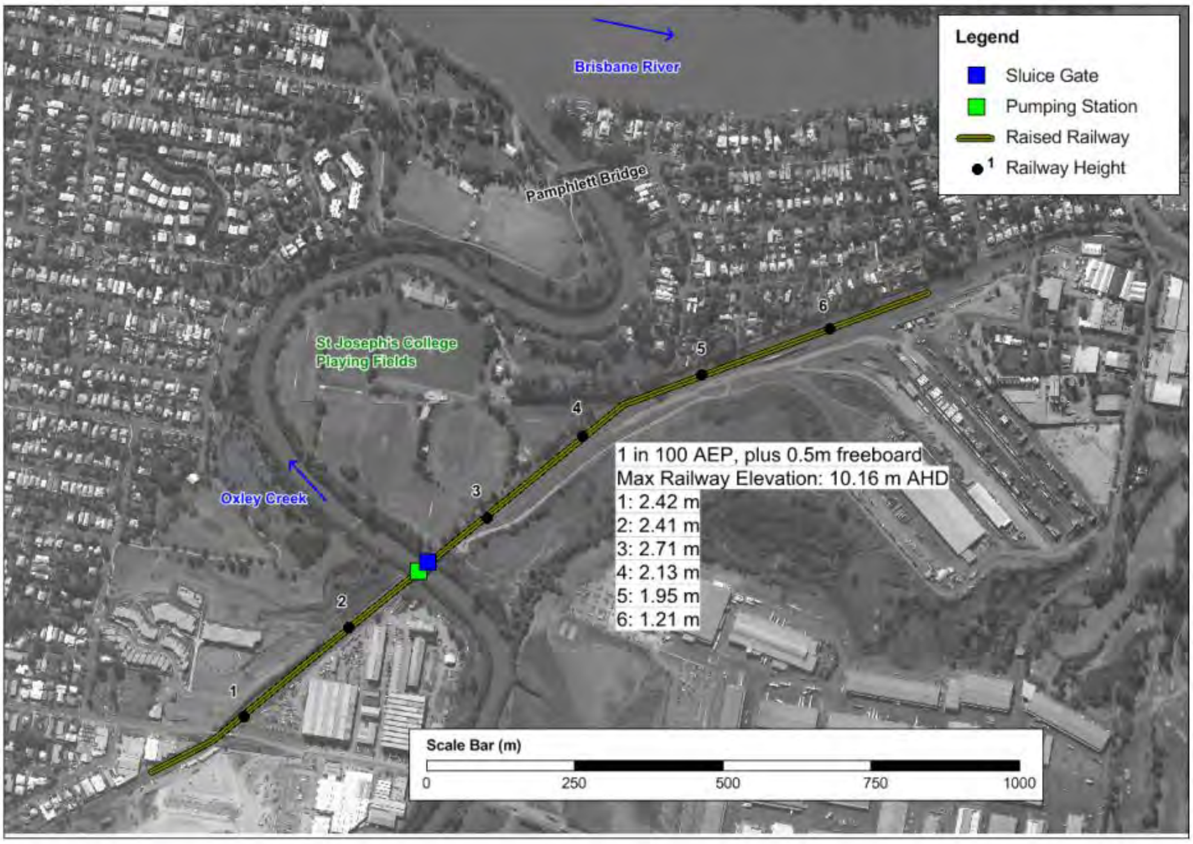


Figure 8-24 Location of Oxley Creek raised railway levee and sluice gates

8.4.8.3 Indicative Cost

The indicative costing of the 1 in 100 AEP Oxley Creek rail line levee and sluice gate option is presented in Table 8-31 and has been based on the following assumptions:

- The levee height is based on the Phase 2 (Flood Study) and, therefore, does not take into account the potential increase in water level as a result of the option;
- No land purchase will be required;
- No compensation would be provided to Queensland Rail for potential loss of revenue due to track closures;
- The embanked railway would act as a flood barrier, which would require agreement from Queensland Rail;
- The levee would be built with imported materials;
- The dimensions of the levee would be 20m wide (average) at the crest and 1 in 3 batters;
- The pumps are capable of discharging a 1 in 5 AEP local event and require a pumping station with a capacity of 140 m^3/s; and
- The cost of the sluice gate was based on cost estimates for a similar size structure in the Bundaberg Flood Protection Study (DILGP, 2016).

Table 8-31 Indicative Cost for 1 in 100 AEP Oxley Creek rail line levee and sluice gates (2017 costs)

Description	Cost ($)
Traffic and Environmental Management Plans	696,600
Temporary works	2,669,600
Civil / Structures	6,260,900
Earth Works	37,744,500
Other	1,482,000
Pumping stations	137,200,000
Total Direct Job Cost	**$186,053,600**
Indirect Job Costs – On-Site Costs (31%)	57,676,600
Design Costs (9%)	21,935,700
Indirect Costs - Offsite Costs (3%)	7,970,000
Contractors Margin and Profit (9%)	24,627,200
Applications (5%)	14,913,200
Contingencies (excluding pumps) (40%)	70,390,500
Contingencies for pumping stations (40%)	54,880,000
Total Cost Estimate (Excluding Operating Expenses)	**$438,446,700**
Annual Operating Expenses (assume 2% of capex)	$ 8,768,900

8.4.8.4 Hydraulic Impacts

Potential impacts of the proposed 1 in 100 AEP Oxley Creek rail line levee and sluice gates on the hydraulic behaviour of flooding were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

The proposed 1 in 100 AEP Oxley Creek rail line levee and sluice gates removes significant floodplain storage for floodwaters within the Brisbane River catchment. As explained in Section 8.4.7.4, the Oxley Creek floodplain is the largest tributary storage area of the Brisbane River and is important for the overall flood hydraulics of the Brisbane River. The impacts of the 1 in 100 AEP Oxley Creek rail line levee and sluice gates on flood levels in the Brisbane River are presented in Figure 8-25 for the range of flood events from 1 in 10 AEP to 1 in 100 AEP.

A summary of the impacts of the proposed 1 in 100 AEP Oxley Creek rail line levee and sluice gates on properties for the different AEP floods is given in Table 8-32. Maximum afflux presented in Table 8-32 is considered to be the maximum afflux in the Brisbane River. It does not include highly localised impacts in storage areas such as parks.

Table 8-32 Summary of 1 in 100 AEP Oxley Creek rail line levee and sluice gates impacts on properties

AEP	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	< 50mm	< 50mm	< 50mm	0	0	0	0
1 in 5	< 50mm	< 50mm	< 50mm	6	13	0	2
1 in 10	**60mm**	< 50mm	< 50mm	8	96	3	0
1 in 20	**60mm**	< 50mm	< 50mm	16	408	37	23
1 in 50	**120mm**	< 50mm	**70mm**	47	1401	1670	344
1 in 100	**300mm**	< 50mm	**230mm**	1	3466	11373	831
1 in 200	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 500	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0

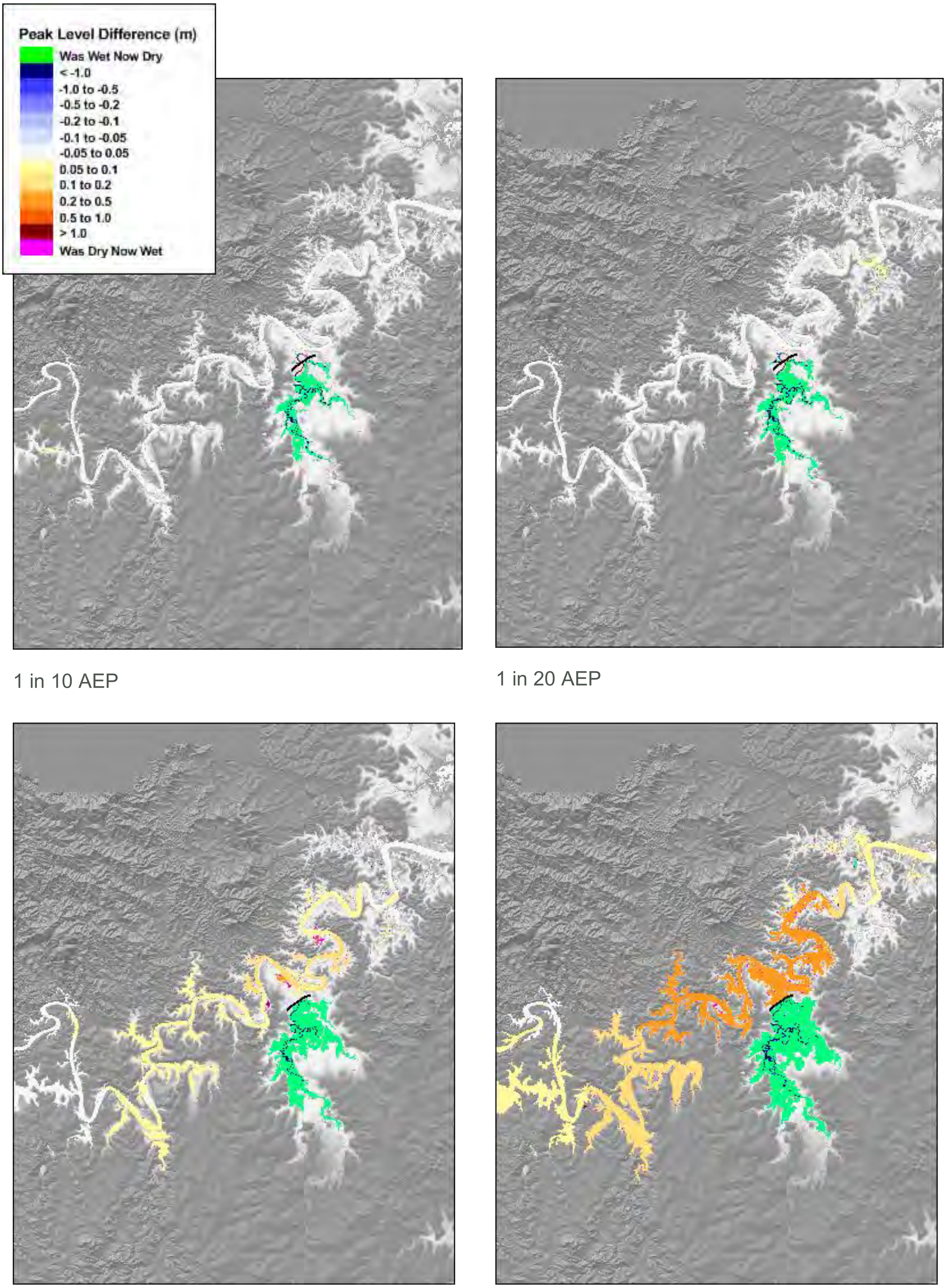
** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.

[2] Building no longer affected by flooding.

[3] Building is flooded to a greater degree, either above or below habitable floor level.

[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.



1 in 10 AEP

1 in 20 AEP

1 in 50 AEP

1 in 100 AEP

Figure 8-25 Oxley Creek 1 in 100 AEP levee and sluice gates: Impacts 1 in 10 AEP to 1 in 100 AEP

Impacts of this option, up to the 1 in 50 AEP flood, are comparable to the impacts established for the 1 in 50 AEP sluice gates, as discussed in Section 8.4.7. Numbers of properties protected are slightly lower that the former option as the location of the 1 in 100 AEP structure is further upstream within the Oxley Creek floodplain.

For the 1 in 100 AEP flood, the levee and sluice gate structure will continue to afford protection to properties upstream, totalling approximately 3,500, of which about 1,500 are residential properties and about 1,700 are commercial properties. As well as the HR1 and HR2 areas protected by the 1 in 50 AEP levee and sluice gates, the residential and commercial properties protected by this option include a large number located within other HR2 and HR3 Potential Hydraulic Risk areas.

As presented in Figure 8-25, exclusion of the Oxley Creek flood storage area for the 1 in 100 AEP flood has significant and widespread impact of flood behaviour within the Brisbane River, resulting in increased flood levels elsewhere. As given in Table 8-32, the maximum afflux (increased flood level) at the 1 in 100 AEP event for this option is 0.3 metres, while an afflux of 0.23m is calculated at Brisbane CBD. Some 12,000 properties downstream of Oxley Creek would be impacted by higher flood levels, about 8,500 of which are residential properties. Properties impacted elsewhere are currently located within HR2 and HR3 areas.

For floods larger than the 1 in 100 AEP event, the levee and sluice gate structure would be overtopped, effectively re-engaging the flood storage area of Oxley Creek. As such, the impacts on floods greater than 1 in 100 AEP would be minimal, with flooding largely as per existing conditions for such events. In these larger events, it is assumed that there would be no reduction in damages.

8.4.8.5 Benefit / Cost Analysis

A summary of the benefit / cost analysis for the Oxley Creek 1 in 100 AEP rail line levee and flood gate option is presented in Table 8-33.

Table 8-33 Benefit/cost analysis summary for Oxley Creek 1 in 100 AEP rail line levee and flood gate option

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case (1)	288.7	267.0	21.7	**0.52**
Sensitivity 1: No intangibles	186.8	166.5	20.4	**0.49**
Sensitivity 2: with Wivenhoe up.	213.2	192.2	21.0	**0.50**
Sensitivity 3: 4% discount rate				**0.79**
Sensitivity 4: 10% discount rate				**0.38**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

The levee and flood gate, with a capital cost of almost $440m and an annual maintenance cost of about $9 million, will generate a net annual average benefit of $22 million, leading to a benefit/cost ratio of 0.52 when adopting a discount rate of 7% over a 100 year period. Similar to the Oxley Creek 1 in 50 AEP flood gate, benefits are restricted to the properties located on the upstream side of the structure, while there are a large number of properties on the downstream side and along Brisbane

River that will have a dis-benefit from increased flood level. The net positive annual average benefit means that the reduction in damages behind the structure is far greater than the relatively marginal increase in damages for properties on the downstream side. Again, the impact on the large number of properties downstream render this option unacceptable.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-33. If benefits were limited to reductions in tangible damages, the annual average benefit of the works would reduce to $20 million, giving a net benefit/cost ratio of 0.49. As there are a large number of commercial properties benefiting from this option, the result is somewhat insensitive to the intangibles uplift (as the uplift only applies to residential properties). Potential upgrades to Wivenhoe Dam could reduce the impact of flooding within the Oxley Creek floodplain, resulting in a reduction in the annual average benefit of the structure to $21 million per annum, leading to a benefit/cost ratio of 0.50.

Sensitivity was also undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 0.79, while for a higher discount rate of 10%, the benefit/cost ration reduces to 0.38.

8.4.8.6 Multi-Criteria Review

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.4.8.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	Approximately 3,500 properties (mostly within HR2 and HR3 Potential Hydraulic Risk areas) would benefit directly from preventing Brisbane River backwater into Oxley Creek for flooding up to the 1 in 100 AEP event. As for the previous option, benefits would only be achieved if local catchment runoff was also prevented from inundating these properties, which would require very large pumps (assuming that local catchment runoff coincides with Brisbane River flooding). Events larger than the 1 in 100 AEP would overtop the structure and would impact all Oxley Creek properties as per existing conditions. A large number of properties in the vicinity of Oxley Creek, but downstream of the railway line, would not benefit from this option. As for the previous option, removal of flood storage from within the Oxley Creek floodplain would result in increased flood levels in the Brisbane River. This would have the unacceptable impact of exacerbating flooding at the 1 in 100 AEP level for approximately 12,000 properties (mostly within current HR2 and HR3 areas).	1.0
Improve time for evacuation (now and future)	Evacuation routes located behind the structure benefit from the flood immunity up to the 1 in 100 AEP flood. This includes the regional evacuation route (State controlled road) the Ipswich	1.0

	Motorway. Currently the motorway is susceptible to flooding at the 1 in 20 AEP flood (refer Section 4 Current Flood Risk). While there would be improved time for evacuation in areas adjacent to Oxley Creek behind the flood gate structure, the increase in flood levels along the Brisbane River would reduce available warning time for a large number of properties and affect local evacuation routes..	

8.4.8.6.2 Social

Targets vulnerable community members or areas	The population benefiting from this option includes the suburbs of Inala and Oxley, which are considered to be more vulnerable than average, as detailed in Section 4 Current Flood Risk. Areas where flooding is exacerbated by this option include Sherwood, Graceville and Fairfield, which also include some more vulnerable people. On balance, there is a much larger number of properties detrimentally affected than benefiting from this option.	2.0
Social health benefits	While there are some areas that benefit from this option, there is a much higher number that are detrimentally affected. On balance, the social health benefits would be considerably worse than existing conditions under this option.	1.5
Improves community flood resilience (now and future)	The option provides benefits to some residents, but at the expense of worsening conditions for a much larger number of residents. The installation of the flood gate structure would not provide any significant regional community resilience, as there would be a tendency for the community to rely on infrastructure to manage flooding rather than taking effective measures themselves. On balance, and due to the widespread impacts, community resilience under this option would be notably lower than existing conditions. The protection afforded by the rail line levee and sluice gates would directly benefit two emergency management facilities, four critical energy infrastructure items and two critical water infrastructure items. However, the increase in flooding elsewhere in the floodplain would exacerbate issues at three emergency management facilities, 23 critical energy infrastructure items, one critical telecommunications item, and two critical water infrastructure items. It would also cause new flooding at another critical energy infrastructure item.	1.5

Recreation and amenity	This option would potentially restrict waterway access along Oxley Creek. The lower reaches of the waterway are used for recreational boating and there are a number of private jetties along the waterway banks. Passive watercraft, such as kayaks and canoes, may be used more extensively upstream of the structure. Depending on the design, the structure may provide pedestrian access across the creek at this location, which may improve local amenity.	1.5
Connection and collaboration	This option would potentially detract from the community's connectedness to the river and watercourses as it involves constructing a very large artificial structure across the natural waterway.	1.5

8.4.8.6.3 Economic

Reduce damages and costs to residential property (now and future)	Similar for the 1 in 50 AEP flood gates described before, this option will result in significant benefits for residential properties located behind the structure. The economic dis-benefits to a large number of properties downstream of the structure and elsewhere in the Brisbane River floodplain is less than the benefits to properties behind the structure. The net benefit for this option (for all property types) is almost $22 million per year.	4.0
Reduce damages and costs to business and industry (now and future)	As per the residential properties, the benefits to commercial properties behind the structure is significant and outweighs the detrimental impact to properties downstream.	4.0
Option likely to be cost beneficial (now and future)	As outlined in Table 8-33, the high average annual benefit results in a benefit/cost ratio of around 0.5 which typically signals a reasonable likelihood that the option could be implemented depending on other benefits and impacts.	2.5

8.4.8.6.4 Feasibility

Physical / technical (now and future)	The design and construction of the 1 in 100 AEP Oxley Creek sluice gates would be relatively straightforward, however, raising the existing rail line would be more challenging as it would render the rail line inoperable during the works period. The geotechnical condition of the existing rail embankment would need to be assessed to determine if it can be raised and withstand the additional loading of material.	2.5

	This measure would need to involve early consultation with Queensland Rail and/or the Department of Transport and Main Roads to ensure its technical viability for the safe and efficient operation of the existing railway and also how this aligns with any future railway upgrade requirements (e.g. possible Inland Rail link to Port of Brisbane).	
Legal / approval risk	There are a number of exemptions for approval requirements where DTMR are undertaking government supported transport infrastructure. Consultation with DTMR/QR will be required to determine if the raising of the railway line can be considered government supported transport infrastructure and if they will undertake the work particularly if this corridor is subject to future upgrades. If this is not the case, an application for Building works (and possibly Operational Works) within a State Transport Corridor would be required, however there would be consent requirements and other approvals (such as undertaking works on a railway line) that would need to be secured as part of this. Depending on the design and location of the pump station, approval may be required for a utility installation associated with this. Without consultation with DTMR/QR and without a clear understanding of how the design relates to the operation of the railway line, approval likelihood is difficult to determine.	4.0
Potential for additional funding sources	The benefit-cost assessment indicates that there is a somewhat low return on investment for such a structure through reduction of damages over time. Given the significant costs though, it would be difficult to formulate a business case that would receive positive support from potential funding bodies. The rail line may form part of the national Inland Rail program. This program seeks to upgrade existing rail lines for increased service, and in doing so, should aim to keep the rail operable up to the 1 in 100 AEP event. As such, improvements to the rail line component could be funded through this program. It is worthy to note that the bulk of the costs for this option are the pump stations, which are independent of the rail line, so this alternative funding may not necessarily make a strong case for pursuing this option.	1.5

8.4.8.6.5 Attitude

Decision makers	With a reasonably low economic return on this option, it is unlikely to receive significant government support for implementation. Furthermore, the worsening of flooding for a significant number of downstream properties can not be supported.	1.5
Community	Results from the community survey (refer to Section 11 Community Awareness and Resilience) showed residents of BCC had no particular preference for or against the use of levees. Although there are some 3,500 properties that would be protected by the structure, the impacts of the structure would exacerbate flood impacts for more than 12,000 properties at the 1 in 100 AEP flood level. It is expected that this option would not have much community support, and indeed may face significant community opposition to the use of funds.	1.0

8.4.8.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	This option will improve local access on roads within the Oxley Creek floodplain for floods up to the 1 in 100 AEP event. This includes providing road access for some 3,500 properties within the floodplain, which may assist in evacuation during a flood event. However, the impacts of this option will create higher flood levels elsewhere affecting some 12,000 properties, and may have a detrimental impact on the function of transport and infrastructure in neighbouring suburbs. This option will also maintain operability of the rail line for floods up to 1 in 100 AEP. This rail line is used for delivering freight to the Tennyson Toll depot, which is then distributed throughout the Brisbane area.	2.0
Protection of regional water supply quality and security – catchment protection (quality and yield)	This option would have no impact on regional water quality or quantity.	2.5

8.4.8.6.7 Environment and Natural Resource Management

Species impacts	There would be no significant impact to species richness or diversity. The structure would impede aquatic species movement during times of flood, however, this would be for a relatively short	2.0

	period. Nonetheless, there may be some impact on species that rely on floods for movement through the river environment.	
Vegetation and habitat impacts	There would be no significant impact on terrestrial vegetation and habitats. The location of the levee, means that there would be little to no net loss of valued habitat due to construction. The restriction of flow during times of flood, however, may have an impact on aquatic habitats that rely on floods, including upstream wetlands.	2.0
Ecosystem health connectivity (fish passage/fauna movement)	There would be no impact on ecosystem health connectivity through fish and fauna passage with the exception of fish passage during times of flood. It is recognised that waterways provide a natural corridor for some species. The structure proposed is unlikely to have a significant detrimental effect on species movement in the long term. Pondage of local flood waters behind the levee has the potential to form anoxic in-stream conditions through the decay or organic matter washed into waterways during the flood event. On the basis that ponded water is pumped into the Brisbane River, this would not be of concern, however, if pumping was to be insufficient and allow extended ponding of floodwaters, anoxia within the water may degrade the ecosystem health with the potential for lasting impacts.	2.5
Reduction in landscape salinity / improved moisture retention and groundwater recharge	There would be no impact to the landscape salinity or moisture, as this option does not encourage local ponding or water storage.	2.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	There would be no impact to the erosive capacity of the catchment or channel stability providing that higher velocities in and around the sluice gate structure itself are managed through bed and bank protection works.	2.5

8.4.8.7 *Assessment of Option Against Multiple Criteria*

Similar to the 1 in 50 AEP Oxley Creek option, and as outlined in Section 8.10.2, the 1 in 100 AEP Oxley Creek rail line levee and sluice gates option has an overall multi-criteria assessment result of -0.37, where a value of 0.0 represents a net ‘no change’ condition across the various criteria. Thus, with a negative score it has been determined that the option would have a net overall detrimental impact when weighed against the various criteria.

The levee is ranked 15th out of the 16 options considered in the MCA (refer Table 8-64).

The lowest scoring criteria for this option were the safety of people and community attitude criteria (value of 1.0), while the best related to reduced residential and commercial damages and legal/approval risk (value of 4.0) (with legal/approval issues benefiting from the existing rail line infrastructure). Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.4.8.8 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The proposed 1 in 100 AEP Oxley Creek rail line levee and sluice gates will address flooding for events up to the 1 in 100 AEP flood only. Larger events will still impact on the local population at risk with no residual mitigation by the levee. There are many residential areas downstream of the levee and adjacent to the Brisbane River that would not be protected by the levee and sluice gates.
environmental or social disadvantage	The 1 in 100 AEP Oxley Creek rail line levee and sluice gates should not create environmental or social disadvantage providing they are operated in accordance with design and do not allow extended periods of ponding of local flood waters.
an unacceptable economic cost to State, local government, community or individual	The 1 in 100 AEP Oxley Creek rail line levee and sluice gates would attract a high very cost given the limited numbers of beneficiaries. This could be considered an unacceptable economic cost.
technical impracticability	The levee and sluice gates would be technically feasible but may have some construction challenges given the site constraints and unknown geotechnical conditions of the existing rail embankment.
other unusual or unique circumstances	There are no obvious other unusual or unique circumstances that would preclude the feasibility of this option.

8.4.9 The Importance of Floodplain Storage

8.4.9.1 Overview

The two previous options, which investigated the merits of flood mitigation structures within Oxley Creek, highlight the importance of the Oxley Creek floodplain to the overall Brisbane River hydraulic behaviour. Reduction of critical storage areas within the Brisbane River floodplain has the potential to significantly increase flood levels elsewhere along the river, as the floodplain is not able to temporarily detain the floodwaters as they move downstream. The sensitivity of the Brisbane River floodplain to changes in hydraulics was identified in the Phase 2 (Flood Study) and noted further in Section 4 Current Flood Risk.

While Oxley Creek floodplain is large in relation to the overall Brisbane River floodplain, there are many other flood storage areas along the river where floodwaters back up into local creeks and gullies. The floodplains surrounding some of these local creeks and gullies have been urbanised over the years, increasing the damage that occurs when the Brisbane River is in flood.

Backflow devices have been introduced into some parts of Brisbane, providing flood protection for low lying areas that are impacted by backwater inundation through an existing stormwater network. Extending this idea further, it is possible that some other smaller backwater storage areas could be protected through small local levees and backflow prevention devices.

This Phase 3 (SFMP) includes a sensitivity assessment to understand the hydraulic importance of these smaller floodplain storage areas that experience backwater flooding when the Brisbane River flood levels are high. Using the Brisbane River detailed hydraulic model from the Phase 2 (Flood Study) and incorporating levees to prevent backwater inundation into these areas, the model was simulated to determine potential impacts elsewhere in the river when the smaller floodplain storages are removed on a cumulative basis.

The assessment considered the removal of these areas up to both the 1 in 50 AEP and 1 in 100 AEP flood levels. Assessments have been carried out on both the Brisbane River, between Pinjarra Hills and St Lucia, and the lower Bremer River, downstream of Leichhardt. The results of the investigations are presented below.

8.4.9.2 Lower Brisbane River Backwater Areas

8.4.9.2.1 General Description of Assessment

For this sensitivity assessment, floodplain storage areas located adjacent to the Brisbane River between Pinjarra Hills and St Lucia were removed from the effective hydraulic area of the flood model. Only areas that represented smaller tributary creeks and gullies were removed. Areas of extensive overbank floodplain adjacent to the Brisbane River directly, such as Chelmer and Graceville, were not removed from the hydraulic area. Locations and extents of side channel storages removed from Brisbane River for this sensitivity assessment are presented in Figure 8-26.

8.4.9.2.2 Hydraulic Impacts

The sensitivity of the side storages in the Brisbane River was assessed by adjusting the Brisbane River detailed hydraulic model to incorporate levees at the designated creeks/gullies with crest elevations at the 1 in 50 AEP and 1 in 100 AEP flood levels, for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below and summarised in Table 8-34, while impact on flood levels is shown in Figure 8-27 to Figure 8-29.

As seen in Figure 8-27 and Figure 8-28, the impacts of loss of these floodplain storages in the Brisbane River are minimal for floods up to and including the 1 in 20 AEP event. For the 1 in 50 AEP event, the side storages are more extensively inundated and become important for flood behaviour. Removal of these storage areas has a material impact on flood levels within the river, by up to 0.15m (and 0.05m at Brisbane CBD).

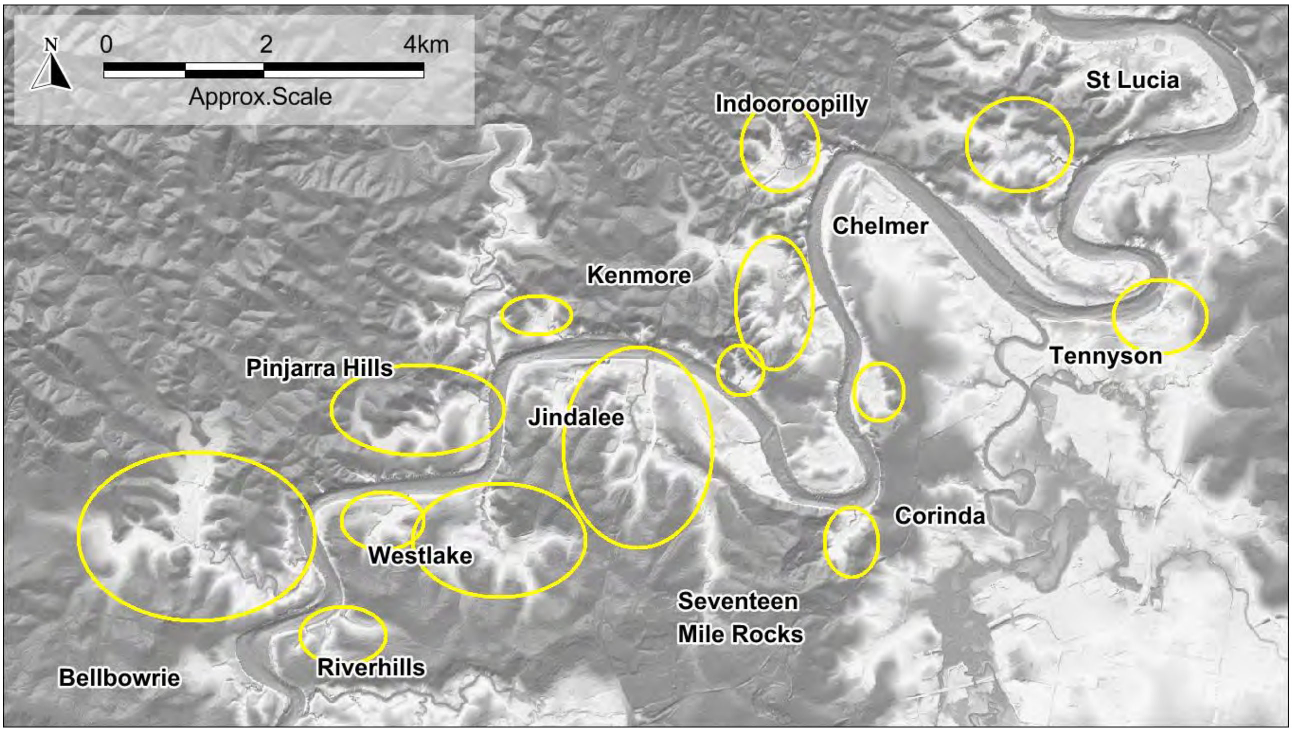
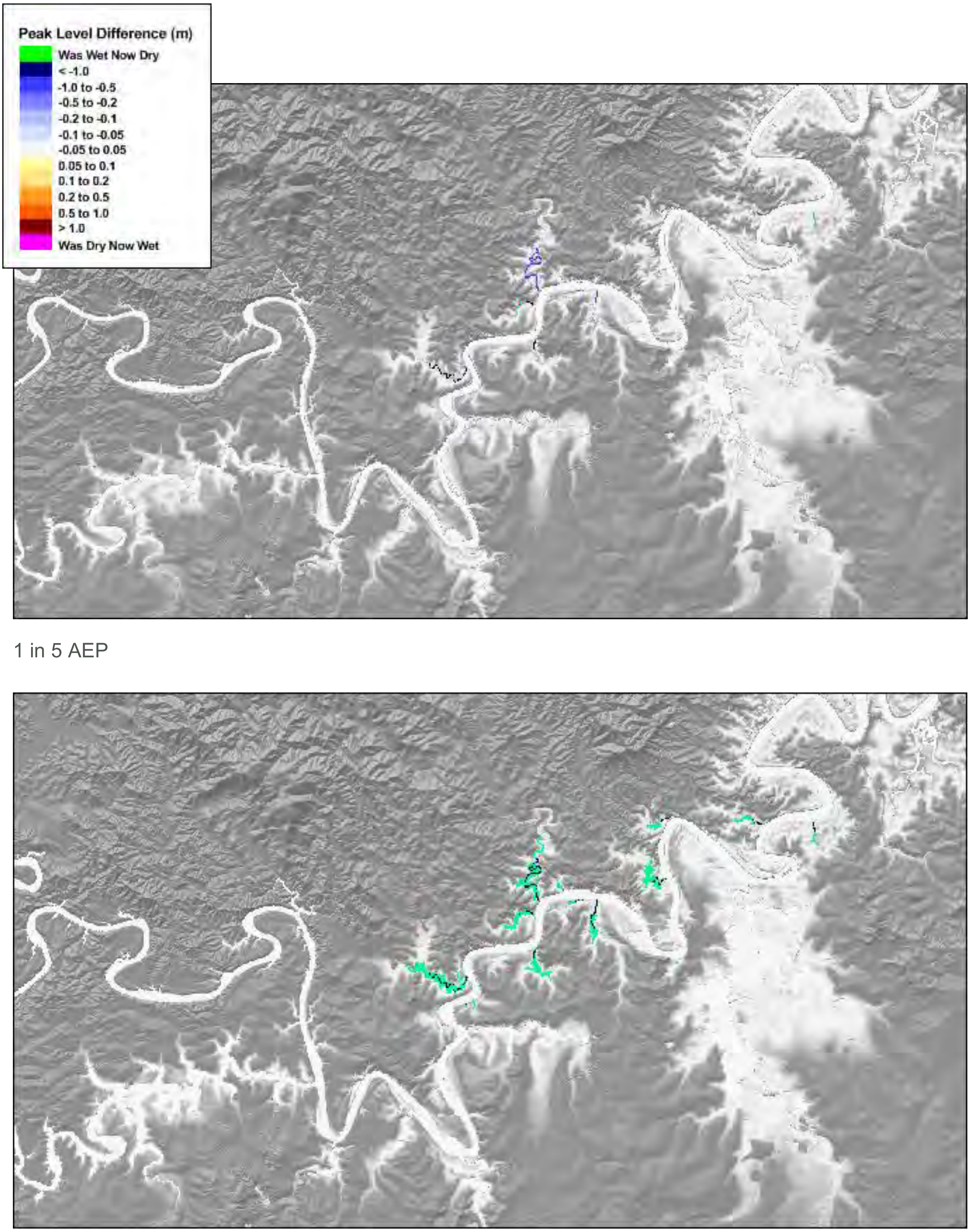


Figure 8-26 Locations of side channel storages removed from Brisbane River for sensitivity assessment

If these floodplain storages are also excluded up to the 1 in 100 AEP event (refer Figure 8-29), the impacts on flood behaviour are very widespread across the Brisbane River floodplain, with afflux both upstream and downstream. In contrast, if side storages are re-engaged above the 1 in 50 AEP level, the impacts on larger floods would be minimal, as there would be no significant reduction of floodplain storage at the peak of the flood.

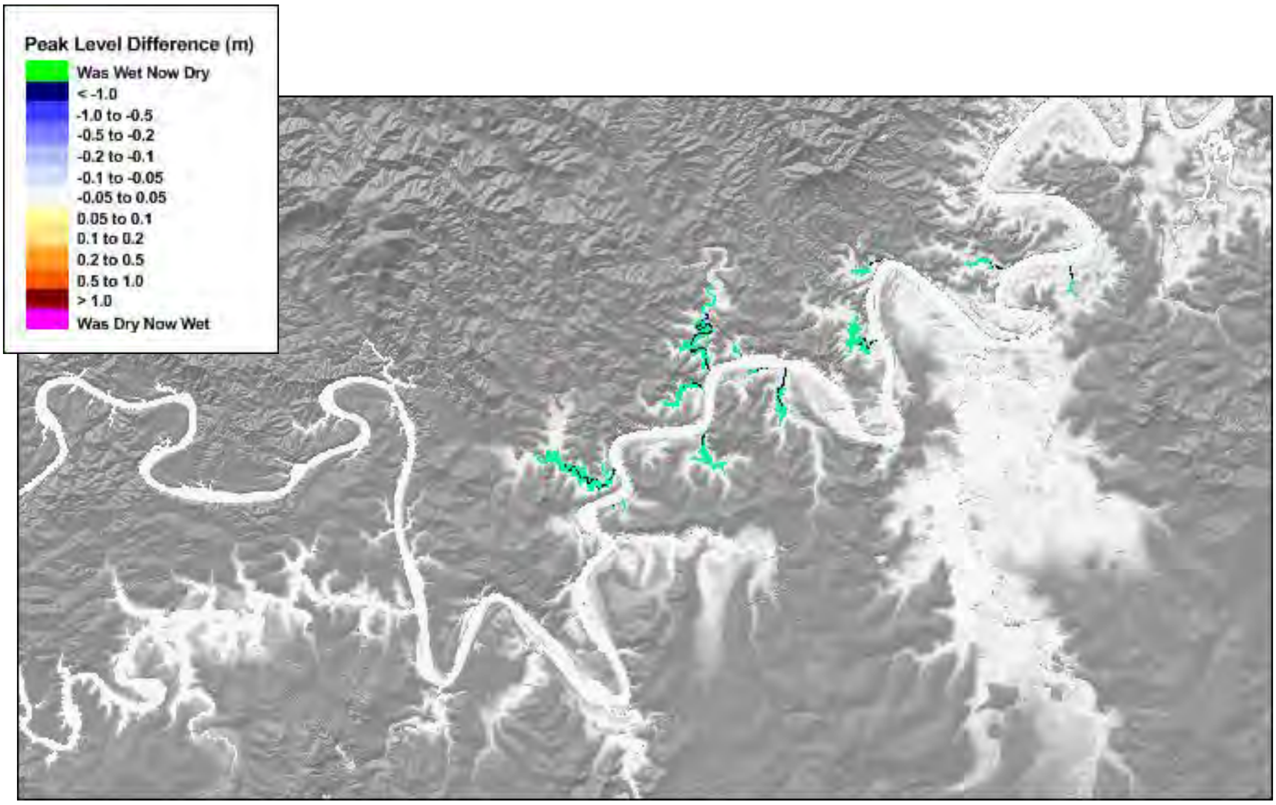
The results of the Oxley Creek options (see Sections 8.4.7 and 8.4.8) highlight the important of the Oxley Creek floodplain as a storage area for floodwater in the Brisbane River catchment. This analysis shows that other smaller side storage areas are also important for flood behaviour when considered on a cumulative basis for floods in the order of a 1 in 50 AEP or larger.



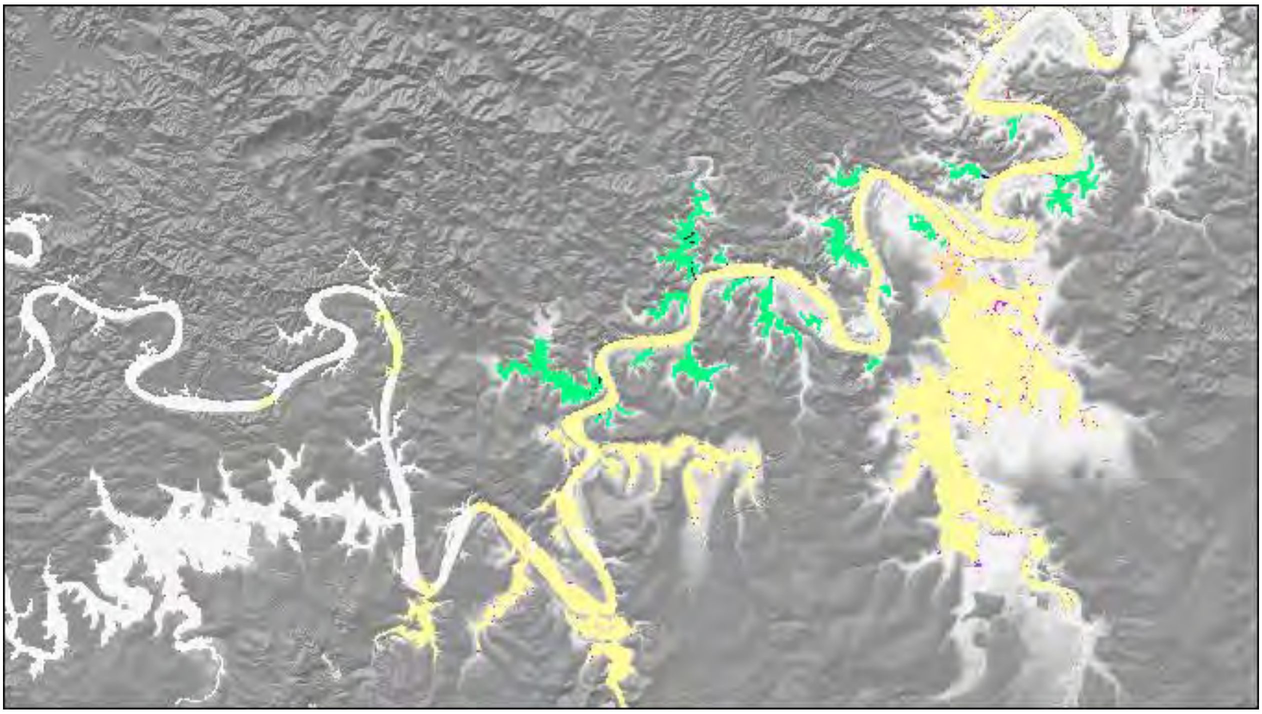
1 in 5 AEP

1 in 10 AEP

Figure 8-27 Lower Brisbane River sensitivity to loss of floodplain storage areas (1 in 5 AEP and 1 in 10 AEP)

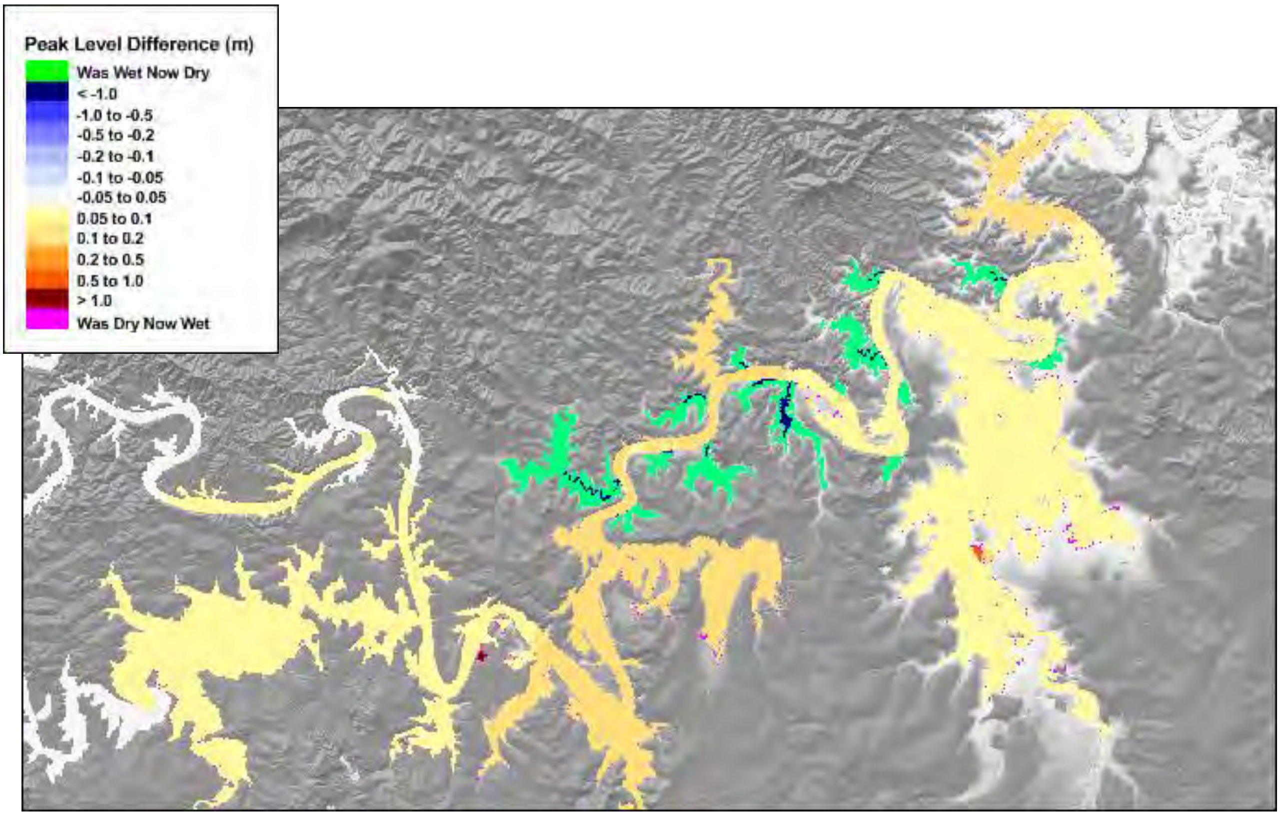


1 in 20 AEP



1 in 50 AEP

Figure 8-28 Lower Brisbane River sensitivity to loss of floodplain storage areas (1 in 20 AEP and 1 in 50 AEP)



1 in 100 AEP (no overtopping of “pseudo levees”)

Figure 8-29 Lower Brisbane River sensitivity to loss of floodplain storage areas (1 in 100 AEP)

Table 8-34 Summary of sensitivity to side channel storages in the Brisbane River

AEP	1 in 50 AEP levee crest			1 in 100 AEP levee crest		
	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD
1 in 2	< 50mm*	< 50mm*	< 50mm*	As per 1 in 50 AEP levee crest		
1 in 5	< 50mm	< 50mm	< 50mm			
1 in 10	< 50mm	< 50mm	< 50mm			
1 in 20	< 50mm	< 50mm	< 50mm			
1 in 50	**150mm**	< 50mm	**50mm**			
1 in 100	< 50mm*	< 50mm*	< 50mm*	**120mm**	< 50mm	**60mm**
1 in 200	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*
1 in 500	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

8.4.9.3 Lower Bremer River Backwater Areas

8.4.9.3.1 General Description of Assessment

For this sensitivity assessment, floodplain storage areas located adjacent to the lower Bremer River downstream of Leichhardt were removed from the effective hydraulic area of the flood model. Only areas that represented smaller tributary creeks and gullies were removed. Areas within larger tributaries of the Bremer River and other extensive overbank floodplains such as downstream of Bundamba Creek, were not removed from the hydraulic area as these areas would be too impractical to separate from the Bremer River. Locations and extents of side channel storages removed from Bremer River for this sensitivity assessment are presented in Figure 8-30.

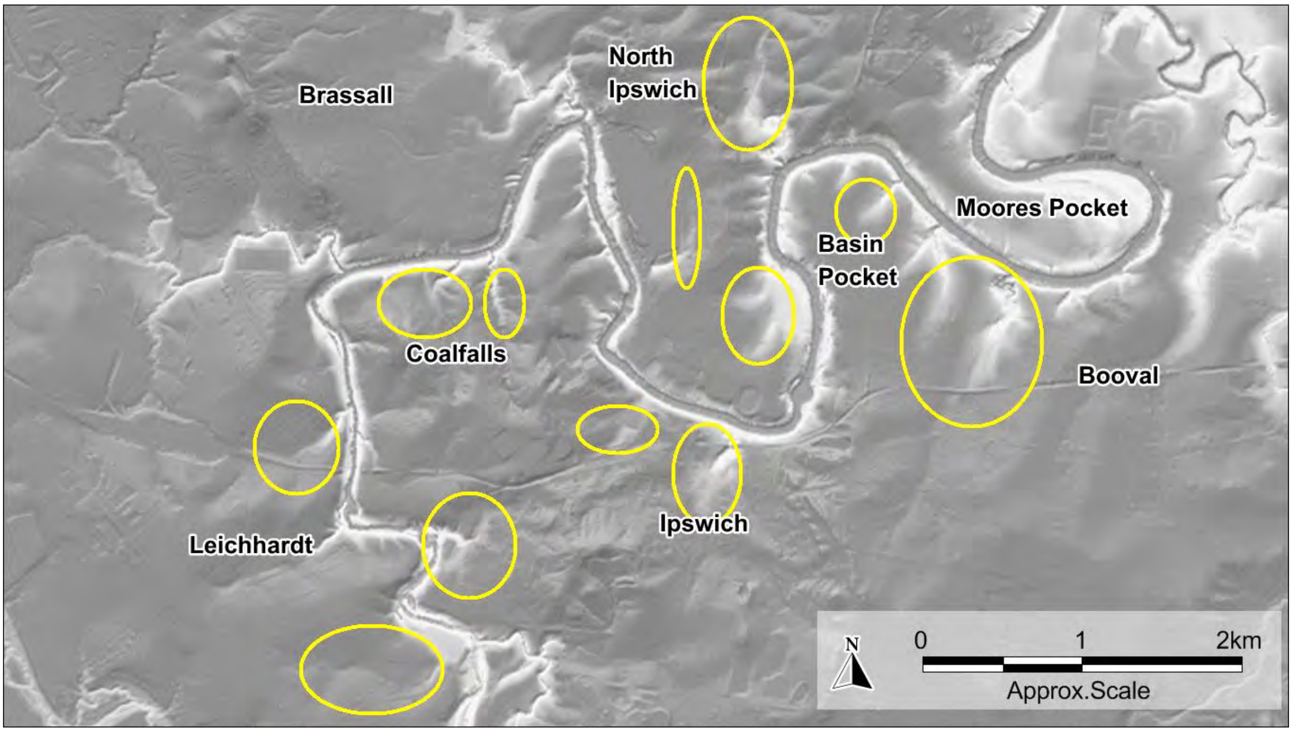


Figure 8-30 Locations of side channel storages removed from Bremer River for sensitivity assessment

8.4.9.3.2 Hydraulic Impacts

The sensitivity of the side storages in the Bremer River was assessed by adjusting the Brisbane River Catchment detailed hydraulic model to incorporate levees at the designated creeks/gullies with crest elevations at the 1 in 50 AEP and 1 in 100 AEP flood levels, for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below and summarised in Table 8-34, while impact on flood levels is shown in Figure 8-31 to Figure 8-33.

Material impacts on flood levels in the Bremer River start to emerge at the 1 in 5 AEP to 1 in 10 AEP flood conditions. For the 1 in 10 AEP flood, afflux of up to 0.1 metre occurs as a result of the loss of side storages within the Bremer River floodplain. For the 1 in 50 AEP event, the afflux at Ipswich CBD is 0.07 metres.

Table 8-35 Summary of sensitivity to side channel storages in the Bremer River

AEP	1 in 50 AEP levee crest			1 in 100 AEP levee crest		
	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD
1 in 2	< 50mm*	< 50mm*	< 50mm*	As per 1 in 50 AEP crest		
1 in 5	**80mm**	< 50mm	< 50mm			
1 in 10	**100mm**	< 50mm	< 50mm			
1 in 20	**60mm**	< 50mm	< 50mm			
1 in 50	**70mm**	**70mm**	< 50mm			
1 in 100	< 50mm*	< 50mm*	< 50mm*	**140mm**	**100mm**	< 50mm
1 in 200	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*
1 in 500	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*	< 50mm*

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

If these floodplain storages are also excluded for the 1 in 100 AEP event (refer Figure 8-33), the impacts on flood behaviour are widespread throughout the lower Bremer River, with afflux both upstream and downstream, peaking at 0.14 metres in the vicinity of One Mile / Yamanto. In contrast, if side storages are re-engaged above the 1 in 50 AEP level, the impacts on larger floods would be minimal, as there would be no significant reduction of floodplain storage at the peak of the flood.

8.4.9.4 Discussion on Floodplain Storage

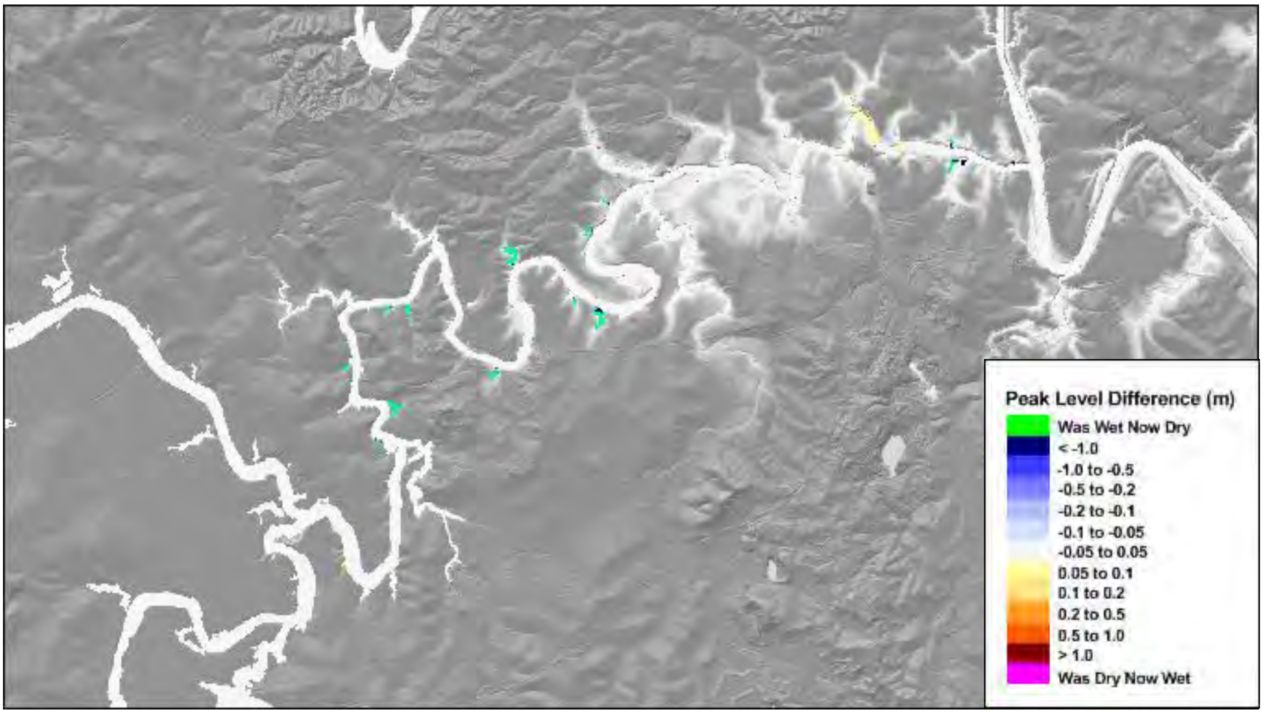
The assessment described here is not intended to represent actual flood mitigation solutions. Rather, the assessment was used to hydraulically test the importance of these side channel floodplain areas and the sensitivity of the river to the loss of such areas.

As expected, the importance of floodplain storage increases with higher AEPs. The contribution of the floodplain to flood detention is dependent on the size of the overbank floodplain and the volume of water that can be held (which is a function of the elevation of the floodplain relative to the AEP flood levels).

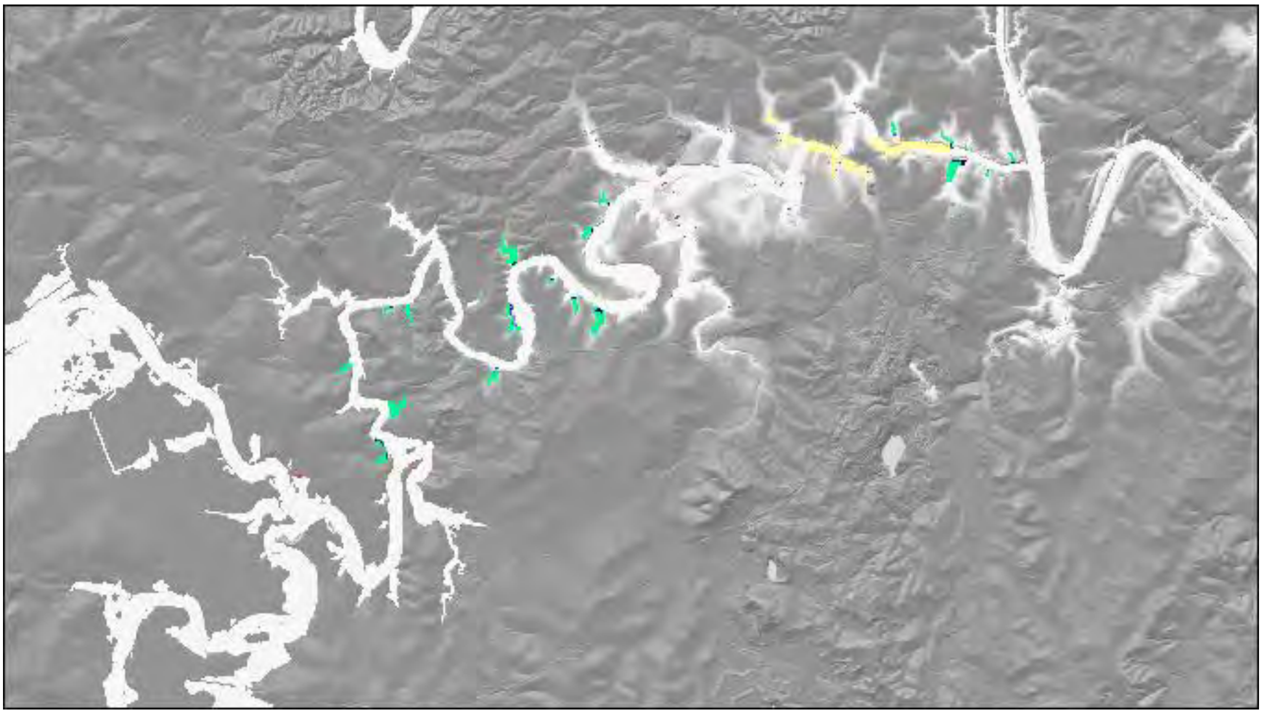
The assessment of floodplain storage described above highlights the sensitivity of the Brisbane River to changes in the floodplain. This is because the incised nature of the valley means that areas for floodplain storage are relatively limited, with the exception of the lower Lockyer Creek and upper Bremer River tributaries. Any loss of floodplain storage therefore has potentially material impacts on hydraulic behaviour. This same conclusion was drawn from the Future Development analysis reported in Section 5 Future Flood Risk.

The sensitivity of the Brisbane River floodplain, and in particular the sensitivity to floodplain storage, is easily represented by a difference plot between the 1 in 50 AEP and 1 in 100 AEP levels (see Figure 8-34). Areas of large difference represent areas where the flood levels in the river are very sensitive to changes in flow and/or floodplain condition. Areas of large difference, and hence sensitivity, are located in the more incised sections of river, notably between Wivenhoe Dam and St Lucia on the Brisbane River, and in the lower reaches of the Bremer River.

The difference between the 1 in 50 AEP and 1 in 100 AEP flood levels at Moggill is about 4.7 metres. By comparison, this difference in levels for other major East Coast rivers including the Richmond, Clarence and Tweed Rivers, is all less than 0.5 metres. The significantly larger values for the Brisbane River highlights the much greater level of sensitivity of the Brisbane River than other similar river systems (given the dearth of natural floodplain storage), and therefore needs particular care and attention when managing flood risks.

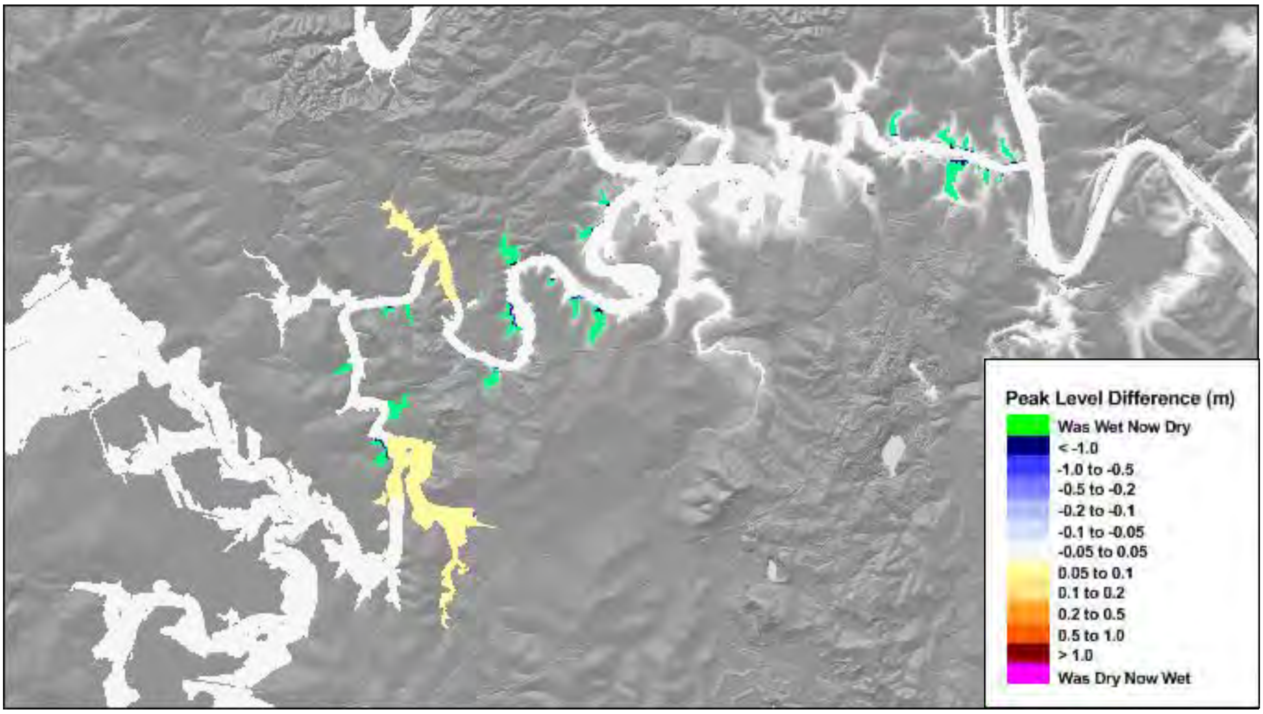


1 in 5 AEP

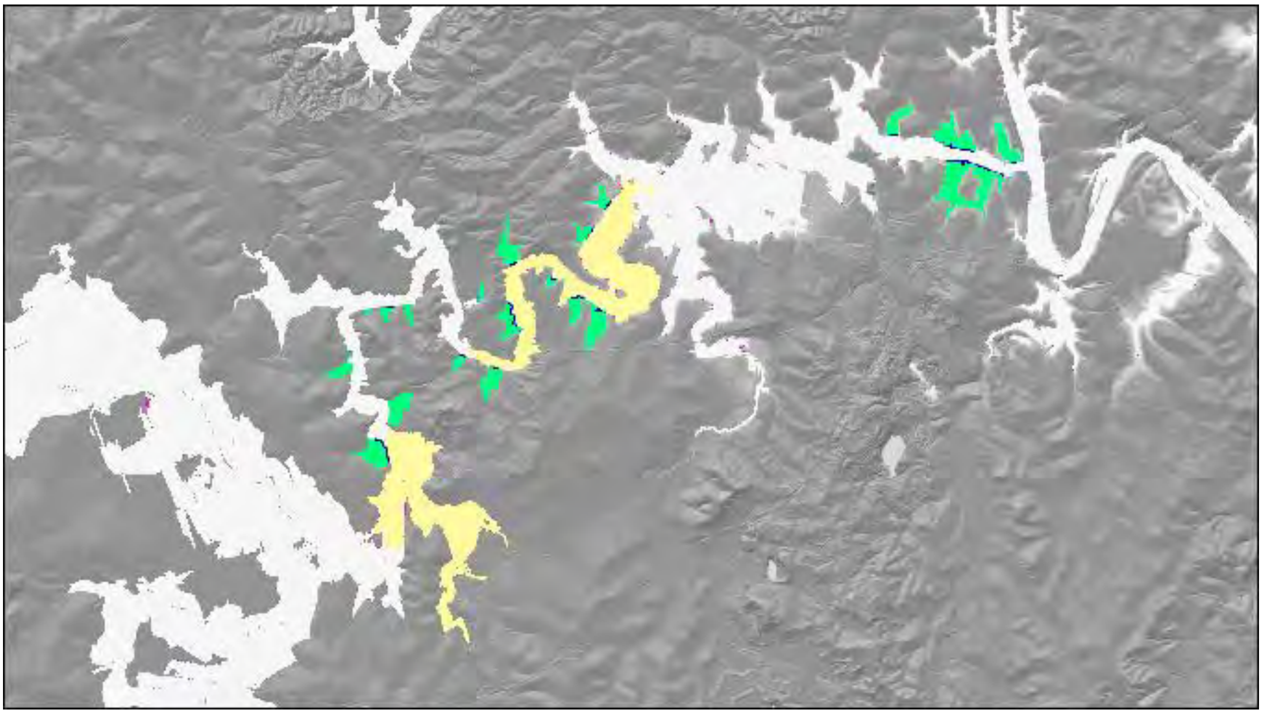


1 in 10 AEP

Figure 8-31 Lower Bremer River sensitivity to loss of floodplain storage areas (1 in 5 AEP and 1 in 10 AEP)

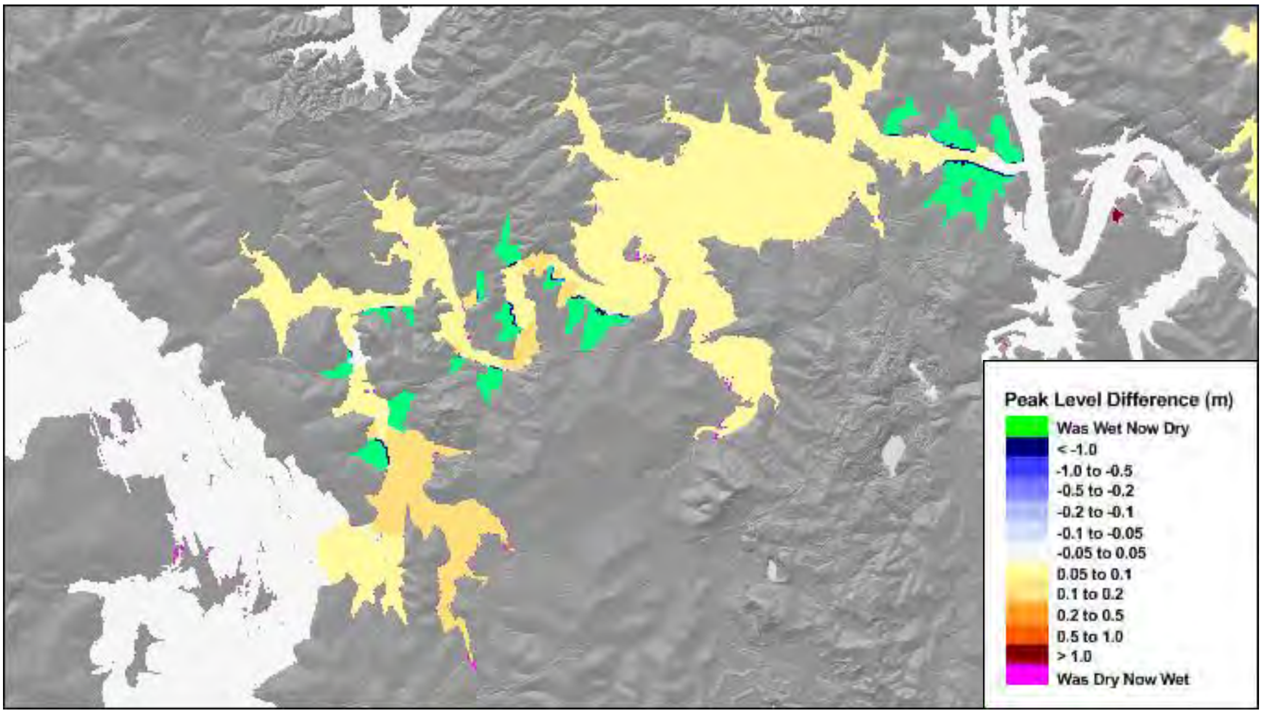


1 in 20 AEP



1 in 50 AEP

Figure 8-32 Lower Bremer River sensitivity to loss of floodplain storage areas (1 in 20 AEP and 1 in 50 AEP)



1 in 100 AEP (no overtopping of “pseudo levees”)

Figure 8-33 Lower Bremer River sensitivity to loss of floodplain storage areas (1 in 100 AEP)

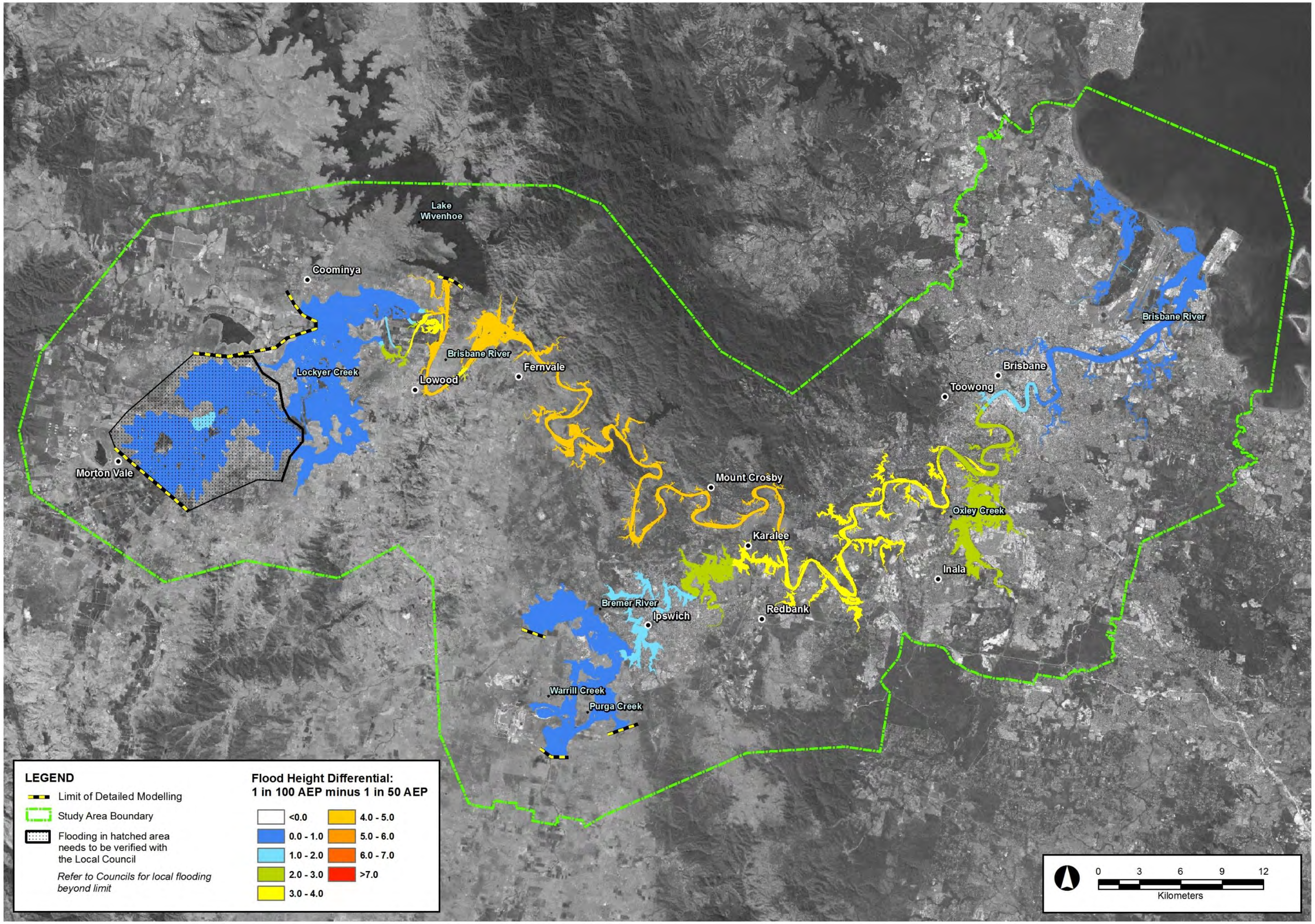


Figure 8-34 Difference between 1 in 50 AEP and 1 in 100 AEP flood levels

8.5 Temporary Barriers

8.5.1 Overview

The following temporary barrier options were short-listed and have been evaluated:

Table 8-36 Temporary Barrier Options Assessed

Location	Description / Immunity level	Report Section
South Brisbane	Levee at 1 in 100 AEP	Section 8.5.2
Brisbane CBD	Levee at 1 in 200 AEP	Section 8.5.3

Protection offered by temporary barriers/levees are limited by the height that they can be installed. Temporary levee barriers are generally comprised of modular fixed panels, or water-filled flexible tubes. Two of the most important considerations for temporary levees are i) the storage of the levee during non-flood times, and ii) the time required to transport, deploy and commission the levee structure.

The advantage of temporary levees is that during non-flood times, the structure is not deployed and therefore does not have amenity issues that would otherwise need to be considered for a permanent levee.

An additional advantage is that temporary barriers could be used in alternative locations (if other areas are flooding and South Brisbane is not), providing that the design and size of the barrier is sufficient and flexible enough to accommodate such deployment. Further investigations are required to determine the viability of this temporary barrier adaptability.

QFES owns 1 km of 1.5 metre high barrier and 160 metres of 1.8 metre high barrier which have been utilised at Rockhampton Airport and in Charleville in recent years and are available to the disaster management stakeholders through a Queensland Disaster Management Arrangements (QDMA) Request for Assistance (RFA). QFES experience has been that, in addition to stormwater drainage outlets, consideration needs to be given to other buried services (e.g. telecommunications) which act as conduits to water ingress. This resource may help inform the viability and design of temporary barriers for use in the Brisbane River floodplain.

8.5.2 South Brisbane

8.5.2.1 General Description of Option and Assessment

South Brisbane in the vicinity of South Bank contains a range of land uses, including multi-unit residential, commercial and community infrastructure. Some of the buildings in the area contain valuable collections (such as the library and museum), while the area is also significant from a tourism and business perspective.

Selected design flood results generated in the Phase 2 (Flood Study) are shown in Table 8-37.

Table 8-37 Peak flood levels at South Bank (from BMT WBM, 2017)

Design Event	Peak level (AHD) at South Bank
1 in 50 AEP	3.8m
1 in 100 AEP	5.4m
1 in 200 AEP	6.8m

Many of the tourism-related buildings are located on the river fringe, with ground levels less than 4 mAHD. The height and length of temporary barriers required to protect these buildings in large floods (e.g. up to a 1 in 100 AEP) would be excessive and unlikely to be feasible. However, the area to the south of the tourist precinct is inundated via Russell Street, which was considered more feasible for the installation of a temporary barrier.

The Phase 2 (Flood Study) suggests that the river bank overtops and flooding occurs down Russell Street between a 1 in 50 and 1 in 100 AEP flood event, with inundation beneath the Brisbane Convention Centre before then flooding lower-lying areas along Cordelia and Merivale Streets, between Melbourne and Glenelg Streets. This was observed in the 2011 Brisbane flood event and resulted in the inundation of a considerable number of residential and commercial properties.

The option consists of implementing a temporary flood barrier across Russell Street (approximately between the QPAC building and the ABC building, at the eastern end of Russell Street) to prevent flooding from the Brisbane River within this section of South Brisbane. This option requires installation of backflow devices to prevent flooding occurring through the existing stormwater system, and to limit short-circuiting of floodwaters through existing underground carparks. It is understood that only one backflow device is currently installed in South Bank with works for remaining outlets subject to available funding and priorities across the city (pers. comm. BCC, 2017).

It is noted that this option does not target flood proofing of community infrastructure along the river bank, such as the galleries, museums, libraries and performance spaces.

Ground levels in the vicinity of the temporary barrier are approximately 4m AHD. The maximum practical level of immunity that could be achieved by temporary barriers would be about a 1 in 100 AEP, with design flood depths in the order of 1.5 metres. To protect to the 1 in 200 AEP level, temporary barriers in excess of 3 metres would be required, which is considered impractical.

8.5.2.2 Concept Design

To achieve the desired flood immunity (1 in 100 AEP) the temporary flood barrier would need to have a crest level no lower than 5.35 m AHD.

There are various temporary flood barriers available on the market, the majority fall within two categories (fixed frame and tube barriers). In general the water filled tube barriers are cheaper and can be installed in a shorter time frame. This assessment was based on a water filled barrier from Aqua Dam (http://conceptservices.com.au/solutions/aqua-dam/).

The option assumes a 35m long temporary flood barrier with an average height of 1.6m. The barrier would be located on the pedestrian area between the ABC building and QPAC building. Based on the Aqua Dam guidelines (http://aquadam.net/Guides/guide5.html), the maximum flood depth of 1.65m would require an Aqua Dam 1.82m high and 5.76m wide (fully inflated).

The location of the barrier can be seen in Figure 8-35, while a typical application of a water-filled tube barrier is presented in Figure 8-36. Confirmation of the most appropriate structure would be confirmed at detailed design stage, however, a possible alternative to the water-filled tube would be a fixed panel arrangement (see Figure 8-37). Fixed panels can be deployed relatively quickly and are more suited to short sections of protection, such as that proposed in Russell Street.

The barrier would protect South Brisbane from Brisbane River flooding. However, the barrier would also prevent overland flow from the local catchment entering the river. Small mobile pumps would be required to drain the local catchment runoff when the temporary flood barrier was in place.

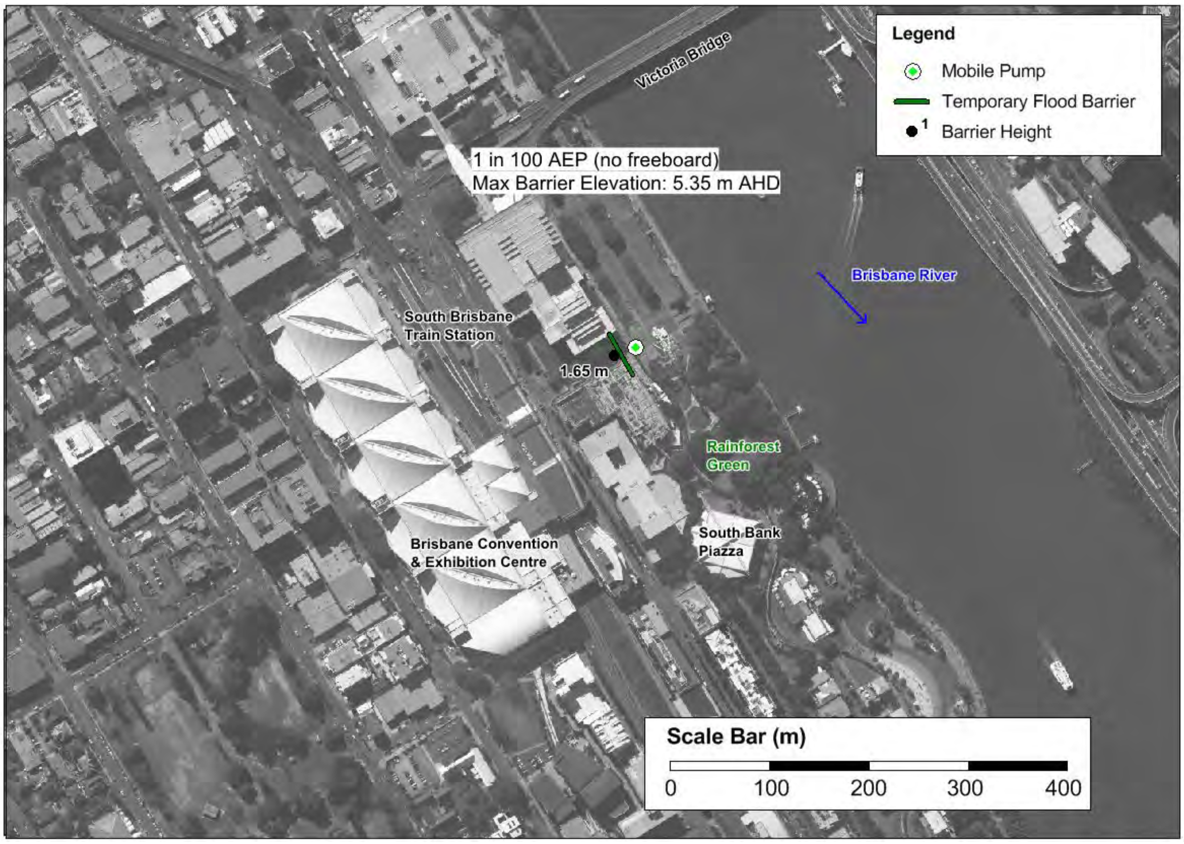


Figure 8-35 Location of South Brisbane temporary barrier

Figure 8-36 Water-filled tube flood barrier [www.readreidread.wordpress.com/]

Figure 8-37 Fixed panel temporary flood barrier [www.floodcontrolinternational.com]

8.5.2.3 Indicative Cost

The costing of the temporary barrier at South Brisbane is presented in Table 8-38 and has been based on the following assumptions:

- The barrier height is based on the Phase 2 (Flood Study) and, therefore, does not take into account the potential increase in water level as a result of the option;
- No land purchase will be required;
- No compensation would be provided to local businesses for potential loss of revenue;
- Sufficient flood warning would be provided to deploy the barrier;
- Council staff would be responsible for the deployment and security of the barrier;
- Eleven (11) stormwater outlets drain the area of South Brisbane that would be inundated, all of which would require backflow prevention devices;
- An adequate storage facility could be rented and located within 1km of South Brisbane; and
- Testing and deployment of temporary barrier every five (5) years.

Table 8-38 Indicative Cost for 1 in 100 AEP South Brisbane temporary barrier (2017 costs)

Description	Cost ($)
Traffic and Environmental Management Plans	155,000
Temporary barrier and deployment	145,000
Mobile pumps	90,000
Total Direct Job Cost	**$385,000**
Indirect Job Costs – On-Site Costs (31%)	119,000
Design Costs (9%)	45,000
Indirect Costs - Offsite Costs (3%)	16,000
Applications (5%)	28,000
Contingencies (40%)	238,000
Backflow Devices (11 outlets at $300,000 ea)	$3,300,000
Total Cost Estimate (Excluding Operating Expenses)	**$4,132,000**
Maintenance of backflow device structure (assume 2% of capex for backflow devices)	66,000
Rented storage space	44,000
Traffic management and deployment drills	1,000
Personnel for deployment drills	700
Total of Annual Operating Expenses	**$111,700**

8.5.2.4 Hydraulic Impacts

Potential impacts of the proposed 1 in 100 AEP South Brisbane temporary barrier on the hydraulic behaviour of flooding were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

The impacts of the temporary barrier on flood levels in the Brisbane River are presented in Figure 8-38 for the 1 in 100 AEP flood event. A summary of the impacts of the proposed South Brisbane temporary barrier on properties for the different AEP floods is given in Table 8-39. Approximately 280 properties benefit from this option with a mix of residential (41), commercial (182) and other (56) properties where flooding is eliminated up to the 1 in 100 AEP flood. Most of the residential properties are currently located in an HR3 Potential Hydraulic Risk area, while the commercial properties are in a combination of HR2 and HR3 areas.

Hydraulic modelling of the 1 in 100 AEP flood indicates that the peak flood afflux generated by the proposed temporary structure is less than 50mm, being the smallest threshold for gradation mapping in this regional assessment (refer Figure 8-38).

Table 8-39 Summary of South Brisbane temporary barrier impacts on properties

AEP	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	n/a	n/a	n/a	0	0	0	0
1 in 5	n/a	n/a	n/a	0	0	0	0
1 in 10	n/a	n/a	n/a	0	0	0	0
1 in 20	n/a	n/a	n/a	0	0	0	0
1 in 50	n/a	n/a	n/a	0	0	0	0
1 in 100	< 50mm	< 50mm	< 50mm	0	279	0	10
1 in 200	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 500	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.

[2] Building no longer affected by flooding.

[3] Building is flooded to a greater degree, either above or below habitable floor level.

[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.

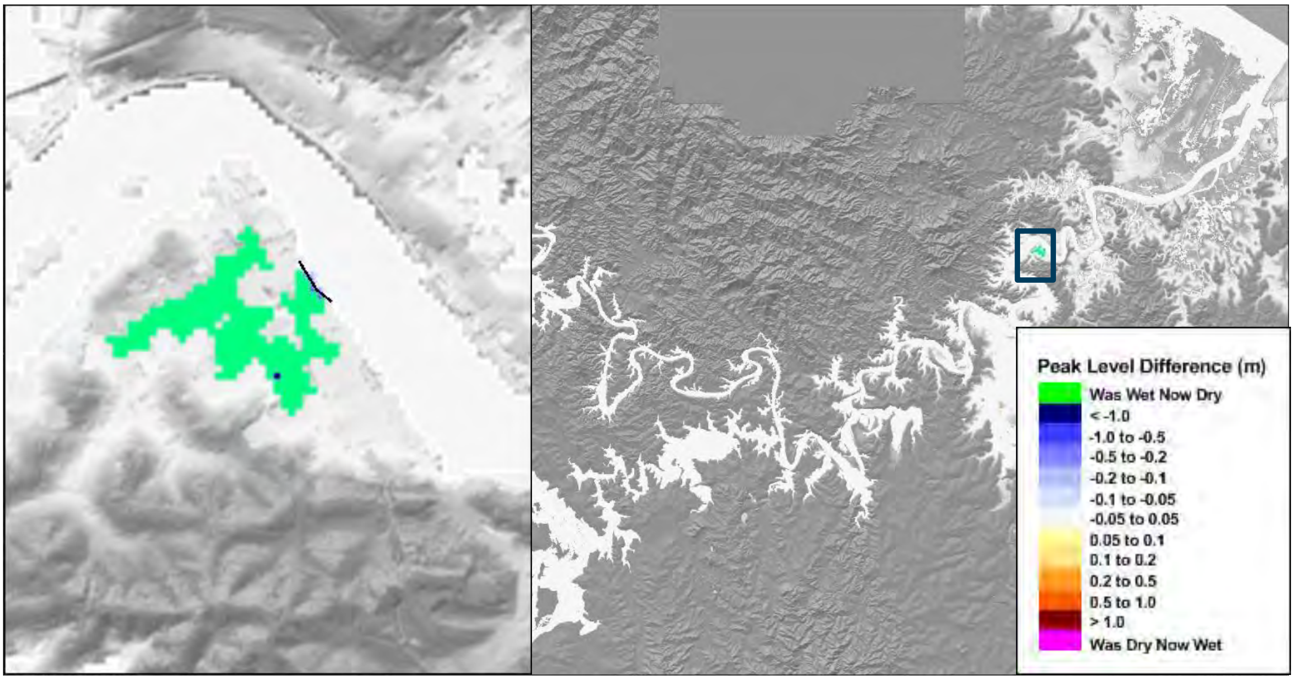


Figure 8-38 South Brisbane temporary barrier water level impacts 1 in 100 AEP

For events larger than the 1 in 100 AEP, the barrier will be overtopped and the overland inundation re-commenced. This would affect properties largely as per current conditions for those AEPs and therefore there is no material benefit from the temporary barrier. The presence of the barrier (albeit overtopped) in larger events does not have a notable impact on flood levels within the river (that is, afflux is less than 50mm).

For floods smaller than the 1 in 100 AEP, the overland flowpath is not activated. Therefore, smaller flood events are not affected by this option.

Overall, it is concluded that the South Brisbane temporary barrier would have positive benefits in terms of reduced inundation extents for the 1 in 100 AEP event only, and would not generate any notable negative impacts in adjacent areas. Benefits and impacts for floods larger or smaller than the 1 in 100 AEP are considered negligible.

8.5.2.5 Benefit / Cost Analysis

A summary of the benefit / cost analysis for the South Brisbane temporary barrier option is presented in Table 8-40.

The temporary barrier (and associated backflow infrastructure), with a capital cost of $4,100,000 and an annual maintenance cost of $112,000, will generate a net annual average benefit of $130,000, leading to a benefit/cost ratio of 0.28 when adopting a discount rate of 7% over a **30 year period**. The benefit of the barrier extends to residential and commercial properties in the South Brisbane area. The benefits are restricted to the 1 in 100 AEP event only, and thus the circumstances in which it is effective is very narrow.

Table 8-40 Benefit/cost analysis summary for South Brisbane temporary barrier option

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case (1)	288.7	288.6	0.13	**0.28**
Sensitivity 1: No intangibles	186.8	186.7	0.13	**0.27**
Sensitivity 2: with Wivenhoe up.	213.2	213.1	0.11	**0.24**
Sensitivity 3: 4% discount rate				**0.36**
Sensitivity 4: 10% discount rate				**0.22**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-40. The benefits are relatively insensitive to reductions in tangible damages, with the net benefit/cost ratio 0.27. Potential upgrades to Wivenhoe Dam could reduce the impact of flooding at South Brisbane, resulting in a reduced annual average benefit of the structure to $110,000 per annum, leading to a benefit/cost ratio of 0.24.

Sensitivity was also undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 0.36, while for a higher discount rate of 10%, the benefit/cost ration reduces to 0.22.

8.5.2.6 Multi-Criteria Review

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.5.2.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	Approximately 280 properties (all mostly located within current HR2 and HR3 Potential Hydraulic Risk areas) would benefit directly from the exclusion of flooding within South Brisbane for the 1 in 100 AEP flood only. Events larger than the 1 in 100 AEP would still impact these properties, while events up to the 1 in 50 AEP do not reach these properties. The potential hydraulic risk within South Brisbane would not change from mostly HR3 under current conditions.	3.5
Improve time for evacuation (now and future)	Approximately 280 properties would have more time to respond to a larger event that would potentially overtop the riverbank. As the warning time is already quite reasonable, the value of the additional time is limited. Regional evacuation routes (State controlled roads) in the vicinity of South Brisbane already have an immunity of 1 in 100 AEP (refer Section 4 Current Flood Risk) would not be impacted.	3.0

8.5.2.6.2 Social

Targets vulnerable community members or areas	The population benefiting from this option is considered to be of average vulnerability, as detailed in Section 4 Current Flood Risk.	2.5
Social health benefits	The reduction in the number of residential properties inundated in the 1 in 100 AEP event would lead to some social health benefits. The number of properties benefiting in the 1 in 100 AEP flood is not large, however, the properties would mostly be high density living and as such, a sizable population would benefit from that option. Benefits for floods smaller or larger than the 1 in 100 AEP event would be negligible.	3.5
Improves community flood resilience (now and future)	The deployment of a temporary flood barrier at South Brisbane would provide occupants of properties affected by flooding a longer period to evacuate. The additional time may be considered of value from a community resilience perspective. As South Brisbane is located well downstream, warning times for a 1 in 100 AEP event would be reasonable, and therefore the extra time would not necessarily provide a significant value to the community. Indeed, the deployment of the barrier may provide a false sense of security to residents and occupants, thereby delaying evacuation. Overtopping of the barrier, should flood levels exceed the 1 in 100 AEP design level, would result in very rapid onset of inundation and may be problematic for people who have not evacuated. Two elements of critical infrastructure would benefit from this option, including one emergency management facility.	3.0
Recreation and amenity	There would be no impact recreation and amenity as a result of this option. Amenity would be affected when deployed, but this would only be during flood times, when the community would be discouraged from the area.	2.5
Connection and collaboration	There would be no impact the community’s connectedness to the river and watercourses. Connectedness to the river would be affected when deployed, but this would only be during flood times, when the community would be discouraged from the area.	2.5

8.5.2.6.3 Economic

Reduce damages and costs to residential	There are approximately 40 residential properties that benefit from this option, for events in the order of a 1 in 100 AEP only. As a result, the economic benefits from reduced flood damages (for	2.5

property (now and future)	all property types) are relatively small at $130,000 per year (combined residential and commercial benefits).	
Reduce damages and costs to business and industry (now and future)	There are approximately 180 businesses and industries that would benefit from this option, for events in the order of a 1 in 100 AEP only.	2.5
Option likely to be cost beneficial (now and future)	The b/c ratio of this option is relatively low (0.28), influenced significantly by the high cost of the eleven backflow prevention devices needed for the local drainage system.	2.0

8.5.2.6.4 Feasibility

Physical / technical (now and future)	The design and construction of the temporary barrier at South Brisbane would be relatively straightforward. There is an existing paved area which would serve as the base for the structure. Feasibility of constructing backflow prevention devices at each outlet would require further consideration.	4.0
Legal / approval risk	The proposed temporary barrier is located within the South Bank Corporation area. BCC is responsible for assessing all development applications within the South Bank Corporation area however, if an application is required the land owner's consent is to be obtained from the South Bank Corporation. The structures proposed do not appear to constitute building work and would not be assessable under the *Planning Act* 2016.	5.0
Potential for additional funding sources	With a relatively modest cost, a large number of properties that benefit and high levels of support from decision makers and the community, this option should qualify for external funding.	3.5

8.5.2.6.5 Attitude

Decision makers	This option has the potential to improve flood risk without significant negative impacts (with the exception of cost). Although the structure does not target the tourism-related infrastructure and businesses, the benefits to residential and commercial properties are significant in a 1 in 100 AEP event. It is expected that decision makers would generally support this option.	4.0
Community	Results from the community survey (refer to Section 11 Community Awareness and Resilience) showed residents of BCC had no particular preference for or against the use of levees.	3.5

	The local community that benefits from this option would likely be very supportive of the works. Temporary barriers do not inhibit amenity outside of flood events. The broader community of Brisbane may expect that a barrier at South Bank should benefit community infrastructure over private properties and therefore may be less supportive generally.	

8.5.2.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	This option will improve access within South Brisbane, which includes major distributor roads servicing Brisbane River crossings. Improved access will be limited though as the temporary barrier will only mitigate flooding up to a 1 in 100 AEP flood. The temporary barrier will not improve the function of community infrastructure located along the river bank, nor will it offer protection to collections stored within these buildings.	3.0
Protection of regional water supply quality and security – catchment protection (quality and yield)	This option has no impact on regional water quality or quantity.	2.5

8.5.2.6.7 Environment and Natural Resource Management

Species impacts	There would be no impact to species richness or diversity.	2.5
Vegetation and habitat impacts	There would be no impact on vegetation and habitats. The location of the levee, on an existing road, means that there would be no net loss of habitat due to construction.	2.5
Ecosystem health connectivity (fish passage/fauna movement)	There would be no impact on the ecosystem health connectivity through fish and fauna passage.	2.5
Reduction in landscape salinity / improved moisture retention and groundwater recharge	There would be no impact on the landscape salinity or moisture, as this option does not encourage local ponding or water storage.	2.5
Reduction in erosive capacity / soil movement – channel	There would be no impact on the erosive capacity of the catchment or the bank stability of waterways.	2.5

stability / geomorphology		

8.5.2.7 Assessment of Option Against Multiple Criteria

As outlined in Section 8.10.2, the South Brisbane temporary barrier has an overall multi-criteria assessment result of 0.63, where a value of 0.0 represents a net ‘no change’ condition across the various criteria. The temporary barrier is ranked 6th out of the 16 options considered in the MCA (refer Table 8-64).

The lowest scoring criterion for this option was the cost beneficial criterion (value of 2.0), while the highest scoring criterion was the legal/approval risk (value of 5.0), given that it is a temporary structure and would be deployed during times of flooding only. The attitude of decision makers was also scored highly (value of 4.0). Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.5.2.8 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The South Brisbane temporary barrier will mitigate flooding for the 1 in 100 AEP flood only. Larger events will still impact properties within South Brisbane with no residual mitigation by the barrier, while buildings located on the river bank (including tourism-related outlets and community infrastructure such as galleries and museums) would not be protected by the temporary barrier.
environmental or social disadvantage	The South Brisbane temporary barrier will not create environmental or social disadvantage.
an unacceptable economic cost to State, local government, community or individual	The South Brisbane temporary barrier has a relatively modest cost given the number of properties benefiting. However, it is expected that the barrier would only be rarely used (1 in 100 chance per year) and has only a narrow window of benefit (i.e. it is not in effect in a 1 in 50 AEP event, but is overtopped and becomes ineffective in a 1 in 200 AEP). Notwithstanding, it may be deployed more often based on conservative forecasts for flood levels at South Brisbane (e.g. if there is a Major warning for the City Gauge – subject to Disaster Management considerations and planning).
technical impracticability	The South Brisbane temporary barrier would be technically practical.

other unusual or unique circumstances	There are no obvious other unusual or unique circumstances that would preclude the feasibility of this option.

8.5.3 Brisbane CBD

8.5.3.1 General Description of Option and Assessment

Brisbane CBD experienced flooding during the 2011 event, as well as previous floods such as 1974. For the 2011 event, which was approximately the same level as a 1 in 100 AEP event, inundation of the CBD occurred as a result of backwater inundation through the stormwater drainage system. Flooding of individual basement carparks also occurred due to direct drainage connections. There was no overtopping of the river foreshore adjacent to the CBD during the 2011 event. Since 2011, BCC has installed several backflow prevention devices on stormwater outlets at the CBD and other locations along the river (see https://www.brisbane.qld.gov.au/environment-waste/water/backflow). The intent of these devices is to stop high river levels inundating low lying lands connected to the river through the stormwater drainage system, where the ground levels at the immediate river edge are higher than land behind.

Overtopping of the Brisbane CBD foreshore occurs once flood levels reach approximately a 1 in 200 AEP level. The Brisbane River foreshore, in the vicinity of the Brisbane CBD, is highly developed with a combination of commercial and residential buildings. A low-lying walkway / cycleway fringes the water's edge. Given the existing development constraints, there is very little practical opportunity for construction of a levee along the river edge that would protect to a 1 in 200 AEP level or higher.

The option considered herein involves the installation of a temporary levee that would be positioned along the public roadway closest to the river. No other alternative locations for the temporary levee are available that would enable ease of installation and a continuous alignment across the low-lying section of foreshore. It is recognised that this proposed levee alignment would not protect properties on the river-side of the structure, many of which are food outlets and other businesses. As such, the economic benefits of such a structure would be reduced.

8.5.3.2 Concept Design

To achieve the desired flood immunity (1 in 200 AEP), the temporary flood barrier would need to have a crest level no lower than 5.90 m AHD. This assessment was based on a water filled barrier from Aqua Dam (http://conceptservices.com.au/solutions/aqua-dam/).

The option assumes a 900m long temporary flood barrier with an average height of 1.30m. The barrier would be located along Eagle Street, Felix Street, Margaret Street, Edward Street and Bunya Walk. Based on the Aqua Dam guidelines (http://aquadam.net/Guides/guide5.html) the maximum flood depth of 2.2m would require an Aqua Dam 3m high and 7m wide. The flood depth will differ greatly along the proposed route, due to changes in ground surface elevation. To optimise on cost and instalment, different size barriers could be used for particular sections. The alignment of the proposed temporary barrier is presented in Figure 8-39, while a picture of a similar barrier in application is presented in Figure 8-36.

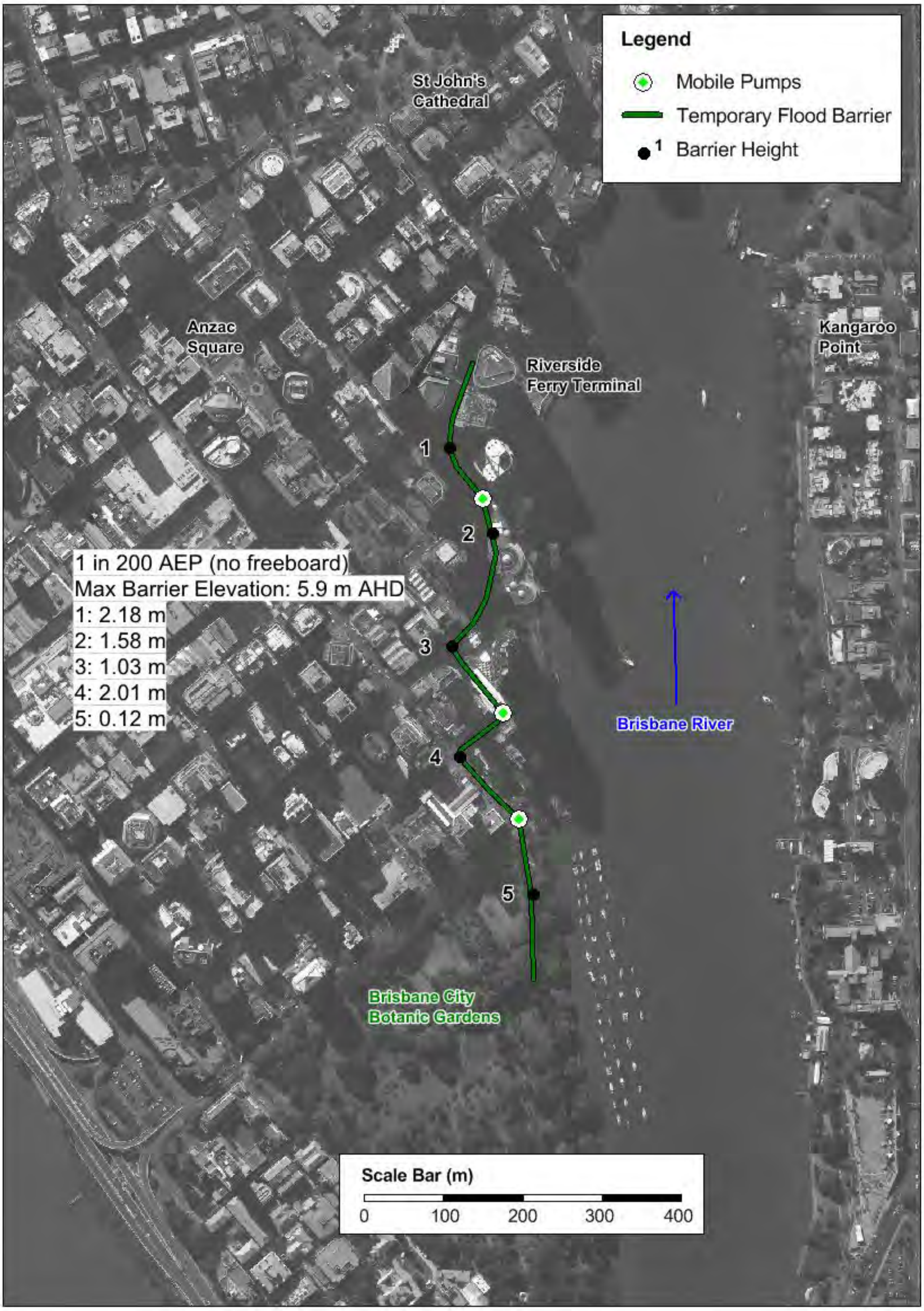


Figure 8-39 Location of Brisbane CBD temporary barrier

The barrier would protect Brisbane CBD from Brisbane River flooding. However, it would also prevent overland flow from the local catchment entering the Brisbane River. Several mobile pumps would therefore be required to drain local catchment runoff and potentially groundwater and / or basement backflow inundation, when the temporary flood barrier was in place. This option also assumes that backflow devices are in place and operational for all stormwater outlets draining the Brisbane CBD.

8.5.3.3 Indicative Cost

The indicative cost of the temporary barrier in the Brisbane CBD is presented in Table 8-41 and has been based on the following assumptions:

- The levee height is based on the Phase 2 (Flood Study) and, therefore, does not take into account the potential increase in water level as a result of the option;
- No land purchase will be required;
- No compensation would be provided to local businesses for potential loss of revenue;
- No changes required to existing road infrastructure and street furniture;
- Sufficient flood warning would be provided to deploy the barrier;
- Council staff would be responsible for the deployment and security of the barrier;
- Assumed storage requirements of $70m^2$ and the cost of rent was assumed to be $624 per square metre per year (average cost 2016);
- Backflow prevention devices are already in place within the trunk drainage;
- Inundation of building basements (through local connections and groundwater seepage) would be controlled locally and would not require specific treatment;
- An adequate storage facility can be rented and located within 1km of the Brisbane CBD; and
- Testing and deployment of temporary levee every five (5) years.

Table 8-41 Indicative Cost for 1 in 200 AEP Brisbane CBD temporary barrier (2017 costs)

Description	Cost ($)
Traffic and Environmental Management Plans	252,000
Temporary barrier and deployment	880,000
Mobile pumps	180,000
Total Direct Job Cost	**$1,310,000**
Indirect Job Costs – On-Site Costs (31%)	406,000
Design Costs (9%)	154,000
Indirect Costs - Offsite Costs (3%)	56,000
Applications (5%)	96,000
Contingencies (40%)	809,000
Total Cost Estimate (Excluding Operating Expenses)	**$2,890,000**

Description	Cost ($)
Rented storage space	156,000
Traffic management and deployment drills	2,000
Personal for deployment drills	3,000
Annual Operating Expenses	**$ 161,000**

8.5.3.4 Hydraulic Impacts

Potential benefits and impacts of the proposed 1 in 200 AEP Brisbane CBD temporary barrier on the hydraulic behaviour of flooding were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

The impacts of the temporary barrier on flood levels in the Brisbane River are presented Figure 8-40 for the 1 in 200 AEP flood event. Hydraulic modelling was also carried out for other AEPs. A summary of the impacts of the proposed Brisbane CBD temporary barrier on properties for the different AEP floods is given in Table 8-42.

Hydraulic modelling of the 1 in 200 AEP flood indicates that the peak flood afflux generated by the proposed temporary structure is less than 50mm, being the smallest threshold for gradation mapping in this regional assessment (refer Figure 8-40).

Table 8-42 Summary of Brisbane CBD temporary barrier impacts on properties

AEP	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	n/a	n/a	n/a	0	0	0	0
1 in 5	n/a	n/a	n/a	0	0	0	0
1 in 10	n/a	n/a	n/a	0	0	0	0
1 in 20	n/a	n/a	n/a	0	0	0	0
1 in 50	n/a	n/a	n/a	0	0	0	0
1 in 100	n/a	n/a	n/a	0	246	2	4
1 in 200	< 50mm	< 50mm	< 50mm	25	376	1	8
1 in 500	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.

[2] Building no longer affected by flooding.

[3] Building is flooded to a greater degree, either above or below habitable floor level.

[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.

As shown in Table 8-42, approximately 250 properties would benefit from this option at the 1 in 100 AEP level. This is the result of backflow prevention devices assumed to be operational during this event, rather than from the temporary barrier as overtopping does not occur in the 1 in 100 AEP level.

At the 1 in 200 AEP event, there are approximately 400 properties that benefit from this option. As the riverbank would otherwise overtop under these flood conditions, all 400 properties would benefit from the temporary barrier (assuming that backflow prevention devices are also in place). About half the properties are residential and half are commercial, most of which are located within existing HR3 Potential Hydraulic Risk areas. Given the properties are within the CBD, the population associated with these residential and commercial properties would be high (as each property is expected to be multi-storey). While higher levels of multi-storey properties would not necessarily be directly inundated by the 1 in 200 AEP flood, the indirect and intangible impacts would still apply, as it is expected that these building would not be able to support occupation during or after inundation at the ground level.

For events larger than the 1 in 200 AEP, the barrier will be overtopped and inundation of properties would largely occur as per current conditions with no material benefit from the temporary barrier. The presence of the barrier (albeit overtopped) in larger events does not have a notable impact on flood levels within the river (that is, afflux is less than 50mm).

For floods smaller than the 1 in 200 AEP, overbank inundation does not occur. Therefore, smaller flood events are not affected by this option.

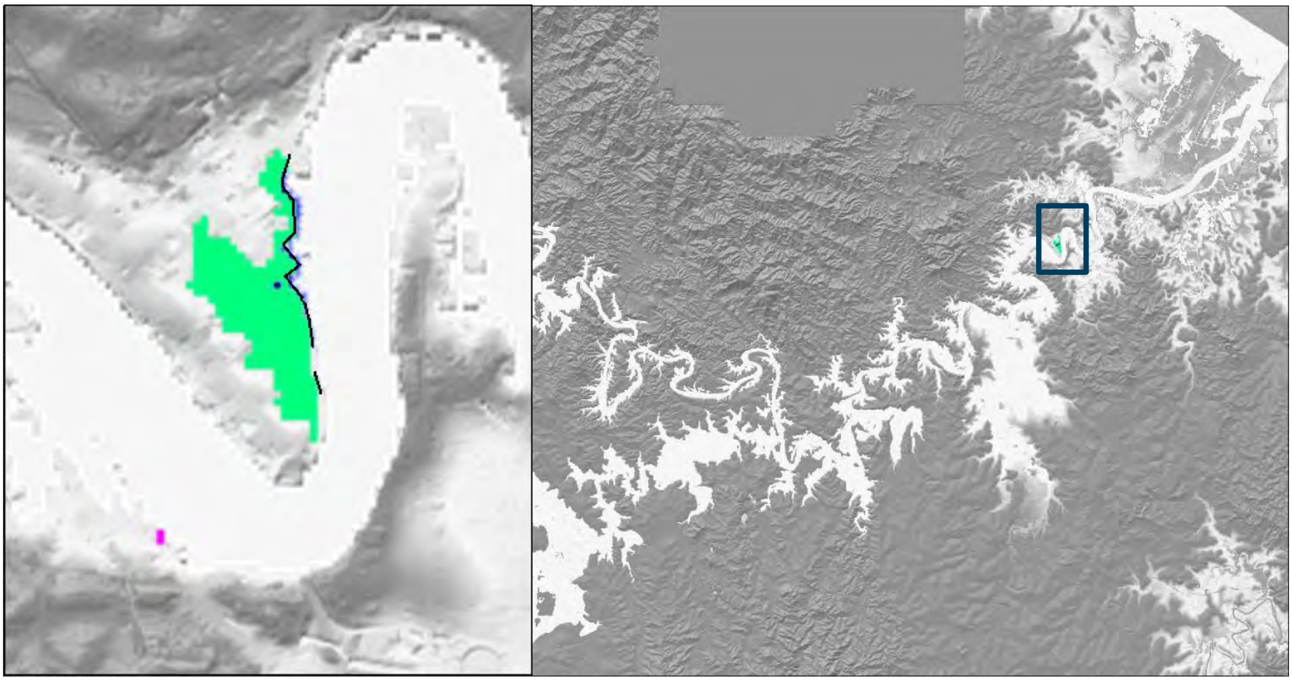


Figure 8-40 Brisbane CBD temporary barrier water level impacts 1 in 200 AEP

8.5.3.5 *Benefit / Cost Analysis*

A summary of the benefit / cost analysis for the Brisbane CBD temporary barrier option is presented in Table 8-43.

Table 8-43 Benefit/cost analysis summary for Brisbane CBD temporary barrier option

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case (1)	288.7	288.4	0.29	**0.71**
Sensitivity 1: No intangibles	186.9	186.6	0.25	**0.62**
Sensitivity 2: with Wivenhoe up.	213.2	213.0	0.19	**0.46**
Sensitivity 3: 4% discount rate				**0.88**
Sensitivity 4: 10% discount rate				**0.59**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

The temporary barrier, with a capital cost of $2.9m and an annual maintenance cost of $160,000, will generate a net annual average benefit of $290,000, leading to a benefit/cost ratio of 0.71 when adopting a discount rate of 7% over a **30 year period**. The benefit of the temporary barrier is restricted to properties impacted by events in the order of a 1 in 200 AEP only. As noted in Section 8.5.3.4, this includes benefits from backflow prevention devices and so the benefit/cost ratio of the barrier may be higher than will be achieved.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-43. If benefits were limited to reductions in tangible damages, the annual average benefit of the works would reduce to $250,000, giving a net benefit/cost ratio of 0.62. Potential upgrades to Wivenhoe Dam could reduce the impact of flooding within the Brisbane CBD, resulting in the annual average benefit of the structure being reduced to $190,000 per annum, and a benefit/cost ratio of 0.46. Sensitivity was also undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 0.88, while for a higher discount rate of 10%, the benefit/cost ration reduces to 0.59.

8.5.3.6 *Multi-Criteria Review*

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.5.3.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	Approximately 400 properties would benefit directly from the exclusion of flooding within Brisbane CBD for events between a 1 in 100 AEP and 1 in 200 AEP flood, almost all of which are in existing HR3 Potential Hydraulic Risk areas. Events larger than the 1 in 200 AEP would still impact these properties, while events up to the 1 in 100 AEP do not reach these properties.	4.0

	The potential hydraulic risk within Brisbane CBD would not change from mostly HR3 under current conditions.	
Improve time for evacuation (now and future)	Approximately 400 properties would have more time to respond to a larger event that would potentially overtop the riverbank. As the warning time is already quite reasonable, the value of the additional time is limited. Flood immunity of regional evacuation routes (i.e. the State controlled roads as identified in Section 4 Current Flood Risk) will not be improved by this option.	3.0

8.5.3.6.2 Social

Targets vulnerable community members or areas	The population benefiting from this option is considered to be of average vulnerability, as detailed in Section 4 Current Flood Risk.	2.5
Social health benefits	The reduction in the number of residential properties inundated in the 1 in 200 AEP event would lead to some social health benefits. The population benefiting in the 1 in 200 AEP flood is expected to be significant given the multi-storey high density nature of the residential properties within the Brisbane CBD. Benefits for floods smaller or larger than the 1 in 200 AEP event would be negligible. The likelihood of a 1 in 200 AEP event is small and therefore the potential for benefits is limited.	3.5
Improves community flood resilience (now and future)	The deployment of a temporary flood barrier in the Brisbane CBD would provide occupants of properties affected by flooding a longer period to evacuate. The additional time may be considered of value from a community resilience perspective. As the Brisbane CBD is located well downstream, warning times for a 1 in 200 AEP event would be reasonable, and therefore the extra time would not necessarily provide a significant value to the community. Indeed, the deployment of the barrier may provide a false sense of security to residents and occupants, thereby delaying evacuation. Overtopping of the barrier, should flood levels exceed the 1 in 200 AEP level, would result in very rapid onset of inundation and may be problematic for people who have not evacuated. There are 22 elements of critical energy infrastructure (primarily substations) that would benefit from protection by the temporary barrier to a 1 in 200 AEP level. This infrastructure would service the properties protected by the structure, as well as many other	3.0

	properties that would not be directly inundated by a 1 in 200 AEP flood.	
Recreation and amenity	There would be no impact on recreation and amenity as a result of this option. Amenity would be affected when deployed, but this would only be during flood times, when the community would be discouraged from the area.	2.5
Connection and collaboration	There would be impact on the community's connectedness to the river and watercourses. Connectedness would be affected when deployed, but this would only be during flood times, when the community would be discouraged from the area.	2.5

8.5.3.6.3 Economic

Reduce damages and costs to residential property (now and future)	There are approximately 160 residential properties that benefit from this option with each property expected to support a large number of individual dwellings. These properties benefit for floods in the order of a 1 in 200 AEP event only. As a result, the economic benefits (for all property types) from reduced flood damages are relatively small at $290,000 per year.	2.5
Reduce damages and costs to business and industry (now and future)	There are approximately 210 commercial properties that would benefit from this option during a 1 in 200 AEP flood.	2.5
Option likely to be cost beneficial (now and future)	A although the economic benefits through reduced damages are low (as the frequency of benefit being only a 1 in 200 chance each year), the capital cost of the temporary barrier is also low. When considered over a 30 year lifetime for the structure, the b/c ratio of 0.71 suggests a reasonable likelihood of implementation, depending on other benefits and impacts.	2.5

8.5.3.6.4 Feasibility

Physical / technical (now and future)	The design and construction of the temporary barrier in the Brisbane CBD would be relatively straightforward. Existing roads would serve as the base for the structure.	4.0
Legal / approval risk	The temporary barrier proposed will be predominantly located in a local government road reserve and will require an approval for works in a roadway (this is a process outside of the Planning Act 2016).	4.5

	It is also noted that part of the barrier traverses the Brisbane Botanic Gardens which is a Queensland heritage place and there may be a requirement to obtain an Exemption Certificate for the temporary barriers. Further liaison with the Department of Environment and Heritage Protection will clarify these requirements.	
Potential for additional funding sources	With a relatively affordable cost, a large number of properties that benefit and high levels of support from decision makers and the community, this option should qualify for external funding.	3.5

8.5.3.6.5 Attitude

Decision makers	This option would improve flood risk without significant negative impacts (with the exception of cost). The benefits to residential and commercial properties is significant for the 1 in 200 AEP event. It is expected that decision makers would generally support this option.	4.0
Community	Results from the community survey (refer to Section 11 Community Awareness and Resilience) showed residents of BCC had no particular preference for or against the use of levees. The local community that benefits from this option would likely be very supportive of the works. The location of the temporary barrier (i.e. on the roadway) means that all immediate riverside properties would remain unprotected from flooding. There may be an expectation by the community that a temporary barrier should protect these riverside properties, including the highly valued Eagle Street Wharf restaurant precinct.	3.0

8.5.3.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	This option will improve access within the Brisbane CBD, which includes major distributor roads servicing Brisbane River crossings. Improved access will be limited though as the temporary barrier will be not required until flooding exceeds the 1 in 100 AEP level. Local roads along the alignment of the barrier will need to be closed during deployment.	3.0
Protection of regional water supply quality and security – catchment protection (quality and yield)	This option would have no impact on regional water quality or quantity.	2.5

8.5.3.6.7 Environment and Natural Resource Management

Species impacts	There would be no impact to species richness or diversity.	2.5
Vegetation and habitat impacts	There would be no impact on vegetation and habitats. The location of the levee, on an existing road, means that there would be no net loss of habitat due to construction.	2.5
Ecosystem health connectivity (fish passage/fauna movement)	There would be no impact on the ecosystem health connectivity through fish and fauna passage.	2.5
Reduction in landscape salinity / improved moisture retention and groundwater recharge	There would be no impact to the landscape salinity or moisture, as this option does not encourage local ponding or water storage.	2.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	There would be no impact on the erosive capacity of the catchment or the bank stability of waterways.	2.5

8.5.3.7 Assessment of Option Against Multiple Criteria

Similar to the South Brisbane temporary barrier, and as outlined in Section 8.10.2, the Brisbane CBD temporary barrier has an overall multi-criteria assessment result of 0.71, where a value of 0.0 represents a net 'no change' condition across the various criteria. The temporary barrier is ranked 4th out of the 16 options considered in the MCA (refer Table 8-64).

No criteria had a value of less than 2.5 (the 'no change' score), while the highest scoring criterion was the legal/approval risk (value of 4.5), given that it is a temporary structure and would be deployed during times of flooding only (but a comparatively lower score than South Brisbane structure as it would need to be deployed along public roads). There are no specific factors that would automatically rule out this option from further consideration. Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.5.3.8 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious	The proposed Brisbane CBD temporary barrier will address localised flooding for events in the order of a 1 in 200 AEP only. Larger events will still impact properties within Brisbane CBD with

harm to persons or property on the premises	no residual mitigation by the barrier, while buildings located along the Eagle Street Wharf precinct on the river bank (including tourism-related outlets) would not be protected by the temporary barrier.
environmental or social disadvantage	The Brisbane CBD temporary barrier will not create environmental or social disadvantage.
an unacceptable economic cost to State, local government, community or individual	The Brisbane CBD temporary barrier has a relatively modest cost given the number of properties benefiting. However, it is expected that the barrier would be rarely used (1 in 200 chance per year) and has only a narrow window of benefit (i.e. it is not in effect in a 1 in 100 AEP event, but is overtopped and becomes ineffective at the 1 in 500 AEP).
technical impracticability	The Brisbane CBD temporary barrier would be technically practical.
other unusual or unique circumstances	There are no obvious other unusual or unique circumstances that would preclude the feasibility of this option.

8.6 Flood Mitigation Dams

8.6.1 Overview

The following flood mitigation dam options were short-listed and have been evaluated:

Table 8-44 Flood Mitigation Dam Options Assessed

Location	Description	Report Section
Wivenhoe and Somerset Dam	Dam upgrades and operations	Progressing as separate study
Warrill Creek, Willowbank	Dry flood mitigation dam	Section 8.6.2
Kholo	Flood mitigation dam	Section 8.6.3

Small detention basins are often used within local catchments to abate the impact of urbanisation of hydrology and catchment runoff. For this regional-scale assessment, small urban / suburban detention basins were not evaluated as they would have limited impact on the overall Brisbane River flood hydraulics.

The former DEWS (now DNRME) has previously carried out an investigation of potential flood mitigation storages across the Brisbane River catchment (DEWS, 2014a). That investigation, known as the Prefeasibility Investigation into Flood Mitigation Storage Infrastructure (PIFMSI), identified a number of potential sites across the catchment, and undertook a first pass assessment of these sites for suitability of flood mitigation storages. The investigation incorporates the Wivenhoe and Somerset Dams Optimisation Study (WSDOS), which considers various options for modifying the existing dams, including raising of the Wivenhoe Dam wall to increase storage capacity. This is being progressed as a separate study (see also Section 8.1.8.2).

Sites for new dams located upstream of Wivenhoe Dam were not considered further as part of this Brisbane River Phase 3 (SFMP), as the impacts in the lower reaches of the river would be governed by dam releases and operational requirements. The most promising new storage site downstream of Wivenhoe Dam was identified on Warrill Creek, south of Amberley. At this location (as well as at other watercourses), the proposed Southern Freight Railway (Inland Rail route) will cross the Warrill Creek floodplain, thus requiring substantial embankments and infrastructure to maintain floodplain conveyance. There is the potential to use this proposed rail infrastructure to temporarily store floodwaters, thus detaining the flood wave as it travels downstream.

Although not identified as part of PIFMSI (DEWS, 2014a), an on-line dry flood mitigation dam has also been identified and assessed as part of this Phase 3 (SFMP) in the vicinity of Kholo. This option has been considered to provide a comparison to the options currently being considered for upgrades to Wivenhoe Dam. The Brisbane River in the vicinity of Kholo is very narrow and theoretically provides an ideal location for dam infrastructure. The Kholo dry flood mitigation dam is considered for the sole purpose of mitigating floods that originate from Lockyer Creek and/or releases from Wivenhoe Dam rather than providing any new water storage facility.

8.6.2 Warrill Creek at Willowbank

8.6.2.1 General Description of Option and Assessment

This option has been taken from the PIFMSI report (DEWS, 2014a) with its location on the lower Warrill Creek AMTD 14.6 km (near Willowbank) coinciding with the proposed Inland Rail route and associated infrastructure (see Figure 8-41). The option involves a dry flood mitigation dam. That is, it would only store water when significant flow is occurring within Warrill Creek. Detention is achieved by restricting the outflow of the dam. Following a flood event, the dam would fully drain with no residual water storage (thus is considered a ‘dry’ flood mitigation dam).

According to DEWS (2014a), the dam would have a peak storage volume of approximately 130,000ML. DEWS (2014a) indicates that approximately 110 properties would be impacted by the dam, including 15 with houses.

The proposed site of the Warrill Creek dam is at the upstream boundary of the Brisbane River detailed hydraulic model. Rather than modelling the dam directly as part of the hydraulic model, inflows to the hydraulic model from Warrill Creek were adjusted to account for the storage impacts. Revised hydrology for Warrill Creek was provided by Seqwater based on design inflows and outflows of the storage for the 60 flood events that define design conditions for the 11 AEPs ranging from a 1 in 2 AEP to 1 in 100,000 AEP.

The inflow and outflow relationship for the Warrill Creek dry flood mitigation dam is described by the scatter plot presented in Figure 8-42.

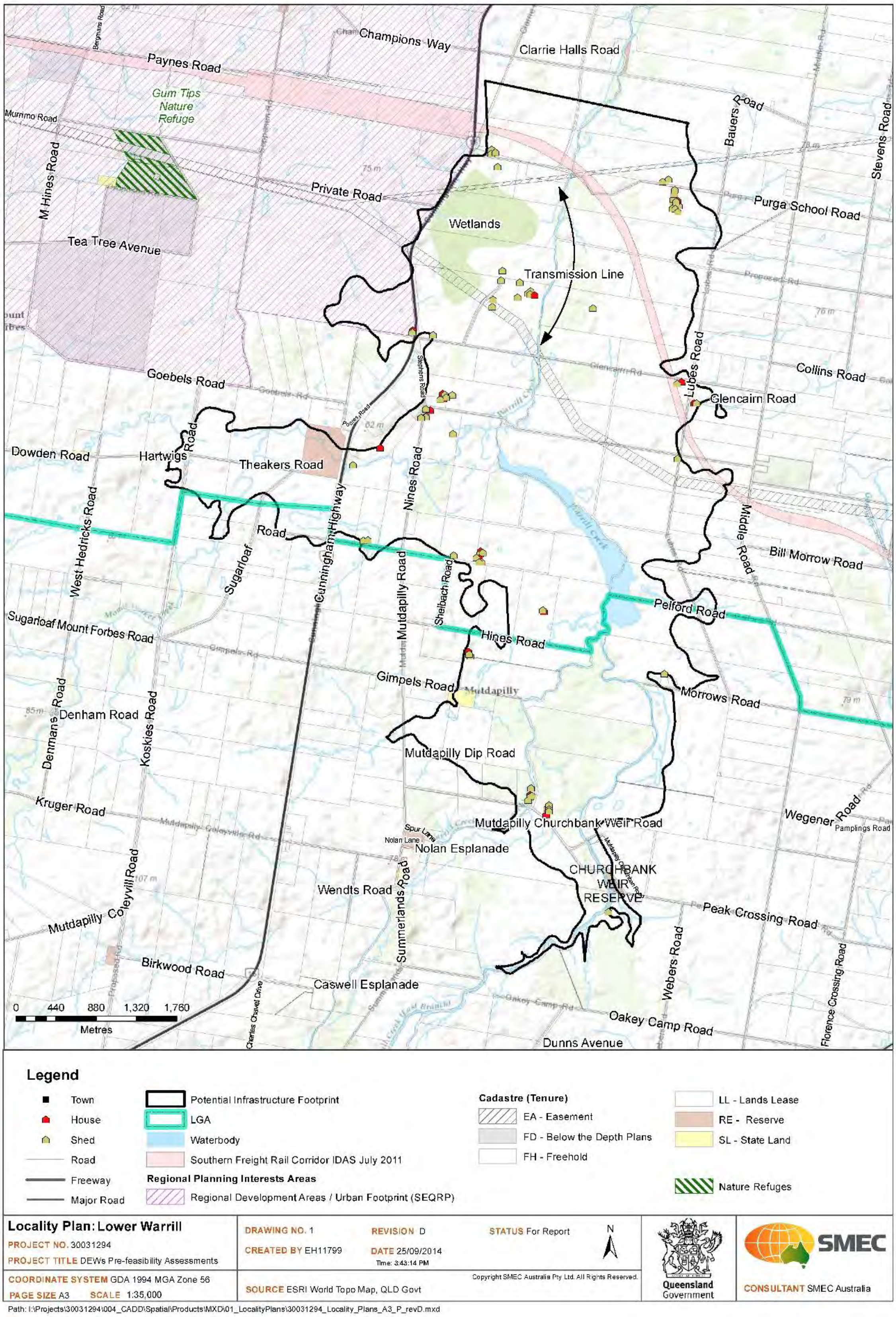


Figure 8-41 Warrill Creek dry flood mitigation dam indicative location (DEWS, 2014a)

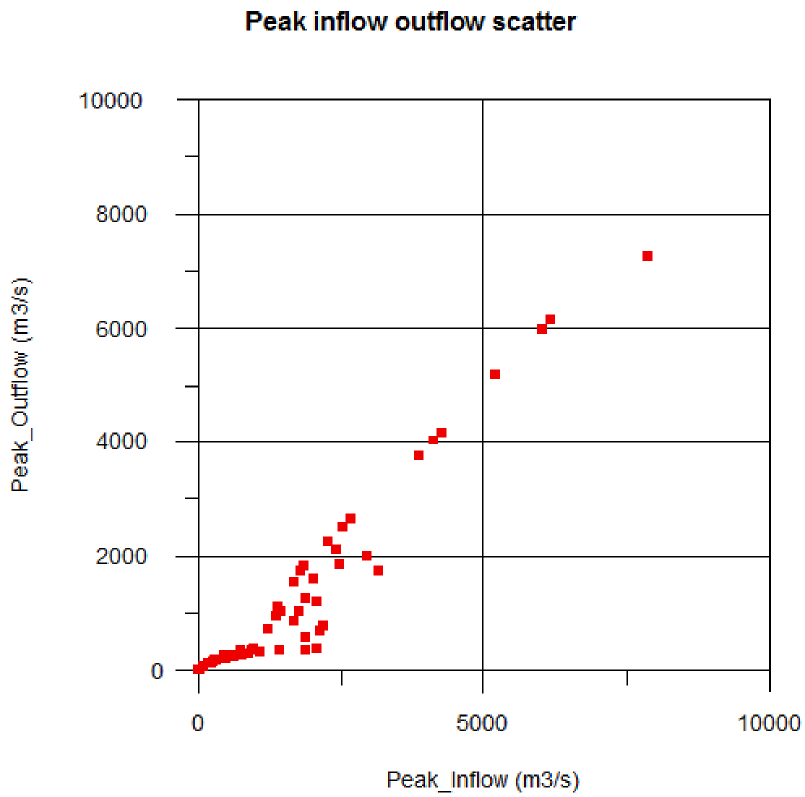


Figure 8-42 Warrill Creek dry flood mitigation dam inflow and outflow relationship

Seqwater (pers. comm., 2017) advised that these results are highly sensitive to the selected arrangement of low level outlet (for common floods) and to a lesser degree for the high level spillway (for large to extreme floods). Also, the storage would significantly modify the Warrill Creek flood hydrograph. As such, with this structure in place, the suitability of the 60 flood events that define peak flood levels across the 11 AEPs would need to be confirmed.

Should this option be pursued further, then a re-evaluation of the design hydrology for the Brisbane River would be required. This would involve re-assessment of the 11,340 events carried out using the fast hydraulic model and a repeat of the Total Probability Theorem (TPT) that determines the most appropriate events for design purposes.

8.6.2.2 Concept Design

The concept design considered for this option is as per the PIFMSI report (DEWS, 2014a), originally designed by SMEC (2014). The design incorporates a spillway width of 300 metres, and a dam crest level of 51m AHD. The overall length of the dam across the floodplain is 5,800 metres. A schematic arrangement of the proposed dry flood mitigation dam is provided in Figure 8-43.

It is expected that should this option be considered worthy of further investigation, there may be refinement to the alignment of the dam wall and changes to the design of the structure to better accommodate other local infrastructure requirements and demands, including Inland Rail, high power voltage lines and the Willowbank EDQ (Economic Development Queensland) industrial park site, as well as consideration of waterway health and fish passage.

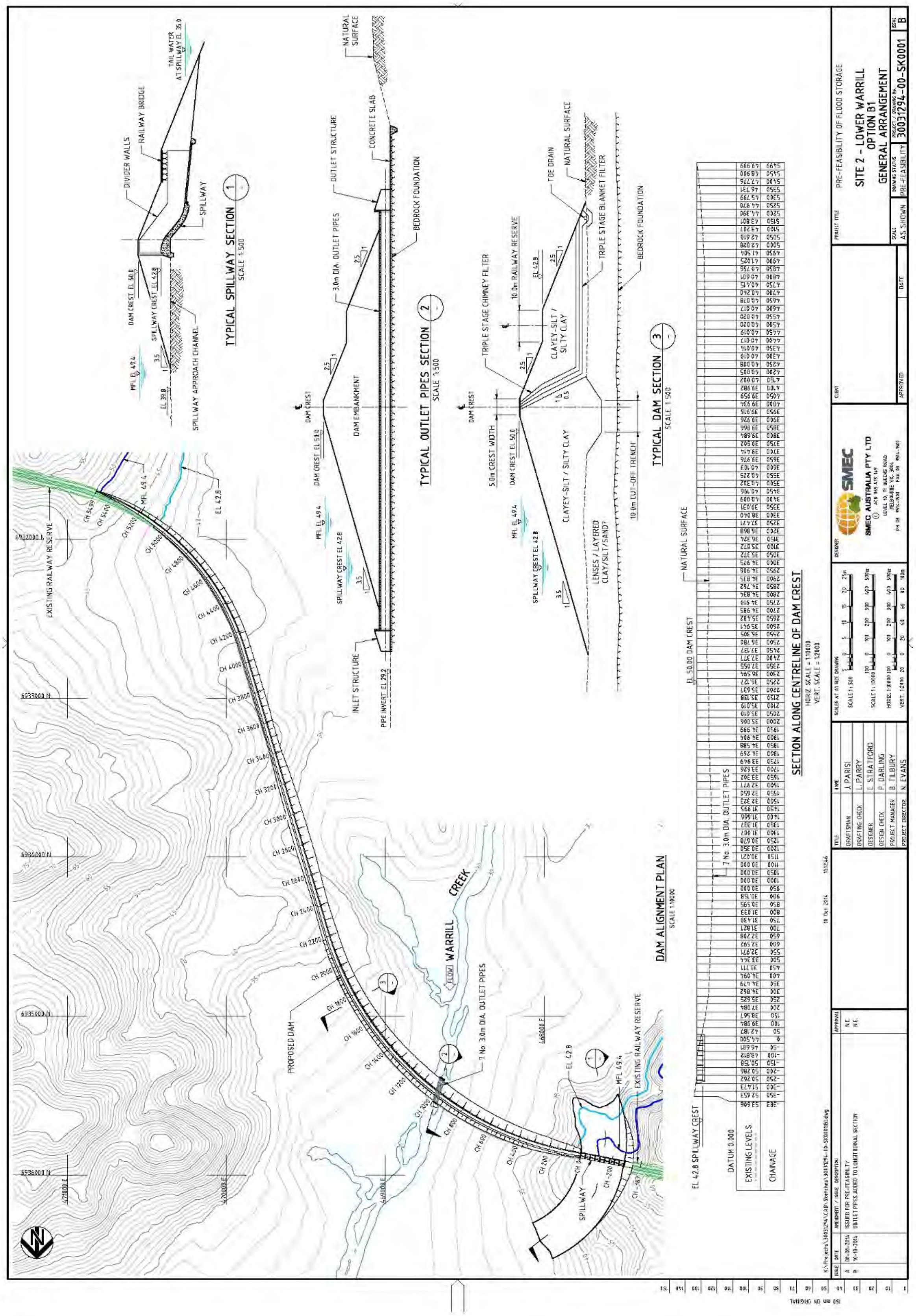


Figure 8-43 Warrill Creek dry flood mitigation dam schematic arrangement (DEWS, 2014a)

8.6.2.3 Indicative Cost

The indicative cost of the Warrill Creek dry flood mitigation dam is presented in Table 8-45. Costs have been taken from DEWS (2014a) and include the following assumptions:

- Deviation of the Cunningham Highway around the potential detention storage area for a length of 4.2 km;
- Relocation of water mains and fibre optic cables;
- Relocation of 9.5km of high voltage power transmission lines around the inundation area to provide better access to the towers and increased safety;
- Land acquisition for affected properties (78 total dispossessions and 33 partial dispossessions), with all land to a level of 43.0m acquired. Total area to be acquired is 4,190 ha;
- No allowance has been made for environmental offsets; and
- DEWS (2014a) costs uplifted based on CPI difference to June 2017.

Table 8-45 Indicative Cost for Warrill Creek Dry flood mitigation dam (2017 costs)

Description	Cost ($)
Dam design and construction	345,800,000
Infrastructure relocations	147,700,000
Land acquisition	52,300,000
Total Cost Estimate (Excluding Operating Expenses)	**$545,800,000**
Annual operating and maintenance expenses	500,000

It is noted that this cost is high for this type of structure due to the proposed configuration and location of existing infrastructure. Should this option have merit, there would be opportunity to refine and optimise the design in order to reduce costs.

8.6.2.4 Hydraulic Impacts

Potential benefits and impacts of the proposed Warrill Creek dry flood mitigation dam on the hydraulic behaviour of flooding were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

The impacts of the dry flood mitigation dam on flood levels in the Brisbane River are presented in Figure 8-44 to Figure 8-48 for the range of flood events from 1 in 5 AEP to 1 in 100,000 AEP, with a summary of the impacts on properties provided in Table 8-46.

In general, the dry flood mitigation dam on Warrill Creek reduces the peak flow in the Bremer River, which reduces flood levels. At Ipswich CBD, the reduction in flood level is up to 1.8m for the 1 in 50 AEP flood, and up to 1.6m for the 1 in 100 AEP flood. This reduction in flow also lowers flood levels in the Brisbane River extending down as far as the Brisbane CBD.

Table 8-46 Summary of Warrill Creek dry flood mitigation dam impacts on properties

AEP	WL reduction at Ipswich CBD	WL reduction at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	< 50 mm*	< 50 mm*	0	0	0	0
1 in 5	1,540 mm	< 50 mm	5	4	0	0
1 in 10	1,280 mm	70 mm	50	128	0	0
1 in 20	1,200 mm	80 mm	285	289	0	2
1 in 50	1,770 mm	60 mm	3,651	1,650	0	1
1 in 100	1,630 mm	150 mm	15,626	2,876	0	3
1 in 200	740 mm	190 mm	27,221	2,845	0	2
1 in 500	170 mm	190 mm	40,888	1,573	0	0
1 in 2,000	90 mm	< 50 mm	12,130	513	0	4
1 in 10,000	70 mm	100 mm	83,586	805	0	0
1 in 100,000	< 50mm	< 50 mm	0	24	4	26

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.

[2] Building no longer affected by flooding.

[3] Building is flooded to a greater degree, either above or below habitable floor level.

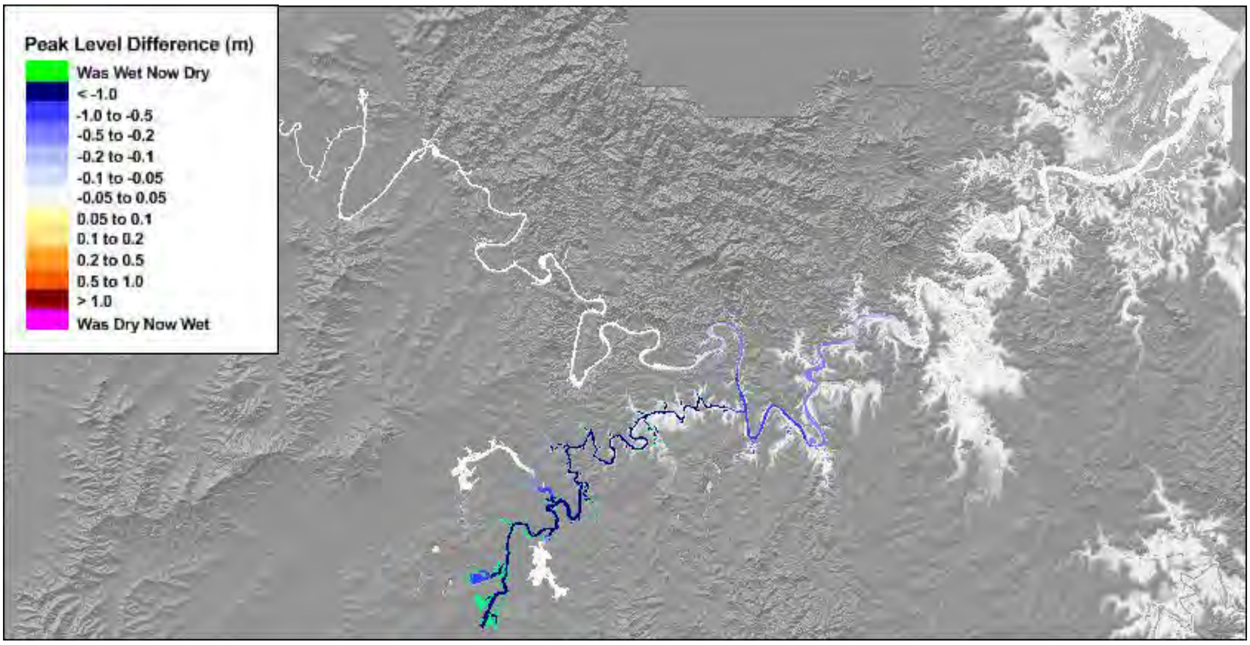
[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.

The flood mitigation benefits of the Warrill Creek dry flood mitigation dam are significant for the 1 in 5 AEP event, with a predicted reduction in flood level at Ipswich CBD of 1.5 metres. Benefits of the 1 in 5 AEP are extensive within the Bremer River. Benefits also extent up the Brisbane River to Mt Crosby Weir and down the Brisbane River as far as Jindalee.

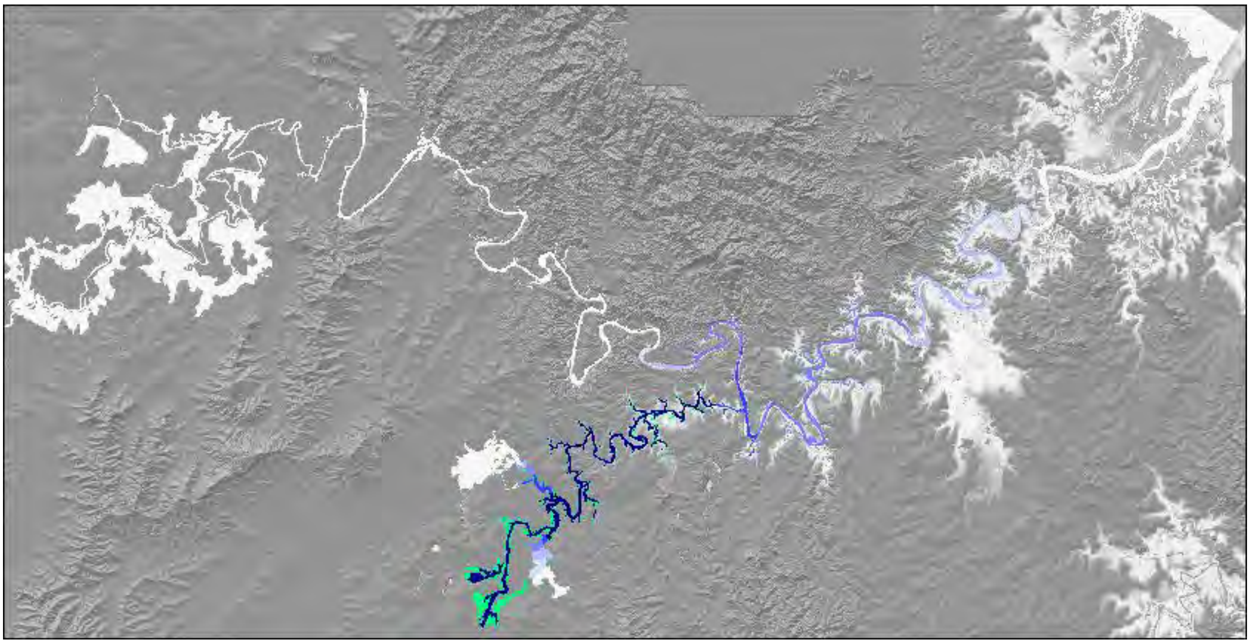
For the 1 in 10 AEP flood, benefits continue to be realised throughout the Bremer River and within the Brisbane River downstream as far as West End.

The largest reduction in flood levels at Ipswich CBD is achieved for the 1 in 50 AEP event, with flood levels reducing by almost 1.8 metres. For the equivalent AEP, flood level reduction at Brisbane CBD is 0.06 metres. Some 5,300 properties would benefit from the Warrill Creek dry flood mitigation dam at the 1 in 50 AEP level, with about 3,400 of these being residential properties.

For the 1 in 100 AEP flood, levels at Ipswich would reduce by about 1.6 metres, while levels at Brisbane CBD would reduce by 0.15 metres. Flood levels in Goodna would reduce by about 1 metre, while levels in Oxley Creek floodplain would reduce by about 0.3 metres. Approximately 12,000 residential properties would benefit from this option during a 1 in 100 AEP event, with either flooding eliminated, or flood levels reduced by more than 0.05 metres.

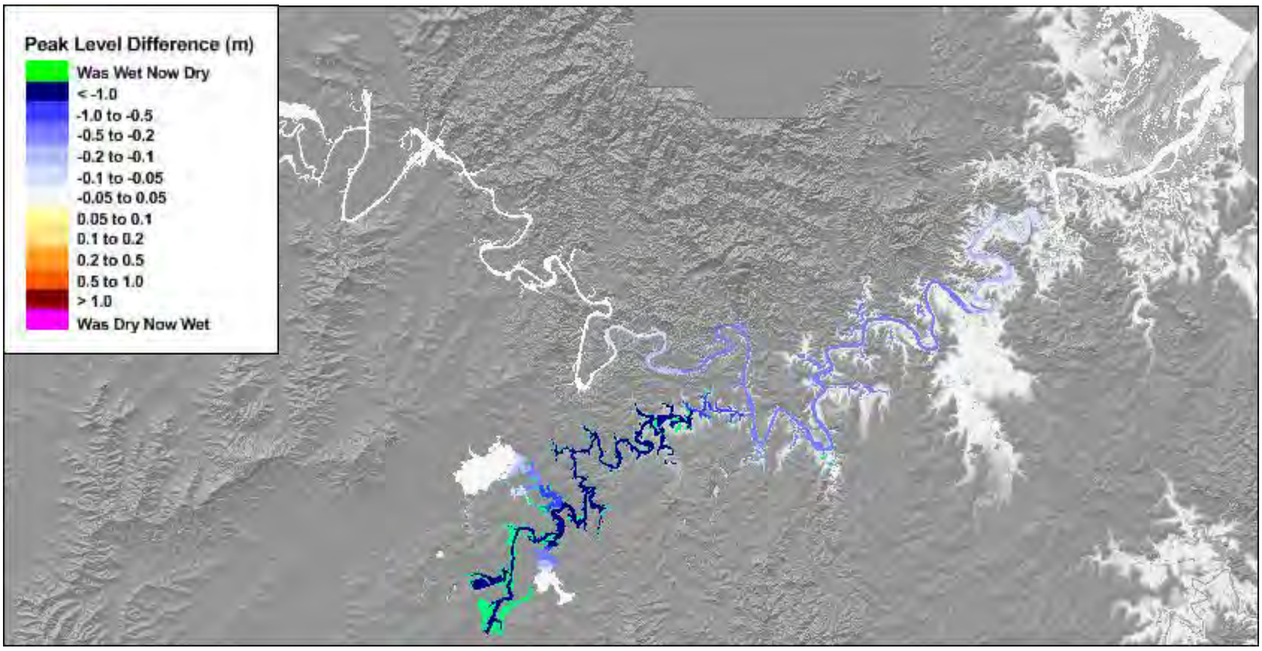


1 in 5 AEP

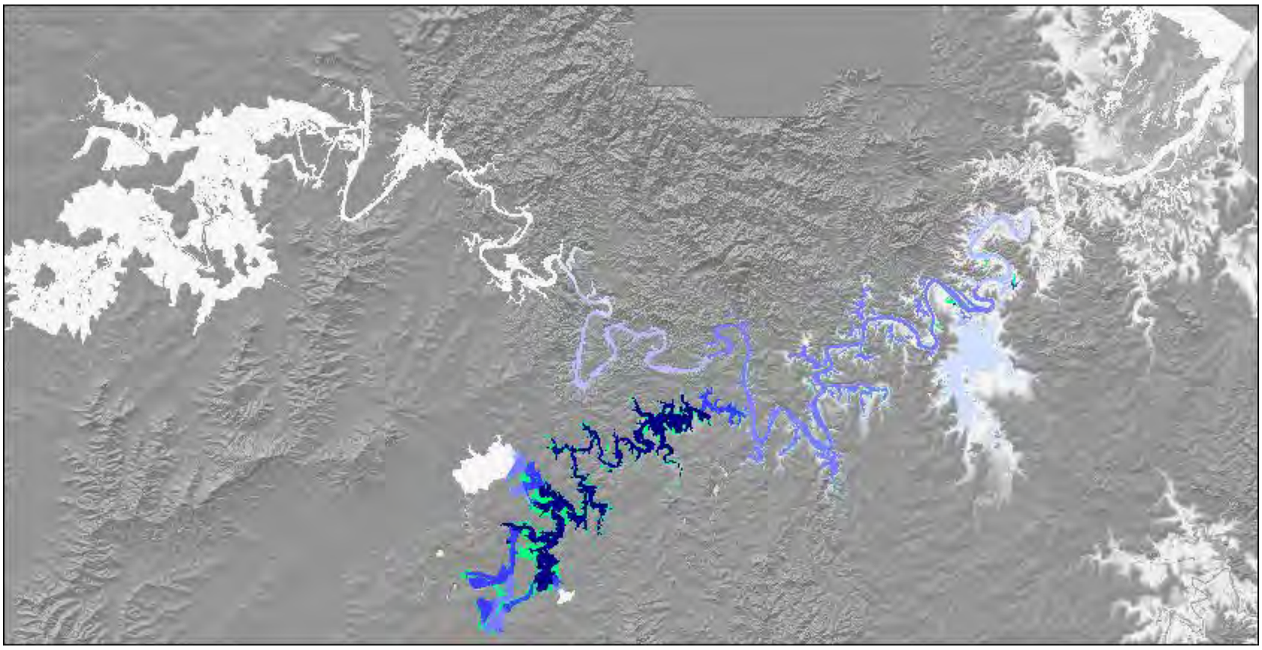


1 in 10 AEP

Figure 8-44 Warrill Creek dry flood mitigation dam: 1 in 5 AEP and 1 in 10 AEP

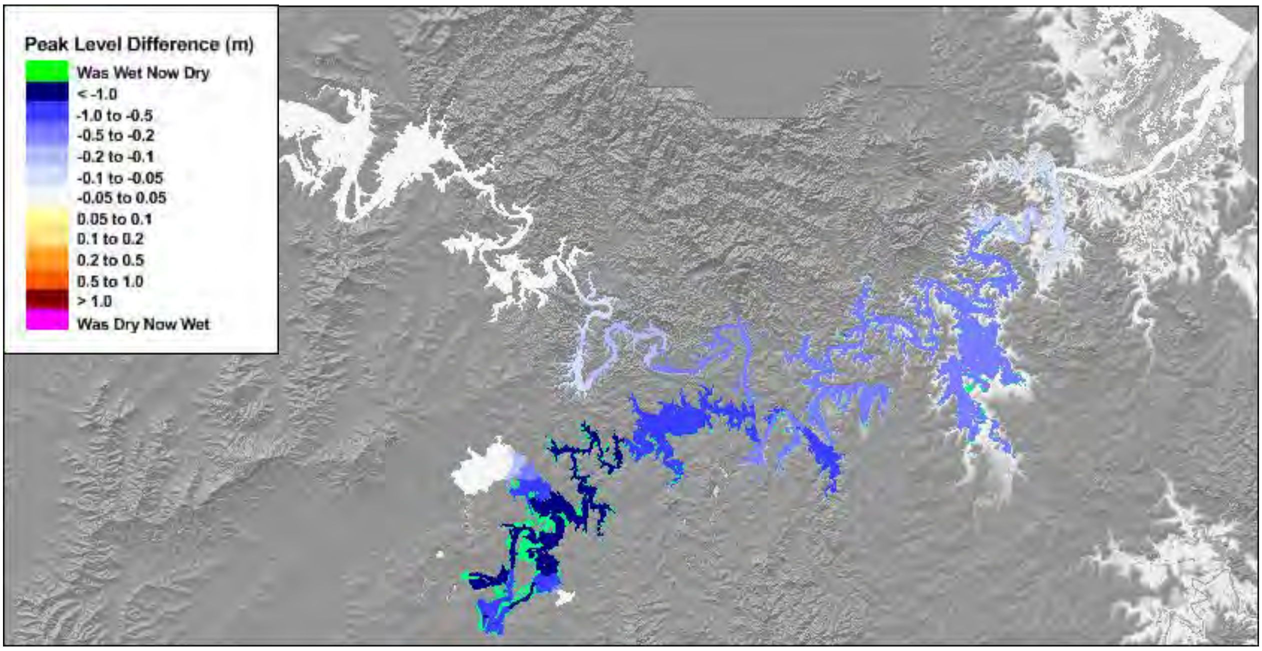


1 in 20 AEP

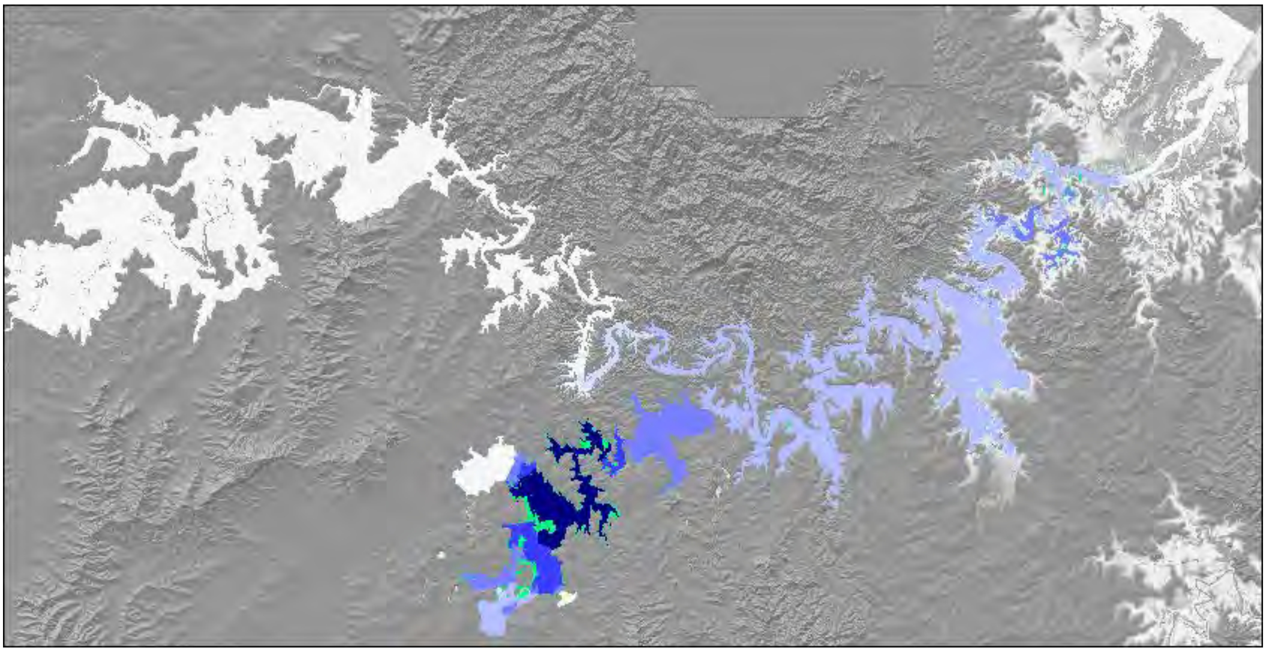


1 in 50 AEP

Figure 8-45 Warrill Creek dry flood mitigation dam: 1 in 20 AEP and 1 in 50 AEP

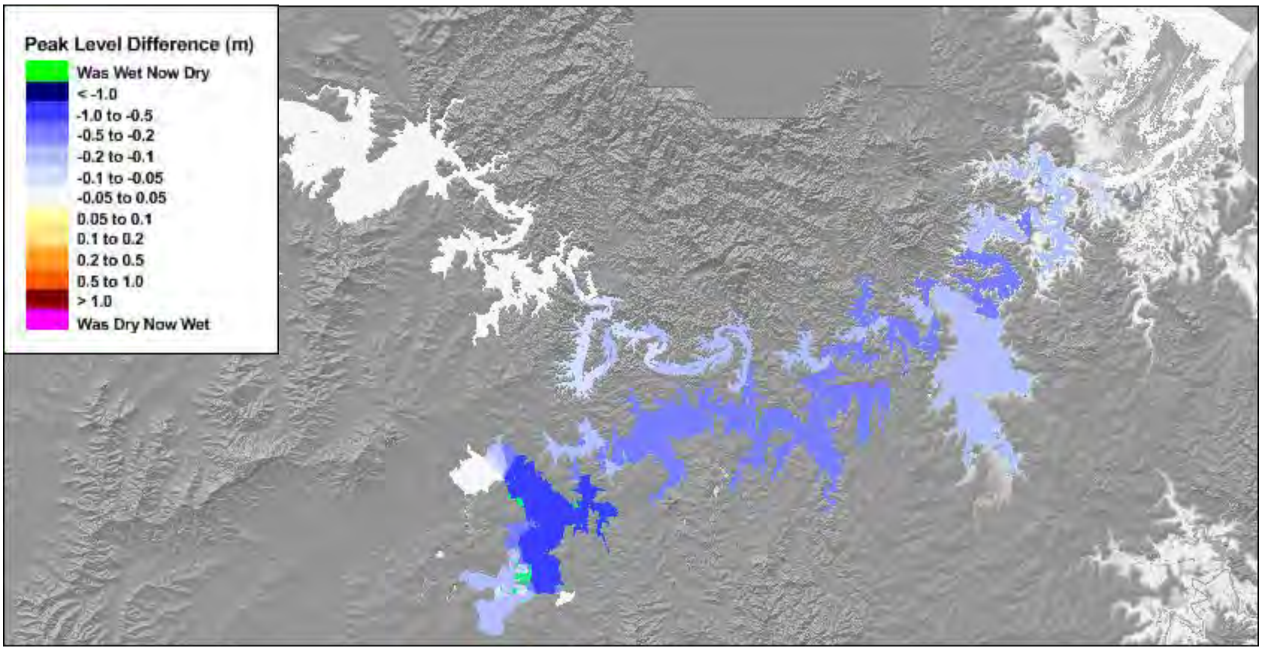


1 in 100 AEP

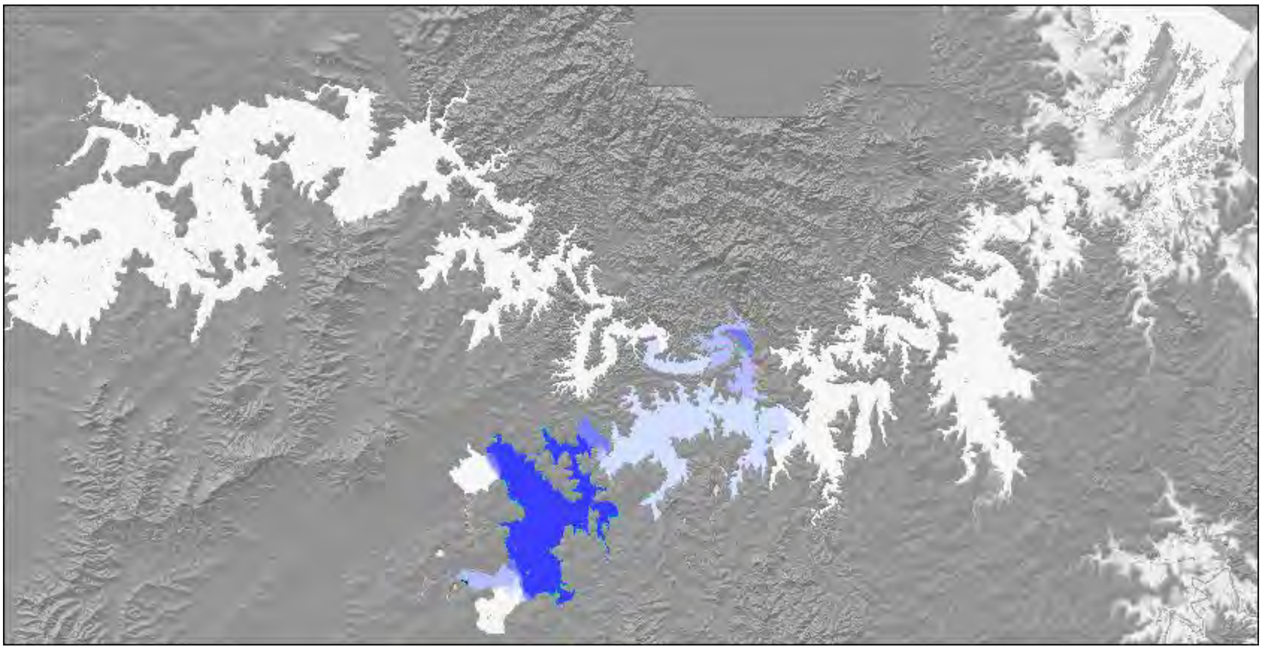


1 in 200 AEP

Figure 8-46 Warrill Creek dry flood mitigation dam: 1 in 100 AEP and 1 in 200 AEP

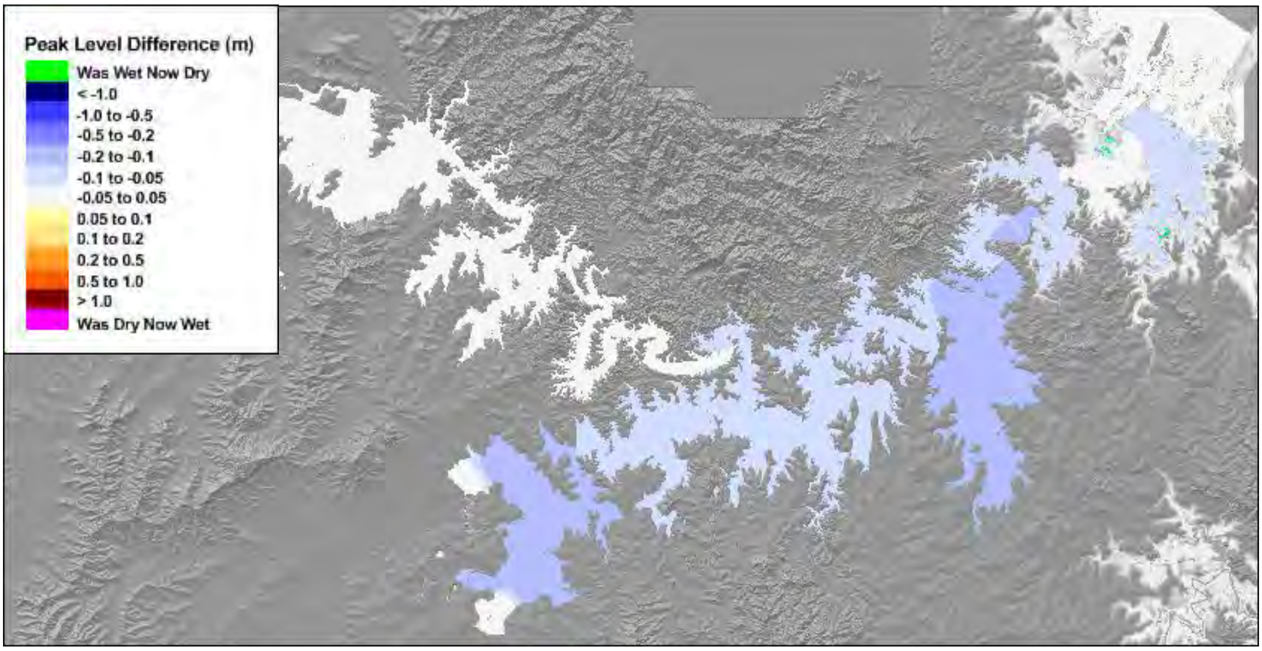


1 in 500 AEP

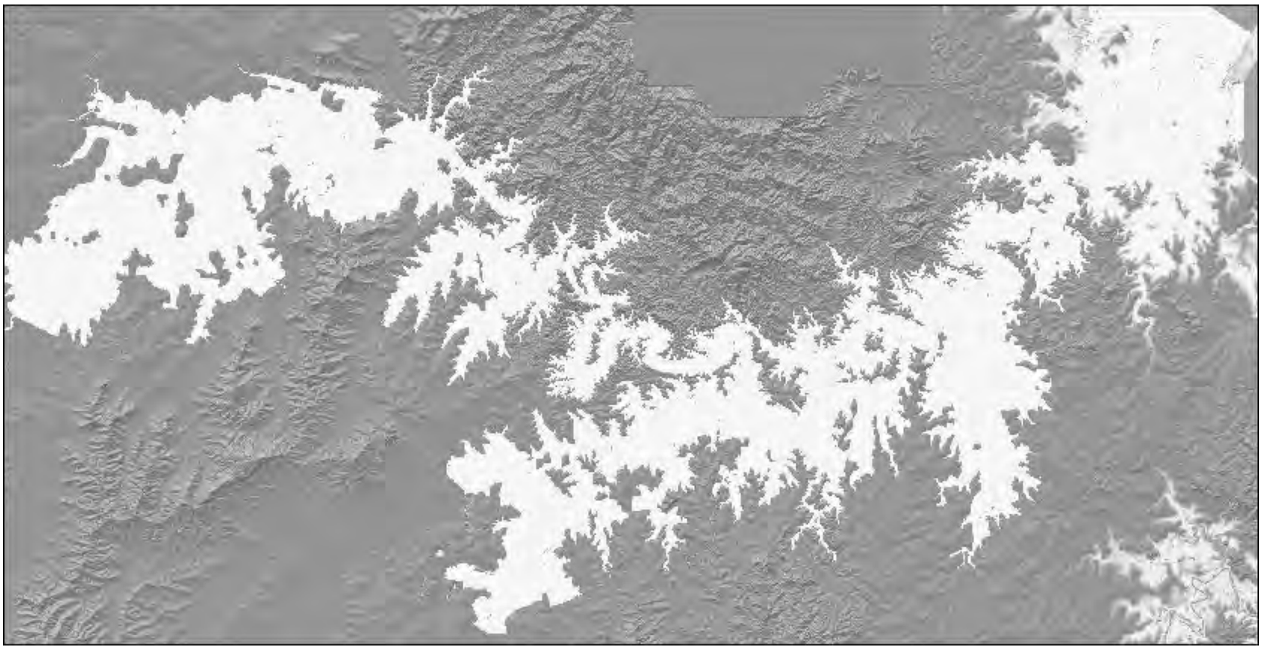


1 in 2000 AEP

Figure 8-47 Warrill Creek dry flood mitigation dam: 1 in 500 AEP and 1 in 2,000 AEP



1 in 10,000 AEP



1 in 100,000 AEP

Figure 8-48 Warrill Creek dry flood mitigation dam: 1 in 10,000 AEP and 1 in 100,000 AEP

Flood mitigative attributes of the Warrill Creek dry flood mitigation dam taper off for floods larger than 1 in 100 AEP, but still provide benefits through reduced flood levels. The 1 in 200 AEP flood would reduce by 0.74 metres at Ipswich and 0.19 metres at Brisbane CBD, while the 1 in 500 AEP flood would reduce by 0.17 metres at Ipswich and 0.19 metres at Brisbane CBD. Impacts in the 1 in 100,000 AEP flood are less than 50mm.

Properties that benefit from this option are spread over the full spectrum of Potential Hydraulic Risk levels, from HR1 to HR5. At the 1 in 20 AEP level, properties mostly benefiting are located within the HR1 area. At the 1 in 100 AEP level, benefits extent to properties mostly within the HR2 area. For the 1 in 500 AEP flood, this option has the greatest benefit to properties located within the HR3 Potential Hydraulic Risk area.

The extensive change in flood levels across all AEPs as a result of the Warrill Creek dry flood mitigation dam will alter the definition of Potential Hydraulic Risk, and especially so within the Bremer River floodplain. Figure 8-49 shows the change to Potential Hydraulic Risk that is achieved by this option. As expected, the major reduction in Potential Hydraulic Risk is immediately downstream of the Warrill Creek dry flood mitigation dam, including Amberley, Yamanto / One Mile, and the Deebing Creek floodplain. However, significant flood risk reduction benefits extend to the majority of the Bremer River, including around Bundamba and North Booval where existing flood risks are significant (HR1 / HR2). Figure 8-49 also shows small areas within the Brisbane River floodplain, mostly downstream of the Bremer River, where there are small changes in potential hydraulic risk. They represent minor changes to transition areas between HR levels.

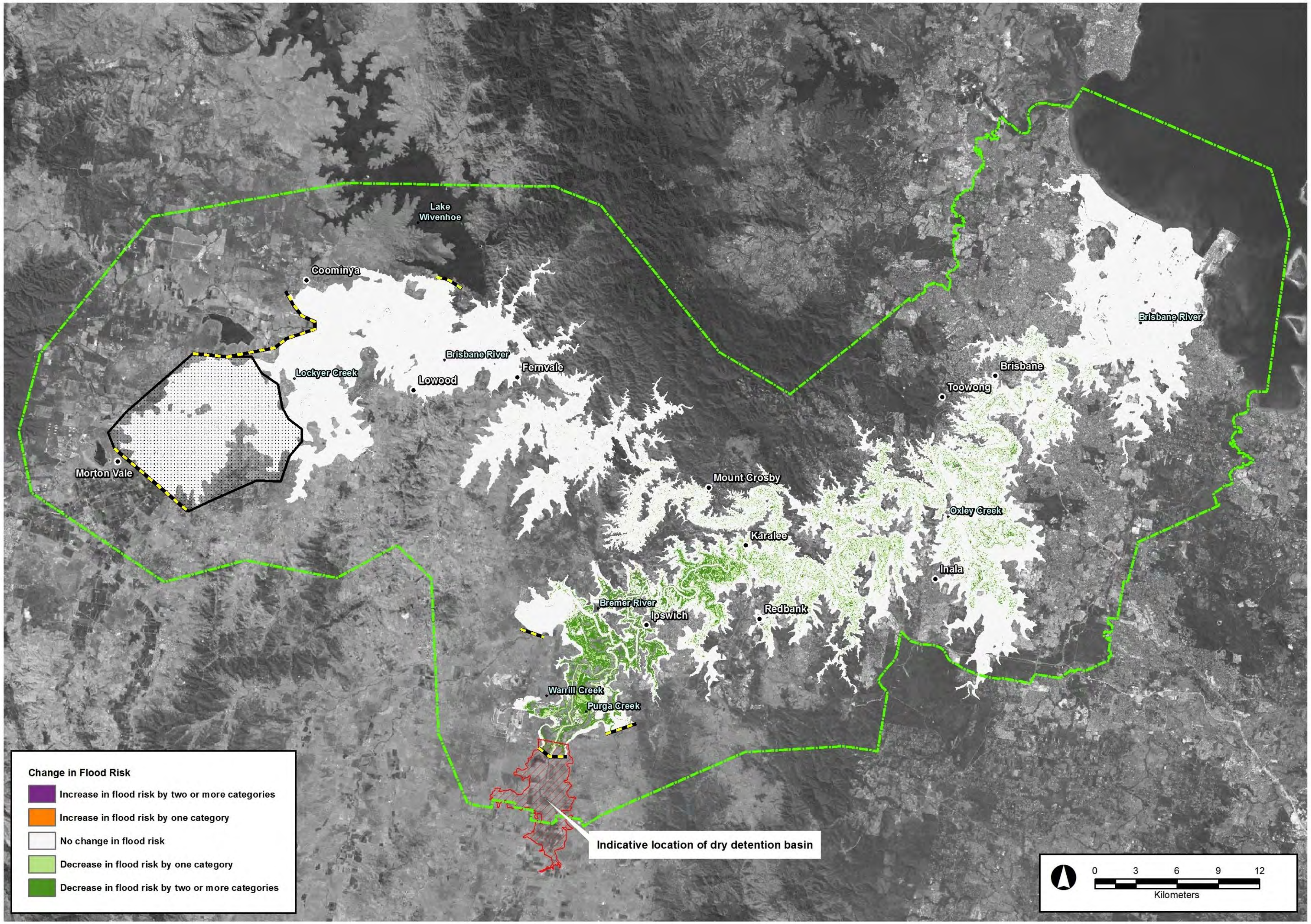


Figure 8-49 Warrill Creek dry flood mitigation dam: Change to Potential Hydraulic Risk

8.6.2.5 Benefit / Cost Analysis

A summary of the benefit / cost analysis for the Warrill Creek dry flood mitigation dam option is presented in Table 8-47.

Table 8-47 Benefit/cost analysis summary for Warrill Creek dry flood mitigation dam option

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case (1)	288.7	259.9	28.8	**0.69**
Sensitivity 1: No intangibles	186.8	166.7	20.2	**0.49**
Sensitivity 2: with Wivenhoe up.	n/a	n/a	n/a	n/a
Sensitivity 3: 4% discount rate				**1.22**
Sensitivity 4: 10% discount rate				**0.47**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

The dry flood mitigation dam, with a capital cost of $546 million and an annual maintenance cost of $500,000, will generate a net annual average benefit of almost $29 million, leading to a benefit/cost ratio of 0.69 when adopting a discount rate of 7% over a 100 year period. The benefit of the dry flood mitigation dam is extensive and covers significant areas within the Bremer River floodplain, as well as regions within the mid-Brisbane River.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-47. If benefits were limited to reductions in tangible damages, the annual average benefit of the works would reduce to $20.2 million, giving a net benefit/cost ratio of 0.49. Sensitivity was also undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 1.22 (i.e. higher than parity), while for a higher discount rate of 10%, the benefit/cost ration reduces to 0.47.

A sensitivity of benefit / cost results to a potential Wivenhoe Dam upgrade option (as discussed in Section 8.1.4.2) was not carried out. The interaction of combined benefits associated with Wivenhoe Dam upgrades and another significant flood mitigation dam in the upper catchment (i.e. Warrill Creek dry flood mitigation dam) would require more detailed modelling and analysis. Providing sensitivity testing as part of this Phase 3 (SFMP) may have unintended and misleading results (pers. comm., Seqwater).

The PIFMSI report (DEWS, 2014a) evaluated benefit/cost for various infrastructure options, including a proposed dry flood mitigation dam on Warrill Creek. DEWS (2014a) calculated a b/c ratio for this option of 0.29, which is notably less that the b/c ratios presented in Table 8-47. A detailed comparison of the differences in the economic assessments has not been carried out, however, it is noted that this Phase 3 (SFMP) has used the most up-to-date damage profile for the Brisbane River (as presented in Section 6 Flood Damages Assessment), and the impacts of the Warrill Creek dry flood mitigation dam have been determined through numerical modelling using the most up-to-date hydraulic model (BMT WBM, 2017). In the absence of this most recent information, DEWS (2014a) estimated damages (and hence benefits generated for options) on the basis of flood damage rating curves developed for WSDOS and historical records of flood events. DEWS (2014a) note that this process may under-estimate the damage costs, as damages for both smaller and larger floods are not included in the analysis. There may also be other significant differences such as assumptions regarding infrastructure operational lifetime.

It is noted that the costs of the Warrill Creek dry flood mitigation dam are high for its size and type of structure. It is expected that costs of the dam could be reduced significantly through optioneering and design optimisation. Assuming that the flood mitigation benefits of the dam would not change, if the undiscounted capital costs could be reduced to $376 million (i.e. a reduction of 30%), then the b/c ratio would be 1.0.

8.6.2.6 Multi-Criteria Review

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.6.2.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	At the 1 in 100 AEP flood level, some 15,600 properties would have lower inundation levels, while almost 2,900 properties would be flood-free that were otherwise inundated. Benefits for flooding are recognised across a broad spectrum of AEPs, from a 1 in 5 AEP up to the 1 in 10,000 AEP. Up to the 1 in 500 AEP flood, properties benefiting from this option are mostly located within HR1 to HR3 Potential Hydraulic Risk areas. Potential Hydraulic Risk across the Bremer River floodplain will reduce as a result of this option given the significant reductions in flood level across the full range of AEPs, as presented in Figure 8-49. It is noted that the area within the inundation zone of the dry flood mitigation dam would experience significant detrimental impact due to significant flood depth on a periodic basis. It is assumed that risks to people in this areas are mitigated through acquisition of land, and therefore relocation from any existing residences. The consequence of failure, whilst unlikely, would be significant and may be triggered by a Moogerah Dam failure upstream, causing cascade storage failures.	4.5
Improve time for evacuation (now and future)	The Warrill Creek dam would detain flows in the Bremer and Brisbane River floodplains. Detention has the effect of slowing the onset of flooding, and lowering the peak flood levels. The change in hydraulic behaviour resulting from the dry flood mitigation dam would improve evacuation times, and notably across the Bremer River floodplain.	4.0

	The lower flood levels across the floodplain, and in particular along the Bremer River, will have a positive effect on regional evacuate routes. In particular, Cunningham Highway will improve from the current 1 in 20 AEP immunity (refer Section 4 Current Flood Risk) to about a 1 in 100 AEP immunity across the Warrill / Purga Creeks floodplain.	

8.6.2.6.2 Social

Targets vulnerable community members or areas	The population mostly benefiting from this option are within the Bremer River floodplain or immediately downstream of the Bremer River, around Redbank and Goodna. As detailed in Section 4 Current Flood Risk, these areas contain populations that are considered more vulnerable than average across the Brisbane River study area, and as such, this option is considered to favour vulnerable communities.	4.5
Social health benefits	The significant reduction in the number of residential properties inundated across the full spectrum of flood events, and in particular within areas that are considered more vulnerable than average, would lead to substantial social health benefits.	4.5
Improves community flood resilience (now and future)	The significant reduction in the number of residential properties inundated across a broad spectrum of flood events would allow the community to better respond to flooding in the future. The dry flood mitigation dam allows for more measured community responses. There is potential however that some community members would falsely assume that the dry flood mitigation dam eliminates flooding and thus does not require a community response. That said, a flood mitigation dam in the upper catchment still provides more resilience than a local levee, as overtopping of a levee would leave the community at risk of rapid onset of flooding. At the 1 in 100 AEP flood, 22 critical energy infrastructure items and five emergency management facilities will have reduced flooding, while seven critical energy infrastructure items would be free from flooding. At the 1 in 500 AEP flood, 90 critical energy infrastructure items and 12 emergency management facilities would have reduced flooding, while eight critical energy infrastructure items would be free from flooding.	4.0

Recreation and amenity	The dry flood mitigation dam would potentially impact on an existing recreation area (Churchbank Weir Recreational Reserve). As this would only be impacted for short periods of time during rain events, the consequences of this would be relatively minor.	2.5
Connection and collaboration	This option would not impact the community's connectedness to the river and watercourses.	2.5

8.6.2.6.3 Economic

Reduce damages and costs to residential property (now and future)	There are extensive benefits to residential properties that would occur as a result of this option. These benefits are concentrated within the Bremer River floodplain, but also extend to properties within the mid and lower reaches of the Brisbane River. The net annual average benefit (for all property types) is almost $29 million.	4.5
Reduce damages and costs to business and industry (now and future)	There are extensive benefits to commercial properties as a result of this option, mostly within the Bremer River floodplain.	4.5
Option likely to be cost beneficial (now and future)	The overall b/c ratio is considered strong, with a value of 0.69. The extensive benefits are tempered by the high assumed construction costs. It is expected that optioneering on the dry flood mitigation dam design could reduce capital cost from the initial high level estimate. Any reduction in costs would improve this value bringing it closer to parity.	2.5

8.6.2.6.4 Feasibility

Physical / technical (now and future)	The design and construction of the dry flood mitigation dam at Warrill Creek may be feasible. Integrating the dry flood mitigation dam and Inland Rail infrastructure increases complexity, but may lead to a more efficient outcome that is multi-beneficial.	3.5
Legal / approval risk	A dry flood mitigation dam of the potential size proposed is likely to require a submission to be made to the Coordinator-General to be declared as a State significant project for which an Environmental Impact Statement would be required under the State Development and Public Works Organisation Act 1971 (SDPWO Act).	2

	This will facilitate a coordinated assessment and consultation process and is the typical approval pathway for projects of this nature. Any such approval process is complex and lengthy and requires significant and robust technical reporting.	
Potential for additional funding sources	The cost of this infrastructure is significant and beyond the regular funding channels for local and state government. As the works integrate with Inland Rail, there is potential to offset costs with the Commonwealth Government to achieve joint outcomes. Overall, it is expected that funding for this option would be a significant challenge, and particularly if it is considered in addition to investment required for upgrading Wivenhoe Dam as being investigated by other studies (refer Section 8.1.8.2).	1.5

8.6.2.6.5 Attitude

Decision makers	Based on the benefits to communities and in particular to more vulnerable communities, decision makers would potentially support this option. The benefit/cost analysis indicates that the option could be viable, especially if the costs can be reduced (which is understood to be possible through optioneering and design optimisation). Impacts would occur on properties upstream of the dry detention dam, so attitude could be tempered due to this.	3.5
Community	Results from the community survey (refer to Section 11 Community Awareness and Resilience) showed residents in the Brisbane River catchment had a slight preference towards dams and detention basins. Those impacted upstream of the basin would not likely be supportive. The local community that benefits from this option would likely be very supportive of the works. New dams are rare, and are often challenged by environmental and social dis-benefits. As a dry flood mitigation dam, the impacts of the structure would be reduced. The broader community (especially those outside of the area benefiting from the works) might be expected to be supportive if it is considered good value for money.	3.5

8.6.2.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	The significant reduction in flood levels downstream of the dry flood mitigation dam across a broad spectrum of floods would improve the accessibility of some infrastructure and transport links downstream during times of flood compared to current conditions. However for those that remain inundated, it may extend the duration of flooding. The dry flood mitigation dam would not guarantee functionality of existing infrastructure, but would likely extend its usability before being impacted, which would likely have broader benefits to the community. Some infrastructure upstream of the structure may be adversely impacted.	4.0
Protection of regional water supply quality and security – catchment protection (quality and yield)	This option would have no long term positive or negative impacts on regional water quality or quantity. The dry flood mitigation dam would not store water from the catchment for any significant time. The temporary storage, however, may help to reduce sediment load during flood events.	3.0

8.6.2.6.7 Environment and Natural Resource Management

Species impacts	The DEWS (2014a) report indicates that some regionally significant ecosystems and wetlands are located within the potential inundation area. Endangered or vulnerable species listed under the NC Act and the EPBC Act are potentially located in the inundation area. The extent to which species are impacted by the temporary storage of water within the dry flood mitigation dam has not been assessed in detail. As the inundation would be intermittent and temporary, it is expected that impacts would be less compared to a permanent water storage.	2.0
Vegetation and habitat impacts	The change in hydrology of the inundation area is likely to modify the vegetation and habitat contained therein. DEWS (2014a) indicates that at present, the area includes habitat for koala and echidna. As above, no detailed environmental assessments on habitat have been undertaken.	1.5
Ecosystem health connectivity (fish passage/fauna movement)	DEWS (2014a) notes that there are no mapped or otherwise discernible terrestrial fauna movement corridors through the inundation area, however, it is recognised that the waterway itself would be a valued corridor for aquatic species. The dry flood detention dam structure would allow for continuation of low flows	2.5

	through the waterway channel. Subsequent detailed design would include consideration of waterway health and fish passage.	
Reduction in landscape salinity / improved moisture retention and groundwater recharge	The temporary storage of floodwaters within the dry flood mitigation dam would facilitate a higher level of groundwater recharge through soil infiltration. An increase in groundwater table within the inundation area would potentially exacerbate dryland salinity in this area. This could be offset through revegetation of the dam inundation zone with targeted species.	2.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	The detention of flood waters within the Warrill Creek dry flood mitigation dam would reduce peak flows and velocities downstream of the site, however it would also lengthen the duration of flow which could increase the risk of bank erosion and / or slump etc.	2.5

8.6.2.7 Assessment of Option Against Multiple Criteria

As outlined in Section 8.10.2, the Warrill Creek dry flood mitigation dam option has an overall multi-criteria assessment result of 1.10, where a value of 0.0 represents a net ‘no change’ condition across the various criteria. The dry flood mitigation dam is ranked 3rd out of the 16 options considered in the MCA (refer Table 8-64) (only the two combined options that also include the Warrill Creek dry flood mitigation dam are ranked higher).

The lowest scoring criteria for this option were related to potential funding sources (given the very high capital cost) and the vegetation/habitat impacts (given the impacts of periodic deep water inundation) both with a value of 1.5. The best scoring criteria related to reducing flood risk, social benefits, and reducing damages (value of 4.5). There are no specific factors that would automatically rule out this option from further consideration. Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.6.2.8 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The proposed Warrill Creek dry flood mitigation dam will have a positive impact on downstream flood conditions, and in particular areas along the Bremer River. The dam will not eliminate flooding, but the detention effect reduces peak flood flows, which will result in lower peak levels in the area most influenced by flows in Warrill Creek. Flood levels in the Brisbane River upstream of the Bremer River would remain unaffected, while the benefits of the dam diminish downstream of the Bremer River.

environmental or social disadvantage	The Warrill Creek dry flood mitigation dam would have local environmental or social consequences. The extent of the environmental impacts are yet to be determined though less than for a permanent water storage (dam), while social impacts could be abated through acquisition of affected lands and properties (approximately 115 in total).
an unacceptable economic cost to State, local government, community or individual	The estimated cost of the Warrill Creek dry flood mitigation dam is very large, and outside regular budgets for local or state governments. The benefit/cost analysis shows that the cost of the works could be balanced by the benefits (with a b/c ratio >1) if the costs can be reduced somewhat and/or a less conservative discount rate is used in the economic analysis.
technical impracticability	The Warrill Creek dry flood mitigation dam would be technically practical, and indeed it is opportune to pursue given the plans to construct the Southern Freight Railway together with which the infrastructure can be multi-purposed.
other unusual or unique circumstances	There are no obvious other unusual or unique circumstances that would preclude the feasibility of this option.

8.6.3 Brisbane River at Kholo

8.6.3.1 General Description of Option and Assessment

The Brisbane River between Lockyer Creek and the Bremer River is characterised by a narrow gorge-like valley. These conditions are typically sought for establishing artificial flow constraints, such as dams or weirs, as they are more feasible to construct and regulate flow. A dry flood mitigation dam was considered in this section of the river, in the vicinity of Kholo. The dam would temporarily store and detain floodwaters from Lockyer Creek, as well as discharges from Wivenhoe Dam. During non-flood times, the dam would remain ‘dry’, with low flow hydrology essentially as per existing conditions.

Anecdotal reports (pers. comm. Seqwater) suggest that a flow rate of 4,000m^3/s at Moggill is sufficient to cause significant inundation of private properties along the Brisbane River floodplain. By comparison, the peak flow rate during the 2011 event at Moggill was almost 10,000m^3/s. Should this option show merit, refinement of the target outflow rate would be justified using a damage vs flowrate profile that could be established from the new building database as described within Section 6 Flood Damages Assessment.

The concept for the Kholo dry flood mitigation dam therefore was to provide sufficient capacity for the 2011 event to be detained to a peak flow rate of less than 4,000m^3/s at Moggill. The volume required to achieve such detention was estimated using the recorded hydrograph of the 2011 event and calculating the area under the hydrograph curve that was above the 4,000m^3/s threshold (see Figure 8-50). Note that significant flood flow is introduced into the Brisbane River from the Bremer

River, downstream of Moggill. Therefore, the Kholo dry flood detention dam would only be effective at mitigating flood flows from Lockyer Creek and the upper Brisbane River (via discharges from Wivenhoe Dam).

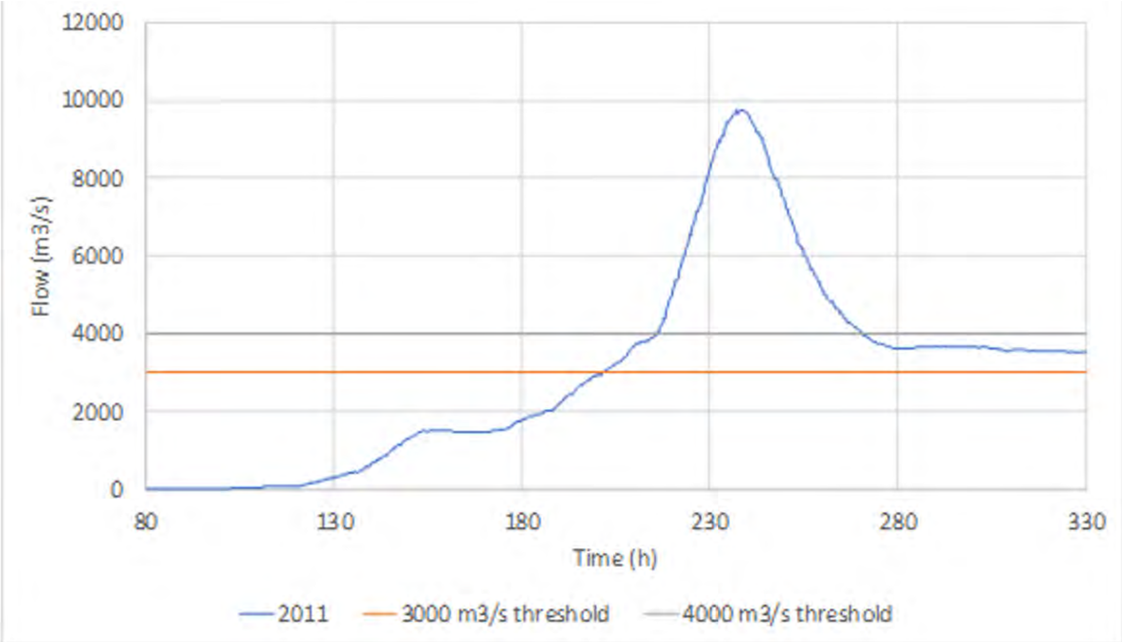


Figure 8-50 Flood hydrograph for the 2011 event near Kholo

To achieve a peak outflow of 4,000m^3/s (for the 2011 flood event), the proposed Kholo dry flood mitigation dam would need to hold a minimum of 550,000 ML. Based on the indicative location of the dam structure, this would result in peak backwater inundation to a level of approximately 44m AHD, requiring a dam wall structure with a height in excess of 35 metres.

Reflective of the sensitivity of the river, if the outflow was constrained further to a peak rate of 3,000m^3/s (for the 2011 flood event), the proposed Kholo dry flood mitigation dam would need to hold about 951,000 ML, with an inundation level of approximately 49.5m AHD, and a dam wall structure higher than 40 metres.

By comparison, the full supply level (FSL) of Wivenhoe Dam contains 1,165,000 ML, while the flood storage volume offered by Wivenhoe above the FSL is a further 1,967,000 ML.

The proposal for this dam structure is not to permanently store water, but rather, to temporarily detain flood flows and limit peak discharge. The structure would be operated during an event to maximise detention and minimise downstream flood impacts. The indicative size of the dam would also require a spillway capacity to safely pass the PMF for which there may be insufficient space. Without proven merit, design has remained at a conceptual volumetric level only.

8.6.3.2 *Indicative Cost*

Dam infrastructure is very expensive to construct. Costs for dams are dependent on site specific conditions, including the topography (which also determines the length and height of the dam wall) and the geology (which governs foundation conditions and requirements). A general engineering rule of thumb for new dams is a cost of $1m per 1,000 ML (Jacobs, 2016). At this cost rate, the proposed Kholo dry flood mitigation dam would cost $550 million for a level of 44m AHD, or $950 million for a level of 49.5m AHD.

The PIFMSI report (DEWS, 2014a) investigated options for a number of new water storages/dams within the Brisbane River catchment. Cost rates for new dams adopted by PIFMSI are considerably higher than this general rule of thumb. Higher costs would include factors for contingency, concurrent infrastructure works (relocation for example) and potential property acquisition.

8.6.3.3 Hydraulic Impacts

Upon advice from Seqwater, detailed hydrodynamic modelling was not carried out for this option using the Phase 2 (Flood Study) model as it would have a significant effect on hydrology, and therefore requires detailed hydrologic modelling and Monte Carlo assessment in addition to the hydraulic assessment. Rather, the option was assessed as a first pass based on volumetric requirements and inundation extents based on this volume.

Figure 8-51 show the approximate inundation extents behind the Kholo dry flood mitigation dam wall structure for volumes of 550,000ML and 950,000ML. Apart from the flat floodplain areas of lower Lockyer Creek, the inundation extents do not vary significantly for these two options despite the 4.5 metres difference on levels and reflects the steep gorge-like characteristics of the river in this vicinity.

Significantly, inundation for both conditions would affect the existing Fernvale village as well as a large number of rural properties between Fernvale and Kholo. Additionally, the backwater inundation from the new Kholo dry flood mitigation dam would reach the downstream side of the Lake Manchester dam wall as well as the downstream side of the Lake Wivenhoe dam wall, potentially affecting stability and spillway operation.

8.6.3.4 Benefit / Cost Analysis

Based on the impacts of inundation as described above, it is expected that the dam infrastructure costs, as noted in Section 8.6.3.2, would need to be supplemented by significant property acquisition as well as possible costs associated with upgrade of existing dams, if required, to accommodate elevated downstream water level conditions. Overall, high level cost estimates for the Kholo flood mitigation dam option could exceed $1.5 to 2 billion once these additional factors are taken into account, while annual maintenance costs could be in the order of $10 million as it would be a more maintenance-intensive structure than the comparable Warrill Creek dry flood mitigation dam (with maintenance costs as established in DEWS, 2014a).

The costs associated with a new flood mitigation dam at Kholo should be considered relative to costs associated with raising the existing Wivenhoe Dam and the flood mitigation benefits that it brings. The PIFMSI report (DEWS, 2014a) provides high level costs for raising Wivenhoe by 4 metres of approximately $880 million. Raising Wivenhoe Dam by 4 metres could be considered comparable to constructing a new structure at Kholo. As such, the benefit/cost of a new Kholo dry flood mitigation dam would be less than the comparable benefit/cost of undertaking works to the existing Wivenhoe Dam wall given the lower capital investment.

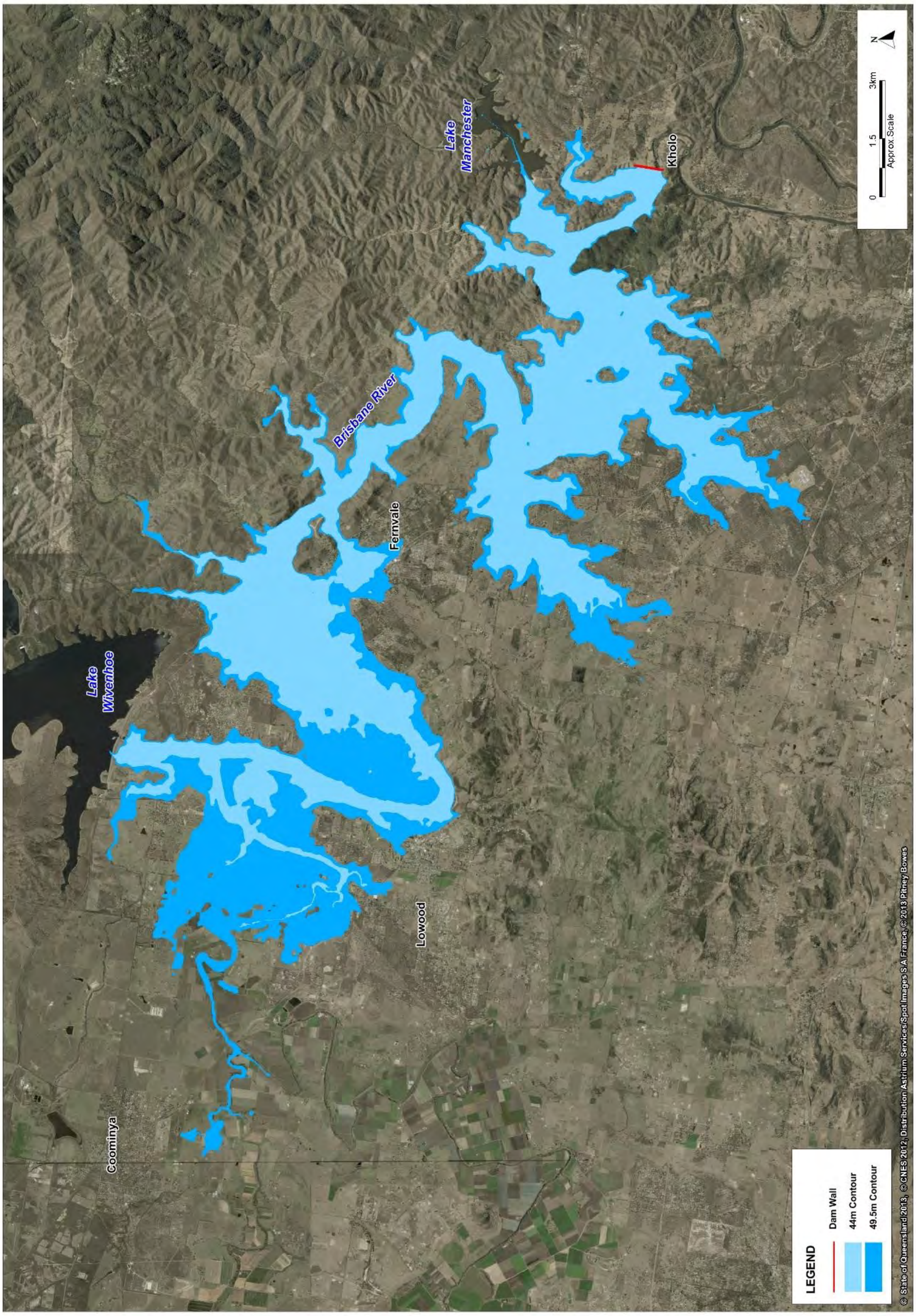


Figure 8-51 Kholo dry flood mitigation dam inundation extents for 550,000ML and 950,000ML storage

For this reason, further detailed investigations of the Kholo dry flood mitigation dam option have not been pursued at this time.

8.6.3.5 Multi-Criteria Review

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.6.3.5.1 Safety of People

Reduce hydraulic risk rating (now and future)	At the 1 in 100 AEP level, benefits to downstream properties would extend to most properties that were affected by the 2011 event, with the exception of properties within the Bremer River (that were largely affected by Bremer River flooding rather than backwater inundation from the Brisbane River). Thus, benefits would be extended to about 10,000 properties, although the degree of benefit is unknown at this stage. The consequence of failure, whilst unlikely, would be significant and may be triggered by a Wivenhoe Dam failure upstream, causing cascade storage failures. Backwater inundation behind the dam would likely affect between 2,000 and 4,000 properties. The frequency and degree of inundation of these properties would require acquisition as the only means of managing flood risk, as the impacts otherwise would be very significant. On balance, it is considered to be a modestly positive benefit.	3.0
Improve time for evacuation (now and future)	The mitigation offered by the Kholo dry flood mitigation dam would be significant for downstream properties. Although it would not necessarily diminish the extents of the floodplain (as larger events would still inundate the downstream floodplain), the detention offered by the dam would create more time for response. The exception to this however, is within the area of backwater inundation behind the dam, where rates of rise would be significantly greater than under existing conditions. Areas within the inundation extents should not be relied upon for evacuation access. This includes the State controlled road – Brisbane Valley Highway, which is a reginal evacuation route, as discussed in Section 4 Current Flood Risk. Other regional evacuation routes downstream of the dam would benefit from lower flood levels and detention of flood volume.	3.0

8.6.3.5.2 Social

Targets vulnerable community members or areas	The population benefiting from this option is considered to have an average vulnerability across the study area, given that the benefits will extend to extensive downstream areas. The population detrimentally affected, i.e. the upstream areas, would be relocated following acquisition of properties.	2.5
Social health benefits	The significant reduction in the number of residential properties inundated in downstream areas, would lead to substantial social health benefits.	4.0
Improves community flood resilience (now and future)	The significant reduction in the number of residential properties inundated downstream would allow the community to better respond to flooding in the future. There is potential however that some community members would falsely assume that the new structure would eliminate flooding and thus not require a community response. That said, an online detention structure in river provides more resilience that a local levee, as overtopping of a levee would leave the community at risk of rapid onset of flooding.	3.0
Recreation and amenity	The online detention structure would have a significant impact on existing recreational areas upstream within the inundation area during times of flood.	1.5
Connection and collaboration	This option will impact the ability of recreational users to navigate the reach during times when the dry detention dam is in operation.	2.0

8.6.3.5.3 Economic

Reduce damages and costs to residential property (now and future)	Detailed modelling of this option was not carried out and therefore the number of properties benefiting cannot be quantified. Nonetheless, the concept of reducing the 1 in 100 AEP flood to an equivalent minor flood level with minimal impacts on properties would have significant positive outcomes. The offset for this would be detrimental impacts to a large number of properties upstream within the impoundment zone, including many rural residential areas and the village of Fernvale. In the absence of more detailed information, it has been considered that the net result would be neutral.	2.5
Reduce damages and costs to business and	As per discussion for the residential property damages above.	2.5

industry (now and future)		
Option likely to be cost beneficial (now and future)	While the benefits from reduced flood damages would be high, the cost associated with construction of the dam, including the acquisition of properties that would be detrimentally affected within the impoundment area would be extraordinarily high. As outlined in Section 8.6.2.5, the b/c ratio would be expected to be lower than alternative options involving modifications to existing water storages.	2.0

8.6.3.5.4 Feasibility

Physical / technical (now and future)	The design and construction of the online structure may not be feasible due to the space required for a PMF spillway.	1.0
Legal / approval risk	A structure (dam) of the potential size proposed is likely to require a submission to be made to the Coordinator-General to be declared as a State significant project for which an Environmental Impact Statements would be required under the State Development and Public Works Organisation Act 1971 (SDPWO Act). This will facilitate a coordinated assessment and consultation process and is the typical approval pathway for projects of this nature. Any such approval process is complex and lengthy and requires significant and robust technical reporting.	1.5
Potential for additional funding sources	The cost of this infrastructure is very significant and beyond the regular funding channels for local and state government. It is expected that funding for this option would be a significant challenge.	1.0

8.6.3.5.5 Attitude

Decision makers	Given the extraordinary costs of this option, and given that other similar works are already being considered for the Wivenhoe Dam upgrade, it is expected that decision makers would have a low level of support for this option.	1.5
Community	Results from the community survey (refer to Section 11 Community Awareness and Resilience) showed residents in the Brisbane River catchment had a slight preference towards dams	1.5

	and detention basins. Those impacted upstream of the basin would not be supportive. While the downstream community would benefit from this option, the social disruption associated with acquisition of properties within the inundation area would be significant. New dams are rare, and are often challenged by environmental and social dis-benefits. Opposition would be expected from some community members.	

8.6.3.5.6 Key Infrastructure and Transport

Improve availability and function (now and future)	The significant reduction in flood levels downstream of the structure would improve the accessibility of some infrastructure and transport links downstream during times of flood compared to current conditions. However for those that remain inundated, it may extend the duration of flooding. The structure would not guarantee functionality of existing infrastructure, but would likely extend its usability before being impacted, which would likely have broader benefits to the community. Some infrastructure upstream of the structure would be adversely impacted.	3.0
Protection of regional water supply quality and security – catchment protection (quality and yield)	This option would have no long term positive or negative impacts on regional water quality. The temporary storage of waters during and following flood events may help to reduce sediment load during flood events. The structure may adversely impact existing irrigator access to water between Wivenhoe Dam and Mt Crosby during times of flood, including inundation of pumping infrastructure.	2.5

8.6.3.5.7 Environment and Natural Resource Management

Species impacts	An environmental assessment of this structure has not been conducted, however, it is expected that the period and temporary inundation of flood waters would impact on species within the inundation area. In the absence of more detailed information, the same score as Warrill Creek dry flood mitigation dam has been adopted.	2.0
Vegetation and habitat impacts	The change in hydrology of the inundation area is likely to modify the vegetation and habitat contained therein. As above, no detailed environmental assessments on habitat have been undertaken. In the absence of more detailed information, the same score as Warrill Creek dry flood mitigation dam has been adopted.	1.5

Ecosystem health connectivity (fish passage/fauna movement)	No detailed environmental assessments have been conducted, however, any change in habitat would likely impact on ecosystem health and connectivity. The waterway structure would allow for continuation of flows through the main river channel during normal (non-flood) times. In the absence of more detailed information, the same score as Warrill Creek dry flood mitigation dam has been adopted.	2.5
Reduction in landscape salinity / improved moisture retention and groundwater recharge	There are no known significant groundwater aquifers likely to be affected by this option.	2.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	The detention of flood waters would reduce peak flows and levels downstream of the site, however it would also lengthen the duration of flow which could increase the risk of bank erosion and / or slump.	2.5

8.6.3.6 Assessment of Option Against Multiple Criteria

As outlined in Section 8.10.2, the Kholo dry flood mitigation dam option has an overall multi-criteria assessment result of -0.20, where a value of 0.0 represents a net 'no change' condition across the various criteria. Thus, with a negative score it has been determined that the option would have no net overall benefit compared to existing conditions when weighed against the various criteria.

The dam is ranked 13th out of the 16 options considered in the MCA (refer Table 8-64).

The lowest scoring criterion for this option was the potential funding and physical / technical feasibility criteria (value of 1.0), given that capital cost would be in the order of $1.5-2 billion. The best scoring criteria related to social health benefits due to the significant reduction in downstream properties inundated (value of 4.0). Given the likely feasibility and funding issues, this option does not warrant further consideration. Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.6.3.7 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The proposed Kholo dry flood mitigation dam will generally have a positive impact on downstream flood conditions. The flood dam will not eliminate flooding, but the detention effect reduces peak flood flows, which will result in lower peak levels along the Brisbane River. Flood levels in the Bremer River would also

	reduce, but to a lesser degree and would be dependent on the coincidence of flooding from runoff within the Bremer River catchment. The detention of floodwaters would however increase the duration of (lower levels of) inundation.
environmental or social disadvantage	The Kholo dry flood mitigation dam would have local environmental and social consequences, notably for the significant population that currently lives within the potential inundation area. The extent of the environmental impacts are yet to be determined, while social impacts would need to be addressed through acquisition of affected lands and properties (the number of affected properties is significant, including the majority of the village of Fernvale), disaster management planning, and targeted community awareness and resilience activities.
an unacceptable economic cost to State, local government, community or individual	The estimated cost of the Kholo dry flood mitigation dam is very expensive, and outside regular budgets for local or state governments.
technical impracticability	The structure may not be technically feasible, due to the space required for a PMF spillway. The potential inundation would extend to the downstream sides of Wivenhoe Dam and Lake Manchester. Significant structural works may also be required (if indeed feasible) to maintain integrity of these existing structures.
other unusual or unique circumstances	The structure would complicate the operation of Wivenhoe Dam.

8.7 Combined Options

8.7.1 Overview

It is recognised that no one single option will be able to mitigate the impacts of Brisbane River flooding across the floodplain. Indeed, from an integrated catchment and flood management perspective, management of flooding needs to consider an array of approaches and techniques beyond infrastructure, which are discussed in other chapters of this Phase 3 (SFMP).

The following combined options were short-listed and have been evaluated (refer Table 8-48). Combinations of options are simulating possible ‘end states’ following implementation of feasible the structural measures. The importance of simulating the options together is to determine if there are any compounding or cascading effects that do not manifest when analysing impacts on an individual options basis.

Note that this isn't a definitive list of preferred combinations, and other combinations of structural options may warrant worth further investigation. There is no single, optimal combination of structural options and therefore, given the preliminary nature of these investigations, the multi-criteria review was limited to a select number of combinations. As more detailed assessments of the potential structural options are completed, the preferred suite of measures will need to be updated and re-assessed.

Table 8-48 Combined Options Assessed

Location	Description / Immunity level	Report Section
Oxley, Norman and Breakfast Creeks	1 in 100 AEP	Section 8.7.2
Selected options including Amberley Air Base	various	Section 8.7.3
Selected options excluding Amberley Air Base	various	Section 8.7.4

8.7.2 Oxley, Norman and Breakfast Creeks

8.7.2.1 General Description of Option and Assessment

Oxley Creek is the largest tributary of the lower Brisbane River, and contains approximately 3,200 properties within the floodplain that are potentially inundated by 1 in 100 AEP Brisbane River flooding. Norman Creek and Breakfast Creek are also major urban tributaries with a large number of properties located within their respective floodplains. Approximately 920 properties along Norman Creek within the suburbs of East Brisbane, Coorparoo, Norman Park and Greenslopes would be potentially inundated by the 1 in 100 AEP Brisbane River flood, while approximately 970 properties along Breakfast Creek from the suburbs of Ashgrove to Newstead would be similarly affected.

This option involves backwater prevention in the Oxley Creek, Norman Creek and Breakfast Creek floodplains to the 1 in 100 AEP level. The same option in respect to the Oxley Creek floodplain only is presented in Section 8.4.8.

For Oxley Creek, this option consists of raising an existing railway line that crosses Oxley Creek and installing flood gates across Oxley Creek at the rail line crossing to prevent backwater inundation. For Norman Creek, this option consists of installing flood gates at the downstream end of the tributary, on the downstream side of Wynnum Road. For Breakfast Creek, this option consists of installing floodgates at the downstream end of the tributary, between Newstead House and Kingsford Smith Drive, as well as other ancillary levees to prevent backwater inundation through the low-lying sections of Albion to the north or Breakfast Creek.

8.7.2.2 Concept Design

At Oxley Creek, the option (as presented in Section 7.9) would involve raising the existing railway line and installing multiple sluice gates within a concrete wall crossing Oxley Creek. A pumping station would be constructed to remove runoff from local Oxley Creek flood events when the gates are closed.

The flood barrier at Norman Creek would require a crest level no lower than 4 m AHD to achieve the target immunity (1 in 100 AEP) with freeboard (0.5m). The barrier would consist of a concrete wall situated within the creek, which would include eight sluice gates. The height of the wall depends on the elevation of the creek bed. However, it would likely be approximately 6m high. The location of the wall and sluice gates can be seen in Figure 8-52. To prevent local flood inundation, the option would require a pumping station to drain the local catchment runoff. The pumps would require a capacity to pump flows from a 1 in 5 AEP 24 hour duration rainfall event and be located within the Norman Bridge Reserve.

The flood barrier at Breakfast Creek would need to have a crest level no lower than 3.3 m AHD to achieve the target immunity (1 in 100 AEP) with freeboard (0.5m). The barrier would consist of a levee on the right bank of Breakfast Creek and a concrete wall within the channel, which would house eight sluice gates. The height of the wall would depend on the elevation of the creek bed. However, it would likely be approximately 6m high. The location of the wall and sluice gates can be seen in Figure 8-53. To prevent local flood inundation, the option would require a pumping station to drain local catchment runoff. The pumps would require a capacity to pump flows from a 1 in 5 AEP 24 hour duration rainfall event and be located within Newstead Park.

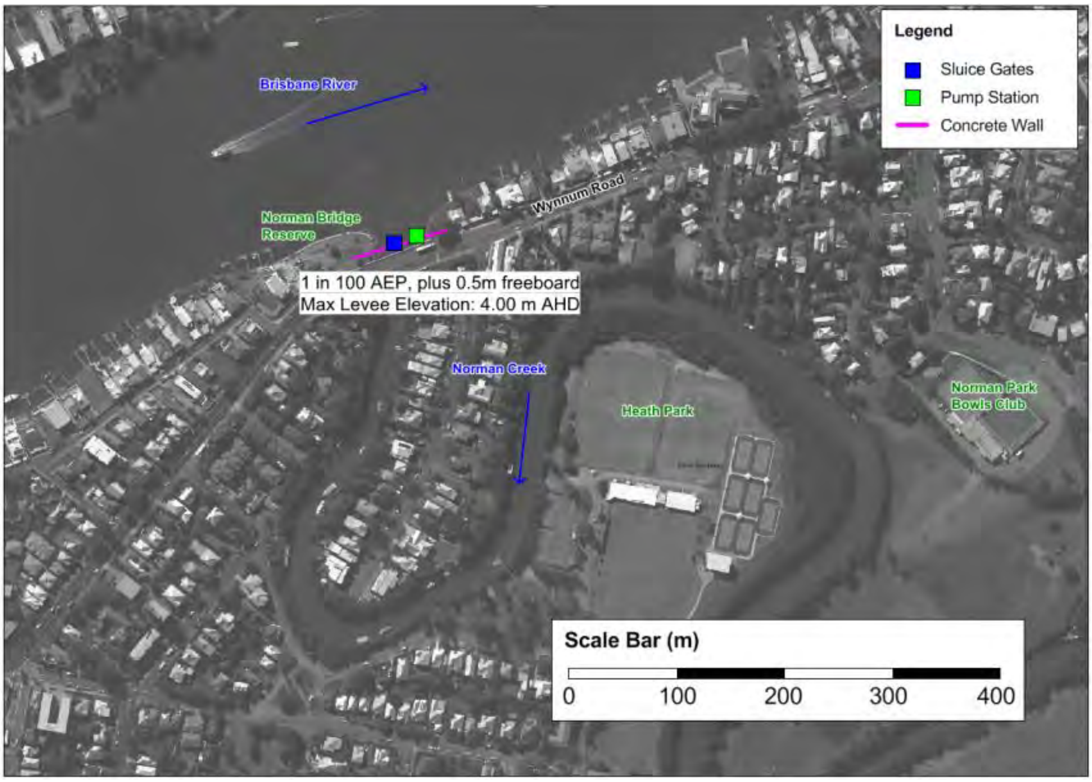


Figure 8-52 Location of Norman Creek barrier and sluice gates

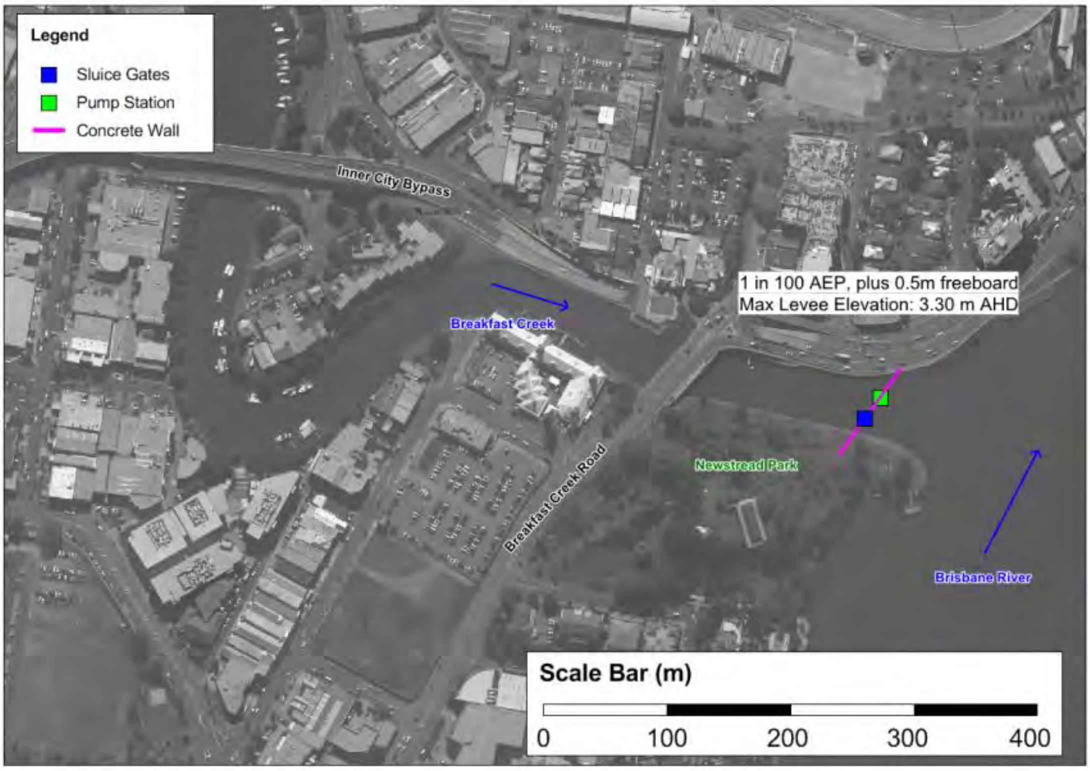


Figure 8-53 Location of Breakfast Creek barrier and sluice gates

8.7.2.3 *Indicative Cost*

The indicative costs of this combined option are presented in Table 8-49 based on the following assumptions:

- The levee heights are based on the Phase 2 (Flood Study) and, therefore, do not take into account the potential increase in water levels as a result of the options;
- No land purchase will be required;
- The existing topsoil is not contaminated and, therefore, requires no treatment;
- The levees would be built with imported materials;
- The dimensions of the levees would be 3m wide at the crest and 1 in 3 batters;
- The site setup would be within the Norman Bridge Reserve and Newstead Park;
- Concept design does not allow for navigation of vessels through the gates structures;
- The pumps are capable of a pumping out a 1 in 5 AEP local catchment flood event; and
- The cost of the sluice gate was based on cost estimates for a similar size structure in the Bundaberg Flood Protection Study (DILGP, 2016).

Table 8-49 Indicative Cost for 1 in 100 AEP Oxley Creek, Breakfast Creek and Norman Creek sluice gates (2017 costs)

Description	Oxley Ck ($)	Breakfast Ck	Norman Ck
Traffic & Environmental Management Plans	696,600	436,200	436,200
Temporary works	2,669,600	5,339,100	2,927,200
Civil / Structures	6,260,900	8,027,200	3,411,100
Earth Works	37,744,500	97,800	97,800
Other	1,482,000	3,250,000	1,625,000
Pumping stations	137,200,000	83,300,000	34,300,000
Total Direct Job Cost	**$186,053,600**	**$100,450,300**	**$42,797,100**
Indirect Job Costs – On-Site Costs (31%)	57,676,600	31,179,800	13,284,200
Design Costs (9%)	21,935,700	11,846,700	5,047,300
Indirect Costs - Offsite Costs (3%)	7,970,000	4,304,300	1,833,900
Contractors Margin and Profit (9%)	24,627,200	13,300,300	5,666,600
Applications (5%)	14,913,200	8,054,100	3,431,500
Contingencies (excluding pumps) (40%)	70,390,500	34,334,200	15,104,300
Contingencies for pumping stations (40%)	54,880,000	33,320,000	13,720,000
Total Cost Estimate (Ex. Op. Expenses)	**$438,446,700**	**$203,469,500**	**$87,164,900**
Annual Operating Expenses (assume 2% of capex)	$ 8,768,900	$ 4,069,400	$ 1,743,300

The total cost estimate for works across all three locations is $729 million, with an annual operational expense of approximately $14.6 million.

8.7.2.4 Hydraulic Impacts

Potential benefits and impacts of the proposed 1 in 100 AEP works within Oxley Creek, Norman Creek and Breakfast Creek on the hydraulic behaviour of flooding were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

The impacts of the works on flood levels across the Brisbane River floodplain are presented in Figure 8-54 for the range of flood events from 1 in 10 AEP to 1 in 100 AEP, while a summary of the impacts on properties for the different AEP floods is given in Table 8-50.

Comparing these results with the hydraulic impacts reported for Oxley Creek alone (refer Section 8.4.8.4), it is apparent that the removal of the Oxley Creek floodplain from the Brisbane River hydraulic behaviour has the vast majority of impact for this option. Oxley Creek is a significant floodplain storage for floodwaters in the Brisbane River and therefore plays an important role in controlling flood behaviour in the river. By inference, the removal of floodplain storage from Norman Creek and Breakfast Creek has less impact on the Brisbane River flood behaviour. This is because these tributaries are located further downstream where flood gradients are relatively small.

Table 8-50 Summary of 1 in 100 AEP Oxley Creek, Norman Creek and Breakfast Creek levees and sluice gates impacts on properties

AEP	Maximum afflux	Afflux at Ipswich CBD	Afflux at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	< 50mm*	< 50mm*	< 50mm*	0	4	0	0
1 in 5	< 50mm*	< 50mm*	< 50mm*	6	18	0	2
1 in 10	**80mm**	< 50mm	< 50mm	8	104	3	0
1 in 20	**60mm**	< 50mm	< 50mm	16	489	2	3
1 in 50	**130mm**	< 50mm	**70mm**	47	1,780	1,672	324
1 in 100	**320mm**	< 50mm	**230mm**	9	4,806	10,912	806
1 in 200	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 500	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 2,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 10,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0
1 in 100,000	< 50mm*	< 50mm*	< 50mm*	0	0	0	0

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.

[2] Building no longer affected by flooding.

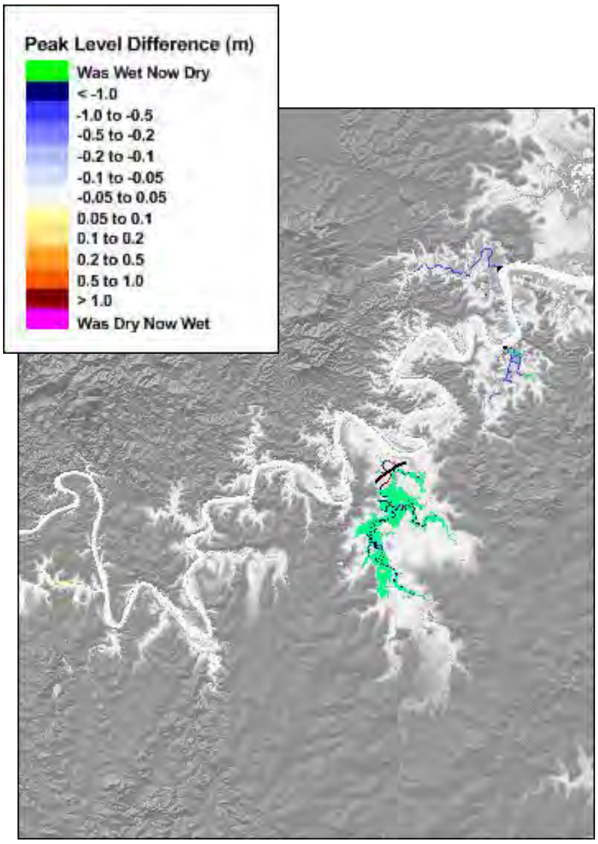
[3] Building is flooded to a greater degree, either above or below habitable floor level.

[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.

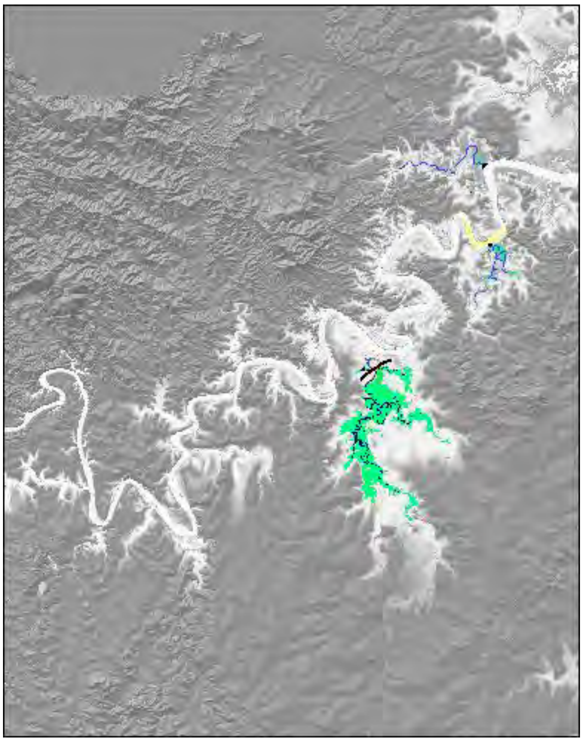
Up to the 1 in 20 AEP level, off-site impacts are very limited, while benefits of the structures extend to about 500 properties (approximately 230 of which are residential). For the 1 in 50 AEP flood, benefits increase to some 1,800 properties, however, about 2,000 properties would experience worse flood conditions, including >1,200 residential properties. The maximum afflux for the 1 in 50 AEP flood would be about 0.13 metres (0.07 metres at Brisbane CBD).

For the 1 in 100 AEP flood, approximately 4,800 properties would benefit from the structures (of which about 2,100 are residential properties, split between existing HR2 and HR3 Potential Hydraulic Risk areas). The consequence, however, is detrimental impacts for ~11,700 properties elsewhere in the floodplain, including ~8,500 residential properties (most of which are in HR2 or HR3 areas). The maximum afflux for the 1 in 100 AEP flood is 0.32 metres (0.23 metres at Brisbane CBD).

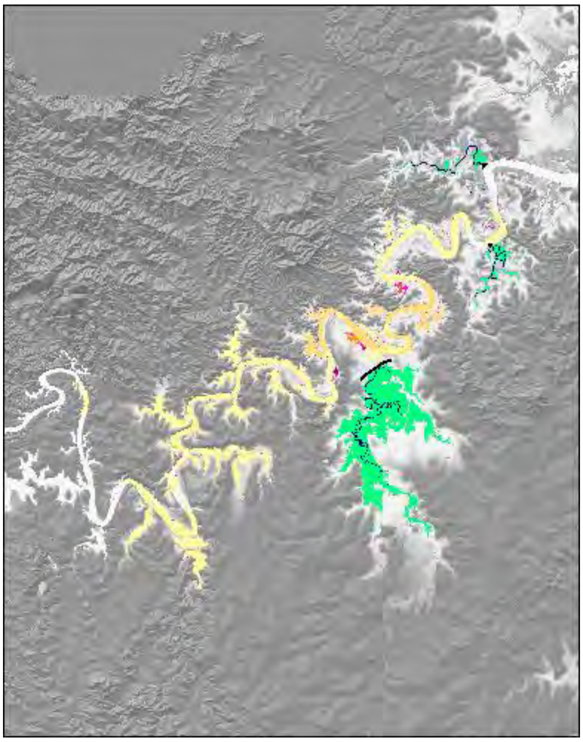
For floods larger than the 1 in 100 AEP, the structures would overtop and the flood storage areas behind the levees and sluice gates would re-engage with the river. Flooding extents for these larger floods would be as per existing conditions.



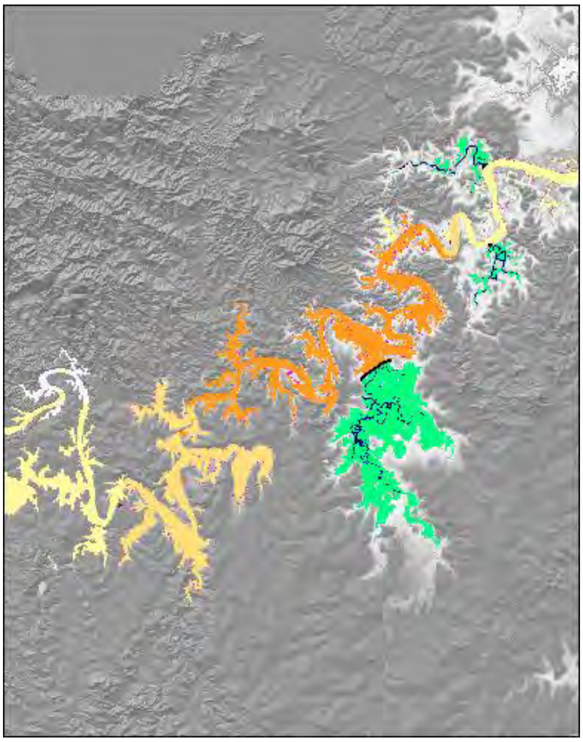
1 in 10 AEP



1 in 20 AEP



1 in 50 AEP



1 in 100 AEP

Figure 8-54 Oxley, Norman and Breakfast Creeks 1 in 100 AEP levees and sluice gates: Impacts 1 in 10 AEP to 1 in 100 AEP

8.7.2.5 Benefit / Cost Analysis

A summary of the benefit / cost analysis for the combined levees and flood gates option at Oxley Creek, Norman Creek and Breakfast Creek, is presented in Table 8-51.

Table 8-51 Benefit/cost analysis summary for combined Oxley, Norman and Breakfast Creeks 1 in 100 AEP levees and flood gates option

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case (1)	288.7	265.8	22.9	**0.33**
Sensitivity 1: No intangibles	186.8	165.4	21.4	**0.31**
Sensitivity 2: with Wivenhoe up.	213.2	191.0	22.2	**0.32**
Sensitivity 3: 4% discount rate				**0.50**
Sensitivity 4: 10% discount rate				**0.24**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

The levees and flood gates, with a capital cost of $729 million and an annual maintenance cost of almost $15 million, will generate a net annual average benefit of $23 million, leading to a benefit/cost ratio of 0.33 when adopting a discount rate of 7% over a 100 year period. As for the assessment of the Oxley Creek levee on its own, the benefits are confined to those properties that are located behind the structures, while there is dis-benefit to a large number of properties elsewhere in the Brisbane River floodplain, as outlined in Table 8-50. Overall, the monetary benefits to the properties behind the levees outweighs the additional losses incurred by properties elsewhere, giving a net positive economic gain. The extensive impacts of the works, however, render this option unacceptable.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-51. If benefits were limited to reductions in tangible damages, the annual average benefit of the works would reduce to $21 million, giving a net benefit/cost ratio of 0.30. Potential upgrade to Wivenhoe Dam upgrade could reduce the impact of flooding throughout the Brisbane River floodplain, resulting in a reduction in the annual average benefit of the option to $22 million per annum, leading to a benefit/cost ratio of 0.32. Sensitivity was also undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 0.50, while for a higher discount rate of 10%, the benefit/cost ration reduces to 0.24.

8.7.2.6 Multi-Criteria Review

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.7.2.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	Approximately 4,800 properties (located mostly within HR2 and HR3 Potential Hydraulic Risk areas) would benefit directly from preventing Brisbane River backwater into Oxley Creek, Norman	1.0

	Creek and Breakfast Creek for flooding up to the 1 in 100 AEP event (with 3,500 of these within the Oxley Creek floodplain). Benefits would only be achieved if local catchment runoff was also prevented from inundating these properties, which would require very large pumps (assuming that local catchment runoff coincides with Brisbane River flooding). Events larger than the 1 in 100 AEP would overtop the structures and would impact properties as per existing conditions. Removal of flood storage, notably from within the Oxley Creek floodplain, would result in increased flood levels in the Brisbane River. This would have the unacceptable impact of exacerbating flooding at the 1 in 100 AEP level for approximately 11,700 properties, including 8,500 residential properties (which are currently in HR2 or HR3 areas).	
Improve time for evacuation (now and future)	While there would be improved time for evacuation in areas adjacent to Oxley Creek, Norman Creek and Breakfast Creek behind the flood gate structures, the increase in flood levels along the Brisbane River would reduce available warning time for a much larger number of properties. Significant (regional) evacuation routes located behind the structures would benefit from the increase in flood immunity. This includes the Ipswich Motorway across the Oxley Creek floodplain which is currently impacted by the 1 in 20 AEP flood (refer Section 4 Current Flood Risk).	1.0

8.7.2.6.2 Social

Targets vulnerable community members or areas	The population benefiting from this option includes the suburbs of Inala and Oxley within the Oxley Creek floodplain; Greenslopes to Norman Park within the Norman Creek floodplain; and Ashgrove to Newstead within the Breakfast Creek floodplain. Overall, these areas are considered to be a little more vulnerable than average, as detailed in Section 4 Current Flood Risk. Areas where flooding is exacerbated by this option include Sherwood, Graceville and Fairfield, some of which also contain more vulnerable people. On balance, there is a much larger number of properties detrimentally affected than benefiting from this option.	2.0
Social health benefits	While there are some areas that benefit from this option, there is a much higher number that are detrimentally affected. On	1.5

	balance, the social health benefits would be considerably worse than existing conditions under this option.	
Improves community flood resilience (now and future)	The option provides benefits to some residents, but at the expense of worsening conditions for a much larger number of residents. The installation of the structures across the three creeks would not provide any significant regional community resilience, as there would be a tendency for the community to rely on infrastructure to manage flooding rather than taking effective measures themselves. On balance, and due to the widespread impacts, community resilience under this option would be notably lower than existing conditions. Benefits of this option extend to two emergency management facilities, however, the increase in flooding in other parts of the floodplain exacerbate issues for three emergency management facilities elsewhere, as well as 24 critical energy infrastructure items.	1.5
Recreation and amenity	This option would potentially restrict waterway access along Oxley Creek, Norman Creek and Breakfast Creek. Both Norman Creek and Breakfast Creek are used extensively by water vessels, with Breakfast Creek also supporting a small boating industry. Private jetties are located along the banks of all three creeks. Depending on the design, the structure may provide pedestrian access across the creeks at these locations, which may improve local amenity.	1.0
Connection and collaboration	This option would potentially detract from the community's connectedness to the river and watercourses as it involves constructing very large artificial structures across the natural waterways.	1.5

8.7.2.6.3 Economic

Reduce damages and costs to residential property (now and future)	The combined structures in Oxley, Norman and Breakfast Creeks would provide benefit to a large number of residential properties. There would be negative impact to a large number of properties as well, however, the net result is a positive economic benefit (across all property types) of annual average benefit of $23 million. The bulk of these gains are due to the Oxley Creek structure, which provides a gain of $22 million, as discussed previously in Section 8.4.8.6.3.	4.0

Reduce damages and costs to business and industry (now and future)	Commercial properties would benefit from this option, notably the commercial properties within the Oxley Creek floodplain.	4.0
Option likely to be cost beneficial (now and future)	The b/c ratio of this option is low at 0.33, and notably lower than the Oxley Creek structure only (0.52), as there is only marginal benefit gain from the Norman Creek and Breakfast Creek structures for high capital and maintenance costs	2.0

8.7.2.6.4 Feasibility

Physical / technical (now and future)	The design and construction of the levees and sluice gate structures across the three creeks would be feasible. Raising the existing rail line in Oxley Creek would be more challenging as it would render the rail line inoperable during the works period. The geotechnical condition of the existing rail embankment would need to be assessed to determine if it can be raised and withstand the additional loading of material. This measure would need to involve early consultation with the Queensland Rail and/or Department of Transport and Main Roads to ensure its technical viability for the safe and efficient operation of the existing railway and also how this aligns with any future railway upgrade requirements (e.g. possible Inland Rail link to Port of Brisbane).	2.0
Legal / approval risk	Oxley Creek See Section 8.4.8.6.4. Norman Creek The proposed structures will be located within the Norman Creek waterway and on land either side which is in the Open Space (local) zone of the City Plan 2014. Land on the western bank is also included within the local heritage overlay of the City Plan. The proposed structures (including the pump station) will likely require an Impact assessable application assessable by both Brisbane City Council and SARA. These applications are for building works not associated with an MCU, operational works/building works in a local heritage place and operational works that are Waterway Barrier Works and works within the erosion prone area of the Coastal Management District.	2.0

	Approval for this development would be likely, though noting that there would also be a statutory requirement for public notification where submitters have appeal rights. Any applications will require comprehensive engineering documentation, and technical reporting to address impacts on heritage elements along with ecological and coastal processes. Land owners consent from relevant parties will be required to support the applications. Breakfast Creek The proposed structures will be located within the Breakfast Creek waterway and on land either side, which to the south contains Newstead Park which is a Queensland Heritage Place (and also locally listed) along with being included Open Space (metropolitan) Zone; and to the north includes the Council-owned road Kingsford Smith Drive. The proposed structures (including the pump station) will likely require an Impact assessable application assessable by both Brisbane City Council and SARA. These applications are for building works not associated with an MCU, operational works/building works in a local heritage place and operational works that are Waterway Barrier Works, works within the erosion prone area of the Coastal Management District, and building works in a Queensland Heritage Place. Approval for this development has some risks particularly associated with the State heritage listing of Newstead Park, and development within the Kingsford Smith Drive road reserve. Accordingly, significant consultation with the Department of Environment and Heritage Protection, and Brisbane City Council would be required to determine approval prospects. There would also be a statutory requirement for public notification where submitters have appeal rights. Any applications will require comprehensive engineering documentation, and technical reporting to address impacts on heritage elements along with ecological and coastal processes. Land owners consent from relevant parties will be required to support the applications.	
Potential for additional funding sources	The benefit-cost assessment indicates that there is relatively low return on investment. As such, it would be difficult to formulate a	1.5

	business case that would receive positive support from potential funding bodies. The possibility of linking the Oxley Creek works to the national Inland Rail program was discussed in Section 8.4.8.6.4.	

8.7.2.6.5 Attitude

Decision makers	With a low economic return on this option and a worsening of flooding at a significant number of properties, this option is unlikely to be supported for implementation.	1.5
Community	Although there are some 4,800 properties that would be protected by the structures, the impacts would exacerbate flooding for approximately 11,700 properties at the 1 in 100 AEP flood level. With a high cost and limited benefits, it is expected that this option would not have much community support, and indeed face significant community opposition to the use of funds.	1.0

8.7.2.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	This option will improve local access on roads within the three floodplains for floods up to the 1 in 100 AEP event. This includes providing road access for some 4,800 properties within the floodplain, which may assist in evacuation during a flood event. However, the impacts of this option will create higher flood levels elsewhere affecting some 11,700 properties, and may have a detrimental impact on the function of transport and infrastructure in other locations. As discussed in Section 8.4.8.6.6, the elevated rail line may provide benefits for the rail link in Oxley Creek.	2.0
Protection of regional water supply quality and security – catchment protection (quality and yield)	This option would have no impact on regional water quality or quantity.	2.5

8.7.2.6.7 Environment and Natural Resource Management

Species impacts	There would be no significant impact to species richness or diversity. The structures would impede aquatic species movement during times of flood, however this would be for a relatively short period. Nonetheless, there may be some impact	2.0

	on species that rely on floods for movement through the river environment.	
Vegetation and habitat impacts	There would be no significant impact on terrestrial vegetation and habitats. The location of the levees, means that there would be little to no net loss of valued habitat due to construction. The restriction of flow during times of flood, however, may have an impact on aquatic habitats that rely on floods, including upstream wetlands.	2.0
Ecosystem health connectivity (fish passage/fauna movement)	There would be no impact on the ecosystem health connectivity through fish and fauna passage with the exception of fish passage during times of flood. It is recognised that waterways provide a natural corridor for some species. The structure proposed is unlikely to have a significant detrimental effect on species movement in the long term. Pondage of local flood waters behind the levee has the potential to form anoxic in-stream conditions through the decay or organic matter washed into waterways during the flood event. On the basis that ponded water is pumped into the Brisbane River, this would not be of concern, however, if pumping was to be insufficient and allow extended ponding of floodwaters, anoxia within the water may degrade the ecosystem health with the potential for lasting impacts.	2.5
Reduction in landscape salinity / improved moisture retention and groundwater recharge	There would be no impact to the landscape salinity or moisture, as this option does not encourage local ponding or water storage.	2.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	There would be no impact to the erosive capacity of the catchment or channel stability providing that higher velocities in and around the sluice gate structure itself are managed through bed and bank protection works.	2.5

8.7.2.7 Assessment of Option Against Multiple Criteria

As outlined in Section 8.10.2, the combined 1 in 100 AEP Oxley Creek, Norman Creek and Breakfast Creek levees and sluice gates option has an overall multi-criteria assessment result of -0.54, where a value of 0.0 represents a net 'no change' condition across the various criteria. Thus, with a negative score it has been determined that the option would have a net overall detrimental impact when weighed against the various criteria. The levee combination is ranked 16th out of the 16 options considered in the MCA (refer Table 8-64).

The lowest scoring criteria for this option were the safety of people and community attitude criteria (value of 1.0), while the best related to reduced residential and commercial damages (value of 4.0). With a very low score for people safety and community attitude, this option would not warrant further consideration. Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.7.2.8 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The proposed 1 in 100 AEP levees and sluice gates across the three creeks will address flooding for events up to the 1 in 100 AEP flood only. Larger events will still impact on the local population at risk with no residual mitigation by the levee.
environmental or social disadvantage	The proposed structures within the creeks should not create environmental or social disadvantage providing they are operated in accordance with design and do not allow extended periods of ponding of local flood waters.
an unacceptable economic cost to State, local government, community or individual	The proposed structures would attract a high very cost given the limited numbers of beneficiaries. This could be considered an unacceptable economic cost.
technical impracticability	The levees and sluice gates would be technically feasible but may have some construction challenges given the site constraints and unknown geotechnical conditions of the existing rail embankment.
other unusual or unique circumstances	There are no obvious other unusual or unique circumstances that would preclude the feasibility of this option.

8.7.3 Selected Options Including Amberley levee

8.7.3.1 General Description of Option and Assessment

A suite of options were chosen to be assessed cumulatively to determine if there were any additional benefits or dis-benefits when considered in combination. The options chosen were selected by stakeholders based on preliminary appreciation of benefits and costs for individual options.

The options that were included in this assessment were:

- Fernvale levee (refer Section 8.4.2);
- Ipswich CBD flood gate (refer Section 8.4.6);
- South Brisbane temporary barrier (refer Section 8.5.2);

- Brisbane CBD temporary barrier (refer Section 8.5.3);
- Warrill Creek dry flood mitigation dam (refer Section 8.6.2); and
- Amberley RAAF Air Base levee (refer Section 8.4.3).

Although options were chosen for this scenario without the benefit of the completed benefit/cost analysis and multi-criteria assessment for each option, the preliminary hydraulic impacts and indicative costs were sufficient to determine which options would most likely provide potentially feasible solutions and those that would not. Despite impacts on downstream properties as outlined in Section 8.4.3, Amberley RAAF Air Base was included in this scenario assessment as it provides significant benefit to maintaining operations at the defence site. The inclusion of Warrill Creek dry flood mitigation dam with the Amberley Air Base levee was seen as a way to potentially offset the detrimental impacts of the levee afflux as well as provide further flood benefits downstream.

The inclusion of Warrill Creek dry flood mitigation dam would also result in Cunningham Highway remaining open for up to the 1 in 100 AEP flood. At present, the susceptibility of Cunningham Highway across the Warrill Creek and Purga Creek floodplain is a major constraint to the operations of Amberley Air Base during times of flood. Should the Amberley Air Base levee proceed, then accompanying works would also be required to ensure that access to and from the base, such as Cunningham Highway, was improved to a similar flood immunity standard.

8.7.3.2 Concept Design

Concept designs for the individual options that make up this combined option scenario were discussed in the previous relevant sections of this chapter.

8.7.3.3 Indicative Cost

The total cost estimate (excluding maintenance costs) for the combined options as outlined above is approximately $641 million, of which about 86% represents the cost of the Warrill Creek dry flood mitigation dam, and 12% represents the Amberley RAAF Air Base levee.

The total annual maintenance cost for the combined options as outlined above is approximately $2.46 million, of which 20% is the maintenance cost of the Warrill Creek dry flood mitigation dam, and about 62% is the maintenance cost of the Amberley RAAF Air Base levee.

8.7.3.4 Hydraulic Impacts

Potential benefits and impacts of the combined options, including Amberley Air Base levee, on the hydraulic behaviour were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

The impacts of the combined options including Amberley Air Base levee on flood levels in the Brisbane River are presented in Figure 8-55 to Figure 8-59 for the range of flood events from 1 in 5 AEP to 1 in 100,000 AEP, with a summary of the impacts on properties provided in Table 8-52. As the results of this combined scenario are dominated by the impacts of Warrill Creek dry flood mitigation dam, there is essentially no afflux (i.e. higher flood level than existing) recorded within the floodplain. Table 8-52 therefore provides details of reductions in peak flood levels at Ipswich CBD and Brisbane CBD that are achieved across the AEPs considered.

With the exception of Warrill Creek dry flood mitigation dam and the Amberley Air Base levee, the impacts of the options do not interact when considered in a combined basis.

In general, the figures and table show that the options significantly reduce flood levels in the upper Bremer River, including at Ipswich CBD, across a spectrum of floods, from the 1 in 5 AEP to the 1 in 500 AEP. The influence of Amberley Air Base levee is restricted to areas immediately downstream of the Air Base only, and are more than offset by the mitigative benefit of the Warrill Creek dry flood mitigation dam.

The reductions in flood levels expected at Brisbane CBD are achieved by the Warrill Creek dry flood mitigation dam rather that other works specifically at South Brisbane or Brisbane CBD, as included in this combined option. Those works, however, still benefit properties behind the barriers and contribute to the number of properties that benefit from the combined works, as detailed in Table 8-52.

Of note, the comparatively small flood level reduction achieved at Brisbane CBD and South Brisbane by Warrill Creek dry flood mitigation dam is not sufficient to significantly change the susceptibility of properties to flooding in this area given the sensitivity of the river flow and AEP differences (that is, a reduction of 150-200mm is relatively small given that the difference in flood level between 1 in 50 AEP and 1 in 100 AEP is about 1.5 metres, while the difference between 1 in 100 AEP and 1 in 200 AEP is about 1.3 metres, at Brisbane CBD).

Overall, some 18,500 properties would directly benefit through flood immunity from these combined options in a 1 in 100 AEP, rising to 30,000 properties in a 1 in 200 AEP event (but recognising that properties in South Brisbane and Fernvale would still be impacted at the 1 in 200 AEP event as the temporary barrier and levee options at these locations would be overtopped by such an event). The economic value of reduced damages to these properties is discussed in Section Table 8-52.

Table 8-52 Summary of Combined Options (including Amberley levee) impacts on properties

AEP	WL reduction at Ipswich CBD	WL reduction at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	< 50mm*	< 50mm*	0	0	0	0
1 in 5	1,540mm	< 50mm	4	5	0	1
1 in 10	1,270mm	70mm	49	128	0	0
1 in 20	1,170mm	70mm	257	321	0	0
1 in 50	1,740mm	80mm	3,602	1,712	0	1
1 in 100	1,620mm	150mm	15,139	3,423	0	2
1 in 200	720mm	190mm	26,854	3,211	0	2
1 in 500	200mm	190mm	40,884	1,607	0	0
1 in 2,000	80mm	< 50mm	12,054	512	2	3
1 in 10,000	70mm	100mm	83,803	821	0	0
1 in 100,000	< 50mm	< 50mm	0	24	4	27

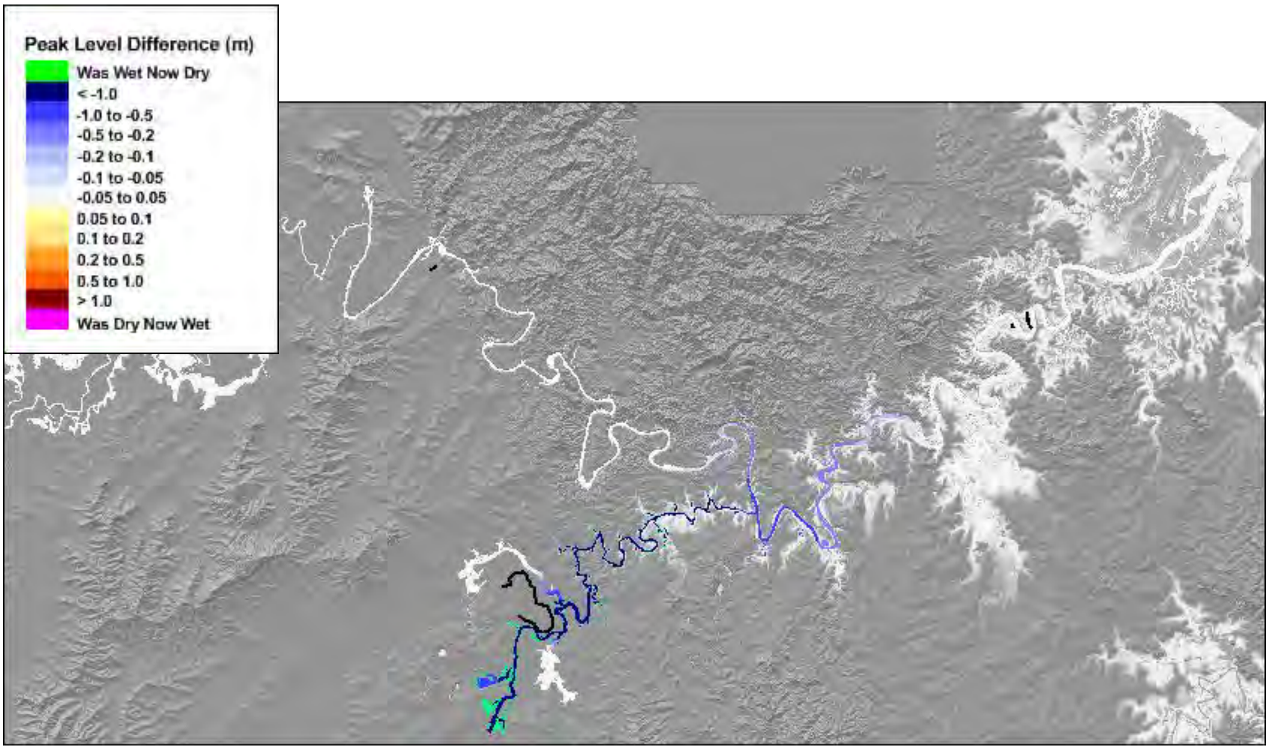
** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.

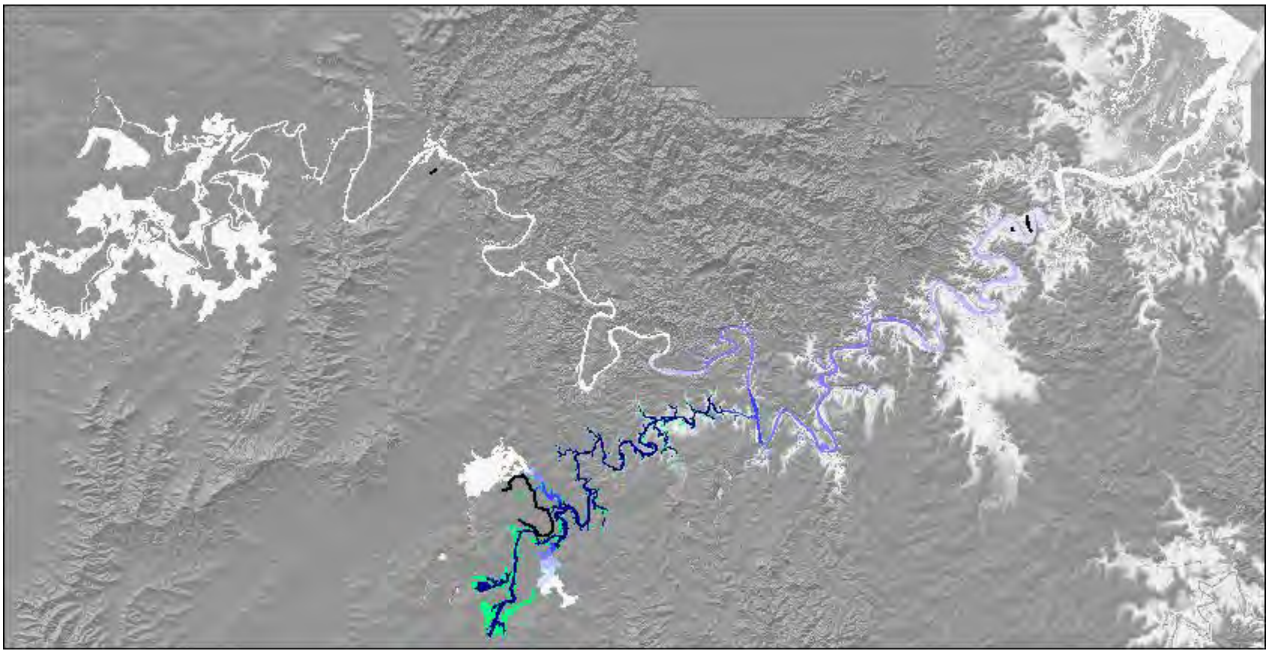
[2] Building no longer affected by flooding.

[3] Building is flooded to a greater degree, either above or below habitable floor level.

[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.

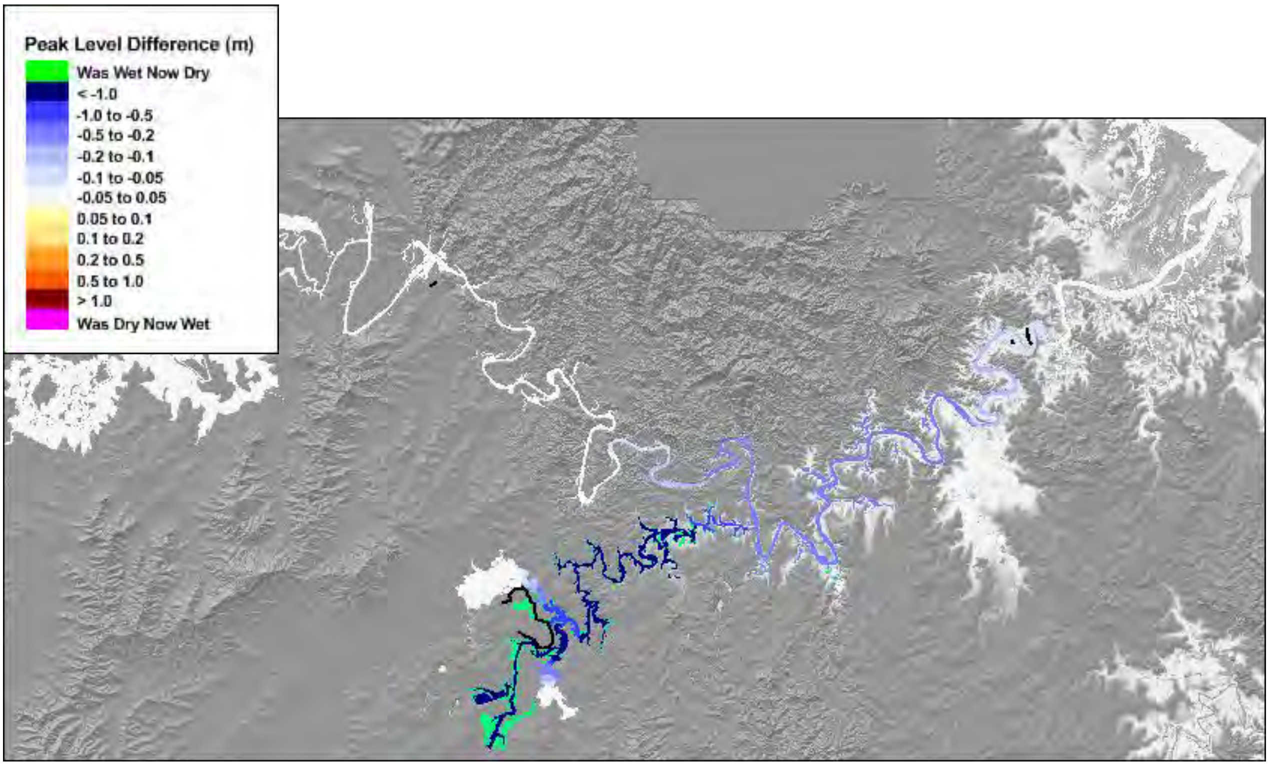


1 in 5 AEP

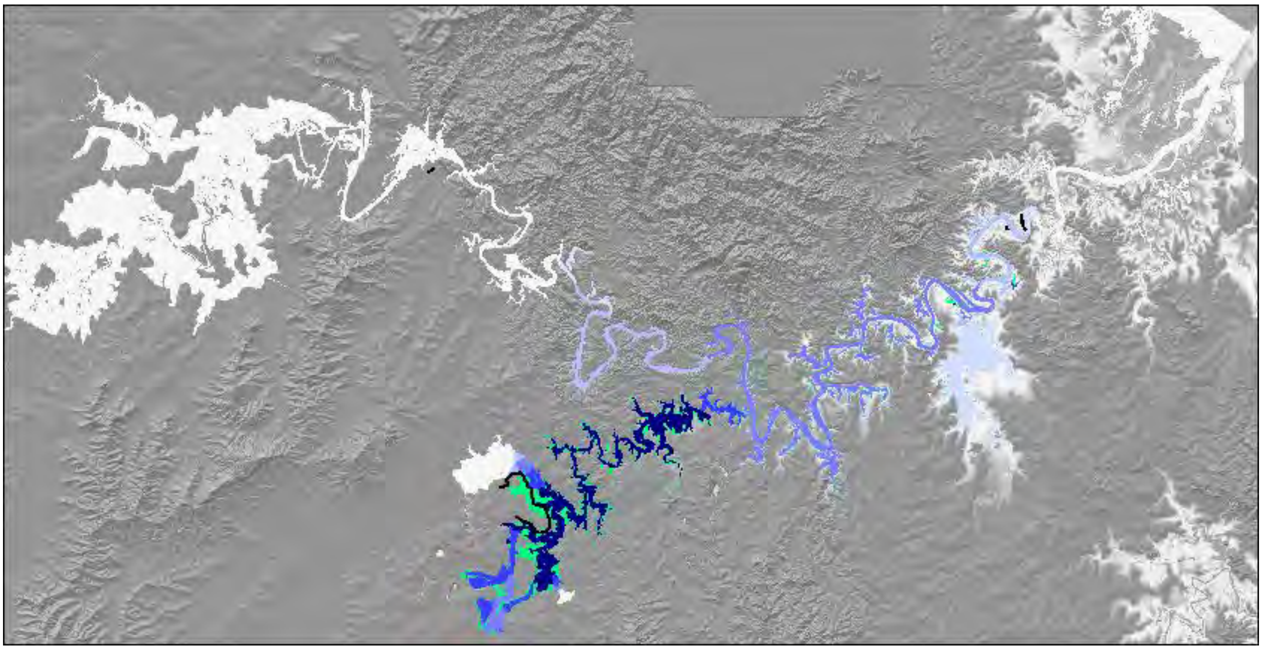


1 in 10 AEP

Figure 8-55 Combined Options with Amberley levee: 1 in 5 AEP and 1 in 10 AEP

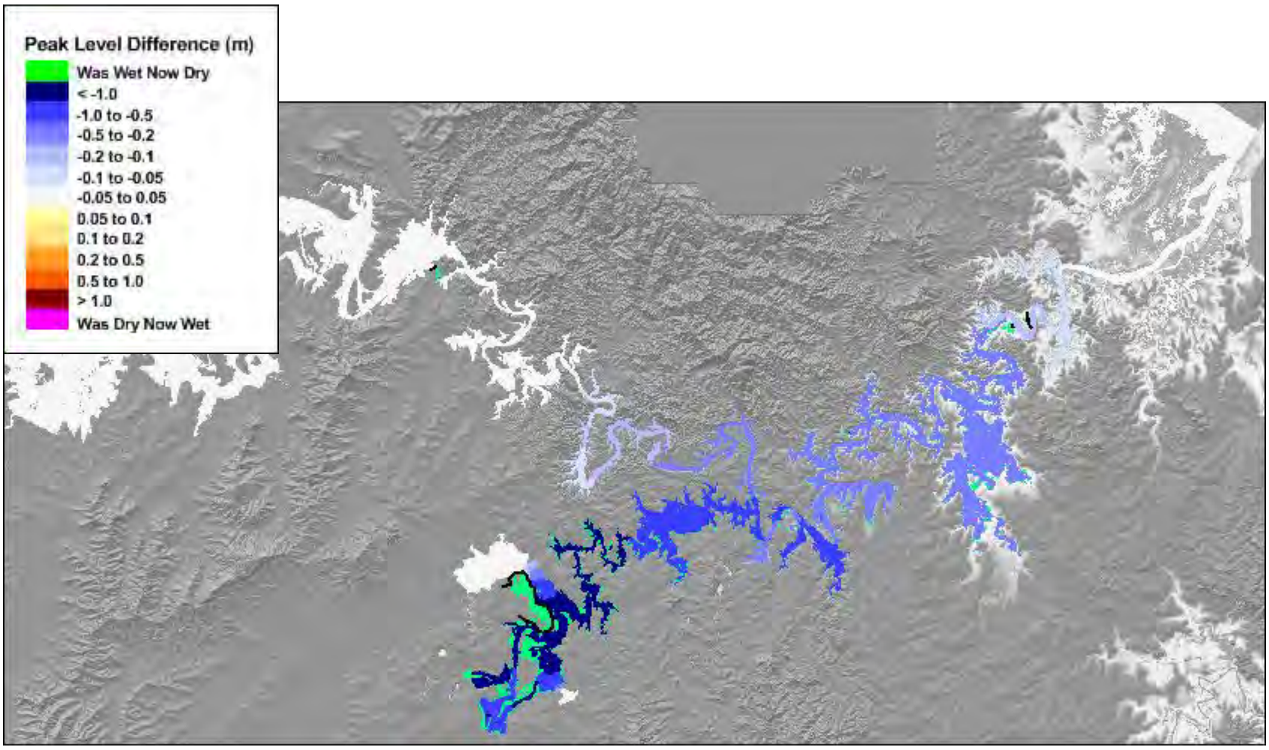


1 in 20 AEP

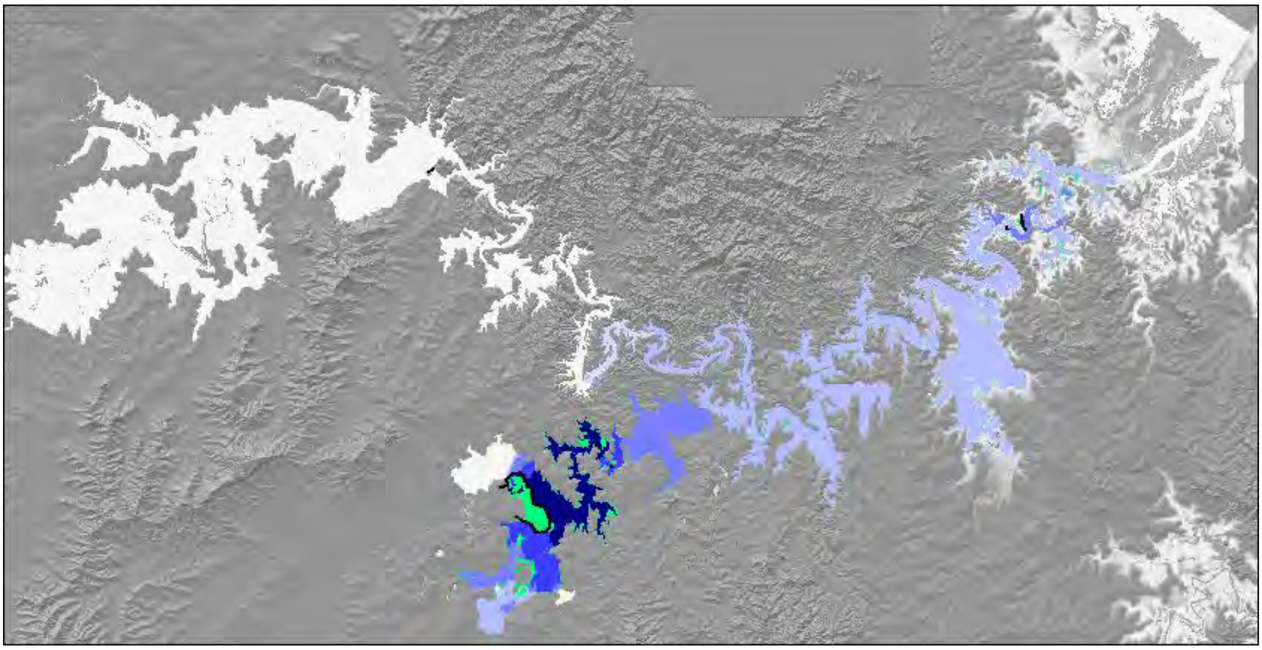


1 in 50 AEP

Figure 8-56 Combined Options with Amberley levee: 1 in 20 AEP and 1 in 50 AEP

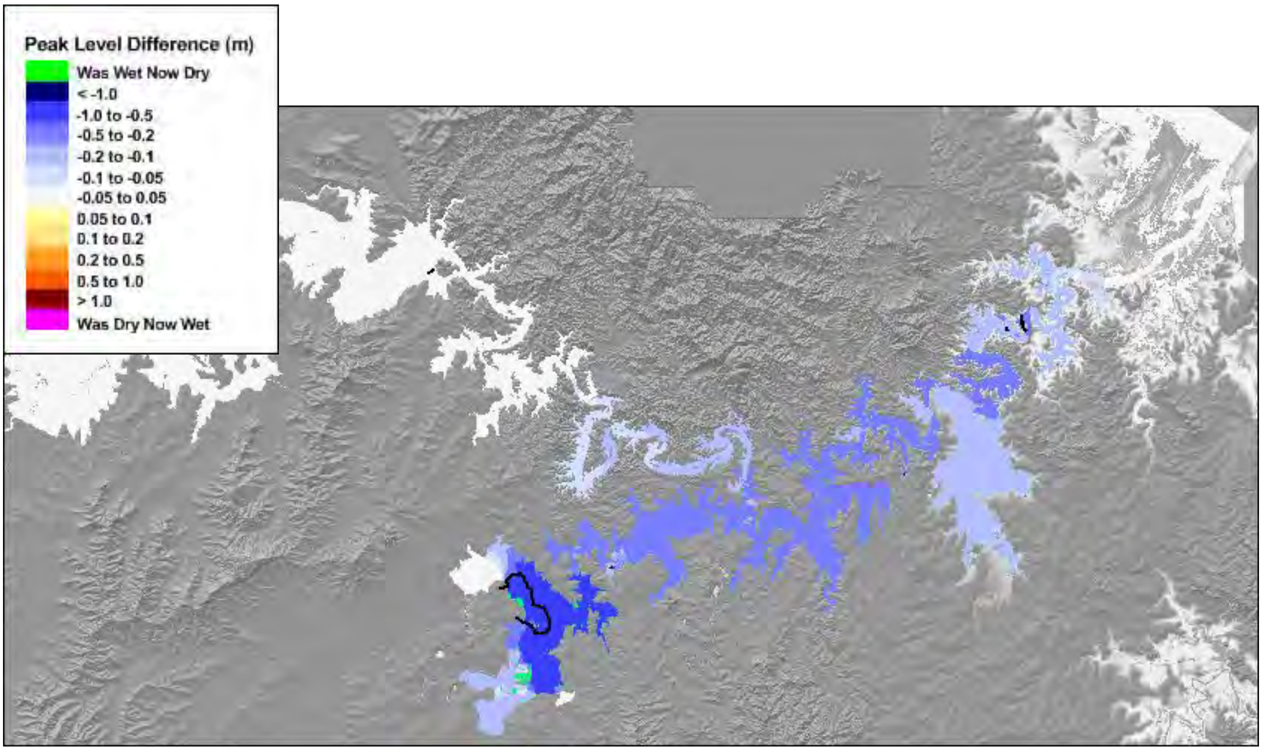


1 in 100 AEP

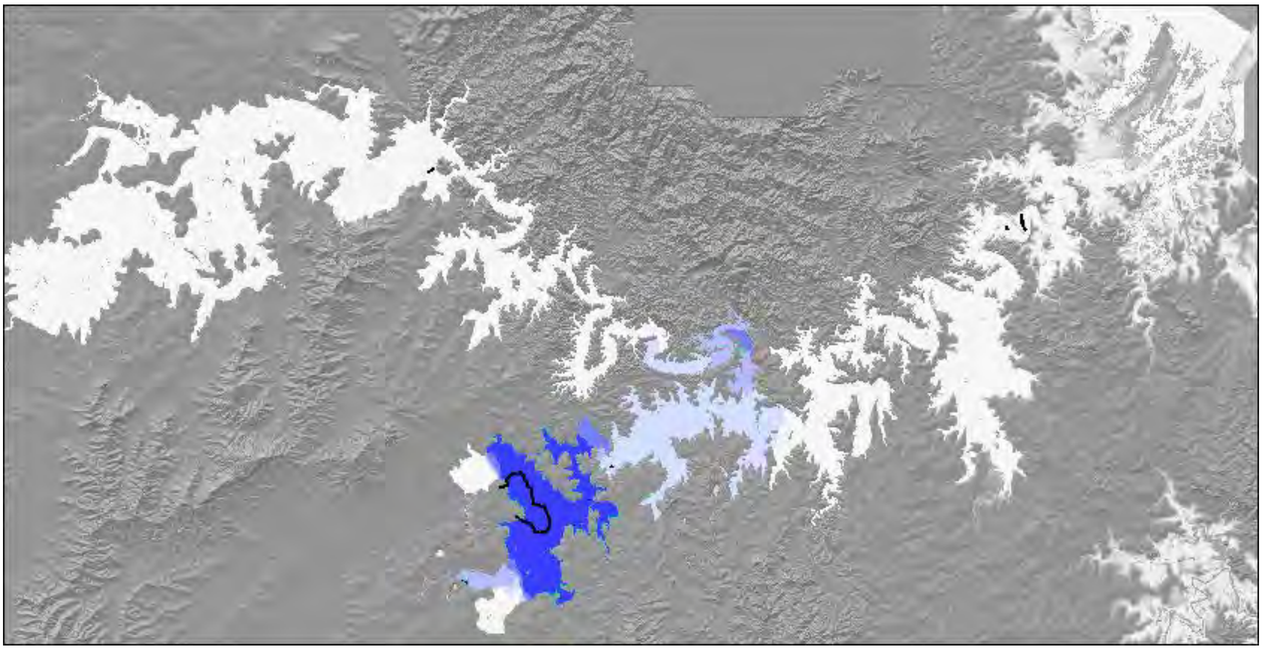


1 in 200 AEP

Figure 8-57 Combined Options with Amberley levee: 1 in 100 AEP and 1 in 200 AEP

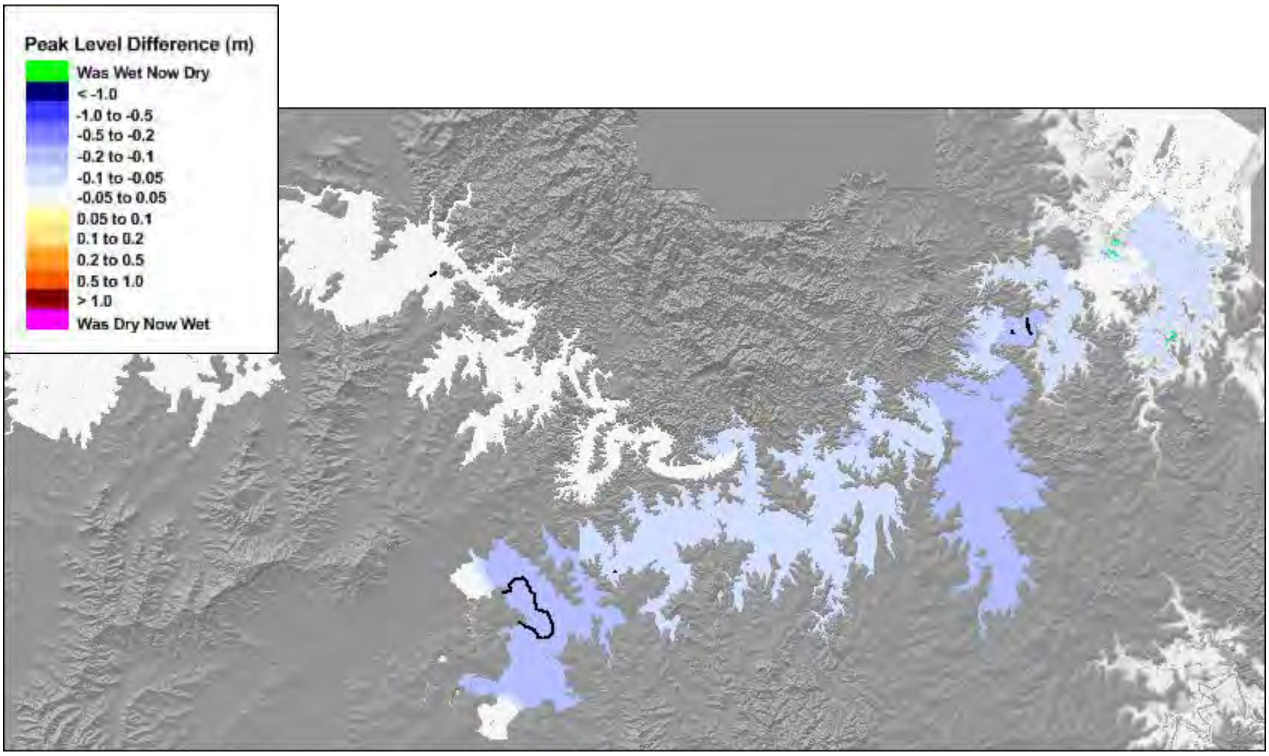


1 in 500 AEP

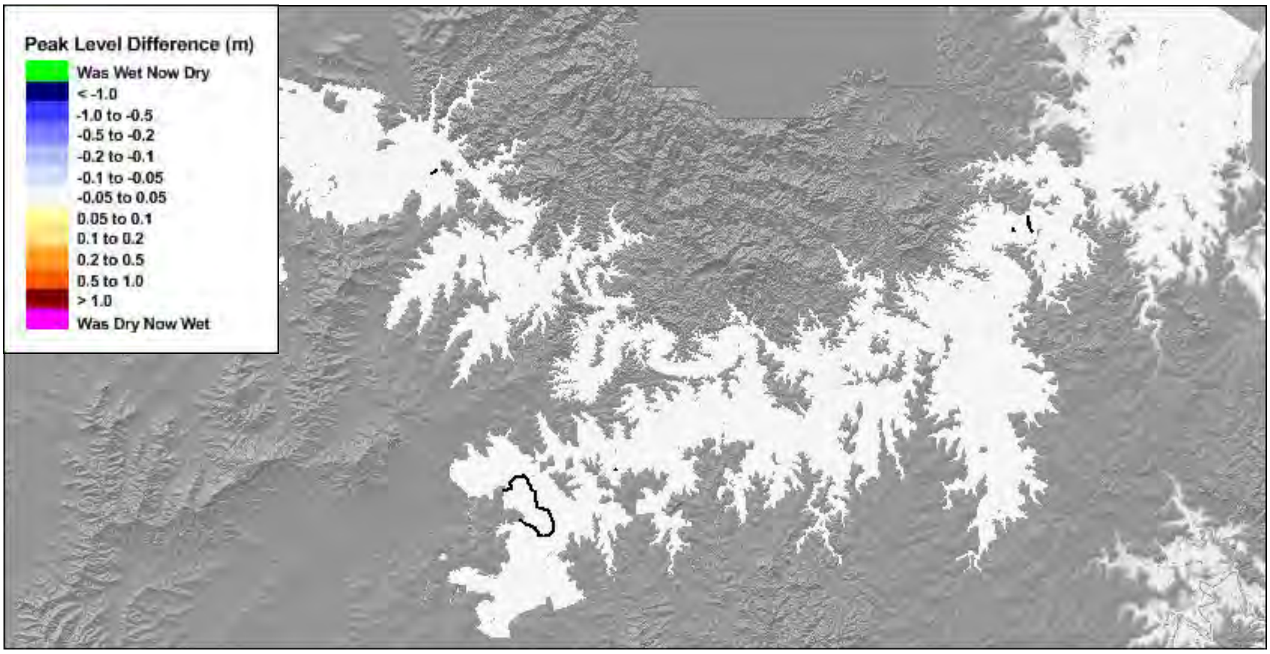


1 in 2,000 AEP

Figure 8-58 Combined Options with Amberley levee: 1 in 500 AEP and 1 in 2,000 AEP



1 in 10,000 AEP



1 in 100,000 AEP

Figure 8-59 Combined Options with Amberley levee: 1 in 10,000 AEP and 1 in 100,000 AEP

8.7.3.5 Benefit / Cost Analysis

A summary of the benefit / cost analysis for the combined options including Amberley Air Base levee is presented in Table 8-53.

Table 8-53 Benefit/cost analysis summary for combined options including Amberley Air base levee

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case (1)	288.7	258.9	29.8	**0.59**
Sensitivity 1: No intangibles	186.9	165.7	21.2	**0.42**
Sensitivity 2: with Wivenhoe up.	n/a	n/a	n/a	n/a
Sensitivity 3: 4% discount rate				**1.00**
Sensitivity 4: 10% discount rate				**0.41**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

The combined options, with a capital cost of $641 million and an annual maintenance cost of $2.46 million, will generate a net annual average benefit of $30 million, leading to a benefit/cost ratio of 0.59 when adopting a discount rate of 7% over a 100 year period.

As discussed in Section 8.4.3.5, the benefits (tangible and intangible) of a functional and accessible air base are virtually impossible to quantify and have not been included in the economic assessment. It can be expected, however, that the annual average benefits would be substantially higher than those indicated in Table 8-53 if the benefits to the air base were to be included.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-53. If benefits were limited to reductions in tangible damages, the annual average benefit of the works would reduce to $21 million, giving a net benefit/cost ratio of 0.42.

Sensitivity was also undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 1.00 (i.e. parity), while for a higher discount rate of 10%, the benefit/cost ration reduces to 0.41.

As for the Warrill Creek dry flood mitigation dam option, sensitivity to future Wivenhoe Dam upgrades was not carried out because as advised by Seqwater (pers. comm.) a more detailed and rigorous hydrologic assessment of the two significant detention structures would need to be undertaken.

8.7.3.6 Multi-Criteria Review

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.7.3.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	A large number of properties would benefit from the combined option. This includes a considerable number of properties downstream of Warrill Creek dry flood mitigation dam, as well as	5.0

	many properties behind the temporary barriers at South Brisbane and the Brisbane CBD. Potential Hydraulic Risk within the Bremer River floodplain will reduce as a result of Warrill Creek dry flood mitigation dam's contribution to this combined option (refer Figure 8-49). The impact of Amberley levee would be small in the context of Bremer River benefits.	
Improve time for evacuation (now and future)	The combined options would reduce peak flood levels in various parts of the floodplain, which would generally improve time for evacuation. It is noted that overtopping of the temporary barriers may result in sudden onset of flooding in the floodplain behind the barrier, which may be problematic for occupants who have not evacuated already. As discussed for the individual options previously, regional evacuation routes would benefit from this combined option, and in particular, the immunity of Cunningham Highway across the Warrill / Purga Creeks floodplain, where it currently has only a 1 in 20 AEP flood immunity (refer Section 4 Current Flood Risk).	4.0

8.7.3.6.2 Social

Targets vulnerable community members or areas	Potential negative impacts of the Amberley levee would be completely offset by the Warrill Creek dam, and would further benefit the population of the Bremer River floodplain or immediately downstream of the Bremer River, around Redbank and Goodna, who are considered more vulnerable than average.	4.5
Social health benefits	As driven by the Warrill Creek dam benefits, the significant reduction in the number of residential properties inundated across a broad spectrum of flood events, and in particular within areas that are considered more vulnerable than average, would lead to substantial social health benefits.	4.5
Improves community flood resilience (now and future)	As driven by the Warrill Ck dam benefits, the significant reduction in the number of residential properties inundated across the full spectrum of flood events would allow the community to better respond to flooding in the future. As always, there is potential that some community members would falsely assume that the mitigation works eliminate flooding and thus does not require a community response. At the 1 in 100 AEP flood, 12 critical energy infrastructure items and four emergency management facilities will have reduced	4.0

	flooding, while 17 critical energy infrastructure items, one critical telecommunications infrastructure item, and one emergency management facility would be free from flooding. At the 1 in 500 AEP flood, 90 critical energy infrastructure items and 12 emergency management facilities would have reduced flooding, while eight critical energy infrastructure items and one emergency management facility would be free from flooding.	
Recreation and amenity	The combined options would potentially have a small impact on amenity, but this would be limited to periods of significant flooding only.	2.5
Connection and collaboration	The combined options would not specifically improve or reduce the community's connectedness to the river and watercourses.	2.5

8.7.3.6.3 Economic

Reduce damages and costs to residential property (now and future)	The benefits of the combined option are significant at the 1 in 100 AEP flood level, and similar in magnitude to the Warrill Creek dry flood mitigation dam alone. The benefits associated with this combined option, which includes Amberley Air Base levee, total $30 million per year, on average (when valuing all property types).	4.5
Reduce damages and costs to business and industry (now and future)	As above, the benefits are significant, and extend to an additional 45 or so commercial properties across the floodplain in the 1 in 100 AEP flood when compared with the Warrill Creek dry flood mitigation dam alone.	4.5
Option likely to be cost beneficial (now and future)	The combined options produce significant benefits, but also come at significant capital and maintenance costs. A large component of the maintenance cost for this option is for the Air Base levee. As outlined in Table 8-53, the b/c ratio for this combined option is 0.59. It is expected that once intangible damages are included for the Amberley Air Base, the b/c ratio would increase, closer to 0.7.	2.5

8.7.3.6.4 Feasibility

Physical / technical (now and future)	The design and construction of the proposed options in this combination are all feasible. The dry flood mitigation dam at Warrill Creek and the Amberley Air Base levee would both attract high capital costs. Opportunities exist for considering flood management on a more consolidated basis with respect to Warrill Creek and Amberley, including providing greater immunity to the Cunningham Highway to support RAAF base operations.	3.5

Legal / approval risk	The legal/approval conditions for each of the options included in this combined scenario have been outlined in the relevant sections of this chapter. The dry flood mitigation dam on Warrill Creek would likely be the most challenging component of works, with the approval process for this expected to be complex, lengthy and demanding.	2
Potential for additional funding sources	The cost of the combined infrastructure is very significant and beyond the regular funding channels for local and state government. It is expected that funding for all of the works in this option would be a significant challenge. There is a possibility that the Commonwealth Government (representing the Department of Defence) could contribute to the cost of the Warrill Creek dry flood mitigation dam, in addition funding the air base levee, as compensatory measures for the otherwise detrimental impacts that the air base levee would create to downstream properties.	1.5

8.7.3.6.5 Attitude

Decision makers	Based on the benefits to communities and in particular to more vulnerable communities, as well as the benefits to Amberley Air Base, decision makers would potentially support this option. The very high costs though would be a challenge and therefore support may not be as high as for other alternatives. Benefit/cost analysis indicates a modest return on investment (with a b/c ratio of 0.59, but which would increase to near parity if a less conservative discount rate was adopted).	3.5
Community	The local communities that benefit from this combined option would likely be very supportive of the works. There would likely be no significant opposition to the temporary barriers and the levee in Amberley (providing downstream impacts are offset), however, construction of the dry flood mitigation dam may be more challenged on environmental, social and economic grounds. Good value for money is generally a test for community acceptance. The benefit/cost analysis shows that there is reasonable value for money over the longer term.	4.0

8.7.3.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	The significant reduction in flood levels across the Bremer River floodplain, as well as in South Brisbane and the Brisbane CBD, would improve the performance of infrastructure and transport links during times of flood compared to current conditions. In addition, the improvement to the function of Amberley Air Base as a result of the levee would be significant, which would be boosted by improved access along the Cunningham Highway as a result of the Warrill Creek dry flood mitigation dam.	4.5
Protection of regional water supply quality and security – catchment protection (quality and yield)	The combined option would have no long term positive or negative impacts on regional water quality or quantity. The dry flood mitigation dam in Warrill Creek may help to reduce sediment load during flood events.	3.0

8.7.3.6.7 Environment and Natural Resource Management

Species impacts	Only the dry flood mitigation dam would potentially impact on species, as described previously.	2.0
Vegetation and habitat impacts	Only the dry flood mitigation dam would potentially impact on existing vegetation and important habitats, as described previously.	1.5
Ecosystem health connectivity (fish passage/fauna movement)	Proposed works are unlikely to have any discernible impact on fauna movement corridors including fish passage, as no permanent in-channel infrastructure is proposed as part of these combined options.	2.5
Reduction in landscape salinity / improved moisture retention and groundwater recharge	Only the dry flood mitigation dam would potentially impact on landscape salinity and soil moisture, as described previously.	2.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	Only the dry flood mitigation dam would potentially impact on erosive capacity and soil stability within the catchment, as described previously.	3.0

8.7.3.7 Assessment of Option Against Multiple Criteria

Scoring for this combined option is dominated by the potential benefits and impacts of the Warrill Creek dry flood mitigation dam. As outlined in Section 8.10.2, this combined option that includes

Amberley air base levee has an overall multi-criteria assessment result of 1.25, where a value of 0.0 represents a net 'no change' condition across the various criteria. The combined option including Amberley levee is ranked 1st out of the 16 options considered in the MCA (refer Table 8-64).

The lowest scoring criterion for this option was related to potential funding sources (given the very high capital cost) and the vegetation/habitat impacts (given the impacts of periodic deep water inundation within the dam area) both with a value of 1.5. The best scoring criteria are related to reducing flood risk (value of 5.0). This scored slightly higher than the dam alone given the additional benefits associated with the other works, including the temporary barriers at South Brisbane and Brisbane CBD where a large number of properties benefit. There are no specific factors that would automatically rule out this option from further consideration. Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.7.3.8 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The proposed combination works will have a positive impact on downstream flood conditions, and in particular on areas along the Bremer River, South Brisbane and the Brisbane CBD. The works will not eliminate flooding, but peak flood levels would be lower in many parts of the floodplain. Some areas of the Brisbane River floodplain would receive no benefit from these works.
environmental or social disadvantage	The works may have some local environmental or social consequences, notably the Warrill Creek dry flood mitigation dam. The extent of the environmental impacts are yet to be determined, while social impacts would need to be addressed through acquisition as required.
an unacceptable economic cost to State, local government, community or individual	The estimated cost of the proposed works is very high, and outside regular budgets for local or state governments. The benefit/cost analysis shows that the cost of the works could be balanced by the benefits (with a b/c ratio >1) if the costs of the dry flood mitigation dam can be reduced somewhat and/or a less conservative discount rate is used in the economic analysis.
technical impracticability	The proposed works would be technically practical. There is opportunity to integrate the proposed Warrill Creek dry flood mitigation dam with works proposed for the Southern Freight Railway.

other unusual or unique circumstances	There are no obvious other unusual or unique circumstances that would preclude the feasibility of this option.

8.7.4 Selected Options Excluding Amberley levee

8.7.4.1 General Description of Option and Assessment

This scenario is the same as that described in Section 8.7.3, except that the levee works associated with Amberley RAAF Air Base were excluded. The Amberley levee on its own has some detrimental impacts downstream, however, if undertaken in combination with the Warrill Creek dry flood mitigation dam, the mitigation benefits of the dam far outweigh the afflux created by the levee (refer discussion in Section 8.7.3.4).

It is virtually impossible to value the benefits of a fully operational RAAF Air Base during times of flood (at least up to a 1 in 100 AEP). The benefit cost assessment described in Section 8.4.3.5 for the Amberley Air Base indicates that a B/C ratio of >1 could be achieved if the net present economic benefit of the works was in excess of $90 million.

On the basis that benefits for the Amberley Air Base cannot be realised, this combined scenario has been assessed to determine the combined benefits, costs and values without the Amberley levee works being undertaken.

8.7.4.2 Concept Design

Concept designs for the individual options that make up this combined option scenario were discussed in the previous relevant sections of this chapter.

8.7.4.3 Indicative Cost

The total cost estimate (excluding maintenance costs) for the combined options as outlined above is approximately $563 million, of which about 97% represents the cost of the Warrill Creek dry flood mitigation dam. Remaining works, comprising temporary barriers at South Brisbane and the Brisbane CBD, as well as the Fernvale levee and the Ipswich CBD flood gate, totalling $18 million.

The total annual maintenance cost for the combined options as outlined above is approximately $1 million.

8.7.4.4 Hydraulic Impacts

Potential benefits and impacts of the combined options, excluding Amberley Air Base levee, on the hydraulic behaviour were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). The results of these scenarios are described below.

The impacts of the combined options excluding Amberley Air Base levee on flood levels in the Brisbane River are presented in Figure 8-60 to Figure 8-64 for the range of flood events from 1 in 5 AEP to 1 in 100,000 AEP, with a summary of the impacts on properties provided in Table 8-54.

As for the previous combined option, the impacts of Warrill Creek dry flood mitigation dam dominate the results throughout the floodplain. Table 8-55 presents a comparison of the reduction in peak flood levels between the Warrill Creek dam only option and the two combined options, at Ipswich CBD and

Brisbane CBD. As shown in this table, the results of the combined option excluding Amberley are the same as the Warrill Creek dam only option at Ipswich CBD. The difference when including Amberley Air Base levee, is a slightly lower peak water level reduction, of up to 30mm (with net reduction still well in excess of 1 metre). At Brisbane CBD, Table 8-55 shows that there is no difference in results for the two combined options, with and without Amberley Air Base levee. As also highlighted in Section 8.4.3, the impacts of Amberley Air Base levee are localised to the area downstream of the Air Base, and thus do not extent to the Brisbane CBD.

Table 8-54 Summary of Combined Options (excluding Amberley levee) impacts on properties

AEP	WL reduction at Ipswich CBD	WL reduction at Brisbane CBD	Number of properties where flooding is reduced[1]	Number of properties where flooding is eliminated[2]	Number of properties where flooding is increased[3]	Number of properties where flooding is created[4]
1 in 2	< 50mm*	< 50mm*	0	0	0	0
1 in 5	1,540mm	< 50mm	4	5	0	1
1 in 10	1,280mm	70mm	49	128	0	0
1 in 20	1,200mm	70mm	279	299	0	0
1 in 50	1,770mm	80mm	3,627	1,690	0	1
1 in 100	1,630mm	150mm	15,179	3,383	0	2
1 in 200	740mm	190mm	26,878	3,188	0	2
1 in 500	170mm	190mm	40,880	1,580	0	0
1 in 2,000	90mm	< 50mm	12,134	512	0	5
1 in 10,000	70mm	100mm	83,732	811	0	0
1 in 100,000	< 50mm	< 50mm	4	25	4	27

** as water level change is less than the limit of mapping, no specific figures have been prepared for these AEPs.*

[1] Building is flooded, but to a lesser degree, either above or below habitable floor level.

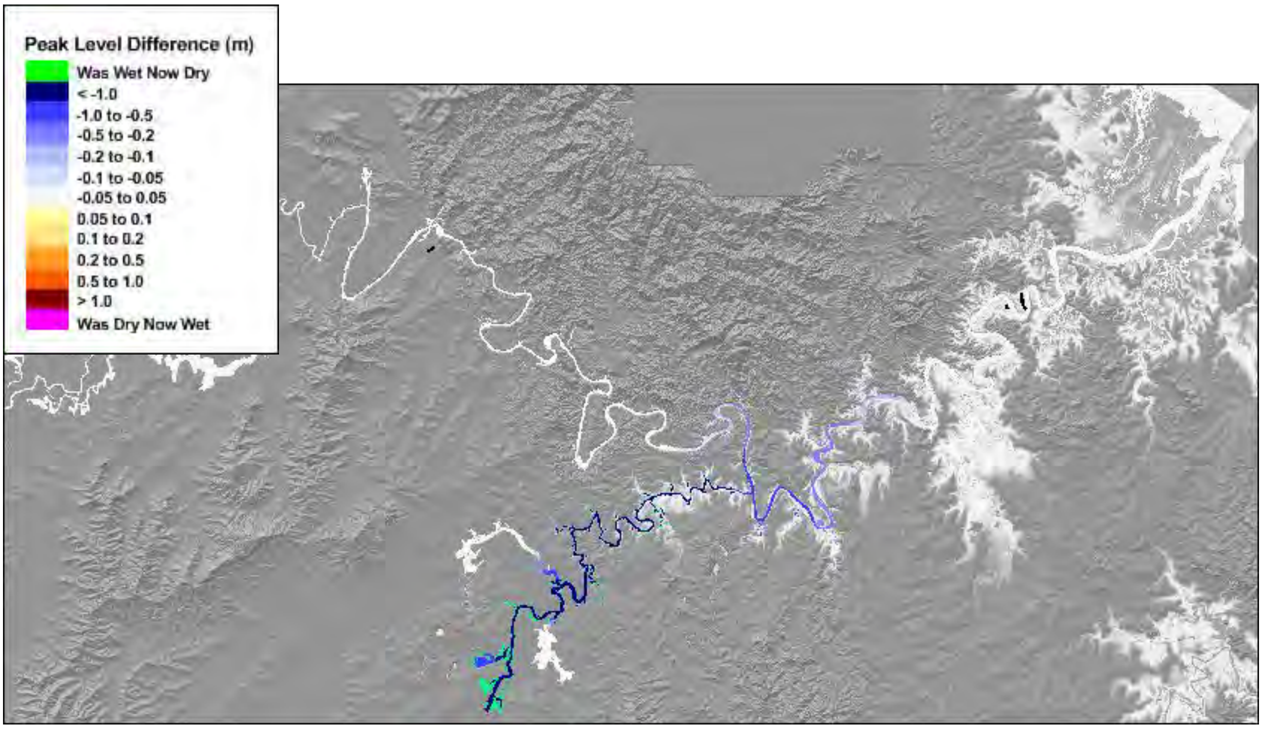
[2] Building no longer affected by flooding.

[3] Building is flooded to a greater degree, either above or below habitable floor level.

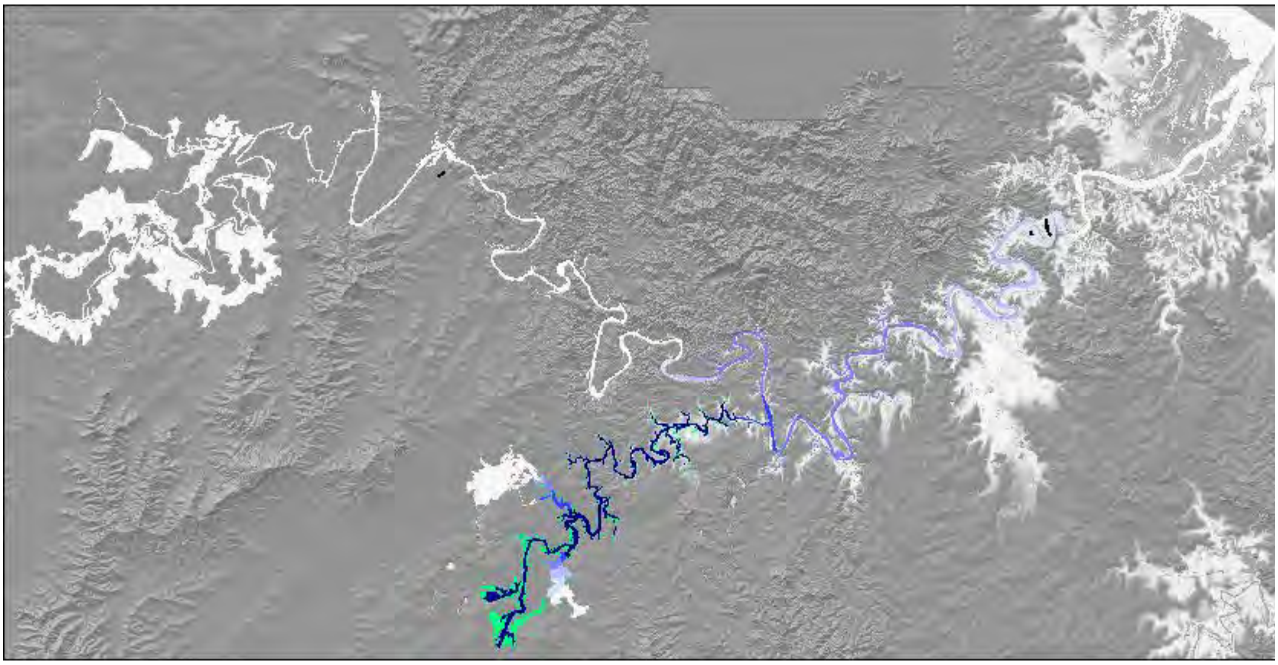
[4] Building is not affected by flooding under current conditions, but becomes affected by flooding in the scenario.

Table 8-55 Comparison of flood level reductions between Warrill Creek dry flood detention dam option and two combined options

	Ipswich CBD			Brisbane CBD		
AEP	Warrill Ck dry flood mitigation dam only	Combined – no Amberley	Combined – with Amberley	Warrill Ck dry flood mitigation dam only	Combined – no Amberley	Combined – with Amberley
1 in 2	< 50 mm	< 50mm	< 50mm	< 50 mm	< 50mm	< 50mm
1 in 5	1,540 mm	1,540mm	1,540mm	< 50 mm	< 50mm	< 50mm
1 in 10	1,280 mm	1,280mm	1,270mm	70 mm	70mm	70mm
1 in 20	1,200 mm	1,200mm	1,170mm	80 mm	70mm	70mm
1 in 50	1,770 mm	1,770mm	1,740mm	60 mm	80mm	80mm
1 in 100	1,630 mm	1,630mm	1,620mm	150 mm	150mm	150mm
1 in 200	740 mm	740mm	720mm	190 mm	190mm	190mm
1 in 500	170 mm	170mm	200mm	190 mm	190mm	190mm
1 in 2,000	90 mm	90mm	80mm	< 50 mm	< 50mm	< 50mm
1 in 10,000	70 mm	70mm	70mm	100 mm	100mm	100mm
1 in 100,000	< 50mm	< 50mm	< 50mm	< 50 mm	< 50mm	< 50mm

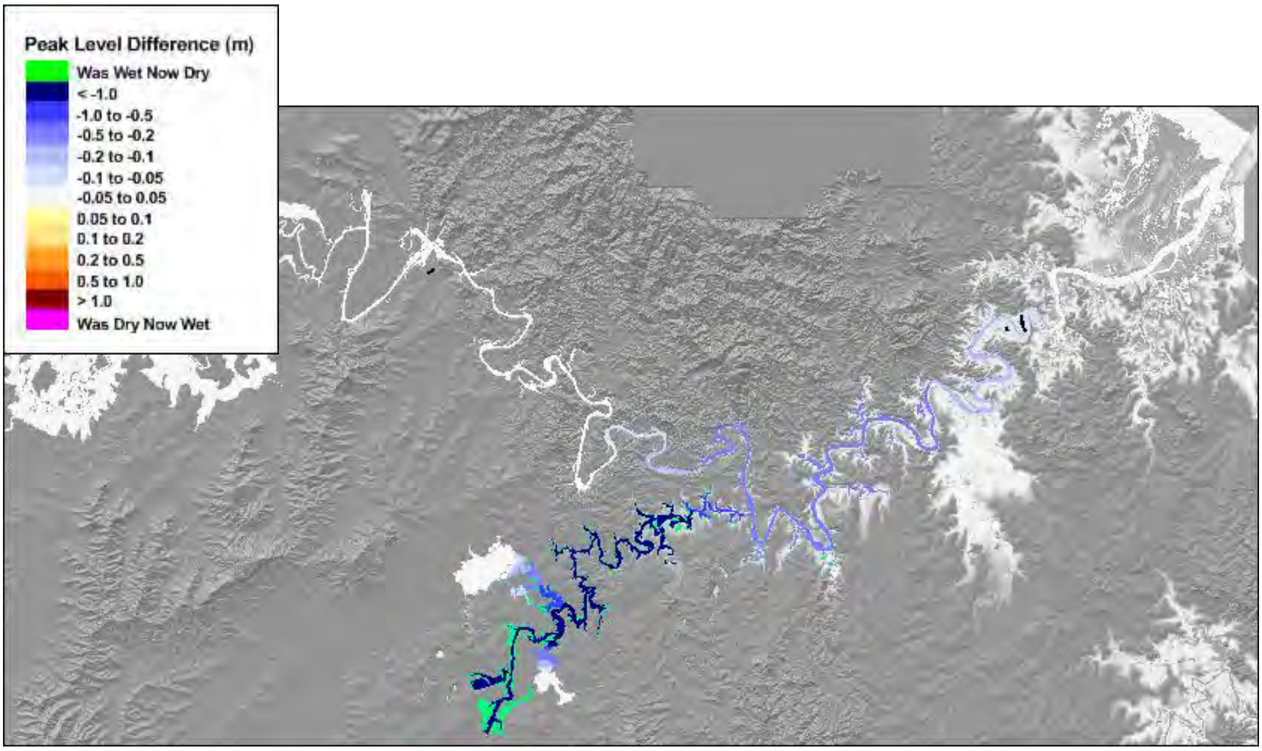


1 in 5 AEP

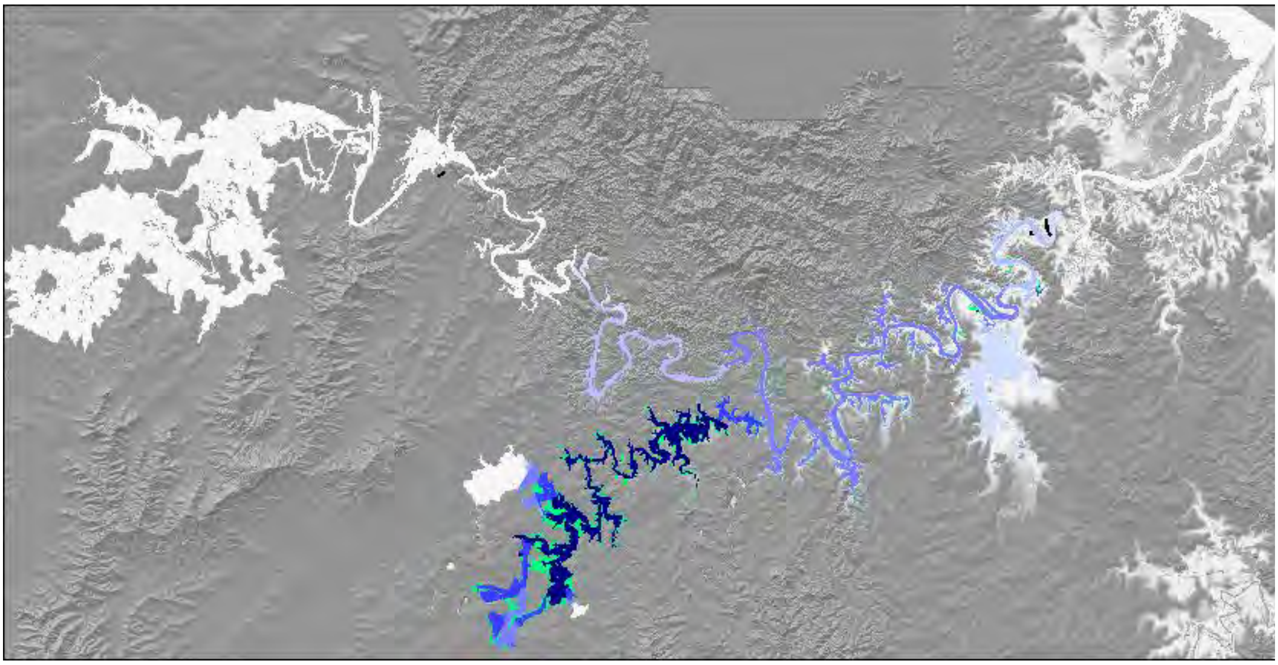


1 in 10 AEP

Figure 8-60 Combined Options without Amberley levee: 1 in 5 AEP and 1 in 10 AEP

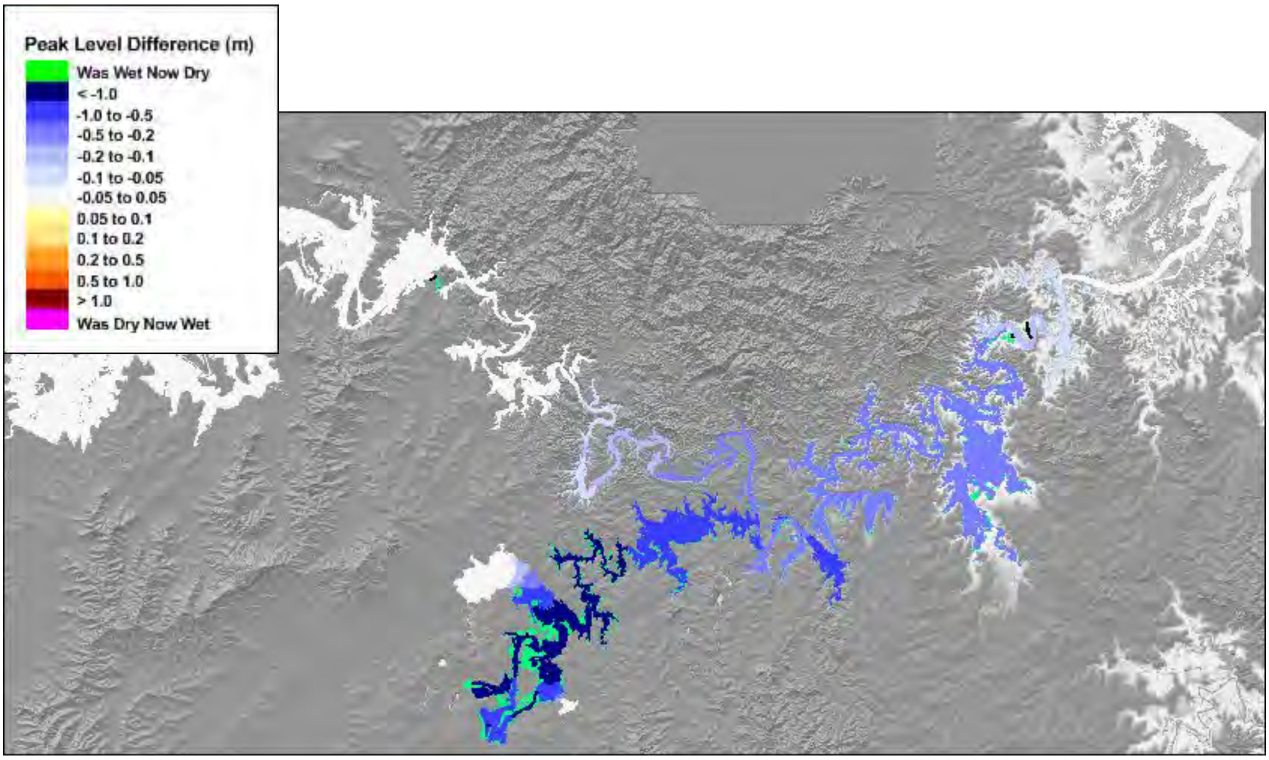


1 in 20 AEP

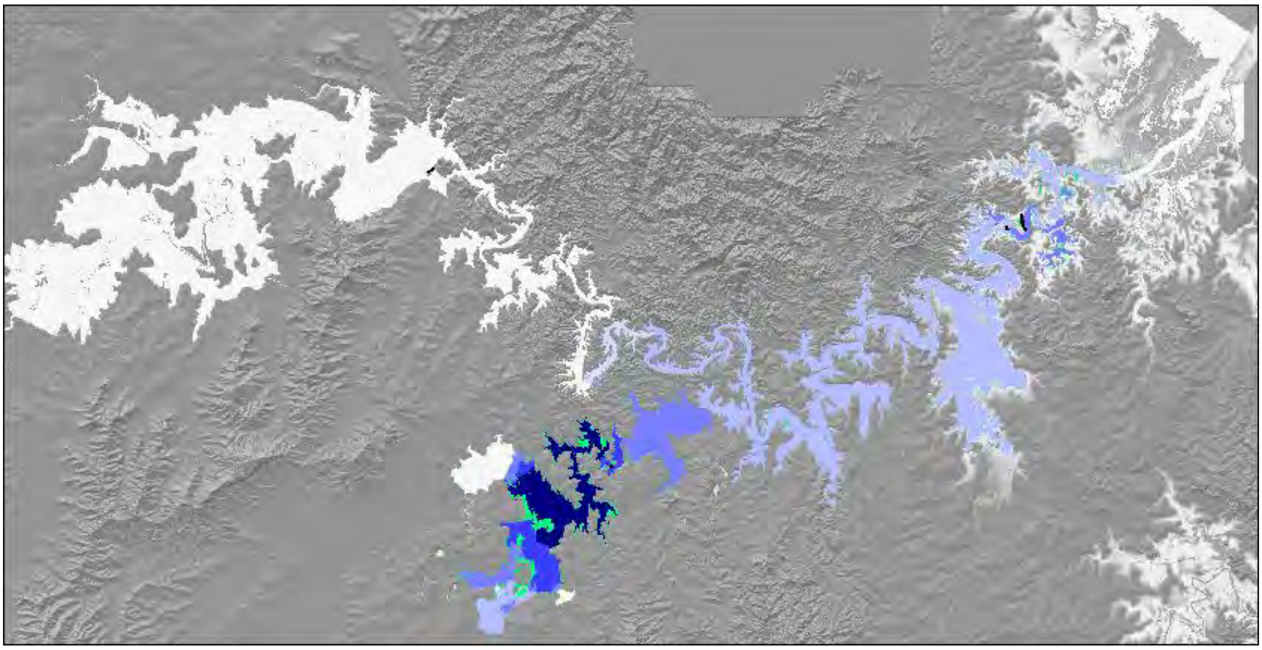


1 in 50 AEP

Figure 8-61 Combined Options without Amberley levee: 1 in 20 AEP and 1 in 50 AEP

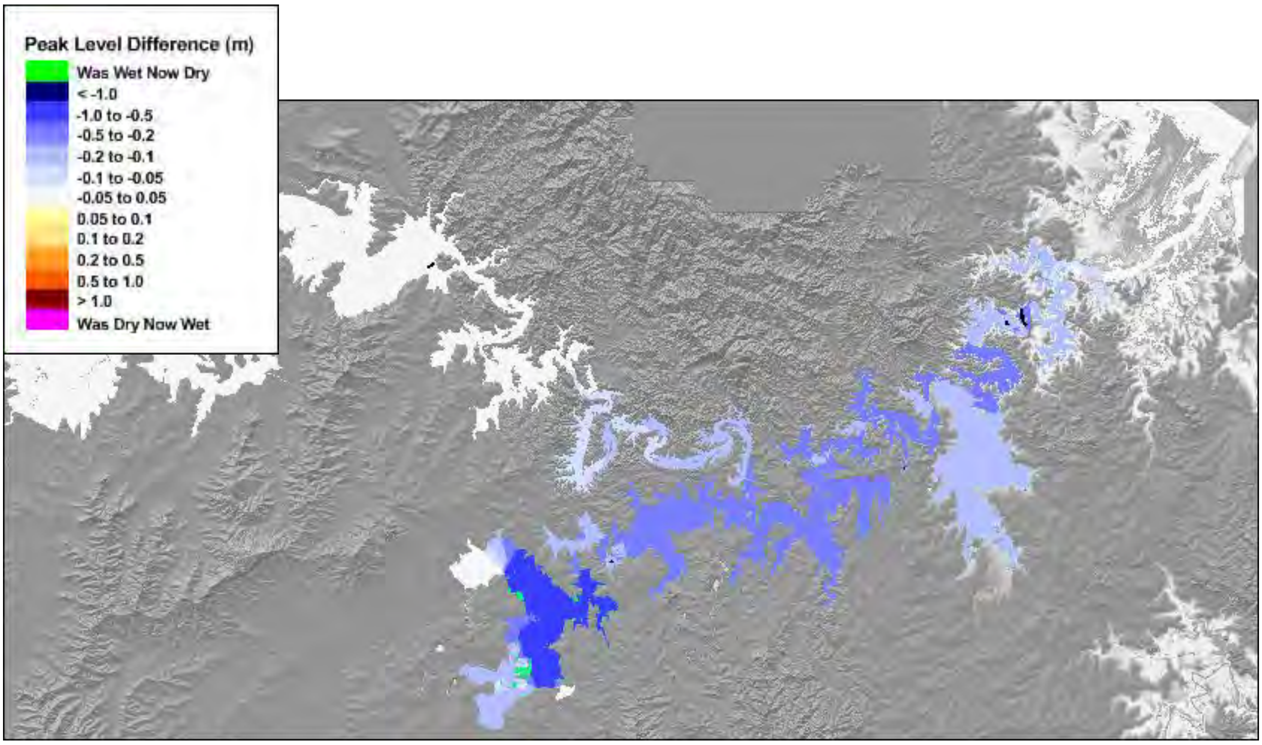


1 in 100 AEP

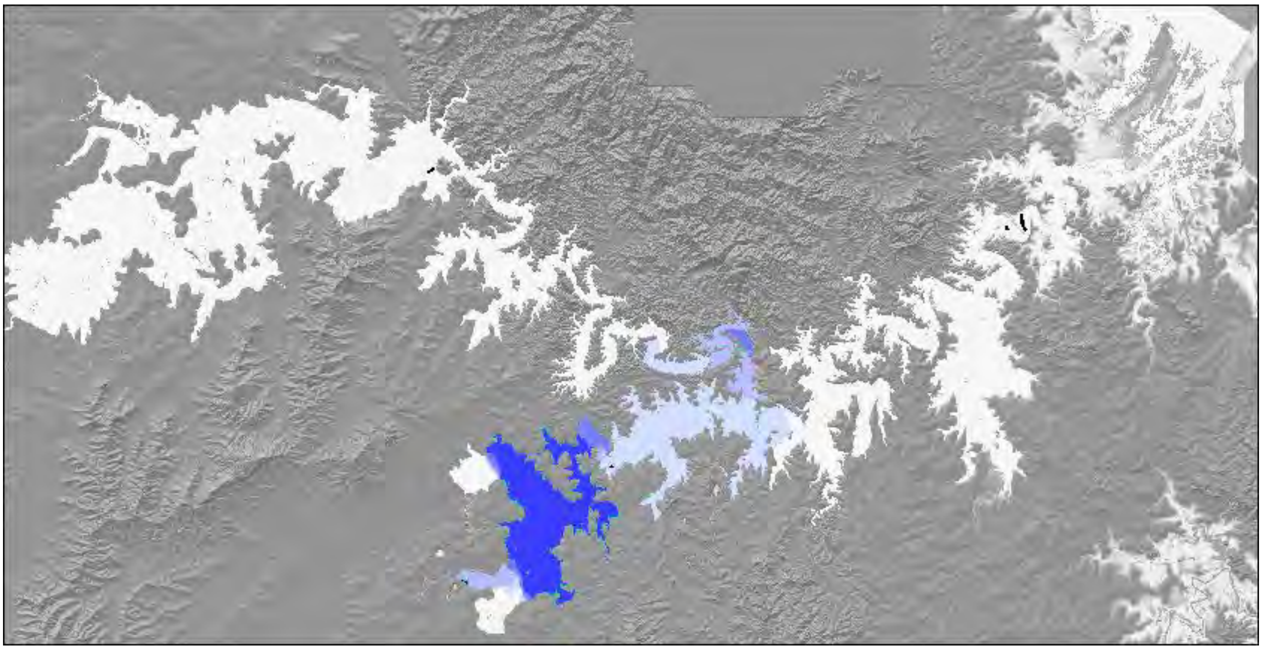


1 in 200 AEP

Figure 8-62 Combined Options without Amberley levee: 1 in 100 AEP and 1 in 200 AEP

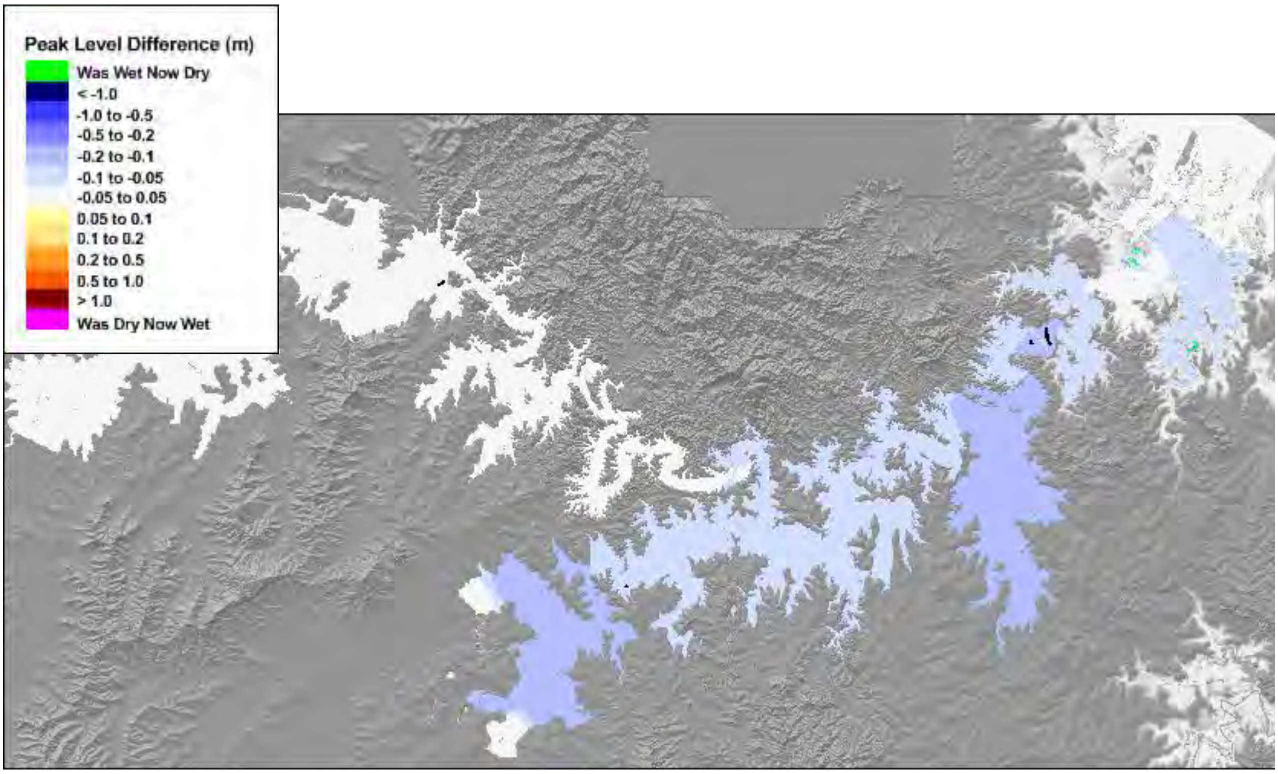


1 in 500 AEP

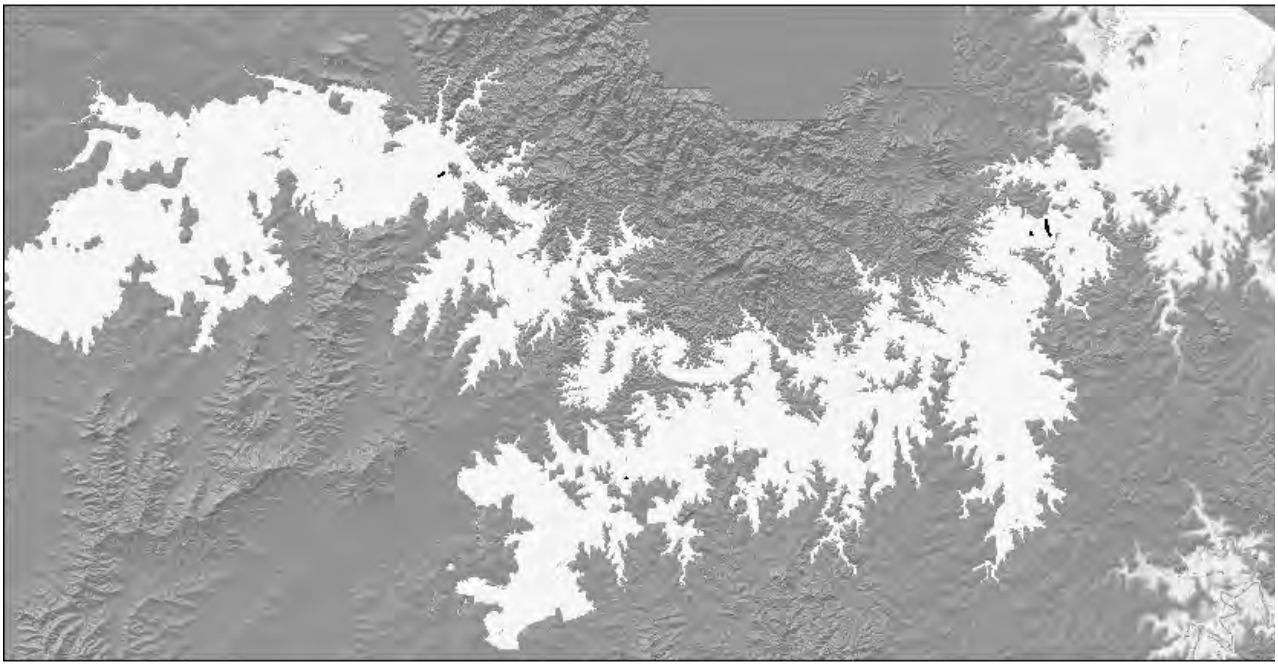


1 in 2,000 AEP

Figure 8-63 Combined Options without Amberley levee: 1 in 500 AEP and 1 in 2,000 AEP



1 in 10,000 AEP



1 in 100,000 AEP

Figure 8-64 Combined Options without Amberley levee: 1 in 10,000 AEP and 1 in 100,000 AEP

8.7.4.5 Benefit / Cost Analysis

A summary of the benefit / cost analysis for the combined options excluding Amberley Air Base levee is presented in Table 8-56.

Table 8-56 Benefit/cost analysis summary for combined options excluding Amberley Air base levee

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case (1)	288.7	258.8	29.9	**0.69**
Sensitivity 1: No intangibles	186.9	165.6	21.3	**0.49**
Sensitivity 2: with Wivenhoe up.	n/a	n/a	n/a	n/a
Sensitivity 3: 4% discount rate				**1.20**
Sensitivity 4: 10% discount rate				**0.47**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

The combined options, with a capital cost of $563 million and an annual maintenance cost of $1 million, will generate a net annual average benefit of $30 million, leading to a benefit/cost ratio of 0.69 when adopting a discount rate of 7% over a 100 year period.

It is noted that the benefits presented in Table 8-56 are marginally higher than the benefits of the combined options including Amberley Air Base, as presented in Table 8-53. As indicated previously, the tangible and intangible benefits of an operational and accessible air base have not been included in this economic assessment as it is virtually impossible to quantify these benefits in monetary terms. The marginal improvement in benefits for this option, which excludes the air base levee, compared to the option that includes the levee, is related to the minor impacts the levee has on properties immediately downstream of the air base which result in a minor reduction in the benefits resulting from the dry flood mitigation dam.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-56. If benefits were limited to reductions in tangible damages, the annual average benefit of the works would reduce to $21 million, giving a net benefit/cost ratio of 0.49.

Sensitivity was also undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 1.20 (better than parity), while for a higher discount rate of 10%, the benefit/cost ration reduces to 0.47.

As for the Warrill Creek dry flood mitigation dam option, sensitivity to future Wivenhoe Dam upgrades was not carried out because as advise by Seqwater (pers. comm.) a more detailed and rigorous hydrologic assessment of the two significant detention structures would need to be undertaken.

8.7.4.6 Multi-Criteria Review

A summary of the multi-criteria assessment is documented below. The summarised scores for each option considered are presented in Section 8.10.2.

8.7.4.6.1 Safety of People

Reduce hydraulic risk rating (now and future)	A large number of properties would benefit from the combined option. This includes a considerable number of properties downstream of Warrill Creek dry flood mitigation dam, as well as many properties behind the temporary barriers at South Brisbane and the Brisbane CBD. This is largely the same as for the combined option including Amberley Air Base levee. Potential Hydraulic Risk within the Bremer River floodplain may reduce as a result of Warrill Creek dry flood mitigation dam's contribution to this combined option.	5.0
Improve time for evacuation (now and future)	The combined options would reduce peak flood levels in various parts of the floodplain, which would generally improve time for evacuation. It is noted that overtopping of the temporary barriers may result in sudden onset of flooding in the floodplain behind the barrier, which may be problematic for occupants who have not evacuated already. As discussed for the individual options previously, regional evacuation routes would benefit from this combined option, and in particular, the immunity of Cunningham Highway across the Warrill / Purga Creeks floodplain, where it currently has only a 1 in 20 AEP flood immunity (refer Section 4 Current Flood Risk).	4.0

8.7.4.6.2 Social

Targets vulnerable community members or areas	The mitigation of flood risk by the Warrill Creek dam would benefit the population of the Bremer River floodplain or immediately downstream of the Bremer River, around Redbank and Goodna, who are considered more vulnerable than average.	4.5
Social health benefits	As driven by the Warrill Ck dam benefits, the significant reduction in the number of residential properties inundated across a broad spectrum of flood events, and in particular within areas that are considered more vulnerable than average, would lead to substantial social health benefits.	4.5
Improves community flood resilience (now and future)	As driven by the Warrill Ck dam benefits, the significant reduction in the number of residential properties inundated across a broad spectrum of flood events would allow the community to better respond to flooding in the future. As always, there is potential that some community members would falsely assume that the mitigation works eliminate flooding and thus does not require a community response.	4.0

	At the 1 in 100 AEP flood, 12 critical energy infrastructure items and four emergency management facilities will have reduced flooding, while 17 critical energy infrastructure items, one critical telecommunications infrastructure item, and one emergency management facility would be free from flooding. At the 1 in 500 AEP flood, 90 critical energy infrastructure items and 12 emergency management facilities would have reduced flooding, while eight critical energy infrastructure items and one emergency management facility would be free from flooding.	
Recreation and amenity	The combined options would potentially have a small impact on amenity, but this would be limited to periods of significant flooding only.	2.5
Connection and collaboration	The combined options would not impact the community's connectedness to the river and watercourses.	2.5

8.7.4.6.3 Economic

Reduce damages and costs to residential property (now and future)	The benefits of the Amberley Air Base levee are essentially intangible benefits associated with a functional air base during times of flood. Without the air base levee, the negative impacts of the levee on downstream properties is removed, meaning that from a pure tangible perspective, the benefits are slightly higher than with the air base levee. The average annual benefit for this option (across all property types) is just over $30 million.	4.5
Reduce damages and costs to business and industry (now and future)	As per above and described for the previous option as well, commercial properties will benefit significantly from the combined option.	4.5
Option likely to be cost beneficial (now and future)	The benefit / cost assessment for this combined option, as presented in Table 8-56, show that the value of undertaking the works is reasonably well founded, with a b/c ratio of 0.69. This is slightly higher than the option with the Air Base levee, as the capital and maintenance cost of the levee do not translate to significant improvements in economic benefits. It is expected that this b/c ratio could move closer to parity if the costs of the dry flood mitigation dam can be reduced and/or a less conservative discount rate is adopted.	2.5

8.7.4.6.4 Feasibility

Physical / technical (now and future)	The design and construction of the proposed options in this combination are all feasible. The dry flood mitigation dam at Warrill Creek would attract high capital costs.	3.5
Legal / approval risk	The legal/approval conditions for each of the options included in this combined scenario have been outlined in the relevant sections of this chapter. The dry flood mitigation dam on Warrill Creek would likely be the most challenging component of works, with the approval process for this expected to be complex, lengthy and demanding.	2
Potential for additional funding sources	The cost of the combined infrastructure (mostly Warrill Creek dry flood mitigation dam) is very significant and beyond the regular funding channels for local and state government. It is expected that funding for all of the works in this option would be a significant challenge.	1.5

8.7.4.6.5 Attitude

Decision makers	Based on the benefits to communities and in particular to more vulnerable communities, decision makers would potentially support this option. The very high costs though would be a challenge and therefore support may not be as high as for other alternatives. Benefit/cost analysis shows the same outcome as for the Warrill Ck option alone. Costs for the dam dominate the total costs for this combined option. Implementation of this option may actually involve piecemeal progress on each element individually subject to separate funding arrangements.	3.5
Community	The local communities that benefit from this combined option would likely be very supportive of the works. There would likely be no significant opposition to the temporary barriers, however, construction of the dry flood mitigation dam may be more challenged on environmental, social and economic grounds. Good value for money is generally a test for community acceptance. The benefit/cost analysis shows that the option could indeed demonstrate good value for money, and especially so if the dam costs can be reduced or the discount rate used is less conservative.	4.0

8.7.4.6.6 Key Infrastructure and Transport

Improve availability and function (now and future)	The significant reduction in flood levels across the Bremer River floodplain, as well as in South Brisbane and the Brisbane CBD, would improve the performance of infrastructure and transport links during times of flood compared to current conditions.	4.0
Protection of regional water supply quality and security – catchment protection (quality and yield)	The combined option would have no long term positive or negative impacts on regional water quality or quantity. The dry flood mitigation dam in Warrill Creek may help to reduce sediment load during flood events.	3.0

8.7.4.6.7 Environment and Natural Resource Management

Species impacts	Only the dry flood mitigation dam would potentially impact on species, as described previously.	2.0
Vegetation and habitat impacts	Only the dry flood mitigation dam would potentially impact on existing vegetation and important habitats, as described previously.	1.5
Ecosystem health connectivity (fish passage/fauna movement)	Proposed works are unlikely to have any discernible impact on fauna movement corridors including fish passage, as no permanent in-channel infrastructure is proposed as part of these combined options.	2.5
Reduction in landscape salinity / improved moisture retention and groundwater recharge	Only the dry flood mitigation dam would potentially impact on landscape salinity and soil moisture, as described previously.	2.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	Only the dry flood mitigation dam would potentially impact on erosive capacity and soil stability within the catchment, as described previously.	3.0

8.7.4.7 Assessment of Option Against Multiple Criteria

As for the previous combined option, scoring for this combined option (excluding Amberley levee) is still dominated by the potential benefits and impacts of the Warrill Creek dry flood mitigation dam. As outlined in Section 8.10.2, this combined option (excluding Amberley air base levee) has an overall multi-criteria assessment result of 1.23, where a value of 0.0 represents a net ‘no change’ condition across the various criteria. The combined option including Amberley levee is ranked 2nd out of the 16 options considered in the MCA (refer Table 8-64). The lowest scoring criterion for this option was once again related to potential funding sources (given the very high capital cost) and the vegetation/habitat impacts (given the impacts of periodic deep water inundation within the dam area) both with a value of 1.5. The best scoring criteria are related to reducing flood risk (value of 5.0). There are no specific factors that would automatically rule out this option from further consideration. Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.7.4.8 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for this option:

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The proposed combination works will have a positive impact on downstream flood conditions, and in particular on areas along the Bremer River, South Brisbane and the Brisbane CBD. The works will not eliminate flooding, but peak flood levels would be lower in many parts of the floodplain. Some areas of the Brisbane River floodplain would receive no benefit from these works.
environmental or social disadvantage	The works may have some local environmental or social consequences, notably the Warrill Creek dry flood mitigation dam. The extent of the environmental impacts are yet to be determined, while social impacts would need to be addressed through acquisition as required.
an unacceptable economic cost to State, local government, community or individual	The estimated cost of the proposed works is very high, and outside regular budgets for local or state governments. The benefit/cost analysis shows that the cost of the works could be balanced by the benefits (with a b/c ratio >1) if the costs of the dry flood mitigation dam can be reduced somewhat and/or a less conservative discount rate is used in the economic analysis.
technical impracticability	The proposed works would be technically practical. There is opportunity to integrate the proposed Warrill Creek dry flood mitigation dam with works proposed for the Southern Freight Railway.
other unusual or unique circumstances	There are no obvious other unusual or unique circumstances that would preclude the feasibility of this option.

8.8 Landscape Management

8.8.1 Scenario 1 – Targeted Catchment Revegetation

8.8.1.1 General Description of Option and Assessment

This scenario broadly includes large scale revegetation works and other landscape management works in the catchment that are currently underway, planned for, or under investigation (e.g. in Catchment Action Plans, results of the Big Flood studies). The works were identified in consultation with stakeholders in the ICP workshop. A summary of the landscape management works envisaged for the various management zones in this scenario is provided in Figure 8-65 and in the following sections, along with a brief assessment of the likely impacts.

Specific hydraulic analysis of this option was not possible for this Phase 3 (SFMP). Changes to the catchment vegetation condition would require changes to the catchment hydrology model. Also, the specific nature of these changes would be difficult to ascertain as there is limited information linking revegetation work and other catchment activities to hydrology parameters, particularly in similar climate / catchment conditions for larger flood events. If the catchment hydrology model were to be adjusted, then re-examination of the adjusted parameters across the 11,340 hydrology and fast-model simulations carried out for the Monte Carlo assessment along with re-calculation of the Total Probability Theorem (TPT) that underpins selection of the events chosen to represent the 11 AEP conditions.

Given the above constraints, only sensitivity testing was carried out on changes to catchment inflows, as outlined in Section 7.3.

Should the merits of this scenario need to be examined further, more detailed studies will need to be undertaken on both the hydrology and hydraulic models that were developed as part of the Phase 2 (Flood Study).

8.8.1.1.1 Upper Brisbane River Catchment

Grazing and Dairy (refer Figure 8-65)

Measures for implementation within the Grazing and Dairy management zone (refer to Figure 8-65) include improving vegetation cover by 30% on grazing and dairy lands in the Upper Brisbane River catchment (upstream of Wivenhoe Dam) and implementing cross floodplain structures.

Cross floodplain structures such as pole and vetiver hedges constructed perpendicular to flows act to increase cross floodplain roughness at strategic locations to create a backwater effect reducing the risk of scour and encouraging sedimentation in the backwater zone (Walker *et al.*, 2014). Hence this solution may assist to improve the flooding resilience of farmlands through protecting crops (from scouring) and water quality (from reduced erosion and sedimentation). However it is noted that these structures can reduce floodplain conveyance and correspondingly increase shear stress and erosion of the main channel.

Reducing sediment loads will also protect a key source of water supply, reducing water quality treatment costs and help to maintain flood storage/water supply capacity of Wivenhoe dam.

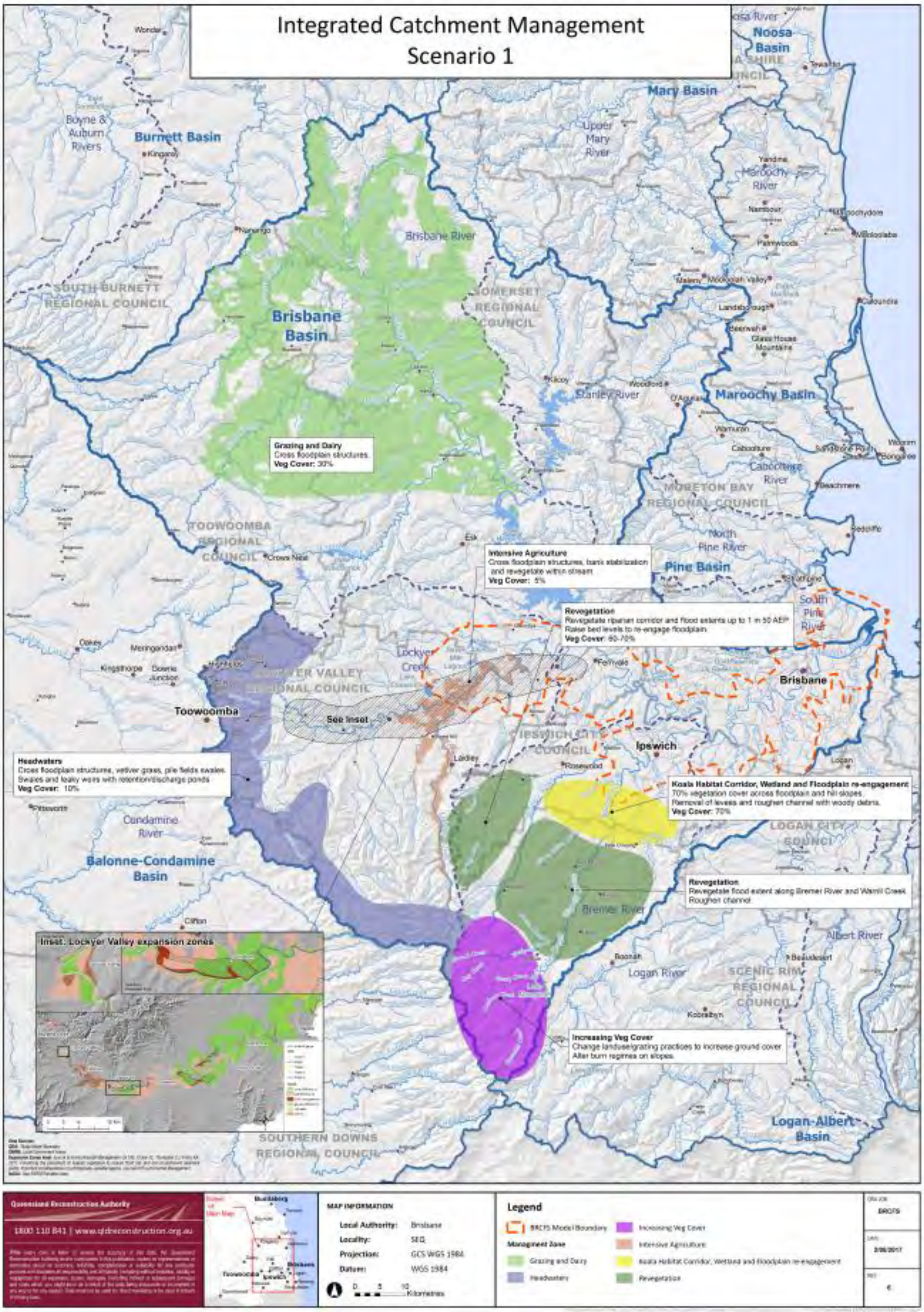


Figure 8-65 Scenario 1: Targeted Catchment Revegetation and Landscape management Works

Restoring catchment vegetation cover by 30% may also mitigate local runoff and small-scale floods, as described in Section 7.2.2. Additional benefits include improved habitat and biodiversity, recharge of groundwater, management of salinity, reducing erosion potential and loss of soil from the catchment and improved water quality and waterway health (e.g. from reduced sediment and nutrients in waterways and groundwater sources).

Reduced erosion and improved water quality / waterway health resulting from these management measures will assist to enhance economic values associated with agricultural lands and waterways (e.g. recreation and tourism), however a conservation security program would be necessary to ensure these areas were retained.

During the workshop, it was noted that re-vegetating farming areas within the Somerset Region of the catchment would not receive significant support.

8.8.1.1.2 Stanley River Catchment

Although no landscape management works were identified within this catchment for assessment through the workshop process, it is noted that the *Moreton Bay Regional Council Total Water Cycle Management Plan* (BMT WBM, 2012) broadly recommended the following future works for the Stanley River Catchment:

- Riparian revegetation on 3rd and 4th order streams;
- Rural Best Management Practices (BMPs) for grazing, including fencing off and revegetation of 1st and 2nd order streams; and
- Rural BMPs for horticulture (which could include cross floodplain structures, groundcover).

Further detailed studies were recommended for prioritising revegetation areas and implementing rural BMPs. Although the assessment of the effectiveness of these measures related primarily to protection of waterway health (e.g. through stabilising banks and reducing sediment and nutrient loads to waterways), these measures may also provide some flood mitigation benefits (refer to Sections 7.2.1, 7.2.4). Reduced sediment loads to Somerset Dam also helps protect drinking water and flood storage capacity of the dam.

8.8.1.1.3 Lockyer Creek Catchment

Headwaters (refer Figure 8-65)

In the upper reaches of Lockyer Creek catchment, there are issues with flash flooding in creeks and gullies, leading to high channel velocity that poses a safety hazard, and also causes erosion of topsoil which affects agricultural production and impacts on water quality (; RRI, 2016). The Helidon Hills, located in this area, have also been identified as a significant recharge area for alluvial aquifers of the Upper Lockyer Valley (RRI, 2016).

Management measures proposed for headwaters of the Lockyer Creek catchment in Scenario 1 (refer to Figure 8-65) include a combination of existing and proposed future measures. These measures include cross floodplain structures (as described above) the use of vetiver grass, pile field swales and leaky weirs with retention ponds. A 10% increase in vegetation cover is also proposed in these headwater areas. These management measures will assist to slow flows, reduce erosion, capture sediment and promote groundwater recharge. Revegetation of ridgelines in the highlands of the Lockyer Creek catchment has also been documented as a key strategy to resist flash flooding (JDA, 2017). Implementation of these management measures is likely to provide benefits in terms of reducing flood hazard (e.g. flash flooding), protecting agricultural production (and associated economic values), protecting water quality and water supply sources (both groundwater aquifers and surface water offtake at Mt Crosby Weir). Reducing sediment and nutrient loads to waterways will also protect social and economic values associated with receiving waters and Moreton Bay.

Intensive Agriculture (refer Figure 8-65)

Landscape management measures proposed on intensive agricultural lands located in the Lockyer Creek Catchment around Laidley Creek Valley and Lockyer Creek (refer to Figure 8-65) include cross floodplain structures, bank stabilization and revegetate within the stream channel. Vegetation cover of 5% is proposed in these areas, with existing riparian vegetation generally either absent or of low density and in poor condition (Walker *et al.*, 2014). Walker *et al.* (2014) identifies that "*The January 2013 flood had significant immediate and ongoing impacts to infrastructure and agricultural production in Laidley Valley… resulting in crop loss, extensive damage to farm equipment and substantial areas of floodplain erosion and sediment accretion. Floodplain scour was most severe in areas of channelized flow, which in numerous locations was aggravated by levee breaches (due to the creek bank eroding from beneath the levees), resulting in large, uncontrolled pulses of flood waters breaking out across the floodplain.*"

The case study on floodplain management within the Laidley Creek Valley by Walker *et al.* (2014) (lead by SEQ Catchments) identified the measures put forward in this Scenario as key management practices to improve resilience of floodplain production (and protect economic values) in Laidley valley. Cross floodplain roughness structures (as described above) are proposed to decrease the risk of scour and encourage sedimentation. Some structures have already been constructed at key locations. Stream restoration works including bank stabilisation and revegetation of the riparian zone were identified for managing the geomorphic processes identified in Laidley Creek. Stabilising channel banks will reduce the risk of future levee failure and the associated channelized flow and floodplain scour this can cause.

Vegetation in the riparian zone will increase stability and assist to reduce channel erosion and migration. Other benefits of landscape management measures proposed here include improved water quality (surface and groundwater) and waterway health, protection of surface and groundwater supply sources, improved ecology and protection of social and economic values of catchment waterways and receiving waters.

Lockyer Valley Expansion Zones (refer Figure 8-65)

Detailed studies of geomorphic processes and consideration of the interaction between inundation frequency and trapping potential on a range of inundation surfaces by Croke *et al.* (2017) within the Lockyer Creek catchment have been used to identify five key priority areas for the placement of riparian vegetation to reduce common flood problems within the catchment. Revegetation of these priority areas form the landscape management strategies for this management zone (refer to Figure 8-65), and include in order of priority:

(1) **Lockyer Creek Macrochannel Areas:** Revegetation of in-channel benches are identified as the key priority in reducing flood risk, keeping soil on the paddock and reducing end of catchment sediment yields for small-moderate scale floods.

(2) **Spill Out Zones (SOZ):** These zones occur where upstream channel capacity is larger and flow is funnelled at high velocity onto the floodplain downstream. Four key SOZs were identified in the Lockyer Valley around Grantham and downstream of Gatton. Strategic revegetation in the flow paths of these zones will significantly reduce flood hazard to people and public property by attenuating the flood wave and promoting sediment deposition.

(3) **Genetic Floodplains**: Genetic floodplains are surfaces approximately 10m above the channel bed and inundated during events up to 20 year ARI. These areas were identified to have the highest aerial sediment trapping potential of all surfaces in the catchment. Furthermore, sediments captured here have extremely long residence times, effectively reducing end of catchment sediment yields. Therefore it was noted that re-engagement of genetic floodplains where possible would be beneficial. Revegetation of genetic floodplains should be adjacent to revegetation within channel benches (priority 1) in the Lockyer Sidings and Grantham expansion zones. Multiple flood mitigation and sediment storage objectives are achieved with strategic revegetation in genetic floodplains, including reducing flood hazard on the floodplain, keeping soil on the paddock and reducing end of catchment sediment yields.

(4) **Hydraulic Floodplains**: Hydraulic floodplains are surfaces approximately 10m to 20m above the channel bed and inundated during discharges of between 1 in 20 and 1 in 200 AEP. They are primarily located between Helidon and Gatton. While the capacity for sediment storage in these areas is similar to in-channel benches, they are inundated less frequently and are considered low priority for reducing end of catchment sediment yields. Revegetation of these areas are only a higher priority where they merge with genetic floodplains to form SOZs.

(5) **Terraces**: Terraces are inundated during discharges approaching the probable maximum flood, and have very low sediment trapping potential. Hence revegetation of these areas is a low priority, however, it is recognised that runoff causing erosion across these surfaces is still connected to the channel and revegetation strategies should be considered.

Revegetation of priority areas to reduce end of catchment sediment yields will protect agricultural production (and associated economic values) as well as water quality and water supply sources (both groundwater aquifers and surface water offtake at Mt Crosby Weir). Reducing sediment and nutrient loads to waterways will also protect social and economic values associated with receiving waters and Moreton Bay.

Lockyer Valley CAP (refer Figure 8-65)

The Catchment Action Plan (CAP) developed for the Lockyer Valley catchment identifies the following key on-ground landscape management actions for implementation (RRI, 2016b):

- Targeted riparian management, including gully and creek bank stabilisation, with initial focus on Laidley, Sandy (Forest Hill), and Tenthill Creeks using an accepted and agreed reach and socio-economic methodology
- Protect soil from damage where the hill-slope meets the floodplain

- Make use of The Big Flood Project outputs, strategically remove sediment slugs in main channel and some tributaries
- Improved grazing and horticultural practices via industry-led programs
- Coordinated fire, weed and vertebrate pest management so that soil is not exposed and riparian zones become stabilised
- Flood debris removal in strategic locations where causing bank erosion
- Tree planting program to manage salinity in Plain and Woolshed Creeks (recharge area) – link to Black Snake Creek in Mid-Brisbane catchment
- Infrastructure and community protection through soil stabilisation or re-siting of services and utilities.

Above management measures in the Lockyer Valley CAP will reduce catchment sediment loads to waterways and keep soil on farmlands, protecting the catchment's significant agricultural production value (over $260 million /year) and protecting regional drinking water supply sources (Mount Crosby West Bank WTP). Reducing sediment loads will also reduce treatment costs at WTPs, and protect economic and recreational values of downstream receiving waters (e.g. tourism, fishing, Port of Brisbane channel navigation, aquaculture). Management measures are also expected to improve groundwater aquifer recharge and groundwater quality, providing resilience for farmlands (which rely on groundwater irrigation) in times of drought and assist to manage salinity issues in the catchment.

8.8.1.1.4 Bremer River Catchment

A summary of the landscape management measures discussed in the workshop for the Bremer River Catchment are detailed below. It is noted that Ipswich City Council are planning on undertaking more detailed investigations of landscape management and ICP options in the Bremer River catchment in early 2018.

Increasing Vegetation Cover (refer Figure 8-65)

Changing landuse/grazing practices to increase ground cover and altering burn regimes on slopes was nominated as a key landscape management measure in the upper region of the Bremer River catchment (refer to Figure 8-65). These management measures are likely to assist in improving soil infiltration and reducing runoff, particularly when applied on a large scale as indicated in this scenario. Enhanced infiltration also assists with groundwater recharge. However, as recognised in Section 7.2.4, the impact that land management practices will have on reducing flooding is largely unknown.

These management measures are predicted to have significant benefits to water quality and waterway health by also providing effective erosion and sediment control. Promotion of infiltration to groundwater aquifers and reducing sediment loads can also protect water supply sources in the catchment. Increasing groundcover also helps to manage salinity in the catchment. By protecting water quality and waterway health, these management measures are also expected to protect social and economic values of waterways and Moreton Bay (e.g. fishing, tourism, aquaculture).

Koala Habitat Corridor, Wetland and Floodplain Re-engagement (refer Figure 8-65)

Landscape management measures proposed in this management zone (refer to Figure 8-65), located in the mid - lower reaches of the Bremer River catchment, include increasing vegetation cover to 70% across the floodplain and hill slopes which is a significant Koala Habitat corridor, and roughening of the channel with woody debris and removal of levees to slow flows and re-engage the floodplain and surrounding natural wetlands.

As outlined in Section 7.2.3, measures proposed to re-engage the floodplain will likely slow flows, promote recharge of groundwater, and potentially reduce / delay flood peaks downstream.

Other benefits include improved ecological values and koala habitat, improved water quality and waterway health, protection of water supply sources. Through improving waterway health, these management measures are also expected to protect social and economic values of catchment waterways and Moreton Bay (e.g. fishing, tourism, aquaculture). Care is required, however, to manage potential conflicting objectives, with respect to flood detention benefits and other environmental benefits (e.g. can koala habitat withstand more frequent flood inundation?).

Revegetation (refer Figure 8-65)

Two 'revegetation' management zone areas are identified within the mid Bremer River catchment. The first area is located along Bremer River and Warrill Creek. Landscape management strategies within this area include revegetating the flood extent along the Bremer River and Warrill Creek, as well as roughening channels in these two waterways to further assist in slowing flows. The second area is located around Spring Creek and Western Creek. Landscape management strategies proposed in this area include revegetating the riparian corridor and flood extents up to a 1 in 50 AEP event. It also includes raising the bed levels to re-engage the floodplain. These strategies slow flows and provide additional storage, providing potential flood mitigation downstream as discussed in Sections 7.2.1 and 7.2.3.

Other benefits of riparian revegetation include stream bank stabilisation, reduced erosion and sedimentation, improved water quality and waterway health, protection of water supply sources and increased biodiversity. Protecting waterway health can also protect important social and economic values of receiving waters (e.g. fishing, tourism, aquaculture).

WSUD

There are opportunities to incorporate WSUD in this catchment due to significant future planned urban development in the region (e.g. Springfield Lakes, Ripley) to assist in delaying and storing floodwaters, however it must be managed to ensure the change in timing does not inadvertently correspond with other catchment inflows and impact downstream reaches. There is potential to provide some local flood mitigation in small events, however WSUD may be able to assist in mitigating larger events when combined with other wider Brisbane River catchment strategies.

Ipswich City Council's Integrated Water Management Strategy (2015) also endorses the principles of WSUD and identifies the importance of WSUD in managing future expected population growth and urban development in the region.

WSUD also provides other benefits such as improved waterway / ecosystem health (through filtering pollutants and maintaining natural hydrology), providing an alternative source of water to supplement potable supplies (e.g. rainwater / stormwater harvesting), improving amenity and improving microclimate (e.g. urban heat island effect). Improved waterway health will also protect social and economic values associated with receiving waters and Moreton Bay. Large planned urban areas and existing large urban areas across the whole catchment are encouraged to adopt WSUD as part of a catchment wide solution to flooding and urban water management.

8.8.1.1.5 Mid Brisbane River Catchment

The mid Brisbane River Catchment Action Plan (CAP) identifies the following key on-ground landscape management actions for implementation (RRI, 2016b):

- Bank stabilisation at high risk sites along macrochannel and raising the bed via in-stream islands or benches to slow sediment. This was identified as a high priority action.
- Fencing of the bank and provision of off-stream watering points/irrigation infrastructure along microchannel delivered as a supported package (voluntary, deliver works on behalf of landholder).
- Tree planting program to manage salinity in Black Snake Creek (recharge area) – link to Plain and Woolshed Creeks in the Lockyer catchment
- Prioritise remediation of high use informal recreation areas along the macrochannel and develop best practice approaches to remediating recreation zones in a water supply catchment (as per the Sapling Pocket demonstration site).
- Strategic purchase of land to provide protection of the macrochannel for multiple benefits (e.g. riparian sites for recreation; riparian sites of good quality vegetation; to protect infrastructure; to stop sediment; flood storage; retire land from current use) based on a voluntary willing seller principle.

8.8.1.1.6 Lower Brisbane River Catchment

Riparian Revegetation

Brisbane City Council have undertaken city-wide sediment studies, and council is looking at re-vegetating the riparian zones of local creeks throughout the city. Refer to Section 7.2.1 and 8.8.1.1.5 for previously described impacts of riparian revegetation.

WSUD

There are opportunities to incorporate WSUD principles and strategies in the Brisbane region. Flood mitigation strategies proposed through WSUD approaches include using the landscape and major tributaries to filter and slow water, and find locations where floodwaters can be diverted from the main channel and stored in open areas to reduce the risk of flooding important infrastructure.

WSUD strategies in the lower Brisbane River tributaries are not anticipated to mitigate river flooding, as the local creek and drainage catchments will typically have reached the Brisbane River before the peak from the upper catchments.

WSUD does provide other benefits such as improved waterway /ecosystem health (through filtering pollutants and maintaining natural hydrology), providing an alternative source of water to supplement potable supplies (e.g. rainwater / stormwater harvesting), improving amenity and improving micro-climate (e.g. urban heat island effect). By improving waterway health, the measures will also protect significant recreational values in the catchment and receiving waters in Moreton Bay.

Brisbane City Council's WaterSmart strategy (2015) also endorses the use of WSUD strategies to help achieve the region's vision for water.

8.8.1.2 *Indicative Cost*

It is extremely difficult to cost Scenario 1 (Targeted Catchment Revegetation) as described here and identified by stakeholders at the workshop. The works would likely be undertaken via non-commercial avenues (e.g. volunteering labour, green army, etc), and significant in-kind contributions from individual landowners. While it may be possible to crudely estimate the number of trees required across lands identified for revegetation in this scenario, tree stock could be provided by councils at little or no direct cost.

Furthermore, it is impractical to consider the full scale cost of the landscape management works within the context of flooding and potential flood benefits, because the primary objective of the works would be to improve environmental health, including water quality and sedimentation within the rivers and waterways throughout the catchment. Costs of the works should therefore be balanced against the full spectrum of benefits gained, not just the marginal benefits to flooding at the most downstream end of the catchment within the Brisbane River Catchment Study Area.

For the above reasons, costs for Scenario 1 (Targeted Catchment Revegetation) have not been calculated. Notwithstanding, a general discussion of the economic benefits of this option is still provided as part of the MCA (see Section 8.8.1.3.3).

8.8.1.3 *Multi-Criteria Review*

A review of this option against the criteria detailed in Section 8.3 is provided below. Also provided below are the relative scores for each criterion (value between 1 and 5), as defined by the scoring scale presented in Table 8-7. The collated and summarised scores for each option against the criteria are presented in Section 8.10.2.

8.8.1.3.1 Safety of People

Reduce hydraulic risk rating (now and future)	Proposed landscape management strategies such as strategic vegetation around ridgelines (e.g. headwaters of the Lockyer Creek catchment) and across spill out zones (e.g. Grantham and downstream of Gatton) (refer to Section 8.8.1.1) can reduce the force and velocity of waters, assisting to reduce flash flooding and improving the safety of people, but also increasing potential debris hazard. The extent of potential benefits would be limited for this scenario given the limited scope across the catchment. Benefits would more likely be limited to small flood events, which have a very small impact on existing development within the Brisbane River catchment.	3.0

Improve time for evacuation (now and future)	Landscape management strategies such as revegetation and re-engagement of floodplains have been demonstrated to delay the flood peak (Liu *et al.* 2004; Nisbet and Thomas 2006; Nisbet and Thomas 2008; Nisbet *et al.* 2011; Rutherford *et al.* 2007), increasing the time for issuing and responding to flood warnings. The extent of potential benefits would be limited for this scenario given the limited scope across the catchment. It may be possible that some regional evacuation routes within the upper floodplain areas of the study area could benefit from this option, and particularly where the current levels of flood immunity on these routes is at a low AEP (notably across the lower Lockyer Creek floodplain - refer to Section 4 Current Flood Risk and Section 5 Current Flood Risk), where landscape management has a better potential to impact on flood behaviour.	3.0

8.8.1.3.2 Social

Targets vulnerable community members or areas	Any flood mitigation benefits from this scenario would be spread across the entire Brisbane River Floodplain. Although modelling of this particular scenario has not been carried out, the sensitivity modelling undertaken (refer Section 7.3) indicates that benefits can concentrate within the Bremer River, in the vicinity of Ipswich, as well are areas immediately downstream of the Bremer in the Brisbane River. These parts of the river are fringed by communities that are considered more vulnerable than average on multiple vulnerability scales, as presented in Section 4 Current Flood Risk and Section 5 Current Flood Risk.	3.5
Social health benefits	Landscape management strategies are likely to provide some social health benefits by reducing the incidence of flash flooding, through strategic vegetation along ridgelines and in spill out zones. Protection of valuable farmland through the implementation of land management practices is also expected to provide positive social health benefits. Sensitivity testing results (refer Section 7.3) indicate the potential for reduced peak catchment flows to reduced flooding impacts, particularly in the Bremer River, though requires consideration of the timing of inflows from other tributaries and dam operations. Re-engaging the floodplain in areas, and potential voluntary buy back / loss of land required for strategic revegetation from existing property owners may however have some negative social health impacts.	3.5

	Overall, the strategies are expected to improve social health.	
Improves community flood resilience (now and future)	Landscape management strategies pertaining to land management practices and revegetation are likely to improve flood resilience on farms (Walker *et al*. 2014). Implementation of landscape management actions will require consultation with local landowners and the community. As such, opportunities will be created for improving community understanding of flood risk and appropriate actions to reduce the impacts and improve flood resilience (e.g. such as farming land management practices). The extent of potential benefits would be limited for this scenario given the limited scope across the catchment.	3.5
Recreation and amenity	Revegetation and floodplain re-engagement projects will improve landscape amenity and provide opportunities for passive / active recreation to be integrated. The extent of potential benefits would be limited for this scenario given the limited scope across the catchment, and a large proportion of works being undertaken on private land (limited community access).	3.5
Connection and collaboration	Collaboration with the community on landscape management projects and increased opportunities to engage the communities with waterways will also help create a sense of place and connection with local waterways (i.e. through community planting days, interpretive signage, reclaimed nature reserves/ floodplain wetlands). The extent of potential benefits would be limited for this scenario given the limited scope across the catchment.	4.0

8.8.1.3.3 Economic

Reduce damages and costs to residential property (now and future)	It is unknown how effective this particular strategy is at reducing catchment inflows, and therefore its impact on the flood behaviour of the Brisbane River. DEHP (2012) conclude that landscape management actions are more likely to modify catchment hydrology in smaller floods. This study has shown that there are 78 residential properties within Ipswich that experience above floor flooding at a 1 in 10 AEP, and a further 212 at a 1 in 20 AEP. As shown by the sensitivity test results (refer Section 7.3), Ipswich would likely be an area that would benefit from landscape	3.0

	management works more so than the lower reaches in Brisbane City.	
Reduce damages and costs to business and industry (now and future)	Measures are likely to reduce damages and protect farming land through retaining soil on ground, and improving the resilience of crops to flooding. Fruit and vegetable production in the Lockyer Valley alone is valued at $260 million/yr (RRI, 2016a). Landscape management measures also reduce the cost of dredging sediment at the Port of Brisbane to maintain vessel navigability, and provide cost effective treatment of sediment loads (as an offset) to help meet regulatory requirements. The cost is $10/tonne of sediment removal (for Laidley Creek restoration project) versus $3,000/tonne of sediment for on-site treatment using bioretention (M Linde, pers. comm., 5/9/17). There are a limited number of commercial and industrial properties exposed to minor floods in the Brisbane River (refer to Section 6 Flood Damages Assessment) The extent of potential benefits would be limited for this scenario given the limited scope across the catchment.	3.0
Option likely to be cost beneficial (now and future)	It is impossible to provide a true benefit/cost valuation of this scenario given the difficulties in estimating actual costs for the works, and attributing those costs to community economic benefits. Moreover, benefits extend well beyond flood mitigation, and include environmental health and 'ecosystem services' benefits, which are largely intangible. For consideration though, cost benefit assessment of ecosystem services provided by ICP measures implemented in the Slowing the *Flow at Pickering project* identified that from a societal perspective the public benefits significantly outweighed the costs (Nisbet *et al.* 2011; Nisbet *et al.* 2015). The highest ecosystem benefits provided by the woodland revegetation measures were (in order) climate regulation, flood regulation and habitat creation (Nisbet *et al.* 2015). Furthermore, the benefit cost ratio for the woodland revegetation component was determined to be 5.6 for the Pickering Beck catchment and 2.5 for the River Seven catchment. The lower benefit cost ratio in the River Seven catchment was primarily due to the resumption of better quality farmland for planting. Examples of cost benefits provided by this scenario include: • Protection /security of drinking water supplies	2.5

	• Reduced WTP treatment costs (reduced sediment loads) • Protection of farming land through retaining soil on ground, improving the resilience of crops to flooding, recharging groundwater aquifers for irrigation (providing resilience in times of drought). Fruit and vegetable production in the Lockyer Valley alone is valued at $260 million/yr (RRI, 2016a). • Reduced costs for removing and disposing of accumulated sediment washed into waterways (e.g. dredging at the Port of Brisbane to maintain vessel navigability, cleaning sediment basins). • Protecting industries in SEQ that depend on healthy waterways and Moreton Bay. Primary industries, nature based tourism, recreation and recreational fishing and are valued at more than five billion dollars annually (QCC, 2012). Reducing sediment and nutrient loads to our waterways through landscape management measures protect the health of waterways and Moreton Bay and the value of these dependent industries. • Provision of habitat (including significant koala habitat) and increased biodiversity. • Climate change regulation through carbon sequestration.	

8.8.1.3.4 Feasibility

Physical / technical (now and future)	The feasibility of landscape management measures varies. Most farming land management measures have good feasibility with demonstrated effectiveness, however some revegetation / floodplain re-engagement strategies may encounter challenges where voluntary land resumption is required. Community engagement and education will be fundamental to implementing these measures. Further detailed technical assessments (both at a local and regional scale) are also required to identify the most cost effective locations for prioritised implementation, and further demonstrate the effectiveness of implementing landscape management measures at a total catchment scale.	2.5
Legal / approval risk	Revegetation will not be likely to trigger approvals, unless vegetation clearing or other operational works are required to implement the WSUD or revegetation work. Typically clearing for essential management is exempt from State approval requirements, however this will need to be reviewed on a case by case basis and operational works approvals for clearing that are assessable by local government might be required. A conservation security program would be necessary to ensure these areas were retained. Furthermore it is also noted that the *Planning Act* 2016 and *Planning Regulation* 2017 contains provisions that prohibit certain	2.5

	works from being made assessable in local government planning schemes, and this includes operational work for agriculture relating to the conservation or restoration of the natural environment (as defined under the Environmental Protection Act). In areas where works are proposed on private land, obtaining legal consent from landowners to undertake works presents a high risk (particularly revegetation projects).	
Potential for additional funding sources	Potential exists for additional funding sources, from government sources (e.g. 20 Million Trees project and National Landcare program) in addition to private industry (as part of offset schemes such Port of Brisbane and Queensland Urban Utilities funding of the Laidley Creek restoration project). Funding for acquisition of land to implement works is less available, meaning that success will be driven by landowner co-operation and private/public collaboration.	4.0

8.8.1.3.5 Attitude

Decision makers	There is general and increasing political recognition of the importance of adopting an ICP approach to flood management (DEHP 2012; DNRM 2014; Council of Mayors (SEQ) 2015; ICC 2015; BCC 2015; QAO 2016; ARC 2017)	4.0
Community	The key issue of contention around attitude resides with the voluntary resumption / loss of land to implement such measures. Nisbet *et al.* (2015) identifies that persuading private landowners to plant woodland in target locations was very difficult and that financial incentives may help.	3.0

8.8.1.3.6 Key Infrastructure and Transport

Improve availability and function (now and future)	Should landscape management actions reduce peak flows coming off the catchment, then there is potential that resulting lower flood levels across the floodplain will improve accessibility of some transport infrastructure and other critical services that are currently exposed at low levels of flooding. This would include low level crossings, causeways and cross-floodplain embankments, and covers numerous roads that are important for evacuation of communities during flooding. However for those that remain inundated, it may extend the duration of flooding.	3.0
Protection of regional water supply quality and	Slowing flows and reducing sediment loads through landscape management measures in areas upstream of the WTP can assist	3.5

security – catchment protection (quality and yield)	in improving water quality of the region. As discussed previously, this is demonstrated by events of the 2013 Australia day floods, in which high sediment loads resulted in the shut down of Mt Crosby WTP, reducing potable water supply to just hours. Recently, landscape management works have been undertaken at Sapling Pocket to help protect the WTP infrastructure (Clarke 2017). Landscape management practices upstream of Wivenhoe resulting in reduced sediment loads may also help protect the water supply capacity of the dam. Promoting infiltration and recharge of groundwater aquifers though landscape management measures is also expected to enhance water supply security for farmlands of economic importance in the region (e.g. Lockyer valley). However, this would also correspondingly reduce runoff to dams supplying urban water. The extent of potential benefits would be limited for this scenario given the limited scope across the catchment.	

8.8.1.3.7 Environment and Natural Resource Management

Species impacts	The widespread adoption of landscape management measures in this scenario, and associated improvements to ecosystem health and habitat (as described further below) are expected to support significantly increased species abundance and biodiversity. The extent of potential benefits for this scenario is restricted by the limited scope for implementing measures across the catchment.	4.5
Vegetation and habitat impacts	Landscape management measures such as riparian revegetation, restoring catchment vegetation and re-engaging the floodplain as proposed by this scenario are expected to provide: • New / improved habitat and sources of food and shelter for stream animals (e.g. through fallen leaf litter, insects and woody debris • New / improved habitat for terrestrial animals The extent of potential benefits for this scenario is restricted by the limited scope for implementing measures across the catchment.	4.5
Ecosystem health connectivity (fish	The landscape management measures outlined in the scenario are all expected to provide improved ecosystem health through	4.5

passage/fauna movement)	improvements to water quality (e.g. trapping sediment, nutrients and other contaminants before they enter waterways). In addition, riparian revegetation will assist to improve in-stream ecosystem health through the shading of waterways, assisting in the control of aquatic weeds. Fallen branches (that form shelter for fish) and reduced in stream velocities from riparian revegetation will also improve fish passage along these areas. Proposed revegetation strategies are also expected to provide new and improved fauna movement corridors (e.g. such as planned revegetation around koala corridors in the Bremer River catchment). The extent of potential benefits for this scenario is restricted by the limited scope for implementing measures across the catchment.	
Reduction in landscape salinity / improved moisture retention and groundwater recharge	Landscape management measures in the upper catchment are expected to reduce runoff and increase soil infiltration which may assist with recharge. Conversely, revegetation strategies in rural, mid-catchment areas may help to lower water tables, assisting to manage soil salinity. Measures can be targeted to areas of greatest benefit. The extent of potential benefits for this scenario is restricted by the limited scope for implementing measures across the catchment.	3.5
Reduction in erosive capacity / soil movement – channel stability / geomorphology	Proposed landscape management measures are all likely to assist in reducing erosion and negative impacts on geomorphic processes through stabilising soils, slowing flow velocities and promoting infiltration of water. Riparian revegetation strategies will also further assist to stabilise banks via their root systems (Croke *et al.* 2017). The extent of potential benefits for this scenario is restricted by the limited scope for implementing measures across the catchment.	4.0

8.8.1.4 Assessment of Option Against Multiple Criteria

As outlined in Section 8.10.2, this landscape management (scenario 1) option has an overall multi-criteria assessment result of 0.67, where a value of 0.0 represents a net 'no change' condition across the various criteria. The landscape management option is ranked 5th out of the 16 options considered in the MCA (refer Table 8-64). The landscape management option scored positively across all criteria and notably the environment and natural resource management criteria.

The lowest scoring criteria for this option were related to cost beneficial criteria and physical and legal/approval feasibility (value of 2.5) although benefits have only been considered on the basis of reducing flood damages, and not all the other ICP related benefits that would be generated from this option. The best scoring criteria are related to environment and natural resource management criteria (value of 4.5). There are no specific factors that would automatically rule out this option from further consideration. Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.8.1.5 Feasible Alternative Assessment

With reference to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, the factors determining whether alternatives are considered not feasible under the provisions of the Planning Act 2016 are described below for the Landscape management Scenario 1 (Targeted Catchment Revegetation):

an unacceptable remaining or residual risk of serious harm to persons or property on the premises	The reduction in serious harm to persons and property achieved through this scenario is indeterminate as it could not be assessed hydraulically. Notwithstanding, the scale of revegetation and restoration works are relatively small compared to the size of the catchment and as such, is unlikely to have a material impact on flooding that would lead to significant flood risk reduction benefits for people or property. The number of properties exposed to flooding for smaller floods (i.e. less than 1 in 20 AEP) is quite small compared to larger events.
environmental or social disadvantage	While environmental conditions would improve as a result of this landscape management scenario, it would require individual private landowners to forgo existing landuse benefits to achieve revegetation outcomes, although the vegetation and / or carbon offset schemes may provide an alternative source of income. It has already been expressed that such actions are unlikely to be supported in the Somerset area.
an unacceptable economic cost to State, local government, community or individual	Although the cost for landscape management Scenario 1 has not been calculated explicitly, it is expected to be significant, and contain considerable in-kind and government-supported on-ground actions. In-kind contributions, both in terms of expenses and time/labour, would be expected from communities and

	individuals (rural landholders). Works would involve programs over several years, with full benefits not realised for decades after.
technical impracticability	The landscape management Scenario 1 is technically practical, subject to agreement with landowners for all lands proposed to be revegetated within the catchment. Similar works, at varying scales, have been achieved in other catchments, as well as some sections of the Brisbane River catchment.
other unusual or unique circumstances	There are no obvious other unusual or unique circumstance relating to reduction of flood risk that would preclude the feasibility of this option.

8.8.2 Scenario 2 – Restore Pre-European Conditions

8.8.2.1 General Description of Option and Assessment

This scenario assumes full catchment revegetation, restoring the catchment to pre-European conditions. This has been included as a hypothetical scenario, to provide a benchmark for the best possible outcome for catchment revegetation to help guide decision making.

Revegetation for this scenario includes pre-European settlement vegetation based on the *Walking The Catchment* maps produced by the Department of Environment and Heritage Protection (see https://wetlandinfo.ehp.qld.gov.au/wetlands/ecology/processes-systems/water/catchment-stories/), and reproduced in Figure 8-66 to Figure 8-70.

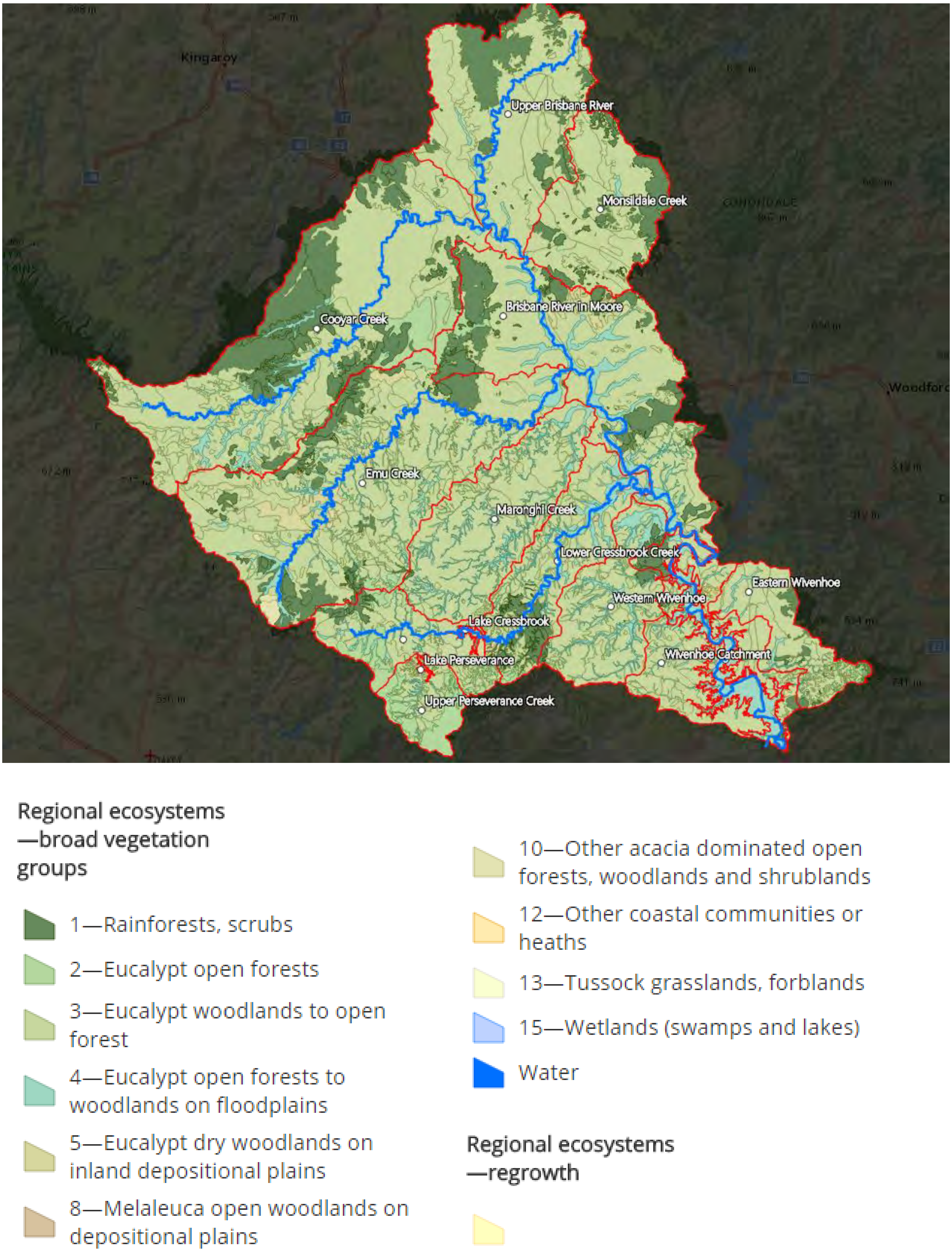


Figure 8-66 Upper Brisbane Catchment: Pre-European Vegetation (source: EHP)

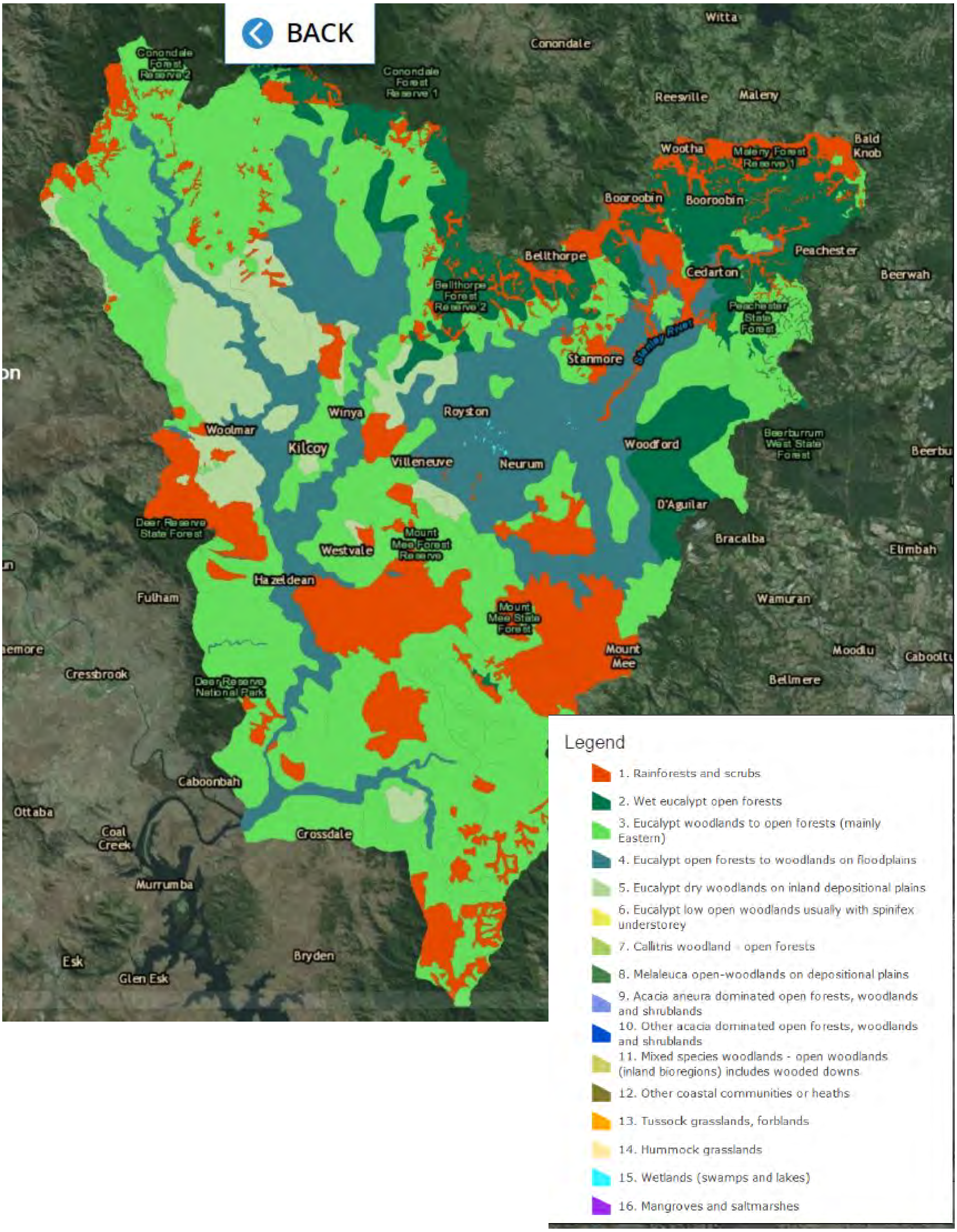


Figure 8-67 Stanley Catchment: Pre-European Vegetation (source: EHP)

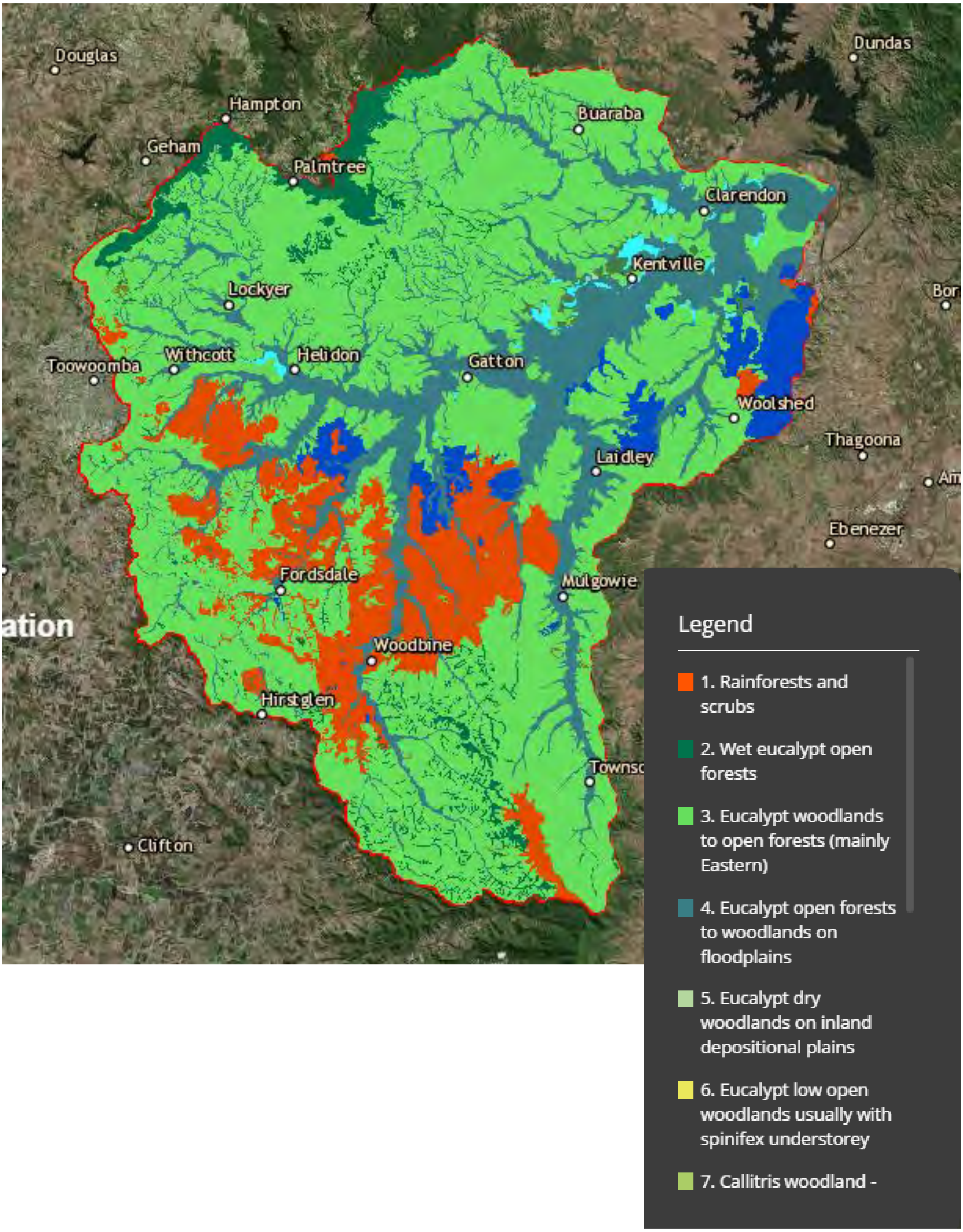


Figure 8-68 Lockyer Catchment: Pre-European Vegetation (source: EHP)

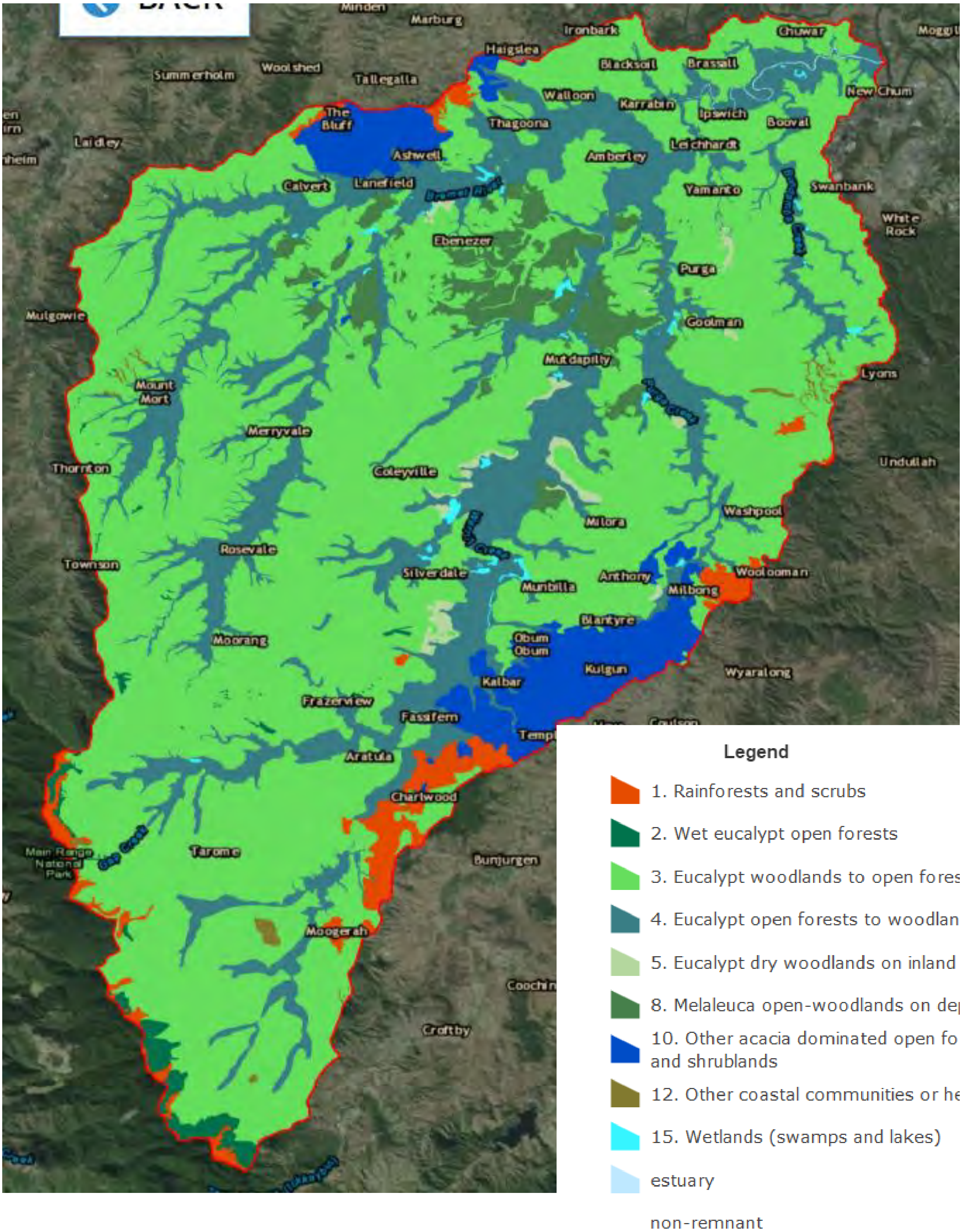


Figure 8-69 Bremer Catchment: Pre-European Vegetation (source: EHP)

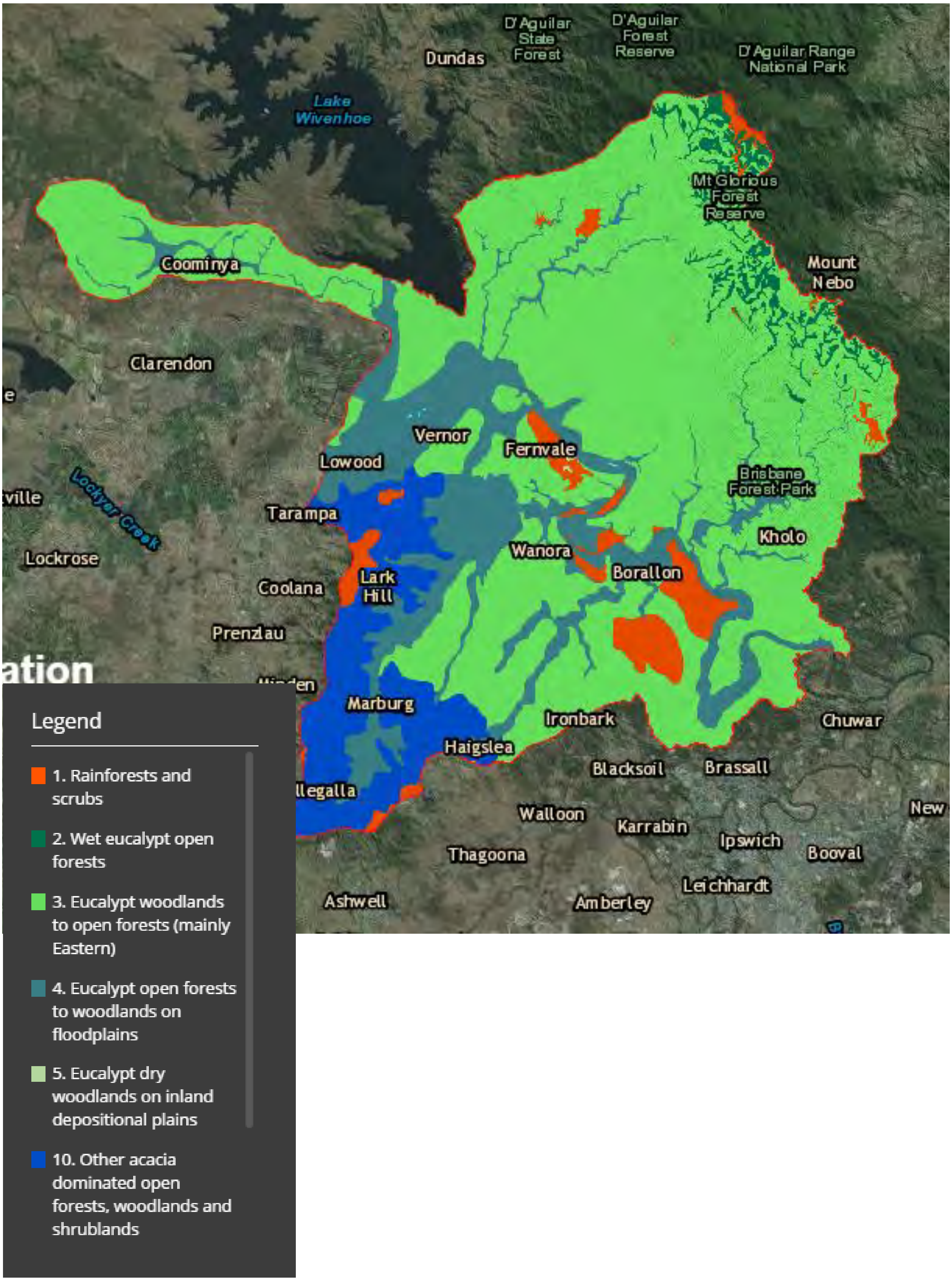


Figure 8-70 Mid Brisbane Catchment: Pre-European Vegetation (source: EHP)

Vegetation in this scenario will slow water, retaining it in the landscape for longer, recharging groundwater aquifers and reducing erosion potential and loss of soil from the catchment. It is recognised that even with a fully vegetated catchment, flooding will still occur and in some areas may actually worsen compared to current conditions due to timing differences from different sub-catchments.

The scenario is anticipated to provide improved waterway health and ecological benefits, however the social and economic impacts of the solution are extensive, due to the hypothetical nature of the scenario.

Furthermore, as outlined in Section 8.8.1.1, specific hydraulic analysis of this option was not possible for this Phase 3 (SFMP) as it would require modifications to the hydrology model to reflect the change in catchment conditions. Further more detailed studies will need to be undertaken on the effects of revegetation and other landscape management works on catchment hydrology and flooding.

8.8.2.2 Indicative Cost

It would be impossible to cost this scenario, as it is an unrealistic option that would change existing landuse and development conditions across the entire catchment.

A high level discussion of the economic benefits of this Scenario is provided as part of the MCA (see Section 8.8.2.3.3).

8.8.2.3 Multi-Criteria Review

The hypothetical nature of this scenario results in much of the multi-criteria review having negative impacts or not being realistically applicable (through population displacement for revegetation). The collated and summarised scores for each option against the criteria are presented in Section 8.10.2.

8.8.2.3.1 Safety of People

Reduce hydraulic risk rating (now and future)	Full revegetation of the catchment is expected to reduce the force and velocity of waters, reducing flash flooding and improving the safety of people. The extent of potential benefits would be higher for this scenario (than targeted revegetation) given the widespread adoption across the catchment. Benefits may be limited to small flood events, which have a very small impact on existing development within the Brisbane River catchment. Large floods are still likely to occur (as in 1841).	4.0
Improve time for evacuation (now and future)	Landscape management strategies such as revegetation and re-engagement of floodplains have been demonstrated to delay the flood peak (Liu *et al.* 2004; Nisbet and Thomas 2006; Nisbet and Thomas 2008; Nisbet *et al.* 2011; Rutherford *et al.* 2007), increasing the time for issuing and responding to flood warnings,	4.0

	however the landscape management sensitivity tests indicated this was not significant.	

8.8.2.3.2 Social

Targets vulnerable community members or areas	As the revegetation applies to the whole catchment, it benefits a mix of high and low average household income, but impacts productive rural land use.	2.5
Social health benefits	Full revegetation of the catchment is likely to provide benefits through reduced flood impacts, however the resumption of land and change of existing landuse required to implement this would overall results in a negative effect on social health.	1.0
Improves community flood resilience (now and future)	Revegetation of the catchment would require extensive consultation and therefore improve the understanding of the community about flood risk, improving flood resilience.	3.0
Recreation and amenity	Full revegetation and naturalisation of the catchment will significantly improve landscape amenity and provide opportunities for passive / active recreation to be integrated.	5.0
Connection and collaboration	Collaboration with the community on revegetation projects and increased opportunities to engage the communities with waterways will also help create a sense of place and connection with local waterways (i.e. through community planting days, interpretive signage, reclaimed nature reserves/ floodplain wetlands).	5.0

8.8.2.3.3 Economic

Reduce damages and costs to residential property (now and future)	Full revegetation of the catchment is likely to reduce peak catchment inflows, which would result in lower flood levels in the Brisbane River.	2.5
Reduce damages and costs to business and industry (now and future)	As for residential properties, full revegetation of the catchment is likely to reduce peak catchment inflows, which would result in lower flood levels in the Brisbane River.	2.5
Option likely to be cost beneficial (now and future)	Significant 'Ecosystem services' benefits, as discussed previously, would be gained through full catchment revegetation. However, the cost associated with achieving this would be astronomical as all existing development within the catchment	1.0

	would need to be relocated. Major economic impact of this option would also come from loss of productive rural land use and loss of employment. This is an unrealistic option and the benefit cost ratio would be near zero or negative.	

8.8.2.3.4 Feasibility

Physical / technical (now and future)	Low physical feasibility of implementing due to the hypothetical nature of this scenario (and unrealistic population displacement for revegetation).	1.0
Legal / approval risk	High approval risk due to the hypothetical nature of this scenario (and unrealistic population displacement for revegetation)	1.0
Potential for additional funding sources	Although there may be potential for additional sources of funding for revegetation projects, however given the large (hypothetical) extent of the project, the relative proportion of funding would be minor.	1.0

8.8.2.3.5 Attitude

Decision makers	There is general and increasing political recognition of the importance of adopting an ICP approach to flood management (DEHP 2012; DNRM 2014; Council of Mayors (SEQ) 2015; ICC 2015; BCC 2015; QAO 2016; ARC 2017). However the hypothetical nature of this scenario and the impractical extent of implementation will result in a low level of political will for implementation.	1.0
Community	The huge amount of land resumption required for this scenario due to its hypothetical nature will result in high community opposition.	1.0

8.8.2.3.6 Key Infrastructure and Transport

Improve availability and function (now and future)	Key infrastructure and transport links would be relocated under this options and therefore negating their current flood risk issues.	5.0
Protection of regional water supply quality and security – catchment protection (quality and yield)	Slowing flows and reducing sediment loads through revegetation of the catchment in areas upstream of the WTP will assist in improving water security of the region. Revegetation upstream of Wivenhoe dam resulting in reduced sediment loads will also assist to protect the water supply capacity of the dam.	5.0

8.8.2.3.7 Environment and Natural Resource Management

Species impacts	Full catchment revegetation in this scenario and associated improvements to ecosystem health and habitat (as described below) are expected to support significantly increased species abundance and biodiversity.	5.0
Vegetation and habitat impacts	Full catchment revegetation in this scenario is expected to provide: • New / improved habitat and sources of food and shelter for stream animals (e.g. through fallen leaf litter, insects and woody debris • New / improved habitat for terrestrial animals The extent of potential benefits would be high for this scenario given the widespread adoption of revegetation across the catchment.	5.0
Ecosystem health connectivity (fish passage/fauna movement)	Revegetation is expected to provide improved ecosystem health through improvements to water quality (e.g. trapping sediment, nutrients and other contaminants before they enter waterways). In addition, riparian revegetation will assist to improve in-stream ecosystem health through the shading of waterways, assisting in the control of aquatic weeds. Fallen branches (that form shelter for fish) and reduced in stream velocities from riparian and catchment revegetation will also improve fish passage along. Full catchment revegetation is also expected to provide new and improved fauna movement corridors. The extent of potential benefits would be high for this scenario given the widespread adoption of revegetation across the catchment.	5.0
Reduction in landscape salinity / improved moisture retention and groundwater recharge	Revegetation in the upper catchment would be expected to reduce runoff and increase soil infiltration which may assist with recharge. Conversely, revegetation strategies in rural, mid-catchment areas may help to lower water tables, assisting to manage soil salinity. The extent of potential benefits are limited to the location of aquifers and recharge zones.	4.0
Reduction in erosive capacity / soil movement – channel	Proposed revegetation will assist in reducing erosion and negative impacts on geomorphic processes through stabilising soils, slowing flow velocities and promoting infiltration of water.	5.0

stability / geomorphology	The extent of potential benefits would be high for this scenario given the widespread adoption of revegetation across the catchment.	

8.8.2.4 Assessment of Option Against Multiple Criteria

This landscape management (scenario 2) option has an overall multi-criteria assessment result of 0.46, where a value of 0.0 represents a net 'no change' condition across the various criteria. The landscape management option is ranked 7th out of the 16 options considered in the MCA (refer Table 8-64). The landscape management option scored exceptionally well on environment criteria, but poorly on feasibility and attitude. As the option is purely a comparative scenario representing pre-European conditions, it is not expected to be realistic or feasible to adopt this option as a solution for floodplain management in the Brisbane River.

As expected, the lowest scoring criteria for this option were related to feasibility and attitude (value of 1.0). Maximum scores were achieved for environment and NRM (with restoration of full catchment revegetation to pre-European conditions). As indicated above, this option has been included for comparative purposes only and is not a legitimate solution for floodplain management. On this basis, this landscape management option would not warrant further consideration. Recommendations and proposed next steps for this option are detailed in Table 8-66.

8.8.2.5 Feasible Alternative Assessment

This option has not been considered with respect to the Feasible Alternative Assessment requirements discussed in Section 8.1.7, as it is hypothetical only and not a true feasible alternative for the catchment.

8.9 Other Options Reviewed

8.9.1 Overview

In addition to the options described in the preceding sections of this chapter, several other options were also considered, but to a lesser degree given particular circumstances around each of these options.

The other options that have been reviewed for this Phase 3 (SFMP) are outlined below.

Table 8-57 Other Options Reviewed

Location	Description / Immunity level	Report Section
Mt Crosby West Bank WTW levee	1 in 10,000 AEP	Section 8.9.2
Dredging of the tidal reaches of Brisbane River	various	Section 8.9.3
Realignment of Oxley Creek mouth	various	Section 8.9.4

Review of the Mt Crosby West Bank WTW levee was carried out at the request of Seqwater. This scenario was modelled for Seqwater purposes only and does not constitute a comparative option for the Phase 3 (SFMP). Mt Crosby West Bank WTW services a population of approximately 1 million people, and as such, is considered critical infrastructure for Seqwater. The hydraulic impacts of the levee around Mt Crosby West Bank WTW have been reported separately to Seqwater.

Dredging of the tidal reaches of the Brisbane River was captured during initial options identification (refer Section 8.2). This option was considered to be unrealistic by stakeholders as part of the first pass assessment, however, it was decided that a review would be useful for comparative purposes only.

8.9.2 Mt Crosby West Bank WTP Levee

The Mount Crosby West Bank Water Treatment Plant is located on the right bank of the Brisbane River, approximately 65km upstream from the Brisbane CBD. The aim of the option is to provide the facility with a 1 in 10,000 AEP flood immunity.

Results from the Phase 2 (Flood Study) suggest that the area around the Mount Crosby West Bank Water Treatment Plant begins to be inundated in a 1 in 200 AEP flood event, with the WTP approximately a 1 in 2,000 AEP immunity. To achieve the desired immunity (1 in 10,000 AEP) with no freeboard allowance, a levee would need to have a crest level no lower than 37.85 m AHD, and an average height of 6.10m. A benefit costs assessment was not carried out as neither the costs nor the monetary benefit of increased flood immunity of the infrastructure was established as part of this Phase 3 (SFMP), as instructed by Seqwater.

Potential impacts of the proposed 1 in 10,000 AEP levee on the hydraulic behaviour of flooding were assessed for the 11 AEPs assessed for the Phase 2 (Flood Study). At the 1 in 100 AEP level, the proposed levee works have essentially no impact on the flood behaviour, as the majority of the infrastructure is already located above this level. At the 1 in 10,000 AEP level, flows are generally constrained at Mt Crosby. The introduction of a levee, which isolates some of the floodplain at this event, further constrains the floodplain, leading to afflux upstream. The extent of this afflux and the probability of such impacts on properties upstream of Mt Crosby will be considered by Seqwater as part of their infrastructure planning program.

8.9.3 Full Tidal Reach Dredging

Dredging of the river up to Mt Crosby Weir (the approximate tidal boundary) was reviewed for flood mitigation potential, primarily for comparative purposes. Dredging of a waterway can reduce flood levels by increasing the conveyance area of the channel that carries the flood flow. Small increases in conveyance would have relatively small benefit, while dredging in only some parts of the river would also only have small benefit overall. This study has therefore assessed the impacts of a much more extensive dredging scenario of the tidal reach.

The conditions reviewed as part of this Phase 3 (SFMP) include dredging of the full tidal extent of the Brisbane River, a distance of approximately 85km, to cater for an increase in conveyance of approximately 20% in a 1 in 100 AEP event. This meant that the bed level of the river (with average width of about 220 metres) was reduced by about 2 metres, on average. Areas of known bedrock substrate within the tidal reaches of the river were not reduced.

The option represents an initial dredging campaign of approximately 38,000,000m^3 followed by re-dredging of a similar volume approximately every 20 years as part of an on-going maintenance dredging program, in order to retain the increased flood conveyance capacity. At present, the Port of Brisbane Limited (PBPL) remove approximately 400,000m^3 of sediment from their channels and berths at the mouth of the Brisbane River each year. Scaling this figure across the whole Brisbane River estuary, it is reasonable to assume that a similar volume (+/- 50%) would need to be dredged from the full 85km river length after 20 years of accumulation.

It has been assumed that the dredged material would be disposed at sea (Moreton Bay) in accordance with environmental guidelines.

The indicative cost of the dredging works required for the Brisbane River is outlined in Table 8-58.

Table 8-58 Indicative Cost for full tidal reach dredging (2017 costs)

Description	Cost ($)
Insurances, navigation and pipeline management	1,250,000
Dredging	570,000,000
Total Direct Job Cost	**$571,250,000**
Indirect Job Costs – On-Site Costs (31%)	177,087,500
Design Costs (9%)	67,350,400
Indirect Costs - Offsite Costs (3%)	24,470,600
Contractors Margin and Profit (9%)	75,614,300
Applications (5%)	45,788,600
Contingencies (40%)	384,624,600
Total Cost Estimate (Excluding Operating Expenses)	**$1,346,186,000**
Annual Operating Expenses	$67,309,300

The indicative cost is based on the following assumptions:

- No laydown sites would be required on land;
- The dredged material is not contaminated and therefore requires no treatment;
- Dredge cost rates are comparable to similar dredging carried out in the lower reaches of the Brisbane River (Port of Brisbane). Previous dredging projects (Port Philip Bay and Geraldton Harbour) have reported a wide range in costs ($6 to $33 per cubic metre), although these rates may also include indirect additions (i.e. Design Costs, Contractors Profit and Contingencies) which have been included separately above. A base dredging cost of $15/m^3 was adopted for the purposes of this indicative costing; and
- Maintenance dredging would be required every 20 years to maintain the desired bed elevation, with operating expenses including the direct and indirect job costs for re-dredging at this interval.

Sediment runoff from the catchment would help to infill the dredged channel during periods of rainfall and catchment runoff. The rate of accumulation of catchment-derived sediment within the dredged channel will depend on the frequency and magnitude of catchment runoff events. Sediment input to the river may also be derived from Moreton Bay, deposited under the influences of tidal flows. It is expected that sediment accumulation rate throughout the river would also be higher immediately following dredging, when conveyance area is largest, meaning that flood and tidal velocities are lowest (allowing for settlement of sediment in the water column).

Potential impacts of full river dredging on the hydraulic behaviour of flooding were assessed by adjusting the Brisbane River detailed hydraulic model to incorporate the lower river bed level and re-running necessary scenarios to cover the 11 AEPs assessed for the Phase 2 (Flood Study). A summary table of reductions in flood level at Brisbane CBD and Ipswich CBD is presented in Table 8-59. Note that no changes were made to the Bremer River bed level in this option, with impacts at Ipswich being the result of backwater conditions from the Brisbane River downstream.

Reduction in flood levels at Brisbane CBD increase with AEP, peaking at the 1 in 2,000 AEP, with a reduction of almost 1.5 metres. For the 1 in 100 AEP, the reduction at Brisbane CBD is half this value. At Ipswich CBD, the maximum flood level reduction was 0.56 m, also for the 1 in 2,000 AEP. The 1 in 100 AEP reduction at Ipswich CBD is 0.29 m.

It is worth noting that flood levels for frequent events (1 in 2 AEP / 1 in 5 AEP) actually increase in some sections of the river. Lower bed levels in the Brisbane River would also increase tidal conveyance and reduce attenuation of the tide as it progresses upstream. Larger tidal range within the river would extend into the tidal tributaries, including Oxley Creek, Breakfast Creek, Norman Creek, and the Bremer River. Larger tides coinciding with smaller floods lead to higher flood levels for these events. For larger floods, the fluvial flows dominate the hydrodynamic behaviour and therefore reduced tidal attenuation is less significant.

The increase in tidal range within the Brisbane River would increase the tidal volume and peak tidal discharges. A detailed assessment of changes to the tidal hydrodynamics of the river as a result of the dredging has not been carried out as part of this study, but was undertaken as part of a previous study undertaken by Cameron McNamara in the late 1980s to phase out previous dredging. This would require further investigation should this option be considered worthy of further consideration.

Table 8-59 Summary of dredging impacts on flood levels at Ipswich CBD and Brisbane CBD

AEP	WL reduction at Ipswich CBD	WL reduction at Brisbane CBD
1 in 2	-130mm (incr.)	<50mm (incr.)
1 in 5	60mm	<50mm (incr.)
1 in 10	60mm	90mm
1 in 20	80mm	270mm
1 in 50	110mm	490mm
1 in 100	290mm	740mm
1 in 200	230mm	900mm
1 in 500	500mm	1070mm
1 in 2,000	560mm	1460mm
1 in 10,000	340mm	1250mm
1 in 100,000	200mm	420mm

A benefit / cost analysis has been carried out based on the indicative cost of the proposed dredging and the economic benefits it generates, as measured by the reduction in average annual property, indirect and intangible flood damages. A summary of the benefit / cost analysis for the full tidal reach dredging option is presented in Table 8-60.

The full river dredging, with a capital cost of $1.35 billion and an annual maintenance cost of $67 million, will generate a net annual average benefit of $55 million, leading to a benefit/cost ratio of 0.33 when adopting a discount rate of 7% over a 100 year period.

Table 8-60 Benefit/cost analysis summary for full tidal reach dredging option

	AAD existing ($ million)	AAD with option ($ million)	Annual average benefit of option ($ million)	Benefit/Cost
Main case (1)	288.7	233.7	55.0	**0.33**
Sensitivity 1: No intangibles	186.8	151.3	35.5	**0.21**
Sensitivity 2: with Wivenhoe up.	213.2	173.5	39.7	**0.24**
Sensitivity 3: 4% discount rate				**0.44**
Sensitivity 4: 10% discount rate				**0.25**

(1) Main case includes total damages/benefits (tangible + intangible), no Wivenhoe upgrade works.

Sensitivity of the benefit/cost analysis was carried out, also as presented in Table 8-60. If benefits were considered on the basis of reduced tangible (monetary) damages only, the annual average benefit of the dredging would reduce to $35 million, giving a net benefit/cost ratio of 0.21. If a Wivenhoe Dam upgrade is carried out, and reduces the impact of flooding throughout the Brisbane River floodplain, the annual average benefit of the dredging would reduce to just under $40 million per annum, leading to a benefit/cost ratio of 0.24. As the dredging would have a significant impact on flood behaviour downstream of Moggill, the sensitivity to Wivenhoe Dam upgrade is indicative only. More detailed and rigorous assessment would be required to more accurately determine the potential combined benefits of dredging and Wivenhoe Dam upgrades.

Sensitivity was also undertaken on the adopted discount rate over the option duration (in this case 100 years). For a lower discount rate of 4%, the benefit/cost ratio increases to 0.44, while for a higher discount rate of 10%, the benefit/cost ratio reduces to 0.25.

8.9.4 Realignment of Oxley Creek Entrance

BCC requested that the option to realign Oxley Creek mouth be investigated to determine if the morphology of the creek channel and interface with the main river channel has a detrimental effect on flooding within the creek.

Oxley Creek undergoes several tight meanders near the confluence with the Brisbane River, with the last meander being constrained by high topography on either side. The creek discharges into the Brisbane River with the creek oriented in an upstream direction at the confluence. The option involves realigning the bottom reach of Oxley Creek to align it in a ‘downstream’ orientation. The new channel would have the same flow conveyance as the existing channel such that there is no impact on local floods from the Oxley Creek catchment.

The option would consist of excavating a new channel, north-east through the Graceville Rugby Fields and Simpsons Playground Reserve, discharging into the Brisbane River, approximately 100 upstream from the existing confluence (see Figure 8-71). The realignment would require the infilling of the existing Oxley Creek to a level of about a 1 in 10 AEP. In larger floods, the existing channel would act as an overland flowpath.

The maximum width of the new channel would be approximately 100m, near Graceville Avenue.

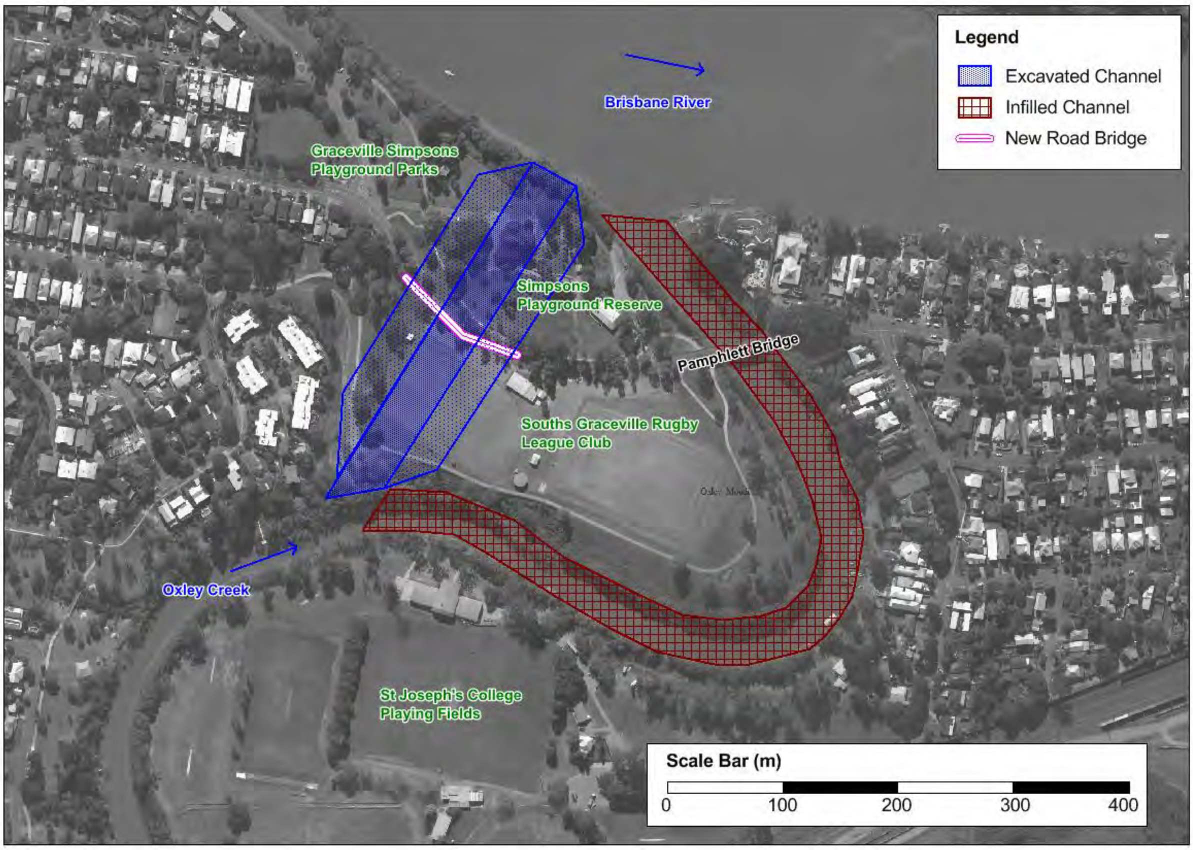


Figure 8-71 Oxley Creek realignment option

A minimum cost for the Oxley Creek entrance realignment is presented in Table 8-61.

The costs include excavation of the new channel (RL -2.0m AHD at the river, 35m wide at base, 1 in 4 side slopes), infilling of the existing channel (to level RL 3.5m AHD) and construction of a new road bridge (approximately 100 metres long) with the same level of flood immunity as the existing Pamphlet Bridge. It does not include costs for the treatment and remediation of contaminated excavated material. Approximately 30 residential properties and three recreational facilities (Pamphlet-Tennyson Sea Scouts, Souths Graceville Rugby League Club and St Joseph's College Gregory Terrace Rowing Club) will lose direct access to the creek. No compensation costs for loss of amenity have been included in the overall cost estimate.

Potential impacts of the Oxley Creek entrance realignment on the hydraulic behaviour of flooding were assessed by adjusting the Brisbane River detailed hydraulic model to incorporate the lower river bed level and re-running necessary scenarios to cover the 11 AEPs assessed for the Phase 2 (Flood Study).

Table 8-61 Indicative Cost for Oxley Creek entrance realignment (2017 costs)

Description	Cost ($)
Temporary works	5,170,000
Civil / Structures	4,920,000
Earth Works	11,321,400
Other	92,800
Total Direct Job Cost	**$21,504,100**
Indirect Job Costs – On-Site Costs (31%)	6,674,900
Design Costs (9%)	2,536,100
Indirect Costs - Offsite Costs (3%)	921,500
Contractors Margin and Profit (9%)	2,847,300
Applications (5%)	1,754,200
Contingencies (40%)	14,483,200
Total Cost Estimate (Excluding Operating Expenses)	**$50,691,300**
Annual Operating Expenses (assume 2% of capex)	$ 1,013,800

The results of the modelling indicate that the realignment of the entrance of Oxley Creek does not have any material impact on flood levels in the Oxley Creek floodplain for floods within the Brisbane River across all AEPs. Inundation within Oxley Creek is largely caused by backwater from the Brisbane River, supplemented by storage of runoff from the local Oxley Creek catchment. The orientation of the creek entrance does not impact on flood behaviour as the flow dynamics associated with converging flows at the junction would be highly localised. The biggest influence on flood behaviour within Oxley Creek is the flood level in the Brisbane River, which controls the level to which backwaters inundate the Oxley Creek floodplain.

As the hydraulic modelling indicates there are no benefits of undertaking the works from a flood mitigation perspective, a benefit/cost analysis was not carried out, nor was a multi-criteria assessment on broader impacts/benefits associated with the works.

8.10 Comparative Assessment of Options

8.10.1 Costs and Benefits Comparison

A summary of the capital and maintenance costs, as well as the annual average benefits and b/c ratio is provided in Table 8-62. This table shows that capital costs for the various options considered varies from less than $1 million to $1.5 billion. Average annual benefits for the options also vary significantly, from $0.05 million to almost $55 million (if excluding Amberley, as intangible benefits for this option have not been quantified). The resulting benefit/cost (b/c) ratios for the options have been calculated and vary from 0.05 to 0.92.

Table 8-62 Summary of costs and benefits of options

Option	Capital cost ($ million)	Maintenance cost ($ million/yr)	Annual Average Benefit (tangible + intangible) ($ million)	b/c ratio
Fernvale levee	3.2	0.06	0.04	0.12
Amberley Air Base levee	77.2	1.51	-0.41 (1)	-0.04 (1)
Woogaroo Ck flood gates	204	4.08	0.89	0.03
Goodna CBD levee/barrier	28.2	0.56	0.22	0.08
Ipswich CBD flood gate	8.5	0.17	0.75	0.92
Oxley 1 in 50 AEP flood gate	342	6.83	10.1	0.31
Oxley 1 in 100 AEP flood gate / levee	438	8.77	21.7	0.52
South Brisbane temporary barrier	4.13	0.11	0.13	0.28
Brisbane CBD temporary barrier	2.89	0.16	0.29	0.71
Warrill Ck dry flood mitigation dam	546	0.50	28.8	0.69
Kholo dry flood mitigation dam	1,500	1.50	n/c (2)	n/c ((2)
Oxley + Norman + Breakfast Creeks	729	14.6	22.9	0.33
Combined options with Amberley	638	2.45	29.8 (1)	0.59 (1)
Combined options without Amberley	560	0.93	29.9	0.69
Landscape management Scenario 1	n/c (2)	n/c (2)	n/c (2)	n/c ((2)
Landscape management Scenario 2	n/c (2)	n/c (2)	n/c (2)	n/c ((2)
Full tidal reach dredging	1,350	67.3	55.0	0.33

(1) Amberley RAAF Air Base intangible benefits do not include the benefits associated with a functional RAAF base during times of flood. Negative result is due to increased damages from higher flood levels downstream of the air base.

(2) not calculated.

Table 8-63 provides a summary of the maximum number of properties (all types of properties) that benefit from each of the options considered, as well as the maximum number of properties that are detrimentally affected by the options.

Table 8-63 Number of properties impacted/benefiting by options

Option	AEP of maximum benefit (1)	Max. properties benefiting (flood levels > 0.05m lower)	Max. properties impacted (flood levels > 0.05m higher)
Fernvale levee	1 in 100	62	4
Amberley Air Base levee	1 in 100	87	1,798
Woogaroo Ck flood gates	1 in 50	278	213
Goodna CBD levee/barrier	1 in 100	37	9
Ipswich CBD flood gate	1 in 20	25	4
Oxley 1 in 50 AEP flood gate	1 in 50	1,603	2,024
Oxley 1 in 100 AEP flood gate / levee	1 in 100	3,467	12,204
South Brisbane temporary barrier	1 in 100	279	10
Brisbane CBD temporary barrier	1 in 200	401	9
Warrill Ck dry flood mitigation dam	1 in 100 (3)	18,502	3
Kholo dry flood mitigation dam	n/c (2)	n/c (2)	n/c (2)
Oxley + Norman + Breakfast Creeks	1 in 100	4,815	11,718
Combined options with Amberley	1 in 100 (3)	18,562	2
Combined options without Amberley	1 in 100 (3)	18,562	2
Landscape management Scenario 1	n/c (2)	n/c (2)	n/c (2)
Landscape management Scenario 2	n/c (2)	n/c (2)	n/c (2)

(1) Maximum benefit defined by maximum afflux, or maximum flood level reduction, not maximum number of properties affected.

(2) not calculated

(3) As the AEP for maximum impact varies along the floodplain, a mid-point AEP has been selected for comparative purposes.

8.10.2 Multi-Criteria Comparison

The summarised results from the multi-criteria assessment (MCA) are documented in Table 8-64.

Table 8-64 Multi-Criteria Assessment Results Summary

	Safety of people	Social	Economic	Feasibility	Attitude	Key infrastructure	Environment & NRM	TOTAL	RESULT = Score relative to no change
NO CHANGE	*0.63*	*0.25*	*0.50*	*0.38*	*0.25*	*0.25*	*0.25*	*2.50*	***0.00***
Fernvale levee	0.63	0.31	0.44	0.50	0.43	0.28	0.25	2.82	0.32
Amberley levee	0.63	0.18	0.39	0.45	0.23	0.38	0.25	2.49	-0.01
Woogaroo Ck flood gate	0.75	0.28	0.49	0.43	0.13	0.28	0.23	2.57	0.07
Goodna CBD levee	0.66	0.29	0.44	0.45	0.18	0.25	0.25	2.51	0.01
Ipswich CBD flood gate	0.66	0.29	0.56	0.52	0.33	0.25	0.25	2.84	0.34
Oxley 1 in 50 AEP gates	0.38	0.20	0.61	0.45	0.13	0.25	0.23	2.24	-0.26
Oxley 1 in 100 AEP gates	0.25	0.16	0.71	0.43	0.13	0.23	0.23	2.13	-0.37
South Brisbane barrier	0.84	0.28	0.47	0.64	0.38	0.28	0.25	3.13	0.63
Brisbane CBD barrier	0.94	0.28	0.50	0.62	0.35	0.28	0.25	3.21	0.71
Warrill Ck flood mit. dam	1.09	0.38	0.78	0.43	0.35	0.35	0.22	3.60	1.10
Kholo dry flood mit. dam	0.75	0.27	0.47	0.17	0.15	0.28	0.22	2.30	-0.20
Oxley+Norman+Breakfast	0.25	0.16	0.68	0.29	0.13	0.23	0.23	1.96	-0.54
Combined with Amberley	1.19	0.38	0.78	0.43	0.38	0.38	0.23	3.75	1.25
Combined without Amber.	1.19	0.38	0.78	0.43	0.38	0.35	0.23	3.73	1.23
Landscape Mod. Scen. 1	0.75	0.36	0.57	0.40	0.35	0.33	0.42	3.17	0.67
Landscape Mod. Scen. 2	1.00	0.32	0.41	0.15	0.10	0.50	0.48	2.96	0.46

The results of the MCA show a score relative to the ‘no change’ option. Positive scores reflect net overall improvements due to the options, while negative scores reflect net overall worsening of conditions with options implemented. Most options would result in improved conditions, with the Warrill Creek options having the highest positive scores.

The detailed MCA scores, as presented in Figure 8-72, show that there was a large range in expected responses of the different options when considered against the agreed criteria. Scores of 4 or more represent significant and widespread benefits for that criteria, while scores of 1 indicate significant and widespread dis-benefit, which would be difficult to offset or accommodate.

A score of 1 within the MCA therefore represents conditions whereby the option cannot reasonably overcome the negative impact on that criterion and for that reason, should not be considered further (i.e. they are ‘show stopper’ results). A number of options had a score of 1 in one or more criteria, including:

- Woogaroo Creek flood gates;
- Oxley Creek 1 in 50 AEP flood gates;
- Oxley Creek 1 in 100 AEP flood gates / levee;
- Kholo dry flood mitigation dam;
- Combined Oxley, Norman and Breakfast Creeks flood gates / levees; and
- Landscape management Scenario 2 (restore pre-European conditions).

Full MCAs were not carried out for the option to dredge the full tidal reach or realign the Oxley Creek entrance (Sections 8.9.3 and 8.9.4 respectively), however these options were also ruled out. This was due to the very significant costs and negative environmental impacts associated with the extensive dredging scenario, and the inefficacy of the Oxley Creek entrance realignment option.

Criteria category	Criteria detail	Overall weighting	NO CHANGE	Fernvale	Amberley	Woogaroo Ck	Goodna CBD	Marsden Parade	Oxley 1 in 50AEP	Oxley 1 in 100AEP	South Brisbane	Brisbane CBD	Warrill Ck dam	Kholo	Ox/Norm/Break	Comb with Amberley	Comb w/o Amberley	LM Scenario 1	LM Scenario 2
Safety of people	Reduce hydraulic risk rating (now and future)	18.8%	2.5	2.5	2.5	3	2.5	2.5	1.5	1	3.5	4	4.5	3	1	5	5	3	4
	Improve time for evacuation (now and future)	6.3%	2.5	2.5	2.5	3	3	3	1.5	1	3	3	4	3	1	4	4	3	4
Social	Targets vulnerable community members or areas	2.5%	2.5	4	1.5	4	3	3	2.5	2	2.5	2.5	4.5	2.5	2	4.5	4.5	3.5	2.5
	Social health benefits	1.5%	2.5	3	1.5	3	3	3	2	1.5	3.5	3.5	4.5	4	1.5	4.5	4.5	3.5	1
	Improves community flood resilience (now and future)	3.0%	2.5	3	1.5	2.5	3	3	2	1.5	3	3	4	3	1.5	4	4	3.5	3
	Recreation and amenity	1.5%	2.5	2.5	2.5	2.5	2.5	2.5	1.5	1.5	2.5	2.5	2.5	1.5	1	2.5	2.5	3.5	5
	Connection and collaboration	1.5%	2.5	2.5	2.5	1.5	2.5	2.5	1.5	1.5	2.5	2.5	2.5	2	1.5	2.5	2.5	4	5
Economic	Reduce damages and costs to residential property (now and future)	9.0%	2.5	2.5	1.5	3	2.5	2.5	3.5	4	2.5	2.5	4.5	2.5	4	4.5	4.5	3	2.5
	Reduce damages and costs to business and industry (now and future)	5.0%	2.5	2.5	2	2.5	2.5	3	3.5	4	2.5	2.5	4.5	2.5	4	4.5	4.5	3	2.5
	Option likely to be cost beneficial (now and future)	6.0%	2.5	1.5	2.5	1.5	1.5	3	2	2.5	2	2.5	2.5	2	2	2.5	2.5	2.5	1
Feasibility	Physical / technical (now and future)	9.0%	2.5	3	3	3	3	3.5	3	2.5	4	4	3.5	1	2	3.5	3.5	2.5	1
	Legal / approval risk	4.5%	2.5	4	3	3	3.5	3.5	3.5	4	5	4.5	2	1.5	2	2	2	2.5	1
	Potential for additional funding sources	1.5%	2.5	3	3	1.5	1.5	3	1.5	1.5	3.5	3.5	1.5	1	1.5	1.5	1.5	4	1
Attitude	Decision makers	5.0%	2.5	4	3	1.5	2	3.5	1.5	1.5	4	4	3.5	1.5	1.5	3.5	3.5	4	1
	Community	5.0%	2.5	4.5	1.5	1	1.5	3	1	1	3.5	3	3.5	1.5	1	4	4	3	1
Key infrastructure and transport	Improve availability and function (now and future)	5.0%	2.5	3	5	3	2.5	2.5	2.5	2	3	3	4	3	2	4.5	4	3	5
	Protection of regional water supply quality and security - catchment protection (quality and yield)	5.0%	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	2.5	2.5	3	3	3.5	5
Environment and natural resource management	Species impacts	2.0%	2.5	2.5	2.5	2	2.5	2.5	2	2	2.5	2.5	2	2	2	2	2	4.5	5
	Vegetation and habitat impacts	2.0%	2.5	2.5	2.5	2	2.5	2.5	2	2	2.5	2.5	1.5	1.5	2	1.5	1.5	4.5	5
	Ecosystem health and connectivity (fish passage/fauna movement)	2.0%	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	4.5	5
	Reduction in landscape salinity / improved moisture retention and groundwater recharge	2.0%	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.5	4
	Reduction in erosive capacity / soil movement - channel stability / geomorphology	2.0%	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	3	4	5

Figure 8-72 Detailed Multi-Criteria Assessment Scores

8.11 Recommendations

8.11.1 Outcomes from Options Assessment

Short-listed options were assessed as part of this Phase 3 (SFMP) and recommended to progress or abandon as summarised in Table 8-65. Those options not recommended for further consideration are considered to have insufficient merit or unacceptable costs or impacts.

A more detailed commentary of the outcomes of the options assessment presented in the preceding chapters, along with recommendations for next steps, are presented in Table 8-66.

Table 8-65 Summary of options and key assessment outcomes

Progress	Wivenhoe and Somerset Dam upgrades and operations	Progressing via separate study
	Warrill Creek dry flood mitigation dam	MCA = +1.10, b/c ratio = 0.69
	Brisbane CBD temporary barrier	MCA = +0.71, b/c ratio = 0.71
	Landscape management scenario 1 (targeted revegetation)	MCA = +0.67
	South Brisbane temporary barrier	MCA = +0.63, b/c ratio = 0.28
	Fernvale levee	MCA = +0.32
	Ipswich CBD flood gate	MCA = +0.34
	Goodna CBD levee and barrier	MCA = +0.01
	Amberley Air Base levee	MCA = -0.01, only if mitigated
	Mt Crosby West Bank WTW levee	Seqwater action only
Abandon	Woogaroo Creek 1 in 50 AEP flood gates	One or more criteria have ‘show stopper’ score of 1.0 representing unacceptable and largely unmitigable impacts
	Oxley Creek 1 in 50 AEP flood gates	
	Oxley Creek 1 in 100 AEP flood gates	
	Kholo dry flood mitigation dam	
	Oxley + Norman + Breakfast Creeks flood gates	
	Full tidal reach dredging	
	Re-alignment of Oxley Creek entrance	MCA = 0.0, no benefit
	Landscape management scenario 2 (restore pre-European conditions)	Hypothetical only

Table 8-66 Recommendations for short-listed floodplain management options for the Brisbane River

Option	Commentary	Progress / Abandon
Fernvale levee	The levee would be beneficial for only a small number of properties and within a narrow range of floods (around the 1 in 100 AEP only). The economic benefits from this are small and are less than annual maintenance costs. If there are other drivers for implementation, then this option could be pursued further, but recognising that benefits are localised. Next steps: Undertake a local options assessment to explore other means of mitigating flood risk in Fernvale for comparison with the levee option.	**Progress**
Amberley Air Base levee	The value of this option relates to the intangible benefits of maintaining a functional RAAF base during times of flood. Further consultation with Department of Defence is recommended to ascertain the relative priority for RAAF to keep this base functional. It is understood that a significant issue for base function is access into and out of the base via public roads, mainly the Cunningham Highway. Works would be required to improve accessibility in concert with the Air Base levee. The proposed Warrill Creek dry flood mitigation dam would also provide sufficient road access for floods up to the design standard of the levee. In the absence of other accompanying flood mitigation works (e.g. Warrill Creek dry flood mitigation dam) the air base levee would have a detrimental and potentially unacceptable impact on a large number of properties downstream. This option should only be considered further if combined with other works that would offset this downstream impact. Next steps: Consult with Department of Defence to determine appetite for collaborative flood mitigation of the Amberley RAAF Air Base.	**Progress**
Woogaroo Creek flood gates	The very high capital cost, including prohibitive pump requirements to remove local catchment flooding, means there are very low economic returns from this option (which protects to a 1 in 50 AEP level only). This option is not recommended due to poor benefit/cost ratio and an expected lack of community support. Next steps: No further action recommended.	**Abandon**
Goodna CBD levee/barrier	Goodna CBD experienced severe flooding in 2011. To protect the area from similar floods in the future, major infrastructure would be required, including flood gates across a very large underpass. The high cost for this option, which directly benefits just 30 businesses, would be difficult to justify and therefore this option is considered a very low priority for further consideration. Next steps: Undertake a local options assessment to explore other means of mitigating flood risk in the Goodna CBD.	**Progress**
Ipswich CBD flood gate	This flood gate at Marsden Parade is reasonably expensive at ~$8m, however, the annual benefits are high as it targets an area that is affected by more frequent flood events. Benefits are limited to the commercial properties in Ipswich CBD, but this indirectly benefits the larger community through improved resilience. Further technical investigations are required regarding the safety of the rail embankment	**Progress**

Option	Commentary	Progress / Abandon
	which would become a default levee of significant flood depth. This option could be pursued further, cautiously, and in close consultation with DTMR. Next steps: Consult with QR/DTMR regarding feasibility of option and integrity of railway embankment for flood impoundment.	
Oxley 1 in 50 AEP flood gate	The Oxley Creek 1 in 50 AEP flood gates worsens flooding for a large number of properties downstream and elsewhere along the Brisbane River. Even though the net economic return is positive (i.e. the economic benefits of properties protected behind the levee exceeds the economic dis-benefit of properties downstream), this option should not be pursued given these off-site impacts and significant cost. This option would not provide protection if a flood equivalent to the 2011 event occurred again. Next steps: No further action recommended.	**Abandon**
Oxley 1 in 100 AEP flood gate / levee	As per the 1 in 50 AEP flood gates, this option should not be pursued due to cost and widespread impacts on downstream properties. Some 12,000 properties would be worse off from this option, while only 3,500 properties would directly benefit. The net economic value of the option is positive given the extent of protection offered to those properties within the Oxley Creek floodplain. This assessment highlights the importance of flood storage areas within the Brisbane River given that there are limited flood storage areas beyond the main river channel area. Next steps: No further action recommended.	**Abandon**
South Brisbane temporary barrier	The South Brisbane temporary barrier benefits a large area of potential inundation in South Brisbane, although the present design as considered does not offer protection to riverside commercial and tourism enterprises due to practicality constraints. This option creates benefit within a very narrow range of floods, only around the 1 in 100 AEP event. As a result, the economic return is limited, especially as the lifespan of the barrier would only be about 30 years before replacement is required. It is recommended that further investigations are carried out to explore a more refined design and costing. This would need to identify all potential avenues for inundation of the South Bank / South Brisbane area, including underground carparks. Depending on the outcomes of this local investigation, the suitability and economic practicality of this option may change. Included within this further investigation should be the option to deploy the barrier at other affected locations (e.g. in smaller flood events that would not inundate South Brisbane). This may increase the economic benefit of the option and improve the b/c ratio. Next steps: Undertake a local investigation at higher resolution to confirm all possible flowpaths for inundation and refine the works and costs associated with temporary impoundment. Commence discussions with manufacturers of temporary barriers regarding design and installation considerations, including appropriate risk mitigation. This would most ideally be done in concert with the Brisbane CBD assessment (see below).	**Progress**

Option	Commentary	Progress / Abandon
Brisbane CBD temporary barrier	The Brisbane CBD barrier benefits a large number of properties, but only for a very narrow range of floods, around the 1 in 200 AEP event. With an expected design life of only 30 years, the probability of deployment during a design life is relatively small. The b/c ratio for this option is 0.71. The temporary nature of this option and the value that it can bring to the Brisbane City economy when deployed is attractive and would garner community and stakeholder support. It is recommended that further investigations are carried out to explore a more refined design and costing. Included within this further investigation should be the option to deploy the barrier at other affected locations (e.g. in smaller flood events that would not inundate the Brisbane CBD). Next steps: Undertake a local flood investigation at higher resolution to confirm all possible flowpaths for inundation and refine the works and costs associated with temporary impoundment. Commence discussions with manufacturers of temporary barriers regarding design and installation considerations, including appropriate risk mitigation. This would most ideally be done in concert with the South Brisbane assessment (see above).	**Progress**
Warrill Creek dry flood mitigation dam	This option would have widespread benefits to properties within the Bremer River, and also to properties in the mid Brisbane River and lower Brisbane River areas. Benefits occur across the full spectrum of floods, but only for floods that have a significant contribution of runoff from Warrill Creek. Benefits extend to regional access, with the Cunningham Highway maintaining trafficability for floods up to the 1 in 100 AEP across the Warrill/Purga floodplain. Previous investigations by the former DEWS (now DNRME) on this option found a low b/c ratio. Refined benefits for downstream flood damages as established by this Phase 3 (SFMP), warrant reconsideration of this option. Further, optioneering of the design and layout of the structure may reduce costs, which would further improve b/c ratio. The opportunity for combining flood mitigation outcomes with a national infrastructure project (Southern Freight Railway) means that costs for the project, which are very high, may be less of a barrier than if it was to be constructed for flood mitigation alone, although the embankment design will need to be to a higher (dam) standard. There may also be other waterway crossings where it is viable to incorporate detention basins into the design of the Southern Freight Railway. Due to the scale and regional benefits of this option, it is recommended that the State Government lead further investigations as proponent, in consultation with ARTC and Seqwater. Progressing this option is a high priority given the Southern Freight Railway project is further advanced. Next steps: Determine State Government proponent agency. Consult with DNRME and Seqwater and undertake more detailed assessment of this option including hydrologic modelling, consideration of interaction with dam operations, and failure assessment. Consult with ARTC regarding the potential for integration of the option into the Southern Freight Railway infrastructure proposed in the same vicinity	**Progress**

Option	Commentary	Progress / Abandon
	as a means of overall cost and footprint reduction. Technical feasibility investigations including geotechnical drilling and test pits.	
Kholo dry flood mitigation dam	While detailed hydraulic modelling of this option was not carried out, the assessment presented in this Phase 3 (SFMP) is sufficient to support abandoning this option from further consideration. The space required for a PMF spillway and the significant impacts on upstream properties would be a major barrier for progress and would require extensive property acquisition including the village of Fernvale. The very high cost associated with dam construction and property acquisition is beyond ordinary budgets. There are a number of alternatives that provide similar levels of flood mitigation, are lower cost, and have less disruption to local communities. For this reason, there is no immediate merit in continuing with this option. Next steps: No further action recommended.	**Abandon**
Oxley + Norman + Breakfast Creeks	Similar to the Oxley 1 in 100 AEP levee and flood gates alone, this combined option would result in widespread downstream impacts, affecting some 12,000 properties. The benefit from this option is limited to the properties located behind the structures only. Although the net benefit is positive (i.e. the positive economic benefits of flood mitigation far outweigh the negative economic dis-benefits from flood worsening), the scale of the off-site impacts are unacceptable. Comparing this option to the Oxley Creek only results, it is clear that the vast majority of properties benefiting from this option are located behind the Oxley Creek structure. The additional high costs associated with levees and flood gates on Norman Creek and Breakfast Creek provide protection to relatively few properties. This option is not recommended due to the unacceptable impacts on off-site properties, as well as the very low b/c ratio. Next steps: No further action recommended.	**Abandon**
Combined options with Amberley	As outlined above, the Warrill Creek dry flood mitigation dam is a high priority option for further consideration. The combined options assessment, including Amberley Air Base, confirms that when the higher priority options are implemented together, they do not have unintentional detrimental outcomes or negate the value of individual solutions. The combination of the Warrill Creek dry flood mitigation dam and Amberley Air Base provides a more targeted local solution to flooding, with the dry flood mitigation dam achieving a level of flood immunity for the Cunningham Highway that would otherwise still be required if the Amberley Air Base was to be pursued. As outlined above, further consideration of the Amberley Air Base levee should be subject to discussions with the Department of Defence. Department of Defence contribution to the Warrill Creek dry flood mitigation dam as a means of gaining access to and from the base during time of flood, as well as federal funding as part of the Southern Freight Railway, should also be explored to build upon a multi-lateral approach to floodplain management. Next steps: Pursue options within this combination separately as detailed above, with the exception of Amberley air base levee, which should only be pursued in concert with, or subsequent to, other works to offset potential downstream impacts on properties.	**-**

Option	Commentary	Progress / Abandon
Combined options without Amberley	In the absence of the Amberley Air Base levee option, other higher priority options can still be pursued, in combination, with an understanding that the benefits associated with these options are essentially cumulative. There may be some cost advantages for pursuing options concurrently, such as the two temporary barriers. Next steps: As detailed above for the individual options.	-
Landscape management Scenario 1	Landscape management Scenario 1 involves targeted revegetation of areas across the upper catchment of the Brisbane River. It is very difficult to assess the flood mitigation benefits that would emerge over time as a result of this work, particularly given that it would take many years/decades for the vegetation to mature and impact on catchment hydrology. Notwithstanding this uncertainty, there are many other benefits and values associated with targeted catchment revegetation, which have been highlighted as part of the MCA. It is recommended that catchment revegetation works are supported and advanced as part of broader Integrated Catchment Planning initiatives underway across the region by various organisations, so that future flood management benefits can be realised. In general, the larger the area of revegetation, the greater the potential for modifying hydrologic behaviour of catchment runoff. Catchment revegetation will be more effective at impacting flooding for smaller events (e.g. less than 1 in 10 AEP) than larger events (1 in 50 AEP or larger). It is noted that very few residential or commercial buildings within the Brisbane River floodplain are impacted by these smaller events. Next steps: Continue to support the implementation of existing CAPs and Resilient Rivers Initiative and ensure that the multi-benefits of landscape measures and Integrated Catchment Planning actions are recognised, including potential for modifying catchment hydrology in smaller flood events and therefore reducing flood impacts downstream.	**Progress**
Landscape management Scenario 2	Landscape management Scenario 2 involves restoring pre-European conditions across the full Brisbane River catchment. This is purely a hypothetical scenario that was included for comparative purposes only. The large population of the catchment would preclude this scenario from being a realistic option. There is no reason for considering this option further beyond a simple comparison to represent fully 'natural' conditions. Next steps: No further action recommended.	**Abandon**
Mt Crosby West Bank WTW levee	This option was not assessed in detail, but rather, modelling results for the 1 in 10,000 AEP levee were provided to Seqwater for their consideration in future infrastructure planning. It is recommended that on-going support is provided to Seqwater in their future considerations of this option and other similar options aimed at improving the resilience of water infrastructure across the region. Next steps: Support Seqwater in further assessment of this option.	**Progress**
Full tidal reach dredging	A detailed MCA was not carried out for this option, as it was discounted in the preliminary stages of this Phase 3 (SFMP). Costings and benefits were assessed for comparative purposes only. Although dredging over the full 85km long tidal reach would lower flood levels, the very high capital and maintenance costs, combined with the	**Abandon**

Option	Commentary	Progress / Abandon
	expected significant environmental impacts (and especially associated with the disposal of the 38 million cubic metres of material), confirm that this option has no realistic merit for further consideration in mitigating flooding in the Brisbane River. Next steps: No further action recommended.	
Oxley Creek entrance realignment	The flood modelling for this option confirms that the current alignment of the entrance of Oxley Creek does not have a material impact on the extent of flooding within the Oxley Creek floodplain or in other surrounding locations. Therefore, with no material benefit, this option is not recommended. Next steps: No further action recommended.	**Abandon**

8.11.2 Further Investigations Summary

A summary of specific further investigations associated with the higher priority options that are recommended as an outcome of the Phase 3 (SFMP) is as follows:

- Warrill Creek dry flood mitigation dam: Determine State Government proponent agency, optioneering and technical feasibility investigations to refine and optimise the design of the structure in order to reduce capital costs and to accommodate the multiple needs of stakeholders, including ARTC regarding Southern Freight railway, DTMR regarding Cunningham Highway and relevant power distribution organisation regarding high voltage power lines.
- Warrill Creek dry flood mitigation dam: Re-evaluation of design hydrology for the Brisbane River including re-assessment of the 11,340 events carried out using the Fast Model and a repeat of the Total Probability Theorem (TPT) with the Warrill Creek dry flood mitigation dam in place to accurately establish the flood mitigation potential of the structure.
- Warrill Creek dry flood mitigation dam: Assessment of the combined effects on flood behaviour throughout the Brisbane and Bremer Rivers when considered in concert with proposed upgrade works for Wivenhoe Dam.
- Wivenhoe Dam: Support on-going investigations by DNRME and Seqwater on whether there is a suitable and appropriate upgrade option for Wivenhoe Dam (or other alternatives) that will reduce existing flood risks throughout the Brisbane River, and help to abate future exacerbation of flood risks due to projected climate change impacts.
- Temporary barriers: Assessment of the portability, storage, installation and safety requirements of temporary barriers and the opportunity to use a barrier at different locations depending on the nature and forecast extent of the flood risk.
- Other dry flood mitigation dams: Using the same concept as the Warrill Creek dry flood mitigation dam, investigate other locations within the Brisbane / Bremer catchments where large scale flood mitigation dams can be established to reduce the magnitude of flood flows from the catchment, by configuring and designing new floodplain crossings of the Southern Freight Railway or other major linear infrastructure to appropriate dam standards for detention of floodwaters.

8.12 Limitations

With respect to structural and landscape management options assessment, there have been a large number of assumptions made, particularly with respect to concept design, costings for works and economic analysis. These assumptions have been noted through this chapter where relevant.

With respect to the hydraulic analysis of structural and landscape management options, only the 60 events used to define the 11 AEPs were considered, as per the Phase 2 (Flood Study). Over 11,000 different events were originally considered as part of the Phase 2 (Flood Study). Where options would significantly modify flood behaviour (such as the Warrill Creek dry flood mitigation dam and landscape management options), re-consideration of all 11,000 events will be required to ensure that appropriate events are chosen based on peak flood levels throughout the river as part of further, more detailed investigations.

9 Land Use Planning

9.1 Planning Context

9.1.1 Land Use Planning as a Response to Flood Risk Management

Land use planning is an effective mechanism available to State and local governments and other planning authorities to reduce the future exposure and vulnerability of people and property to flood hazard by establishing risk appropriate strategic land use policy and development requirements for new development.

Best practice risk based land use planning is underpinned and informed by robust flood hazard and risk assessments and ideally, should be considered as part of an integrated response to flood risk management through a local floodplain risk management planning process. Risk-based planning recognises that different land uses have different degrees of susceptibility to the risks posed by flooding and this means that some land uses are more or less appropriate to different parts of floodplains. The appropriateness of land use to the extent of flood risk depends on the vulnerability of people, land use type, density and built form. Risk-based planning ensures that land use is risk responsive and is appropriately located in the floodplain according to land use sensitivity to the level of flood risk.

9.1.1.1 The Role of Land Use Planning in Avoiding and Mitigating Flood Risk

Land use planning instruments play a primary role in the regulation of new development. They regulate the location, scale, form, function and impact of development proposed to be undertaken within the area of the planning instrument.

Given the role that planning instruments play in shaping communities and regulating development, land use planning plays an instrumental role in avoiding or mitigating flood risk to new development and in managing the impacts of new development on the extent of flood risk experienced by land use in proximity to the new development and elsewhere on the floodplain.

Whilst the role of land use planning risk treatment measures play a critical role in managing flood risk to new development, land use planning is however only one mechanism within an integrated suite of flood risk management responses, as identified in best practice literature (HNFMSC, 2006; QRA, 2012; AIDR, 2016 & 2017) and the recommendations of the Queensland Floods Commission of Inquiry (QFCoI, 2012).

A key challenge in the establishment of land use planning risk treatment responses is the intersection and balance of these treatment measures with others, described herein, such as understanding current and future flood risk, structural mitigation options, disaster management, landscape management, community awareness and resilience and building controls. Further to this, the land use planning process is often undertaken within a context characterised by multiple complexities including the need to consider a broad range of planning issues, constraints and desired community outcomes in the local context.

In Queensland, local governments are also required to consider and 'balance' land use planning responses to all 17 State Planning Policy State interests (see Section 9.5 for further discussion on this matter). In this context, flood risk is only one of a number of issues and constraints to be considered and balanced in the planning process and when determining land use planning and development outcomes.

While it is recognised that flood risk is only one of a number of planning considerations, it is an important one given implications for risk to life and potential for property damage. Therefore, a key objective of the SFMP and supporting Land Use Planning Guidance is not to 'sterilise' development in the Brisbane River floodplain, but to provide better information and 'tools' for the planning process to place risk appropriate land use such as flood sensitive land uses in less hazardous locations, to better manage the design of development in the floodplain and to provide a consistent approach to emergency management and other flood risk management options.

Hence, the consideration of flood risk treatment options, including land use planning responses, should be informed by an integrated flood risk assessment and local floodplain management planning process to ensure that:

- the optimal mix of flood risk treatment measures are identified; and
- the mix of flood risk treatment measures achieves the degree of risk treatment sought.

The key flood risk management outcomes in the Brisbane River floodplain that are being sought specifically through land use planning responses to flood risk are:

- resilience of the region's settlement pattern to current and future flood risk (including climate change factors), through a risk-based planning approach focussing on land use being risk appropriate for the location in the floodplain, including special treatment of vulnerable uses involving vulnerable people; and
- 'no worsening' of flood risk arising from new development.

A key concept influencing risk based land use planning outcomes in the Brisbane River floodplain is 'regional consistency'. 'Regional consistency' can be defined as the achievement of consistent floodplain management outcomes across administrative boundaries in the floodplain.

In the context of land use planning, the application of this concept requires a collaborative, whole of floodplain perspective by planning authorities in the establishment and implementation of local responses to common flood risks in land use planning activities and planning instruments.

Regional consistency is considered to be most effectively achieved by the common implementation of shared flood risk management approaches by floodplain managers across the floodplain. As such, the application of this concept requires collaboration with neighbouring authorities to ensure that regional consistency is achieved.

Section 9.5.4 of this report identifies in detail those matters that are considered to warrant a regionally consistent approach for land use planning.

9.1.1.2 Understanding Flood Hazard and Risk as the Foundation of Risk Based Land Use Planning in the Brisbane River Floodplain

Flooding occurs at a catchment scale and does not respect administrative boundaries. Fundamental to effectively managing flood risk to people and property across a floodplain is having a common understanding of flood behaviour across the full spectrum of hazard conditions and flood likelihoods at a whole of floodplain scale. This means having a regionally consistent approach in how floodplain behaviour and flood risk is defined, characterised, mapped and prioritised across the whole floodplain. Underpinned by a consistent understanding of floodplain behaviour, effective flood risk management also requires an integrated and whole-of-catchment approach using a suite of implementation tools, one of which is land use planning.

The Brisbane River floodplain extends through the four (4) local government areas of Brisbane, Ipswich, Somerset and Lockyer Valley. Current flood risk management responses and approaches, including land use planning, vary across the Brisbane River floodplain with differing methodologies for defining, describing, mapping and assessing the extent and degree of flood risk to people and property. A causative factor of inconsistency in approach is the use of different flood studies, models and methodologies for defining and responding to flood risk across the catchment. It is also recognised there will be differing approaches within and outside the SFMP Study Area and a need for locally tailored responses to account for the complexity, vulnerabilities and differences across the catchment.

In response to flooding in 2010–11, Recommendation 2.2 of the QFCoI identified the need for *"a flood study of the Brisbane River catchment* [to be completed] *in accordance with the process determined by them* [Brisbane City, Ipswich City and Somerset Regional Councils and the Queensland Government]. Chapter 2 of the QFCoI report proper supports a regionally consistent, whole-of-floodplain approach to floodplain management and flood risk response, supported by robust flood data and a risk-based planning approach. These key floodplain management concepts – regionally consistent, whole-of-floodplain, robust flood data, risk-based planning – are first introduced in Chapter 2 (QFCoI) and are discussed below.

The Commissioner's preface (page 31 of the report proper) recognised that *"in land use planning, attention to flood risk has been ad hoc. The recommendations made* [in the QFCoI] *are designed to insert into the land planning system <u>uniform controls which will ensure that the risk of flood is consistently recognised and planning assessments made with regard to it.</u> Queensland also lacks a coherent approach to floodplain management; a number of recommendations have been made relating to the need for current and comprehensive flood studies and flood mapping, particularly in urban areas."* [Emphasis added]

In direct response to Recommendation 2.2, Phase 2 (Flood Study) was prepared using state-of-the-art hydrologic and hydraulic models in accordance with national and state best practice, including Australian Rainfall and Runoff (Ball et al., 2016). The QFCoI's independent review panel *"'strongly recommend(ed)' that a Monte Carlo analysis be performed 'as Council*[s] *moves towards a risk-based approach to flood management'"* (section 2.4.1, page 50 of the report proper). The expert panel found that *"…the* [flood] *study should be comprehensive in use of data sources and range of methodologies."* (section 2.3.2, page 42). Section 2.5.1 of the report (page 54) goes on to recommend that *"a flood study should be completed over a whole catchment to encompass the hydrology and hydraulics of all relevant waterways."*

The scope of work associated with Phase 1 (Data collection) and Phase 2 (Flood Study) has led to one of the most advanced and sophisticated riverine flood models in Australia and internationally. Phase 3 (SFMP), informed by Phase 2 (Flood Study), provides a comprehensive and regionally consistent understanding of flood behaviour by defining potential hydraulic risk across the floodplain. This definition of potential hydraulic risk informed the flood risk management actions for the SFMP, and guidance has been provided on how to use potential hydraulic risk along with other flood risk factor tools, to inform a more refined or nuanced risk-based approach to land use planning.

9.1.1.3 'Potential Hydraulic Risk' as a Shared Foundation of Flood Risk Assessment

Section 4.2 discusses potential hydraulic risk in detail. Application of an agreed Potential Hydraulic Risk matrix provides a technical basis to achieving regional consistency in the identification and prioritisation of flood risk across the floodplain through an integrated risk assessment and local floodplain management planning process. In the Brisbane River floodplain, the SFMP Potential Hydraulic Risk matrix provides a common or shared technical basis to identify and respond to flood risk, including differences in understanding of floodplain behaviour. Potential implications include, for example, not having a consistent understanding of flood behaviour 'impacts' on land use, implications for evacuation planning across the floodplain and understanding where in the floodplain filling should be avoided or minimised to maintain flood flow conveyance areas and storage areas. Therefore, having a common region-wide understanding of flood behaviour is essential to effective and integrated flood risk management and is underpinned by a consistent approach to how flood likelihoods and flood hazard/behaviour (i.e. hydraulic risk) is defined and understood. Understanding the hydraulic risk 'constraints' at the 'whole of floodplain', locality or site based scale is fundamental to informing risk-based land use planning. The use of a common potential hydraulic risk matrix and mapping, together with other flood risk factors, will inform flood risk assessments and flood risk management responses including land use planning (as well as other responses). Regional consistency will be improved through all floodplain managers, including planning authorities, working from the same definition and understanding of hydraulic risk across the Phase 3 (SFMP) Study Area.

To maintain regional consistency in how potential hydraulic risk is defined and understood, it will be important for all floodplain managers to use and apply the agreed SFMP potential hydraulic risk matrix in a consistent way. This can be achieved by:

a) using the defined Potential Hydraulic Risk Matrix (refer Figure 4-4) and mapping from the Phase 3 (SFMP) to inform a local risk assessment and/or a local floodplain management plan; or
b) translating the SFMP defined Potential Hydraulic Risk Matrix and categories into local flood studies, local flood risk assessments or local floodplain management plans that further refine the on-the-ground mapping of the matrix at the local level.

Spatially representing potential hydraulic risk requires judgement by experienced professionals informed by detailed appreciation of the hazards involved and the objectives of the flood risk assessment outcomes. Inconsistent application or independent variation of the agreed potential hydraulic risk matrix across the floodplain, or different approaches to how the flood hazard is defined across local government boundaries, means that regional consistency will not be achieved.

The intent is to ensure, for example, that a HR1 area in one local government area is defined in the same way as a HR1 area in the adjoining local government area. Importantly for land use planning, this will mean that land use planning responses across the floodplain are informed by the same definition of flood characteristics and flood behaviour.

A shared definition and understanding of potential hydraulic risk across the floodplain provides the robust technical basis upon which a regionally consistent risk-based approach to land use planning can be achieved. Of the range of flood risk factors, hydraulic risk is one of the most important flood risk factors for informing risk-based land use planning. This is because an understanding of the hydraulic frequency and flood hazard conditions is a key factor in considering potential risk to life in particular and a determining factor as to whether development may be acceptable, tolerable or intolerable to the level of flood risk, and that it meets community expectations.

The application of an agreed potential hydraulic risk matrix in informing flood risk assessments and/or local floodplain management plans will also assist in addressing (in part) the key requirements mandated by the SPP and QFCoI, such as identifying at least three bands of flood risk and assessing the full range of flood events up to and including an extreme event, such as the Probable Maximum Flood (PMF). The QFCoI panel of experts, in section 2.3.2 of the report (page 42), provided the following recommendation to the Commission: that *“a* [flood] *study should be conducted over a range of possible floods from the flood with a 50 per cent annual exceedance probability through to the probable maximum flood”*. For planning purposes, sections 2.7.5 and 2.8 (pages 63 and 68) of the report conclude that *“the various areas to which planning controls apply should be selected having regard to the likelihood, behaviour and consequences of the full range of possible floods, up to and including the probable maximum flood…When planning for a future flood event, it is necessary to have an understanding of the full range of flood events so as to plan for any eventuality…”*

In addition, the SPP Natural Hazard, Risk and Resilience, (Flood) Guidance Material (State interest policy 2, page 11) provides the following direction in respect of identifying the PMF: *“flood risk assessments should consider the widest range of flood events for which data is available. That is, where a flood study includes a range of design events (from frequent to rare), these should be incorporated in flood risk assessment so that a fuller picture of flood behaviour and risks can be understood across the floodplain.”* The SPP Guidance Material (section 2.4, table 1) recommends that flood risk assessments: *“consider the widest range of flood events possible across the risk spectrum (i.e. for which data is locally available).*

At a minimum this should include:

a) the defined flood event
b) several more frequent floods and a slightly rarer/more extreme flood
c) the probable maximum flood (if available).”

The AIDR Managing the Floodplain (Handbook 7) (AIDR, 2017) also suggests *“considering the full range of flood risk in zonings* [to] *encourage development in locations where it is compatible with flood function and flood hazard…”* (Chapter 8, page 47). The Handbook states that “*knowing the consequences of the full range of flooding can inform decision making on risk reduction to the existing community to more tolerable levels and limit the growth of risk resulting from new development”* (Chapter 7, page 40).

Phase 3 (SFMP) has considered the full range of flood events in defining and mapping potential hydraulic risk – up to and including the 1 in 100,000 AEP (PMF). As such, the Phase 3 (SFMP) Potential Hydraulic Risk matrix is considered the most appropriate tool to identify the ‘full picture’ of potential hydraulic risk as an input into flood risk assessments (and local floodplain management plans) for urban areas of the floodplain, as required by State interest policy 2.

9.1.1.4 Limitations of Commonly Applied Land Use Planning Responses to Flood Hazard and Risk

Longstanding approaches to floodplain management across Australia have primarily relied on mapping a single defined flood event, such as the 1 in 100 AEP, and relying on the Defined Flood Event (DFE) as the main development control to 'design out' flood impacts and provide flood immunity.

This approach is recognised as being too simplistic in responding to flood risk in that it does not represent the full range of floods likely to be experienced, including rarer events up to (and including) the Probable Maximum Flood (PMF) and does not necessarily capture flood behaviour. This can misrepresent the risk to life and property posed by hydraulic risk. In addition, other flood risk factors not necessarily determined by a DFE need also to be considered in establishing a full assessment of flood risk. Also, through mapping of a single event only, this creates a false sense of community safety and messages that can potentially conflict with emergency management plans. Therefore, the mapped flood hazard area does not necessarily represent the full flood risk affecting development, and regulation may not be appropriate to the actual level of flood risk.

The risk-based management approach adopted in the Phase 3 (SFMP) aims to resolve the above issues in the following way:

- by providing better information in the planning process to ensure flood sensitive land uses occur in less hazardous locations;
- to provide clarity and the necessary tools for local governments to address flood risks in planning;
- to better manage the design of development in the floodplain;
- to provide a consistent approach with emergency management objectives; and
- to deal with uncertainty in planning for natural hazards.

The intent of the SFMP and supporting non-statutory SFMP Land Use Planning Guidance Material (see **Land Use Planning Guidance Material Addendum**) is to promote a risk-based approach and to provide guidance on how to use the flood risk factor tools to inform land use planning and development responses that are commensurate to the level of risk.

Understanding hydraulic risk, relative time to inundation and evacuation capability, in particular, are key flood risk factors when considering risk to life from flood and determining if land use is appropriate to its location in the floodplain. Establishing the DFEs and other built form controls for designing development are important for managing risk to property, but should be secondary to first determining whether the land use is appropriate for the location after considering the hydraulic conditions and implications of flood behaviour and other flood risk factors. The establishment of risk appropriate land use and development in the floodplain is an important first principle of risk-based planning. This is identified as the overarching land use planning aspiration (Aspiration 5) in the SFMP, viz: *"land use is planned and located to ensure that development appropriately responds to the level of flood risk"*. The expectation is that planning authorities, through the Phase 4 (LFMP) process, will undertake more detailed analysis through local risk assessments and/or LFMPs and consider land use planning risk treatment responses within the floodplain having regard to the strategic analysis undertaken in Section 9.4.

9.1.2 Current Policy Direction

9.1.2.1 Queensland Floods Commission of Inquiry (QFCoI)

Phase 2 (Flood Study) was prepared in response to one of the pre-eminent recommendations of the Inquiry, Recommendation 2.2: *"Brisbane City Council, Ipswich City Council and Somerset Regional Council and the Queensland Government should ensure that, as soon as possible, a flood study of the Brisbane River catchment is completed in accordance with the process determined by them under recommendation 2.5 and 2.6…"*

What also emerged from the QFCoI was the notion of integrating risk management principles into floodplain management practice. This included a requirement for *"councils in floodplain areas should, resources allowing, develop comprehensive floodplain management plans that accord as closely as practicable with best practice principles"* (Recommendation 2.12). Recommendation 2.13 reinforces these risk-based considerations, and relates to producing flood mapping *"which shows 'zones of risk' (at least three) derived from information about the likelihood and behaviour of flooding."*

The QFCoI report provides the context for, and evidence upon which, the Commission formed its recommendations. It should therefore be read as a whole when interpreting the above recommendations. Section 2.7.3 of the QFCoI report (page 64) emphasises that *"a map showing both likelihood and behaviour is best practice… It allows the risk of flooding to be understood across the full spectrum of floods, thus enabling the appropriate flood-related planning controls to be used in development assessment."* In the context of risk-based planning, these planning controls will be tailored to the different 'zones of risk' and the underlying land use zoning.

The above findings are carried forward in several planning recommendations (5.2, 5.4, 5.6 and 8.1); these recommendations strongly support embedding the different categories or 'bands' of flood risk in all layers of a planning instrument to inform risk-appropriate development assessment provisions – in the levels of assessment, flood overlay code, map and planning scheme policy. The SFMP delivers on this risk-based approach by defining hydraulic conditions for different flood likelihoods and sizes across the floodplain and establishes a consistent technical baseline for regional and local flood risk assessments.

9.1.2.2 State Planning Policy and State Interest Guidance Material – Natural Hazards, Risks and Resilience (Flood)

The State Planning Policy (SPP) 2017, Natural Hazards Risk and Resilience state interest, requires the development of an integrated, evidence-based risk management framework for land use planning and development in natural hazard areas. A fit-for-purpose risk assessment prepared in accordance with the International Risk Standard (AS/NZS ISO 31000:2009) is required under the SPP to inform the preparation of risk-responsive planning instruments.

The SPP (Flood) Guidance Material clarifies that risk assessments should take into account the local circumstances, floodplain behaviour and future development intended for the area in determining where and what type of land uses would be acceptable, tolerable or intolerable to flood risk. This process will also determine the exposure, vulnerability and tolerability of different land uses and development types to flood risk in setting risk-appropriate planning responses.

These assessments are underpinned by the SPP's policy position of *"avoiding or mitigating the risks associated with natural hazards to an acceptable or tolerable level..."* (Natural hazards, risk and resilience state interest, page 50). In particular, State interest policy 4 (page 51) contemplates that development in flood (among other hazard affected) areas *"(a) avoids the natural hazard area, or (b) where it is not possible to avoid the natural hazard area, development mitigates the risks to people and property to an acceptable or tolerable level."* The SPP Guidance for State interest policy 4 also promotes the use of zone allocations to avoid flood risk – *"a risk responsible settlement strategy…for inclusion in the strategic framework and reflected in zoning for at-risk locations"*, especially where other scheme provisions (e.g. built form) will not reduce risk to a tolerable level.

Phase 3 (SFMP) produces a consistent methodology and set of hydraulic hazard and likelihood conditions for mapping flood risk across the floodplain, building on the flood hazard evidence established as part of Phase 2 (Flood Study). Other flood risk factor tools have also been developed in Phase 3 (SFMP) to assist local governments in preparing local risk assessments in accordance with the SPP. Section 9.5 also offers a land use planning toolkit to evaluate risks and identify appropriate response options (e.g. through zoning, assessment benchmarks and in the strategic planning process of future urban areas).

9.1.2.3 ShapingSEQ – South East Queensland Regional Plan 2017

As part of its 'Sustain' theme, the ShapingSEQ - SEQ Regional Plan 2017 (herein Regional Plan) puts forward strategies for integrated risk management planning, adaptation and avoidance of high-risk areas to reduce vulnerability and improve regional resilience.

The Regional Plan's implementation program for the 'Natural Hazard Management (flood risk)' action commits to improving community resilience and the management of flood risks in a coordinated way.

In the Brisbane River Catchment, the Regional Plan acknowledges the SFMP as a mechanism for the implementation of regional policy and incorporates an action that tasks QRA *"to work with relevant local governments to:*

- *prepare the Brisbane River Strategic Floodplain Management Plan*
- *implement outcomes through planning schemes".*

9.1.2.4 Hierarchy of Floodplain Risk Management Plans (FRMP) in the Brisbane River Catchment

The State's interest in natural hazards, risk and resilience, as described in the State Planning Policy – July 2017 (SPP) state interest - natural hazards, risk and resilience, seeks to ensure natural hazards including flooding are properly considered in all levels of the planning system and must be appropriately integrated or considered when undertaking the activities to which the SPP applies. Phase 3 (SFMP) identifies flood risk management issues and mitigation measures that would benefit from regional consistency at the whole of floodplain scale within the Brisbane River floodplain. It also establishes a regional flood risk management (FRM) framework that delivers on the SPP and QFCoI requirements and best practice, and is to inform the preparation of Phase 4 (Local Floodplain Management Plans).

More specifically from a land use planning perspective, Phase 3 (SFMP) advances ShapingSEQ South East Queensland Regional Plan 2017 action, provides context to the SPP state interest - natural hazards, risk and resilience (flood) and provides a framework to shape flood responsive land use planning for the State and local governments in the Brisbane River floodplain and catchment.

The purpose of Phase 3 (SFMP) in land use planning is to provide regional context for flood risk management and strategic land use planning to support implementation of the state interest – natural hazards, risk and resilience through local land use planning processes. While Phase 3 (SFMP) is not statutory in its effect, it will help inform the development of local planning instruments (as outlined in the Minister's Guidelines and Rules (MGR)) and related to the state interest – natural hazards, risk and resilience (flood), specifically SPP policy elements 1, 2, 4, 5 and 6.

Phase 3 (SFMP) seeks to achieve regionally consistent flood risk management outcomes, with flexibility in local implementation approaches and processes. It does not alter the statutory effect of the SPP (including the need to balance other state interests), but provides additional regional strategies and context for flood risk management in future iterations of local planning instruments.

Recommended tools and guidance have also been developed as part of the Brisbane River Phase 3 (SFMP) Land Use Planning Guidance Material. These tools and guidance are also non-statutory and are intended as a resource to assist local governments in addressing Phase 3 (SFMP) outcomes through local planning instruments. They represent one way of meeting the outcomes of Phase 3 (SFMP), without restricting other suitable alternative solutions that also meet the aspirations and strategies of Phase 3 (SFMP).

It is likely that land use planning responses within the various planning instruments will be different depending on the land use context across the floodplain (i.e. in rural, established urban, greenfield areas etc.). Because of the varied and diverse distribution of land uses across the floodplain, and the need to tailor planning responses to the land use context, this guidance material explains how the relevant flood risk factor tools can be applied – individually and collectively – to inform and better understand flood risk in the local circumstance.

Figure 9-1 identifies the relationship the SFMP has with other relevant Queensland statutory plans and policies.

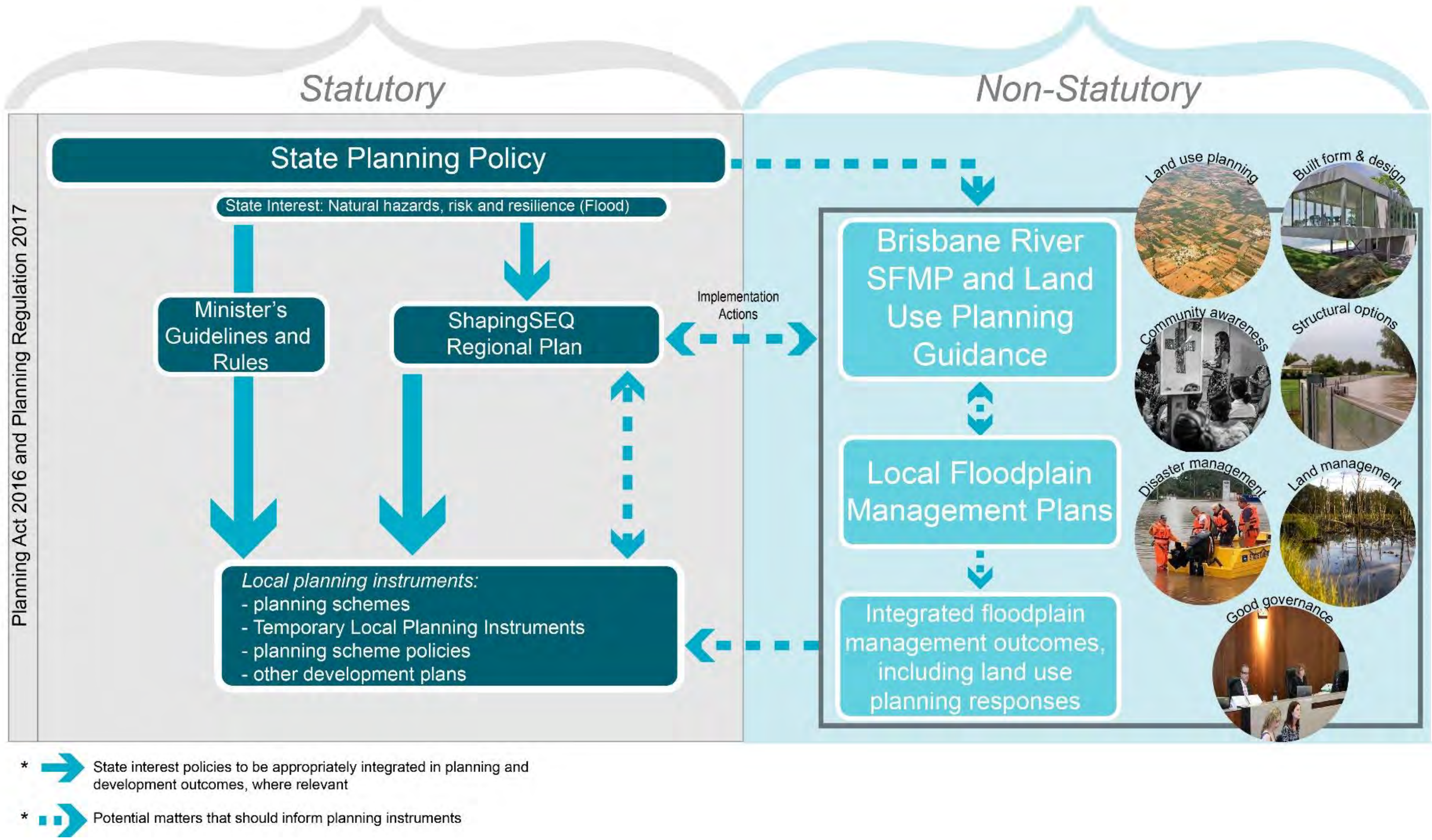


Figure 9-1 Relationship of Brisbane River SFMP to statutory plans and policies

9.2 Risk-Based Planning

9.2.1 Defining Risk-Based Planning

In natural hazard (flood) management, risk-based planning is the practice of assessing hydraulic risk and other flood risk factors across the full spectrum of flood hazard conditions and flood likelihoods at a whole-of-floodplain scale. Risk-based planning ensures that land uses are located and managed according to their sensitivity and are appropriate to the level of flood risk for the location in the floodplain. In the context of land use planning, a risk-based approach provides clear and upfront strategic policy direction on which land uses should occur or are considered appropriate for the location in the floodplain (i.e. areas of the floodplain where risk is acceptable for the land use or can be reduced or mitigated to a tolerable or acceptable level) and identifies those land uses that should not occur or are considered inappropriate (i.e. areas to avoid because risk is intolerable or unacceptable). Determining what land use is appropriate in different parts of the floodplain is an important first principle of risk-based planning and is a requirement of the SPP state interest for natural hazards, risk and resilience. To implement the outcomes of the SPP, planning instruments need to provide direction on, and distinguish between, where development should avoid and where development should mitigate flood risk to protect people and property to an acceptable or tolerable level of risk.

Because flood behaviour is complex and hydraulic risk varies across the floodplain, and the intersection of other flood risk factors further inform detailed assessment of flood risk, it is essential that planning responses are tailored to the nuances of flood behaviour and land use responds to the different areas of flood risk across the floodplain. Sensitivity to flood risk changes across the floodplain depending on people, land use, density and built form. Planning responses can therefore be appropriately tailored or graduated to the different categories of flood risk. This is most effectively embedded in all parts of the planning scheme – from the Strategic Framework, to the allocation of zones, and in relevant assessment benchmarks, including overlay codes, flood hazard/risk mapping and supporting planning scheme policies. This risk-based approach is further explained in Appendix K.

The intent of a risk-based planning approach to flood risk is not to restrict or sterilise urban development within the full extent of the floodplain or across a particular AEP event/s; however, to provide better information to the planning process and inform land use and development policy decision making, such that new development for flood sensitive or vulnerable land uses in higher flood risk areas can be avoided (where the planning authority has determined an intolerable risk to life and property) and those land uses and development types that are better suited or more compatible with the flood risk (where the planning authority has determined a tolerable or acceptable risk to life and property) are designed to improve flood resilience, minimise damage to property and protect evacuation capability.

The outcomes of a local flood risk assessment or local floodplain management plan, provides planning authorities with the technical outputs to more strategically assess flood risk to form a basis for clear and responsive land use and development policy and to underpin the development of planning scheme responses including strategic land use, zoning and more detailed provisions. At a strategic level, the planning scheme should clearly identify whether development should (or should not) occur in particular locations in the floodplain. However, it is also recognised that the planning process is complex and that flood risk is one of many issues to be balanced and considered in formulating land use strategy and development policy for locating such development (e.g. other site constraints – flood risk, coastal hazards risk, bushfire; heritage, natural environment, transport, level of infrastructure and development commitment; pattern of existing development; availability of feasible alternative sites; integrating other relevant state and regional planning interests). Planning authorities in the 'weighing up' of these other planning considerations at the local level, and having an understanding of community expectations and tolerance to flood risk, may decide to 'accept' the risk and support certain land uses in flood risk areas, but not in other parts of the floodplain. A risk based approach provides for more nuanced land use planning responses to flood risk across the full extent of the floodplain and within particular AEP event/s. This also respects the complexity of making land use planning decisions in a floodplain experiencing different rates of urban development and growth.

Figure 9-2 conceptually illustrates the principle of risk based planning and how land use and development can be risk appropriate and 'gradated' to the level of flood risk for the location in the floodplain. It is based on the premise that flood risk changes across the floodplain and some uses are more or less suited or 'tolerant' to flood risk because different people, land use types, densities and built forms have different sensitivity and vulnerability to flood risk. The principle is that planning responses across the floodplain and within a particular AEP event/s are 'risk appropriate' to account for different categories of flood risk.

Figure 9-2 Concept of risk-based planning (adapted from Toowoomba Regional Council Flood Information Sheet 4 – *Flood risk and planning tools*)

9.2.2 Key Flood Risk Management Principles

A review of best practice literature identifies the following seven principles as guiding risk-based planning for floodplain management (HNFMSC, 2006; WMO, 2008; QRA, 2011 & 2012; QFCoI, 2012; PIA, 2015; AIDR, 2016; DILGP, 2016). These consider:

- the full range of flood events;
- the consequence/behaviour of flooding;
- the interaction of behaviour and likelihood in defining flood risk;

- the full known extent of the floodplain;
- different 'bands' or categories of flood risk;
- the tailoring or gradation of land use planning and development to be 'risk-appropriate' to the level of flood risk; and
- opportunities for integration with the suite of delivery tools for flood risk management.

9.2.3 Integrated Floodplain Management Considerations

Effective flood risk management requires a coordinated and integrated response using a suite of delivery and risk management measures. Land use planning is only one of a number of floodplain risk management measures that, when implemented holistically, can be used to respond to flood risk. Other measures include: understanding current and future flood risk, resilient building design, structural mitigation options, community resilience and awareness, disaster management, infrastructure planning, integrated catchment management and environmental programs and insurance schemes. The full suite of flood risk management tools can be seen in Figure 9-3.

Phase 3 (SFMP) provides the framework for integrating the range of floodplain risk management measures at the local level, and will achieve a regionally consistent approach to integrated catchment planning and management. Potential hydraulic risk assessment of the full range of flood events and consequences across the floodplain shows nuances or graduations in hydraulic risk across the floodplain. Responding to these risks and other flood risk factors requires an integrated, whole-of-floodplain suite of measures. The full suite of floodplain management measures is provided in this report (see section Appendix M) and the SFMP (nine in total), as well as priority actions to be delivered by key agencies such as State and local government stakeholders, including roles and responsibilities. Both documents are key resources to ensure Phase 4 (LFMPs):

- reflect the full suite of floodplain management measures;
- deliver regionally consistent outcomes across the floodplain; and
- are appropriately consistent in content using regional-scale information and integrated risk management principles.

Figure 9-3 Suite of floodplain management delivery tools (QRA, 2017)

9.3 Current Local Planning Practice

Part of the appreciation of the need for a regionally consistent response to floodplain behaviour and the categorisation of risk was a review of current approaches to flood regulation in each of the local government planning schemes within the Phase 3 (SFMP) Study Area. Only local government planning schemes and Temporary Local Planning Instruments (Flood) were reviewed to identify current approaches across the floodplain. The review found that while the local planning instruments in the Phase 3 (SFMP) Study Area incorporated differing approaches to the identification, mapping and planning response to flood hazard and risk, each of the planning instruments incorporated elements of risk-based planning to varying degrees in their approaches.

The recommendations and guidance contained herein will assist in transitioning planning instruments within the floodplain to consistent risk-based planning approaches.

All currently adopted planning schemes contain the Minister's acknowledgement that state and regional policy has been appropriately reflected. However, changes to land use planning policy were introduced in the 2017 version of the State Planning Policy (and subsequent July 2017 Guidance Material), which were not available at the time of this review and will influence future scheme amendments.

The scope of this review did not include an assessment of the relationship between the risk-based planning approach and other 'satellite' legislation that may also regulate flood affected development (e.g. *Building Act 1975*, *Building Regulation 2006*, Queensland Development Code (QDC) and the like). Notwithstanding, the SFMP, Land Use Planning Guidance Material and this Technical Evidence Report have been prepared in cognisance of the SPP and SPP Guidance Material requirements related to building assessment provisions. At the time of drafting this report, the State was preparing guidance to improve understanding on the principles, techniques and appropriateness of materials, structural and non-structural options to achieve flood resilient building design.

The SPP Guidance Material (State interest policy 5.2) requires that *"where other instruments regulate development affected by flood hazard, the planning scheme should avoid duplicating assessment and regulation."* Table 17 of the SPP Guidance Material provides direction on the types of provisions within planning schemes that can be included to complement (not duplicate, affect or frustrate) the building assessment provisions. Where a flood study has produced Level 2 (i.e. BRCFS) or Level 3 mapping, the planning scheme can define a DFL and freeboard (greater than 300mm) without duplicating QDC provisions triggered for building work. The Phase 3 (SFMP)'s Land Use Planning Guidance Material (see Addenda) provides examples on how flood risk categories may be translated into overlay mapping as a possible solution, without affecting the designated 'flood hazard area' or other structural provisions under section 13 of the Building Regulation. Phase 3 (SFMP) does not make recommendations as to the siting of buildings in flood hazard areas, which will continue to be determined in accordance with the relevant building assessment provisions (e.g. QDC MP3.5 – Construction of buildings in flood hazard areas and the ABCB National Flood Standard).

The following sections summarise the outcomes from a comprehensive freeboard and scheme review and gap analysis of each local government planning instrument to establish current scheme approaches.

9.3.1 Freeboard Analysis

9.3.1.1 Purpose and Application of Freeboard in the SFMP Study Area

Freeboard *"is added to flood levels to provide reasonable certainty of achieving the desired level of service from setting a general standard or DFE"* (AIDR, 2017). This factor is applied "over and above" the Defined Flood Event (DFE), or other similar planning and design requirement. However, freeboard is independent of, and does not inform, the selection of DFEs. The QFCoI (2012) found that *"councils typically use a 'freeboard' to provide an additional buffer allowing for uncertainty in estimating flood water heights, the effects of wave action and unforeseen variation in local flood behaviour"* (section 9.2, page 210). From a land use planning perspective, freeboard is also used to achieve a tolerable level of risk and can be applied, variously, to the vulnerability and tolerability of the use proposed.

Freeboard provisions are particularly relevant in the Brisbane River floodplain due to its sensitivity to a range of unpredictable factors. These are referenced in Handbook 7: Managing the Floodplain (AIDR, 2017), and include:

a) uncertainty in modelling possible future conditions and impacts, such as the future climate (i.e. changes to rainfall patterns and sea level rise). Note that any flood modelling performed cannot calculate, with any level of certainty, climate change related flood behaviour; freeboard gives a "factor of safety" to development which is likely to be impacted by future climate change;

b) uncertainties in applying estimated design levels and requirements across the floodplain;

c) hydraulic changes resulting from local factors – catchment inflows and local flood hydraulic conditions (e.g. blockages leading to afflux, wave action, strong wind effects, undulations from boat movements, coastal waves etc.). These conditions are not considered as part of the BRCFS; and

d) uncertainties in modelling and estimating design flood levels in the BRCFS which, although one of the most sophisticated studies of its kind, is still subject to limitations. For example, the model has a spatial resolution of 30x30m and a calibration tolerance ranging from ±0.15m downstream of Oxley Creek to ±0.50m upstream of Goodna.

9.3.1.2 Relevant Freeboard Considerations

Sensitivity testing undertaken in Phase 2 (Flood Study) showed that hydraulic behaviour is a relevant determinant in deciding appropriate freeboards. The more incised, narrow reaches of the floodplain (i.e. between Lowood and Brisbane CBD) are more sensitive to uncertainties in modelling and to changes in flood levels resulting from local catchment flows and future climate impacts. This is because flood flows in these areas cannot take advantage of adjacent floodplains, and any increase in flow translates to deeper flood waters in the channel. On the other hand, floodplain areas, such as those characterising Lockyer Creek, are less sensitive to these uncertainties. This is because the flood hydrograph in these areas will more readily store and dissipate any increase in water levels, which can spread out and inundate overbank areas.

Because of the variability of Brisbane River floodplain behaviour, it is reasonable for freeboard estimates to differ and be applied by local governments in a discretionary manner. This also reflects the risk-based planning principle that land uses will have different sensitivities to flooding. Potential Hydraulic Risk categories and other flood risk factors (discussed in Section 9.5) may also require variable freeboard requirements. While freeboard requirements are not mandated in the SPP, the projected impacts arising from climate change are recognised, and land use planning in the natural hazard management area is required to avoid or mitigate risk to life and property.

Freeboards should therefore be applied in response to local uncertainties, including the sensitivity of different areas of the floodplain to uncertainties in the modelling of flood estimates.

9.3.1.3 Policy Guidance

At the time of this review, the (then) SPP Technical Manual recommended comprehensive local flood studies and detailed hazard mapping be undertaken to better account for hydraulic conditions and local uncertainties. The provisions related to making declarations under Section 13 (1)(b) of the

Building Regulation 2006 also provide local governments with the flexibility to set higher freeboards, as relevant, depending on the level of uncertainty and the factors contributing to it. The policy direction provided is to consider local circumstances and flood information, where available, to account for sensitivities in estimating flood levels and those factors creating the flood.

A review of all four local planning instrument approaches to freeboard was undertaken to understand how it is being used and what other factors are being considered. This also identified key risk-based considerations for adopting appropriate freeboard values across the floodplain. In summary, the below observations are made in respect of freeboard in the four local planning instruments. It can be concluded that freeboard is applied variously across the floodplain, in that:

- mandatory freeboard provisions are dealt with in the respective flood overlay codes of planning schemes or Temporary Local Planning Instruments. These are typically within the range of 300–500mm;
- each local planning instrument applies a different freeboard factor and the range of factors used to inform or set the freeboard value also varies across the LGAs, such as: source of flooding, type of development (almost always assigned for habitable floor levels), location within the floodplain, historic flood levels, or advice provided in a site-based flood study;
- freeboard provisions are applied to the exclusion of certain zones or uses (e.g. commercial and industrial). This can underestimate changes in flood level estimates and the subsequent level of risk to the community. Alternatively, this may reflect that a lower level of immunity is considered appropriate for these particular land uses; and
- freeboard values are not always applied in response to the underlying flood behaviour/hydraulic hazard conditions and their sensitivity to change across the floodplain (refer to Section 9.3.1.2).

9.3.1.4 Key Freeboard Options Framework

Consistent factors should be considered in setting risk-appropriate freeboards. The most significant factors that contribute to variable flood levels across the floodplain include:

(1) the sensitivity or uncertainty of changes in flood behaviour as a result of increased catchment inflows, rainfall and sea level rise. This factor also considers how significantly the depth changes between similar AEP events (e.g. between 1 in 50 and 1 in 100 AEPs), with a greater differential (e.g. >1m) indicating higher flood sensitivity; and

(2) the sensitivity of the proposed development to flooding and the impact of property damage. This can be expressed for each land use activity group (e.g. residential, commercial, industrial etc.), or for specific uses (e.g. community use, health care service, relocatable home park etc).

These two factors are presented in the Table 9-1 matrix, which provides a potential framework for determining risk-appropriate freeboard values. The appropriate freeboard applied depends on the combination of development sensitivity and flood behaviour sensitivity/uncertainty in the floodplain. This aligns with a more risk-based approach in recognising that different areas of the floodplain will have higher or lower levels of uncertainty.

Table 9-1 Freeboard options assessment framework

		Flood behaviour sensitivity / uncertainty	
		Low	**High**
Development sensitivity	**Low**	Minimal (minimum 300mm)	Moderate (300 – 500mm)
	High	Moderate (300 – 500mm)	Maximal (at least 500mm)

'Low' development sensitivity and 'Low' flood behaviour sensitivity/uncertainty is determined, respectively, where a less sensitive development is proposed (e.g. rural land use group or a non-habitable structure) in broad floodplain areas that record less than a 1m difference in flood levels between similar AEPs. In the Phase 3 (SFMP) Study Area, 'Low' flood sensitivity areas are located around Lockyer Creek, in the upper reaches of the Bremer River and in tributaries downstream of the Brisbane CBD. Lower freeboards can be applied in these areas.

'High' development sensitivity and 'High' flood behaviour sensitivity/uncertainty is determined, respectively, where a more sensitive development is proposed (e.g. residential land use group or an educational establishment) in the more incised reaches of the floodplain or flow conveyance areas that record more than a 1m difference in flood levels between similar AEPs. In the Phase 3 (SFMP) Study Area, 'High' flood sensitivity areas are located in the area between Lowood and the Brisbane CBD. In these areas, more generous freeboards should be considered.

A full assessment of freeboard options is included as Appendix L to this report.

9.3.2 Preliminary Review of Planning Schemes

A risk-based approach to land use planning and flood risk management is required by the SPP state interest for natural hazards, risk and resilience and is also consistent with the recommendations of the Queensland Floods Commission of Inquiry.

A preliminary review of the four local planning instruments in the Phase 3 (SFMP) Study Area was undertaken to understand existing planning scheme approaches to how flood risk is defined, mapped and regulated and to identify the extent to which existing planning scheme approaches align with best practice risk-based planning principles. This process was also informed through discussions with individual local government planners and engineers involved in the implementation of each of the planning schemes to better appreciate existing approaches and to identify the extent to which current approaches are suited to a risk-based planning approach.

Feedback from stakeholders and understanding the extent to which current planning schemes incorporate elements of risk-based planning was helpful in developing Phase 3 (SFMP) and the supporting SFMP Planning Guidance Material (see Addendum). This included identifying key flood risk management issues for the Phase 3 (SFMP) Study Area that can be influenced by planning schemes and would benefit from having regional direction or a consistent approach across the floodplain. The preliminary review concluded that all planning instruments currently have different approaches to how flood risk is defined, described, mapped and integrated within different sections of the planning scheme from the strategic framework through to detailed assessment benchmarks.

However, all schemes include some elements of risk-based planning to varying degrees. For some planning schemes, achieving full alignment with a best practice risk-based planning approach is unlikely to involve a significant shift.

The four local planning instruments in the Phase 3 (SFMP) Study Area were reviewed to determine the extent of alignment with:

a) the other schemes in the Phase 3 (SFMP) Study Area (being the *Brisbane City Plan 2014*, *Ipswich Planning Scheme 2006*, *Somerset Region Planning Scheme 2016* and the Lockyer *Temporary Local Planning Instrument 2017,* which overrides the *Gatton Planning Scheme 2007* and *Laidley Shire Planning Scheme 2003*);
b) best practice risk-based planning principles identified in Section 9.2.2; and
c) the SPP 2017 (draft at the time of review).

Improving the extent of alignment with the above will be critical to delivering a consistent risk-based approach at the regional level. The preliminary review also aimed to broadly 'locate' each local planning instrument on the risk-based planning spectrum, and to identify gaps to fill in transitioning to a more consistent risk-based approach to land use planning. To determine the extent to which a risk-based approach has been achieved, key evaluation criteria were derived from the best practice review of available research and the SPP (Draft for consultation, November 2016). At the time of review, this comprised the only available information on integrating natural hazard risk-based planning into land use planning. Note that the now released SPP Natural Hazards Risk and Resilience (Flood) Guidance Material 2017 was not available to inform this review. It is also acknowledged that all planning schemes were identified as appropriately integrating State interests for the particular version of the SPP that was applicable at the time of scheme drafting.

A planning instrument that adequately incorporates flood risk within a risk-based planning framework would embed, at all levels, the criteria identified in Figure 9-5. The relevant icons shown in Figure 9-4 (and Figure 9-5) identify the main drivers of each criterion and are given the following attribution:

Figure 9-4 Drivers of criteria used in scheme review and gap analysis

As previously identified, the preliminary gap analysis revealed that all four schemes adopt differing approaches to flood risk identification, assessment, mapping and regulation in both the strategic framework and assessment benchmark elements. Approaches range from including various flood hazard categories for a limited number of AEP events, to relying on a historic flood or single regulation event (e.g. 1 in 100 AEP) across the flood hazard area. There is generally a stronger policy focus on differentiating the flood behaviour characteristics into ‘categories’ of risk across local government areas than on considering multiple event likelihoods, including mapping more extreme (and rare) events. As a result, land use responses achieve *some* gradation or tailoring to the level of hydraulic hazard, demonstrating partial alignment with a best practice risk-based planning approach. It is important to note that the scheme review did not involve a detailed local level analysis of zoning and the implications of Potential Hydraulic Risk and other flood risk factors for existing and future land use beyond the approach identified in Section 9.4. This analysis would need to be undertaken by planning authorities as part of a local flood risk assessment process, required by the SPP.

Notwithstanding, the reviewed local planning instruments are already introducing and referring to key flood risk considerations (e.g. vulnerability, exposure, warning time, evacuation, isolation, ‘full spectrum of impacts’ etc.); the majority have also linked land use tolerability and compatibility to the severity of flooding. There is opportunity to refine scheme approaches to provide greater consistency across planning schemes and clarity and direction on risk appropriate land use at the strategic framework level and in the allocation of land use to zones, with support from overall outcomes, to provide a consistent flood-responsive settlement pattern. At these levels, clear policy statements that explain where in the floodplain and what type of uses will be unacceptable, tolerable or acceptable to the level of risk is needed and should be determined by the respective planning authorities as part of their local flood risk assessments, including confirming tolerability and acceptance of impacts with their local communities.

Risk assessment - a risk assessment has informed the policy and development assessment outcomes

- a fit-for-purpose risk assessment prepared in accordance with ISO 31000:2009 as required by the SPP and Guideline
- an assessment of the full range of possible flood events up to and including the PMF

Strategic Framework

- the policy of *'avoidance of flood hazard, or where it is not possible to avoid the hazard area, development mitigates risks to people and property to an acceptable or tolerable level'* is clearly translated throughout all elements and layers of the planning scheme
- clarity on appropriateness of land use and circumstances of where to *'avoid'* or *'mitigate to an acceptable or tolerable level'* are clearly understandable and align with the differentiated categories of hydraulic risk

Overlay mapping within the planning scheme:

- identifies flood risk (or hydraulic risk) based on severity to a minimum of 3 'zones' or categories of risk, based on flood likelihood and behaviour
- considers multiple likelihoods - not just one single flood event
- identifies the full known extent of the floodplain - not just part of the floodplain

Overlay code - provides clear direction on areas of acceptable, tolerable and unacceptable risk and identifies uses/development appropriate to the risk

- is it clear from the risk categories (in overall outcomes and performance outcomes), what areas/locations have acceptable, tolerable or unacceptable risk for people and property?
- for areas of unacceptable/intolerable risk, is it clear what uses should be avoided or limited and what uses are considered appropriate? Is this embedded in overall outcomes and performance outcomes?
- for areas of tolerable risk, is it clear what types of uses/development are appropriate and how development is managed to mitigate risks to an acceptable level?
- for areas of acceptable risk, is it clear what uses/development are appropriate and what requirements (if any) are needed to mitigate risk?

Level of assessment

- does the flood overlay change the level of assessment?

Zoning - land use and zoning is 'risk appropriate'

- is land use and zoning appropriate to the category of potential hydraulic flood risk across the full extent of the floodplain?
- is zoning and zone code provisions managing the future exposure of people and property to future flood risk?
- Do zone boundaries consistently align with potential hydraulic flood risk extents?
- zoning recognises that different uses and densities have different vulnerabilities to risk.

Evacuation

- does the scheme provide guidance or policy direction on existing or preferred evacuation routes to provide flood free access?

Isolation

- does the scheme provide guidance or policy direction on potential for isolation?

Planning scheme policy

- does the planning scheme include a planning scheme policy addressing flooding?
- planning scheme policy provides guidance to site-based flood hazard and risk assessment and requires the full range of possible flood events affecting the site and flood hazard/behaviour to be considered across the range of permitted land uses.

Figure 9-5 Drivers of criteria used in scheme review and gap analysis

9.4 Strategic Analysis of Land Use Exposure in the Brisbane River Floodplain

9.4.1 Identification of the Flood Risk Problem

The following section presents the results of a strategic analysis of land use zoning across the floodplain to determine current and future exposure to hydraulic risk (other flood risk factors or considerations were not included in this analysis). The objectives of the analysis are fourfold:

(1) Quantify the extent of hydraulic risk to current land use zoning (current risk);

(2) Determine the impact of flooding on future development in the floodplain (future risk);

(3) Discuss the implications of relying on existing approaches to development regulation within the floodplain, and of the assumptions made in respect of land use allocation; and

(4) Inform the range of land use planning tools available, and the land use responses to managing and reducing flood risk regionally.

The above objectives will be addressed through a strategic assessment of current and future land use exposure to hydraulic risk. The analysis does not attempt to resolve potential issues with the allocation of land use in flood risk areas, as reflected in the various local government planning instruments and the SEQ Regional Plan. This will be dealt with as part of the Phase 4 (LFMP) process and local risk assessment.

The analysis is undertaken at the regional (whole-of-floodplain) scale and applies aggregated zoning groups across all local government areas in the floodplain. It therefore does not consider flood risk exposure in the context of local land use planning policy and other strategic planning considerations informing the allocation of land to risk-appropriate zones. Moreover, the effectiveness of existing land use planning responses and development controls in treating the level of flood risk has not been evaluated. Many land use zones identified are committed to existing development (i.e. consolidation areas) and comparatively fewer future urban type zones (i.e. expansion areas) exist in the floodplain. Responding to flood risk in zones accommodating existing development versus future expansion areas will very likely require different land use planning responses in combination with other flood risk mitigation measures. For some areas and circumstances it may mean that a risk mitigation (as opposed to avoidance) strategy is preferred for existing developed areas. The analysis in the following sections does not attempt to resolve these planning responses, which would need to be determined by planning authorities through the Phase 4 (LFMP) and local flood risk assessment processes and in consultation with local communities.

9.4.2 Overview of Methodology

The approach identified in Figure 9-6 has been adopted to present the results of the strategic analysis at the various 'scales' of the flood risk – from regional to local. All spatial analyses were conducted in ESRI ArcGIS (version 10.2) and focussed on the ShapingSEQ 2017 Regional Plan categories and land use zonings under local planning instruments within the floodplain.

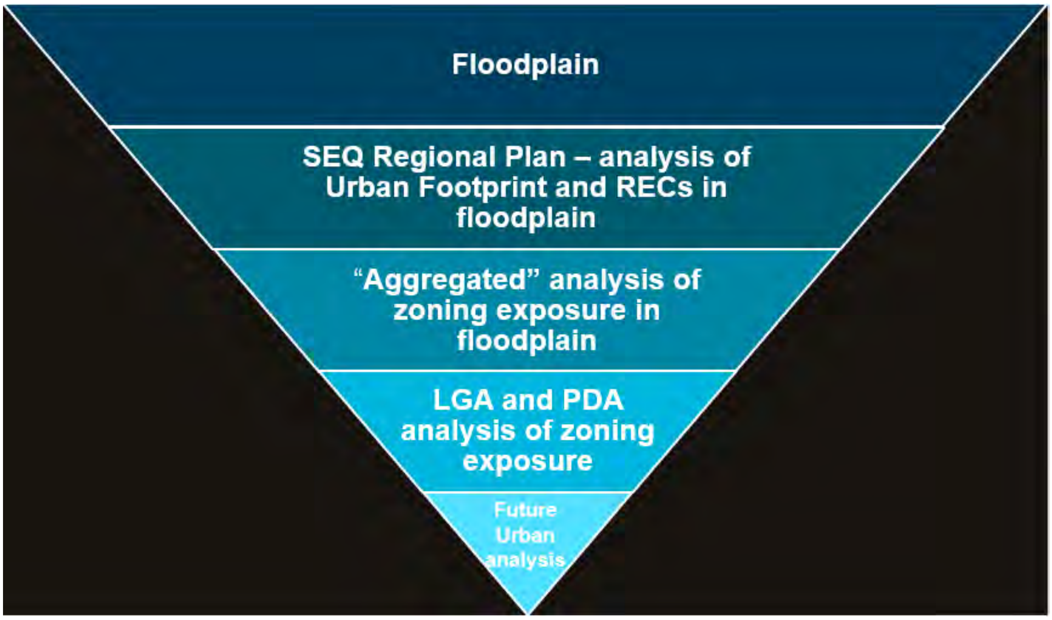


Figure 9-6 Approach to investigating the flood risk problem

9.4.2.1 SEQ Regional Plan Analysis

Regional Plan data were downloaded from the Queensland Spatial Catalogue (Qspatial) website (http://qldspatial.information.qld.gov.au/catalogue); however, only regional land use categories (RLUCs) data were available for download. With this exception, the Regional Plan analysis is predominately qualitative due to the unavailability of other datasets (e.g. regional economic clusters (RECs), urban corridors, major expansion areas etc.). All analyses were undertaken within the extent of the Brisbane River floodplain, potential hydraulic risk (HR) and relative time to inundation (RTI) datasets.

Briefly, the analysis identified the area (in hectares) of intersection between HR and the RLUCs in each of the five HR categories (HR1 to HR5). Of this, the intersected area with limited RTI (i.e. <12 hours) was calculated. The RECs, urban corridors and major expansion areas were georeferenced and digitised using Figure 6 on page 35 of ShapingSEQ as the base map for alignment.

9.4.2.2 Aggregated LGA Analysis

Land use zoning data were collected by QRA in February 2017 from the respective local governments (Brisbane City, Ipswich City, Somerset Regional and Lockyer Valley Regional Councils). Data are assumed to represent the most recent available zoning information in the LGAs and have not been updated to reflect possible changes. Zoning data for Lockyer Valley have been drawn from the draft planning scheme.

Only zones that intersected (i.e. located within) the floodplain were retained for analysis (total of 81 zones). These zones were aggregated into seven (7) broad land use 'groups' to allow for regional comparison: centre, residential – further split into high, medium and low density – future urban, industry, non-urban (open space/environment, rural/rural residential), special use and Priority Development Area. Although this was a subjective process, allocation was undertaken by experienced planners with an appreciation for the purpose of the zone, to allocate each into its most appropriate land use group (refer to Appendix J for the complete zone list).

The area (in hectares) of intersection between HR and the seven zone groups was determined for each of the five HR categories (HR1–5). Of this, the intersected area with limited RTI (i.e. <12 hours) was calculated. Further analysis of the Future urban and Residential zone groups were also undertaken with respect to two climate change scenarios: RCP4.5 (0.63m sea level rise and 10% rainfall increase by 2090) and RCP8.5 (0.8m sea level rise and 20% rainfall increase by 2090). The area (in hectares) of intersection between the HR datasets (adjusted for climate change) and future urban and residential zone land was calculated to determine the change in the amount of land affected.

Statistics were calculated at the LGA level and summed together to represent the whole-of-floodplain. The complete Excel workbook and ESRI ArcGIS map package of the regional strategic zoning analysis will be provided to planning authorities. The comprehensive property database (refer Section 6.3.2) was used to determine property counts within the floodplain.

9.4.3 Summary of Current Flood Risk Findings

9.4.3.1 SEQ Regional Plan

There is approximately 73,615 Ha of zoned land within the Brisbane River floodplain. Approximately 42,194 Ha of this land is identified as Urban Footprint under the Regional Plan. While this represents only 13% of the Urban Footprint within the whole SEQ Region, almost one third of this (or 11,540 Ha) is within the highest HR categories, HR1 and HR2. Of this, three quarters (or 8,629 Ha) has less than 12 hours relative time to inundation (RTI) (refer to Table 9-2).

Table 9-2 Statistics of Urban Footprint within floodplain

	Area within floodplain (Ha)	HR Category	Area within each HR Category (Ha)	% area within each HR Category	Area with <12hrs relative time to inundation	% area with <12hrs relative time to inundation
Urban Footprint	42,194	1	6,958	16	6,647	96
		2	4,582	11	1,982	43
		3	5,523	13	392	7
		4	5,785	14	191	3
		5	19,346	46	0	0

Figure 9-7 and Figure 9-8 illustrate the scale of intersection between the floodplain and HR categories and the various land use planning areas under the Regional Plan. Several major centres, including the Brisbane CBD, Brisbane Airport and Port, Indooroopilly and Ipswich City, are located within the floodplain. The urban corridors, along which infill development is intended in proximity to railway corridors, provide important connections between these centres. Many such transport corridors are also within the floodplain and segments of these – through much of Ipswich and in Brisbane's west – are located in HR1 to HR3 areas.

The majority of regionally significant RECs throughout Brisbane and Ipswich are also within the floodplain. For example, this includes: the Brisbane CBD and inner-city frame (Spring Hill, Fortitude Valley, South Brisbane, Woolloongabba, Kelvin Grove, Herston, Bowen Hills, Newstead etc.); Brisbane Airport and surrounding industrial precinct (Banyo, Northgate, Pinkenba, Eagle Farm, etc.); St Lucia; Wacol; the Darra, Oxley, Rocklea and Archerfield area; and the Ipswich CBD and several specialised hubs (Bundamba, Swanbank, Amberley, Riverview, Redbank, Willowbank etc.). Figure 9-9 shows that many RECs also support concentrations of Future urban land. The balance future urban and industrial areas through Ipswich (Swanbank, Willowbank, Ripley, Springfield, Walloon/Rosewood) are located predominately outside the floodplain and at the extent of the 1 in 100,000 AEP (or nominal PMF) and are identified as having a lower potential hydraulic risk category because the exposure to flood risk from an extreme event of this magnitude is considered highly unlikely. As such, the potential exposure to flood risk from riverine flooding in these areas of the upper catchment is considered lower.

The major expansion areas of Ripley, Springfield and Walloon/Rosewood are predominately located outside the floodplain. Peripheral areas of Ripley and Springfield are within HR4 and HR5 areas. HR3 areas either comprise small geographies (e.g. <1ha) or are assigned to less sensitive zones (e.g. Open space). However, this analysis relates to riverine flooding only, and potential impacts due to local creek flooding have not been assessed.

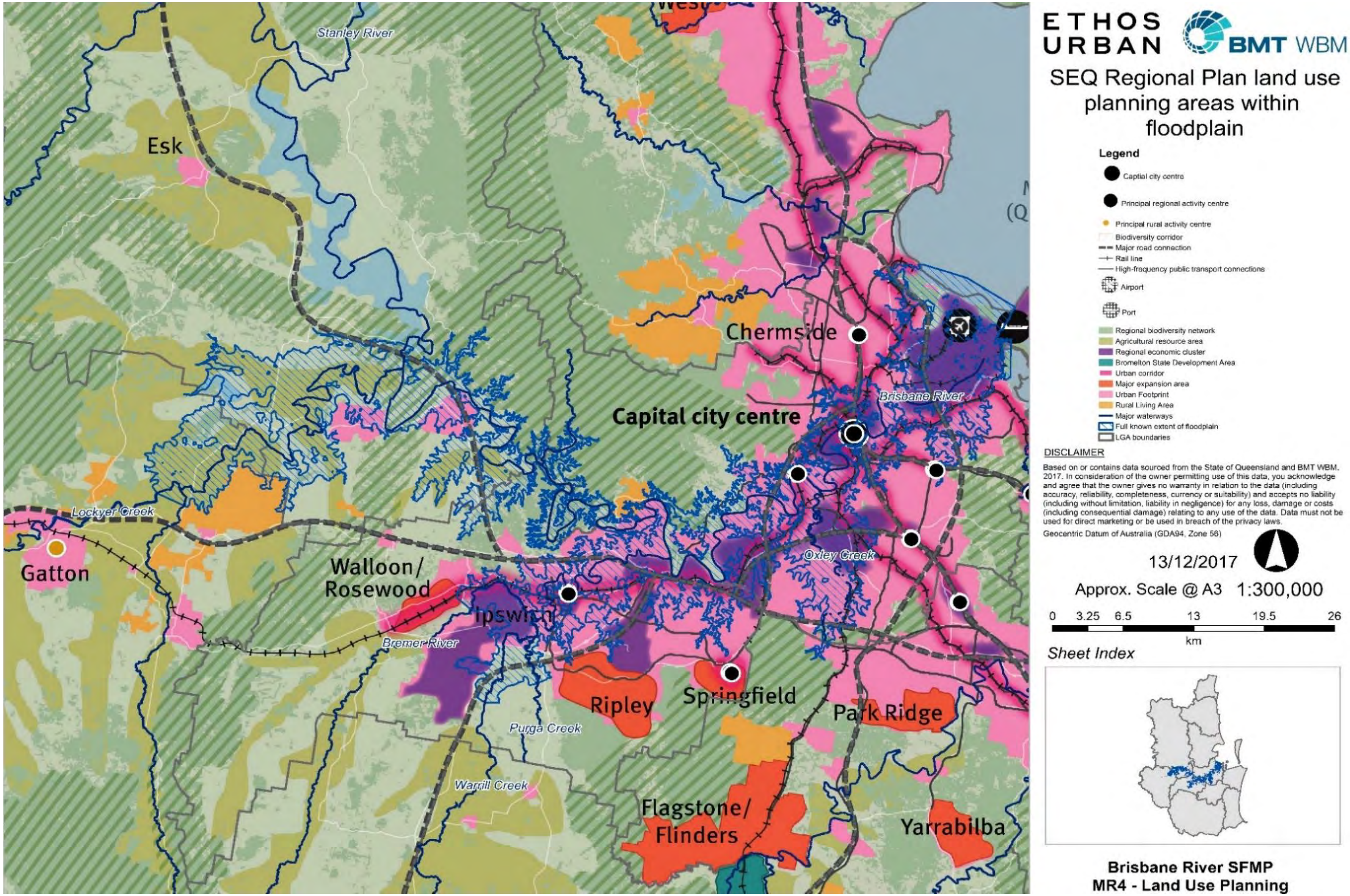


Figure 9-7 Scaled floodplain overlaid with regional land use areas (ShapingSEQ, 2017)

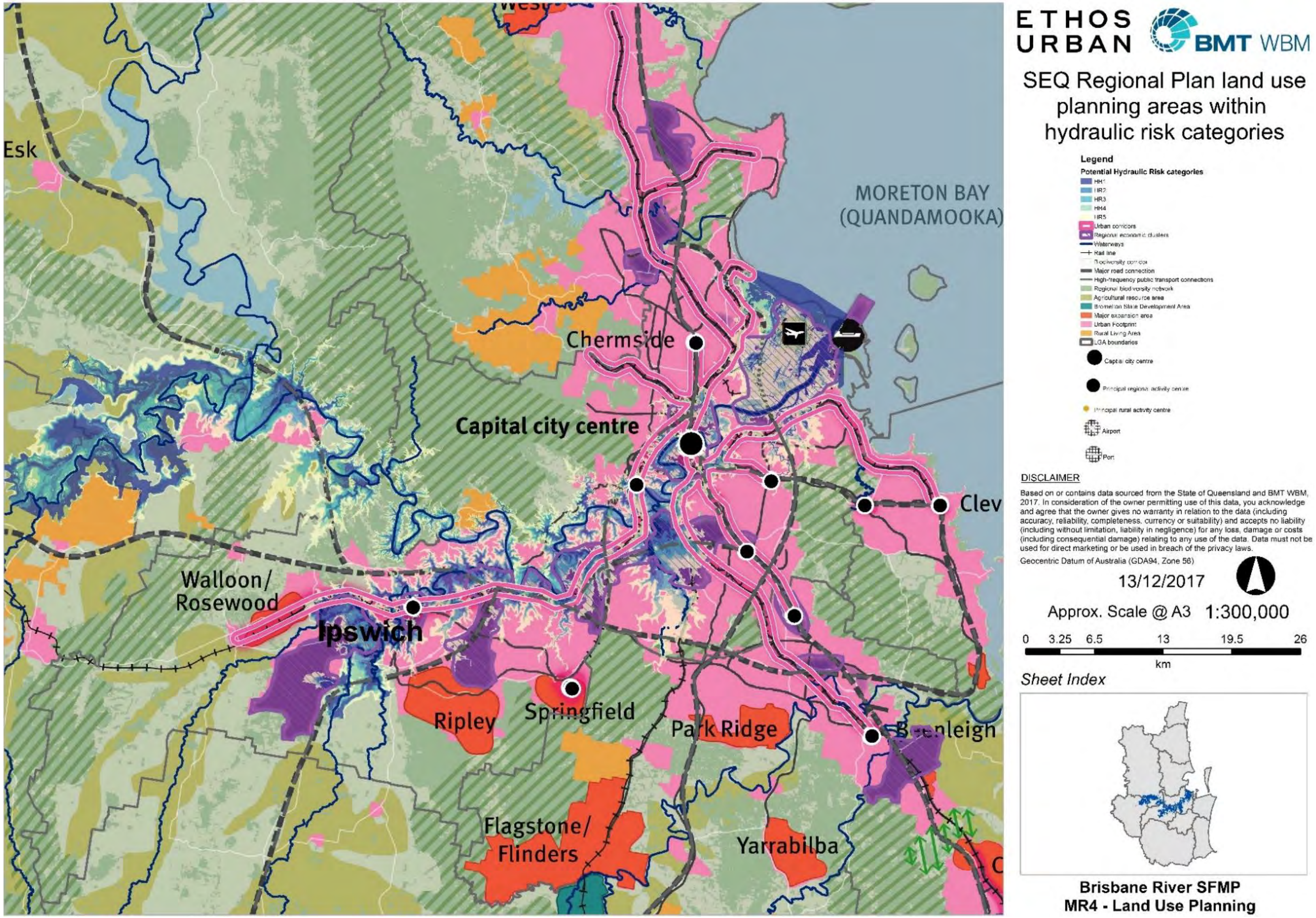


Figure 9-8 Scaled hydraulic risk overlaid with regional land use areas (ShapingSEQ, 2017)

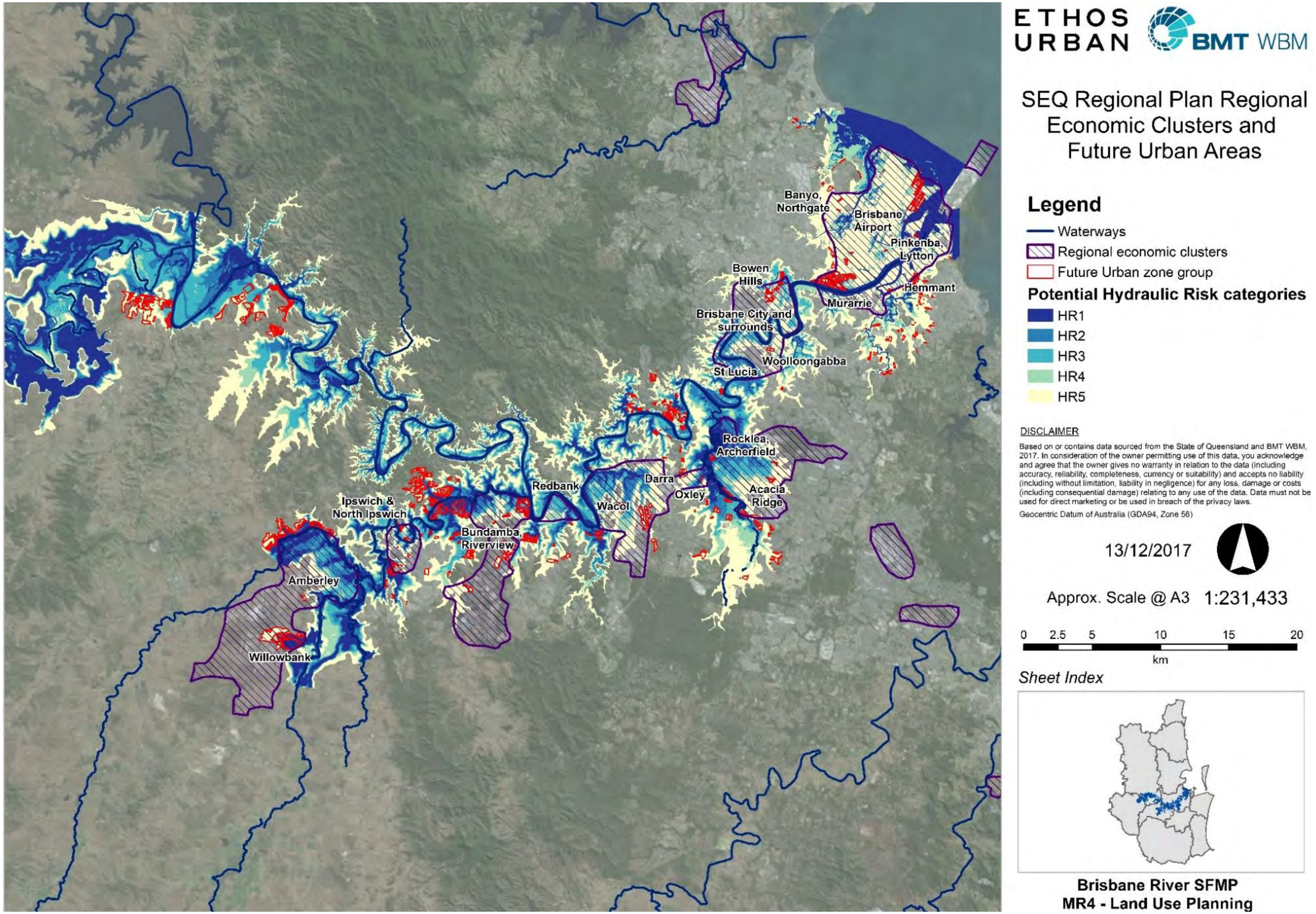


Figure 9-9 Location of Future urban areas relative to RECs

9.4.3.2 Strategic Aggregated Zoning Analysis

9.4.3.2.1 Residential Zone Group

Residential zone land within the floodplain comprises a range of zones and built form types, densities and sensitivities to flood risk. Within the Brisbane River floodplain, approximately 8,149 Ha of land is zoned for residential purposes. This represents about 11% of the total zoned land within the floodplain, of which almost one tenth (or approx. 730 Ha) is within HR1 and HR2. 43% of HR1 and HR2 residential areas have less than 12 hours relative time to inundation.

For residential land, hydraulic risk category, HR3, has also been included in the analysis as this represents the threshold at which flood hazard characteristics become unsafe for self-evacuation of vulnerable persons. HR1 to HR3 areas make up 23% (or 1,879 Ha) of all residential land within the floodplain. These statistics are presented in Table 9-3.

Table 9-3 Statistics of residential zone land within floodplain

Area within floodplain (Ha)	% land area within floodplain	HR Category	Area within HR1 to HR3 (Ha)	% land area within HR1 to HR3	HR1 to HR3 area with <12hrs relative time to inundation	% HR1 to HR3 area with <12hrs relative time to inundation
8,149	11.1%	HR1 to HR3	1,879	23%	334	18%
		HR1	178	2%	165	93%
		HR2	555	7%	151	27%
		HR3	1,146	14%	18	2%

Statistics at the LGA level are summarised in Table 9-4. Brisbane City has 1,148ha or 21% of residential land within HR1 to HR3 areas. Ipswich City has 612 Ha or 26%. However, the amount of HR1 to HR3 residential land in Ipswich City with limited relative time to inundation is greater than other LGAs. Lockyer Valley Region and Somerset Region have comparatively fewer hectares of residential land within HR1 to HR3 areas. While the percentages indicate a higher proportion of residential land in HR1 to HR3 areas, it is appreciated that only part of the Lockyer and Somerset Regional Council local government areas are within the Brisbane River SFMP Study Area and the figures may overestimate the amount of land impacted by HR1 to HR3 flood risk. To more accurately determine the quantum of residential land exposed, it is recommended that the analysis should be undertaken across the whole flood hazard area at the LGA level to account for land outside the floodplain using available local flood data. Notwithstanding, a greater population within the Brisbane City and Ipswich City LGAs has been identified as being exposed to hydraulic risk associated with Brisbane River floods.

Table 9-5 identifies the number of residential buildings potentially at risk within the floodplain. The HR1 to HR3 areas of the floodplain accommodate approximately 22,214 buildings, of which 3,771 are multiple dwelling buildings (i.e. provide attached forms of housing with higher residential densities).

Table 9-4 Residential zone land in each LGA

LGA	Residential land within floodplain (Ha)	Residential land within HR1 to HR3 (Ha)	% residential land within HR1 to HR3	Residential land <12hrs relative time to inundation (Ha)
Brisbane	5,380	1,148	21%	150
Ipswich	2,363	612	26%	167
Somerset	385	111	29%	10
Lockyer	21	8	38%	7

Table 9-5 Residential buildings within floodplain[23]

Property type	Hydraulic Risk category				
	HR1	HR2	HR3	HR4	HR5
Residential	725	5,423	12,295	13,020	61,149
Residential Multi-dwelling	157	922	2,692	3,095	10,268
Total	**882**	**6,345**	**14,987**	**16,115**	**71,417**

The vulnerability profile of the residential population within HR1 to HR3 areas can increase the level of risk above and beyond the base constraint (i.e. hydraulic risk). Using the combined vulnerability mapping (see Section 4.5.2.5), the amount of residential land within HR1 to HR3 areas that is also identified as having high vulnerability (i.e. in quintiles, Q4 and Q5), was calculated. Approximately 866 Ha (or 46%) of residential land is within the upper 40% of vulnerable areas in the floodplain. This indicates an overrepresentation of vulnerable persons in HR1 to HR3 areas of the floodplain.

Table 9-6 shows that the majority of HR1 to HR3 areas in Ipswich have high vulnerability (approx. 555 Ha or 91%). These areas are generally in locations adjoining the Brisbane and Bremer Rivers (e.g. Goodna, Brassall, One Mile, North Ipswich, Basin Pocket, East Ipswich etc.). Brisbane, by comparison, has 26% (302 Ha) of HR1 to HR3 land within highly vulnerable areas. These areas are primarily located in inner city neighbourhoods (e.g. West End, St Lucia, New Farm, Fairfield, Auchenflower, Milton, Toowong etc.) and in proximity to Oxley Creek. Somerset has a smaller HR1 to HR3 area with high vulnerability (Q4 to Q5) (9 Ha or 11%) in and around Lowood. Excerpts of the vulnerability mapping for each LGA are provided in Figure 9-10, Figure 9-11 and Figure 9-12.

[23] These counts are taken from the property database and identify primary land uses only (e.g. multi-dwelling, industrial, commercial etc.). Counts are not linked to specific land use zones in the floodplain. Therefore, it is not possible to identify how many residential buildings are located in the residential, centre, industrial zone groups etc.

Table 9-6 HR1 to HR3 residential zone land within most vulnerable quintiles (by LGA)

LGA	HR Category	Residential land (Ha) within more vulnerable areas (quintiles Q4 & Q5)	% residential land in quintiles Q4 & Q5 within each HR category	Residential land within quintiles Q4 & Q5 with <12hrs relative time to inundation
Brisbane	HR1	16	5%	14
	HR2	110	36%	31
	HR3	176	58%	2
	Total	302	100%	47
Ipswich	HR1	83	15%	82
	HR2	146	26%	62
	HR3	326	59%	8
	Total	555	100%	152
Somerset	HR3	9	100%	0
	Total	9	100%	0
Lockyer	No residential land within quintiles Q4 & Q5			

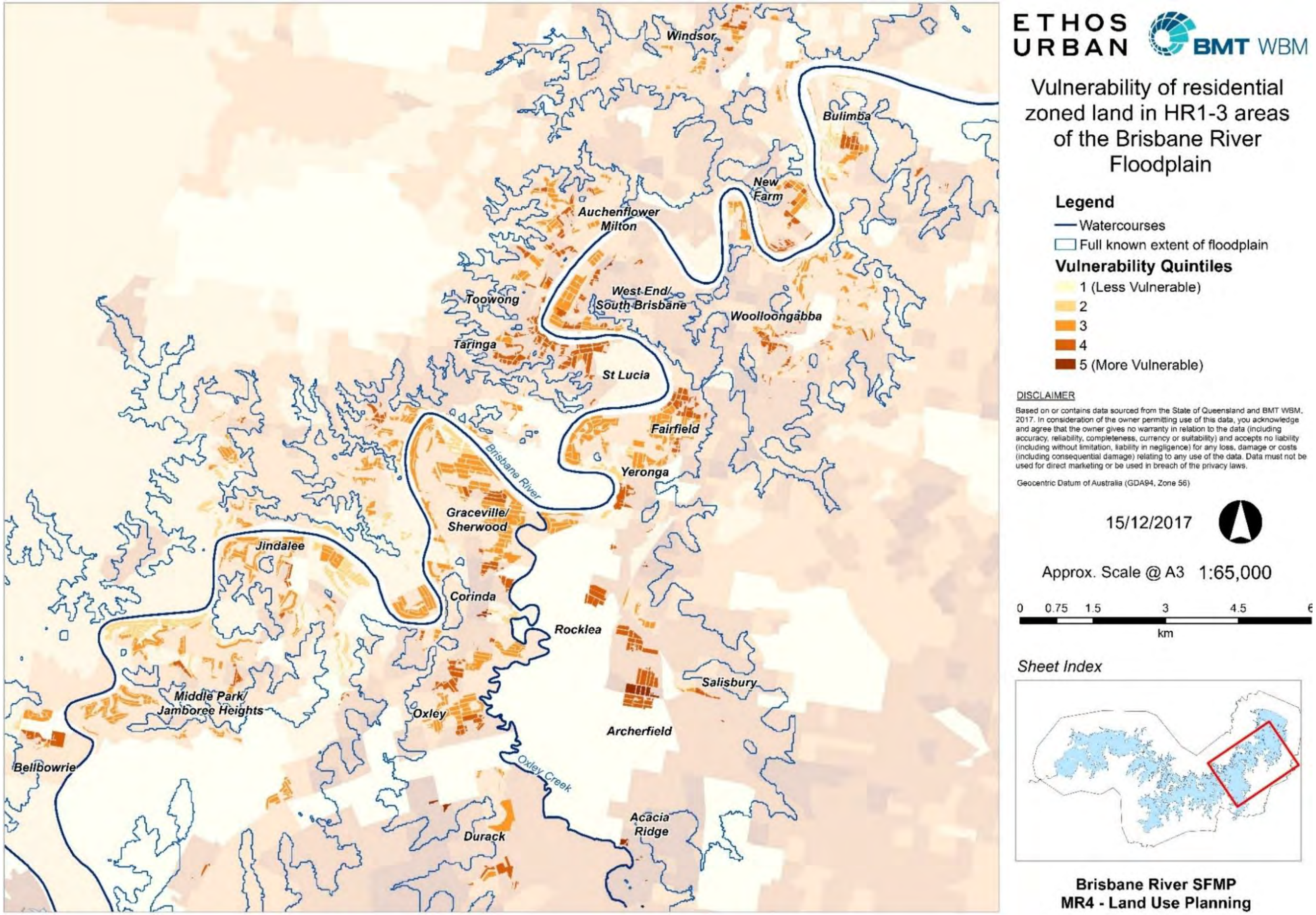


Figure 9-10 HR1 to HR3 residential zoned land within quintiles Q4 and Q5 in Brisbane LGA

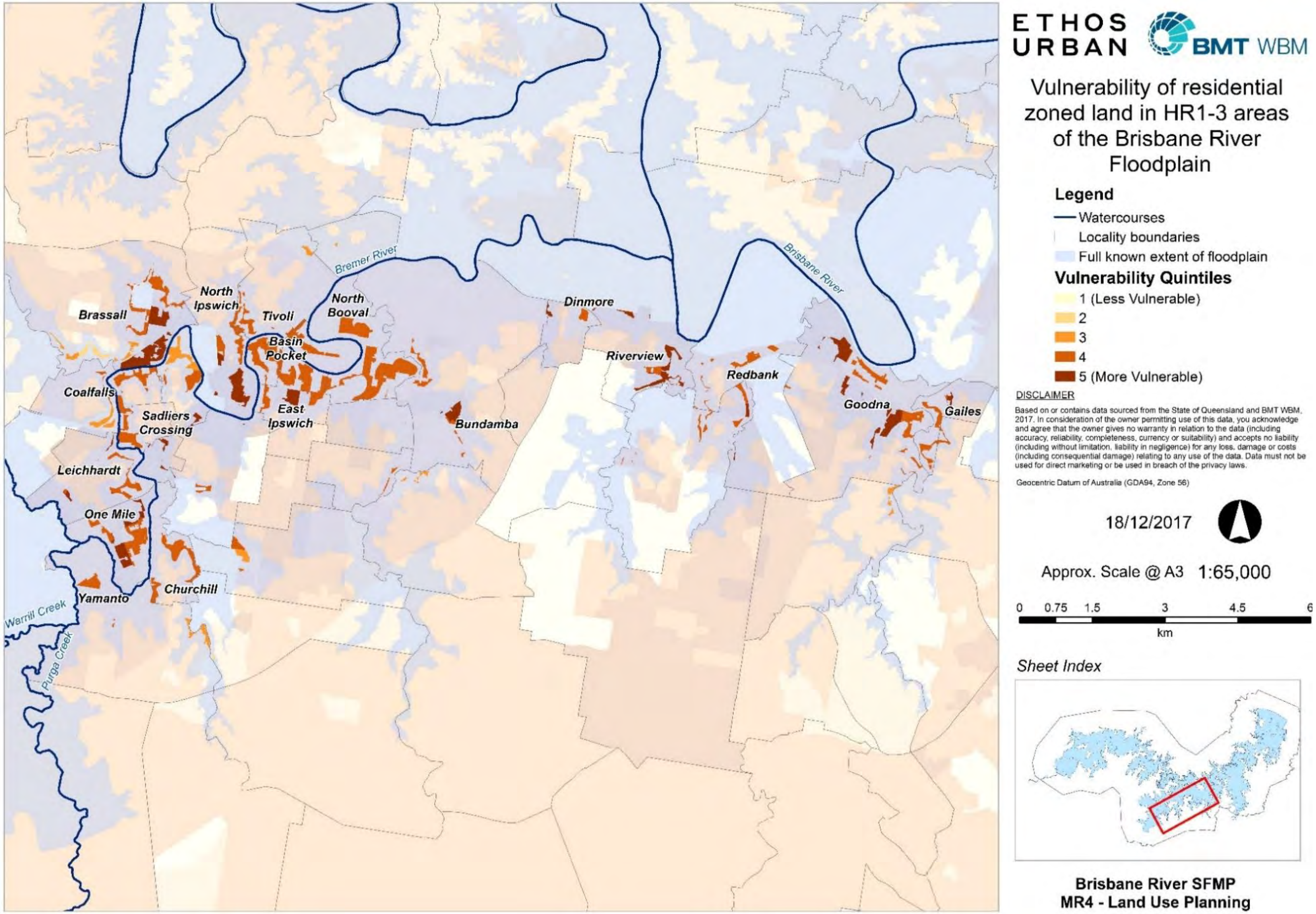


Figure 9-11 HR1 to HR3 residential zoned land within quintiles Q4 and Q5 in Ipswich LGA

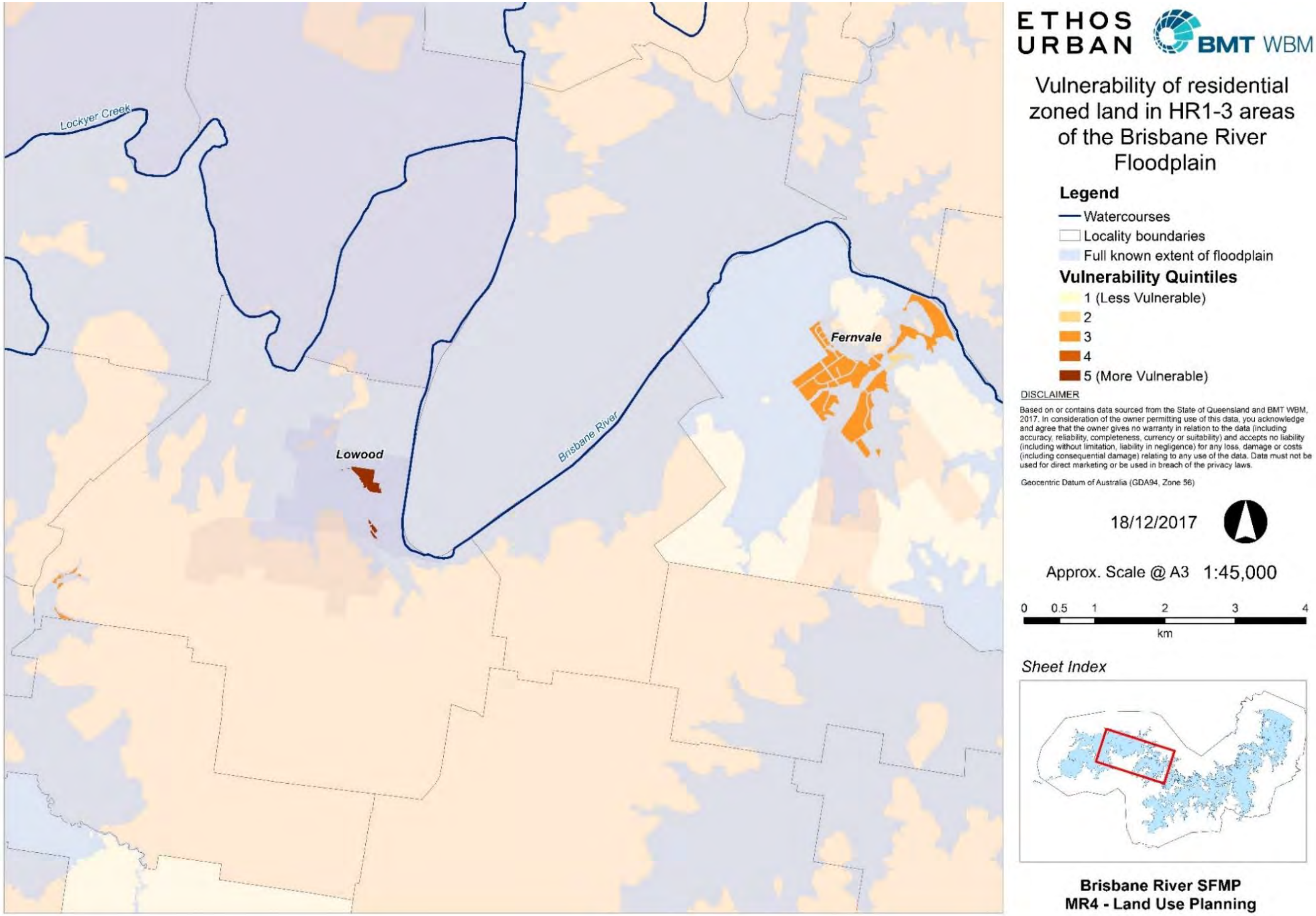


Figure 9-12 HR1 to HR3 residential zoned land within quintiles Q4 and Q5 in Somerset LGA

9.4.3.2.2 Centre Zone Group

Land within the floodplain's Centre zone group contains the most diverse mix of land uses and densities, as well as varied building design and gross floor area intensities. It is assumed that this land includes retail, commercial, business, mixed uses and the like. Within the Brisbane River floodplain, there is approximately 1,232 Ha of land zoned for centre purposes. While proportionally, this only represents approximately 2% of all land use groups within the floodplain, 22% or 268 Ha is in HR1 and HR2 areas. Table 9-7 identifies that 49% of these HR1 and HR2 areas have a relative time to inundation less than 12 hours.

Table 9-7 Statistics of centre zone land within floodplain

Area within floodplain (Ha)	% land area within floodplain	HR Category	Area within HR1 and HR2 (Ha)	% land area within HR1 and HR2	HR1 and HR2 area (Ha) with <12hrs relative time to inundation	% HR1 and HR2 area with <12hrs relative time to inundation
1,232	1.7%	HR1 and HR2	268	22%	132	49%
		HR1	75	6%	70	93%
		HR2	193	16%	62	32%

Statistics at the LGA level are summarised in Table 9-8. Brisbane City has almost half of its centre zone land within the floodplain or 1,003 Ha, of which 226 Ha (23%) is within HR1 and HR2. Many of Brisbane's centres constitute growth nodes on selected transport corridors and are intended for further consolidation and infill development. Approximately half of Centre zone land within HR1 and HR2 areas in Brisbane City also has limited relative time to inundation. Ipswich City has a larger proportion of its centre zone land within the floodplain – 59% or 204 Ha of which 42 Ha (21%) of this land is within HR1 and HR2 areas. Approximately 48% has limited relative time to inundation. Somerset Region has 25 Ha (13%) of centre zone land in the floodplain, none of which is located in HR1 and HR2 areas.

Table 9-8 Centre zone land in each LGA

LGA	Centre land within floodplain (Ha)	Centre land within HR1 and HR2 (Ha)	% centre land within HR1 and HR2	Centre land <12hrs relative time to inundation (Ha)
Brisbane	1,003	226	23%	112
Ipswich	204	42	21%	20
Somerset	25	0	0	0
Lockyer	No centre zone land within floodplain			

Table 9-9 identifies 6,955 commercial buildings across the floodplain. 673 (10%) of these are located in HR1 and HR2 areas. The risk and damage to property is likely to be greater in these higher hydraulic risk areas, as discussed in Section 9.4.3.3.

Table 9-9 Commercial buildings within floodplain

Property type	Hydraulic Risk category				
	HR1	HR2	HR3	HR4	HR5
Commercial	92	581	1,295	1,589	3,398

9.4.3.2.3 Industry Zone Group

The Industry zone group contains a range of industrial activities operating at various intensities across the floodplain (e.g. low, medium, high impact, specialised industry etc.), including buffer areas where adjoining sensitive zones. The floodplain consists of 5,332 Ha of industrial zone land; this makes up approximately 7% of all zoned land (refer to Table 9-10). Almost a quarter of this land (1,186 Ha), however, sits within a HR1 and HR2 area. Of this, 775 Ha (or 65%) has limited relative time to inundation. This exposure has implications for the type and intensity of industrial activity that can occur in higher flood risk areas, and the specific built form controls adopted to reduce risk to a tolerable or acceptable level.

Table 9-10 Statistics of industrial zone land within floodplain

Area within floodplain (Ha)	% land area within floodplain	HR Category	Area within HR1 and HR2 (Ha)	% land area within HR1 and HR2	HR1 and HR2 area (Ha) with <12hrs relative time to inundation	% HR1 and HR2 area with <12hrs relative time to inundation
5,332	7.2%	HR1 and HR2	1,186	22%	775	65%
		HR1	567	10.6%	520	92%
		HR2	619	11.6%	255	41%

Statistics at the LGA level are summarised in Table 9-11. Brisbane City has a high proportion of its industrial zone land within the floodplain at 60%. Although only 15% (522 Ha) of this is within a HR1 and HR2 area, close to 60% (299 Ha) has less than 12 hours relative time to inundation. Similarly, Ipswich City has approximately 40% of its industrial land in the floodplain, 38% of which is within HR1 and HR2. The entire 2% of the Lockyer Valley Region's industrial zone land in the floodplain (where within the boundaries of the Brisbane River SFMP Study Area) is also within HR1 and HR2 areas and has less than 12 hours relative time to inundation. For Brisbane City, Ipswich City and Lockyer Valley, sizable industrial pockets adjoin the Brisbane and Bremer Rivers and Lockyer Creek, indicating the importance of consideration of the management of impacts and potentially hazardous activities.

Table 9-11 Industrial zone land in each LGA

LGA	Industrial land within floodplain (Ha)	% industrial land within floodplain	Industrial land within HR1 and HR2 (Ha)	Industrial land <12hrs relative time to inundation (Ha)
Brisbane	3,590	60%	522	299
Ipswich	1,696	39%	644	456
Somerset	26	17%	0	0
Lockyer	20	2%	20	20

Table 9-12 counts approximately 1,466 industrial buildings within HR1 and HR2 areas, representing 16% of all industrial stock in the floodplain. Higher damages are more likely in these areas, as discussed in section 9.4.3.3.

Table 9-12 Industrial buildings within floodplain

Property type	Hydraulic Risk category				
	HR1	HR2	HR3	HR4	HR5
Industrial	181	1,285	2,119	1,824	4,028

9.4.3.2.4 Priority Development Areas

Seven Priority Development Areas (PDAs) are located across the floodplain in the Brisbane City and Ipswich City LGAs. These are located in Figure 9-13 and relevant statistics are presented in Table 9-13. Ipswich City has 284 Ha (or 2%) of all PDA land within the floodplain. Almost all of this land (99.6%) is within the HR4 and HR5 categories. Only 1 Ha of land within Springfield is located in HR3; however, this is zoned for open space/environment purposes. None of the identified PDA land in Ipswich has limited relative time to inundation.

Brisbane has additional PDA land within the floodplain: approximately 349 Ha or 56%. The Fitzgibbon and (for the most part) Woolloongabba PDAs are located outside the floodplain, or are in areas of lowest hydraulic risk (i.e. HR5). The South Bank and Bowen Hills PDAs have less land area within the floodplain – 41 Ha and 59 Ha respectively. Much of the South Bank (83%) and Bowen Hills (97%) PDAs are also located in lower hydraulic risk areas, HR3 to HR5. However, 240 Ha of the Northshore Hamilton PDA lies within the floodplain. While only 11 Ha of this is within HR1 and HR2, over half of this (55%) has limited relative time to inundation.

The PDAs within Brisbane City support high densities, vertical typologies and a broad mix of land uses. Only 5% of Brisbane's total PDA area within the floodplain has limited relative time to inundation.

Table 9-13 Statistics of PDA land within floodplain

	Area within floodplain (Ha)	% land area within floodplain	HR Category	Area within HR1 and HR2 (Ha)	Area (Ha) <12hrs relative time to inundation
Ipswich					
Ripley	161	1%	HR1	0	0
			HR2	0	0
Springfield	123	1%	HR1	0	0
			HR2	0	0
Brisbane					
Bowen Hills	59	9%	HR1	1	1
			HR2	1	0
Fitzgibbon	0	0	HR1	0	0
			HR2	0	0
Northshore Hamilton	240	38%	HR1	7	4
			HR2	4	2
South Bank Corp.	41	7%	HR1	2	1
			HR2	5	1
Woolloongabba	9	1%	HR1	0	0
			HR2	0	0

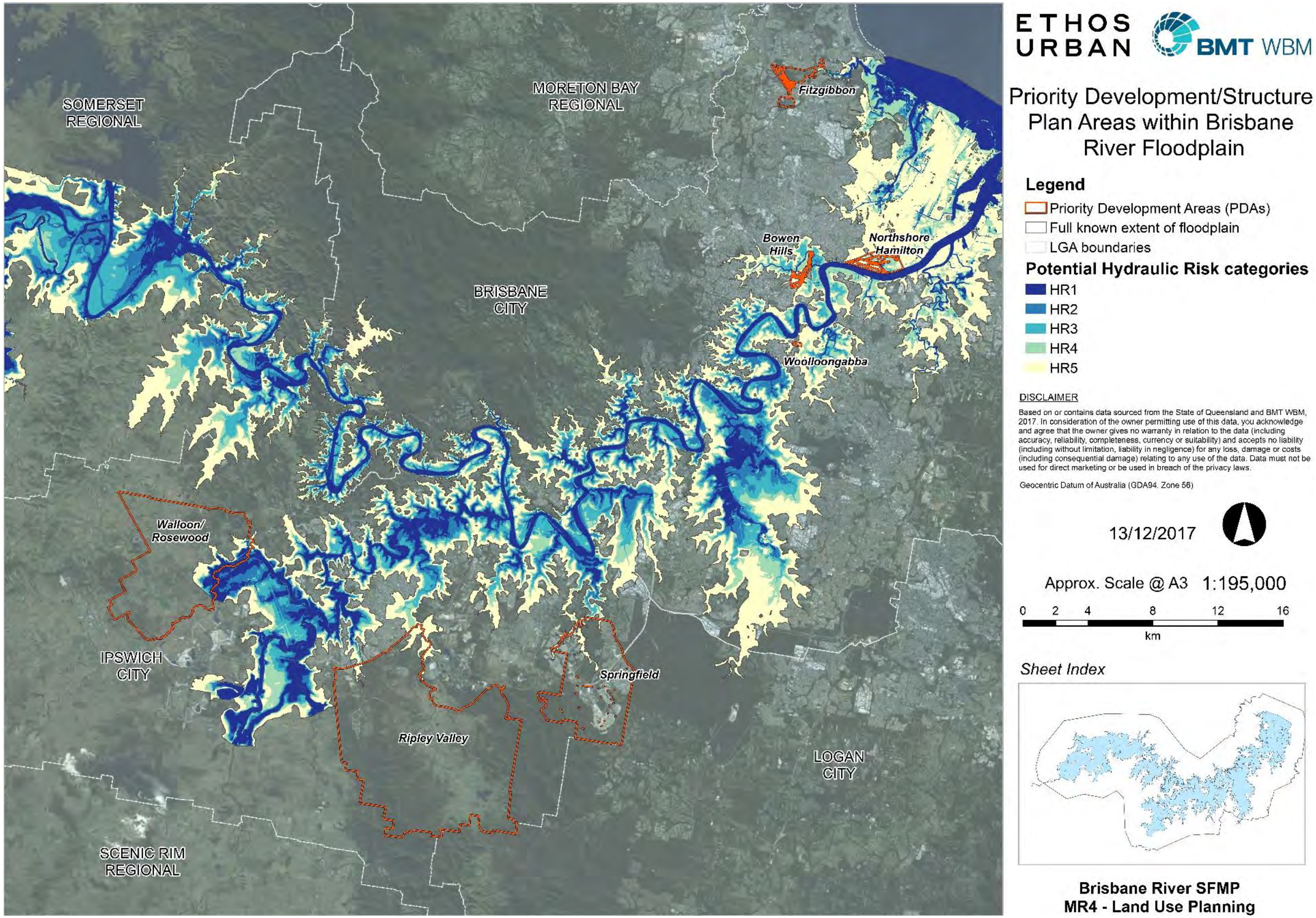


Figure 9-13 Location of PDAs within floodplain

9.4.3.3 Potential Implications of Current Zoning Allocation

The above analysis indicates that there is the potential for flood risk issues to arise in relation to land uses within some areas of the floodplain, as summarised in Table 9-14.

Table 9-14 Summary of current land use zoning exposure

	Urban Footprint (Ha)	Residential (Ha)	Centre (Ha)	Industry (Ha)	Priority Development Area (Ha)
Floodplain	42,194	8,149	1,232	5,332	633
HR1 & HR2	11,540	733	268	1,186	20
<12 hrs RTI	8,629	316	132	775	9

It should be noted that this analysis did not interrogate detailed planning controls of each planning instrument to evaluate the extent to which those planning controls may be directing development outcomes which avoid or mitigate flood risk to people and property. Hence, although there is an identified intersection between land use zoning and hydraulic risk, the extent of risk to life and property as a result of this intersection requires further analysis at the local level, informing Phase 4 (LFMP) to determine the need for refinement of existing land use allocation and planning controls.

The results have focussed on potential hydraulic risk categories, HR1 and HR2, as these areas are characterised by a hydraulic hazard of H4 or greater at the 1 in 100 AEP, where risk to life and property becomes significant and potentially intolerable (i.e. unsafe for all people and resulting in the structural failure of buildings).

The Phase 4 (LFMP) process and/or the local flood risk assessment may refine this analysis and inform the required planning response to flood risk and as such there is an opportunity – through risk-appropriate land use planning and development controls – to maintain and gradually reduce flood risk over time in the development of urban areas within the floodplain.

Existing urban areas of the floodplain that are identified as HR1 or HR2 area and have limited relative time to inundation, need to be consistently identified and understood as high hydraulic risk areas by planning authorities and the community. Where possible, avoidance of these areas for development of land uses that are vulnerable to flood risk, particularly those uses which support vulnerable persons, is prudent. Where substantial infill or redevelopment is intended (e.g. in major centres, along transport corridors, around employment nodes, such as RECs etc.), the tolerability of development will depend on: (a) the underlying hydraulic risk conditions (i.e. base constraint, as defined by the PHR matrix), (b) evacuation capability including accessibility to, and immunity of, evacuation routes and centres to accommodate the increased population exposed, and (c) building design and construction that will reduce risk to persons and property and improve resilience to flood hazard.

In areas of high hydraulic risk (HR1 and HR2), or where community infrastructure and critical services are proposed, evacuation outside the floodplain should be prioritised as the preferred disaster management strategy at a strategic planning level. This is in preference to shelter-in-place or on-site refuge strategies. It is recommended that a regional evacuation assessment across the Brisbane

River floodplain be undertaken to inform the Phase 4 (LFMP) process and to determine evacuation risk at the regional and local levels. BMT WBM, Bewsher and Grech (2014) suggest that the risk appropriateness of development and the planning response adopted will depend, in part, on evacuation risk, and provide the following principles to inform this assessment:

- ability to evacuate to an evacuation centre and the time available versus that required to do so (i.e. is the relative time to inundation less than or greater than the time required for safe evacuation?);
- duration of the flood (short or long term) and the vulnerability of the population accommodated by the proposed development;
- potential for the topography to form high or low flood islands and create an isolation risk;
- availability of on-site refuge located above the PMF, where occupants can retreat to higher ground to minimise risk to life;
- supplies/facilities available to support the number of people seeking refuge, and their health and safety needs; and
- "concessional development" – i.e. risk-appropriate redevelopment of a site that reduces its existing flood risk.

The above principles should be applied both top-down and bottom-up; that is, be expressed in planning authorities' flood policy at a strategic level and be considered by applicants in development assessment. A consistent policy for defining and mapping hydraulic risk and integrating disaster management considerations will measurably reduce current risk to life and property in the Brisbane River floodplain. This will have greatest effect in those more 'constricted' and higher hydraulic risk areas of the floodplain (i.e. HR1 and HR2 flood flow conveyance areas), which are often adjoined by sensitive development and higher residential densities. Even small changes to floodplain behaviour through redevelopment or infill of these existing areas will significantly increase flood level impacts in the context of the Brisbane River floodplain. From a strategic planning perspective, given that areas of HR1 and HR2 perform critical flow conveyance functions, filling and land form change as a development solution in these areas needs to be carefully considered as impacts on flood behaviour in these areas can have implications elsewhere on the floodplain. The establishment of land uses which rely on filling and changes to land form as the 'standard' engineering solution to achieve the required level of tolerability should preferably be avoided in these areas.

Planning controls need to ensure the underlying zoning supports uses that reduce hydraulic impacts and achieve flood resilient redevelopment. Examples of requirements for infill development may include: rising road access, multi-storey built form, interconnected building design at podium level to provide access to communal, above-ground support facilities, provision of refuge areas where evacuation requirements cannot practicably be met, higher residential floor pads, risk appropriate DFEs for different uses etc.

9.4.4 Summary of Future Flood Risk Findings

9.4.4.1 Future Urban Zone Group

Future urban zone land includes all emerging community and investigation type zones. The future use to which these areas can be put is either undefined, or subject to a local structure planning process to determine constraints, values, opportunities and the appropriate mix of uses and sequencing of development. However, in some instances more detailed local master planning processes may have been undertaken to set expectations for, and provide certainty around, intended future land use, development and infrastructure delivery in these areas. In most circumstances, land is intended for urban purposes in the future. The Brisbane River floodplain has approximately 3,112 Ha or 4% of land within the Future urban zone group. Almost a quarter of this land is within a HR1 and HR2 area (approx. 702 Ha), and a high proportion of this has limited relative time to inundation (480 Ha), as summarised in Table 9-15. Figure 9-14 maps the distribution of future urban land across the floodplain.

Table 9-15 Statistics of Future urban zone land within floodplain

Area within floodplain (Ha)	% land area within floodplain	HR Category	Area within HR1 and HR2 (Ha)	% land area within HR1 and HR2	HR1 and HR2 area (Ha) with <12hrs relative time to inundation	% HR1 and HR2 area with <12hrs relative time to inundation
3,112	4.2%	HR1 and HR2	702	23%	480	68%
		HR1	374	12%	360	96%
		HR2	328	11%	120	37%

Statistics at the LGA level are summarised in Table 9-16. A quarter of Brisbane City's future urban land is provided in the floodplain. A smaller proportion of this (68 Ha, or 7%) is in HR1 and HR2. Ipswich City has 17% within the floodplain – however, 520 Ha is in the highest hydraulic risk categories and approximately 75% of this has limited relative time to inundation. Somerset Region has 32% (653 Ha) of future urban land within the floodplain. However, much less of this land is within areas of high hydraulic risk (i.e. 539 Ha sits in HR3 to HR5).

Table 9-16 Future urban zone land in each LGA

LGA	Future urban land within floodplain (Ha)	Future urban land within HR1 and HR2 (Ha)	% future urban land within HR1 and HR2	Future urban land <12hrs relative time to inundation (Ha)
Brisbane	913	68	7%	39
Ipswich	1,546	520	34%	382
Somerset	653	114	17%	59
Lockyer	0	0	0	0

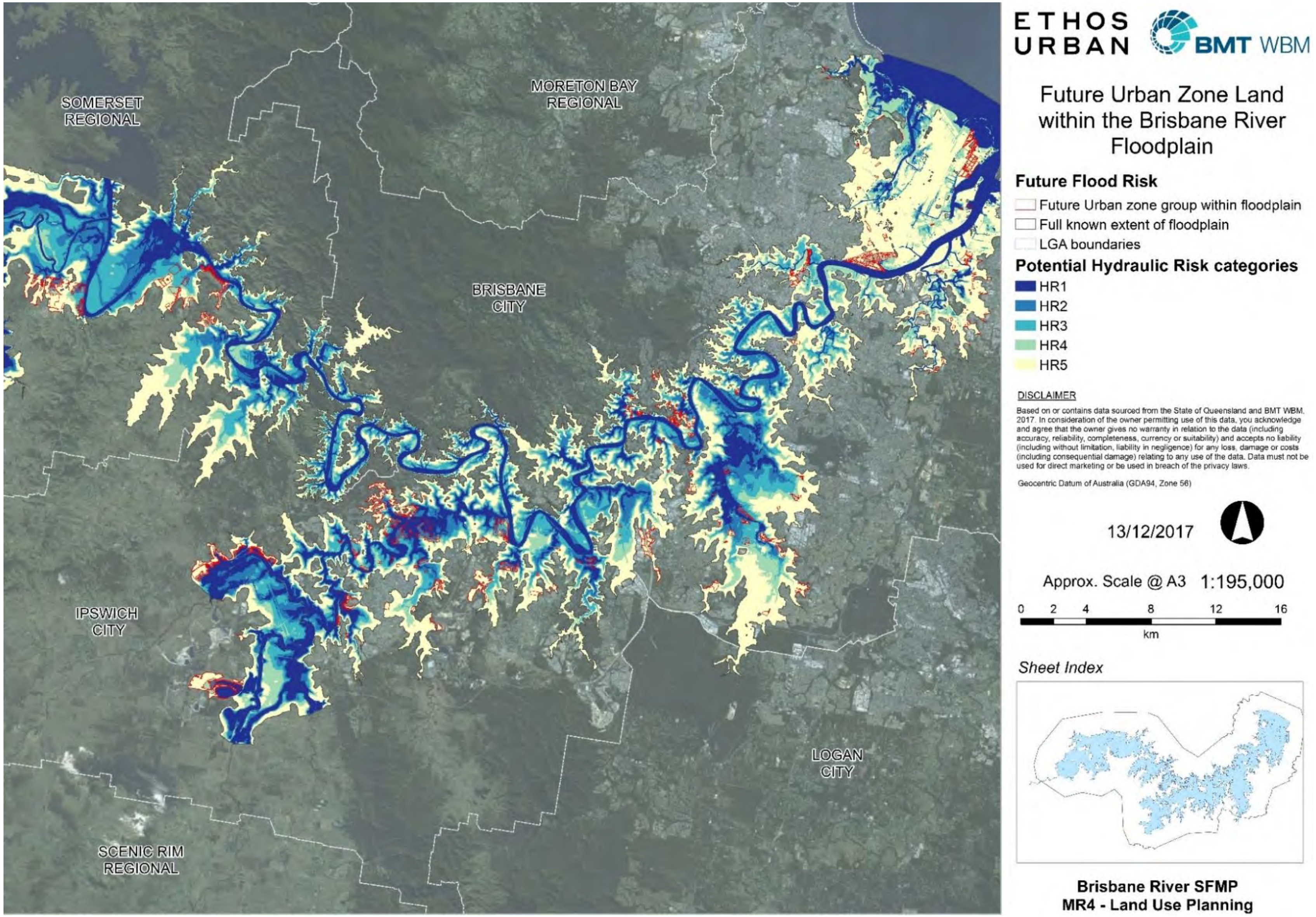


Figure 9-14 Future urban land areas within floodplain

9.4.4.2 Climate Change Impacts

9.4.4.2.1 Future Urban

The change in the extent of Future urban zone land impacted by hydraulic risk under current and future climate conditions, was compared. Two climate change scenarios as discussed in Section 5.2 of the TER were applied to this analysis:

- CC5 – assumes 10% and 0.63m increase in rainfall intensity and sea level rise respectively, by 2090; and
- CC4 – assumes 20% and 0.8m increase in rainfall intensity and sea level rise respectively, by 2090.

Table 9-17 identifies that the hydraulic risk profile characterised by HR1, HR2 and HR4 will increase under both CC5 and CC4 scenarios. Of note is the 20% increase (from 702 Ha to 843 Ha) in the amount of Future urban zone land in HR1 and HR2 areas under CC5. However, a much higher proportion of land – 40% – will move to HR1 and HR2 areas under CC4 (from 702 Ha to 983 Ha). The percentage change between the CC4 and CC5 scenarios shows that, respectively, an additional 24% and 8% of land will have HR1 and HR2 characteristics (i.e. the risk profile will increase, as more Future urban land is located in higher HR categories).

Table 9-17 Future urban zone land impacted under climate change scenarios

HR Category	Current future urban land within floodplain (Ha)	Future urban land impacted under CC5 (Ha)	% change between current & CC5 risk	Future urban land impacted under CC4 (Ha)	% change between current & CC4 risk	% change between CC4 & CC5
HR1	374	441	↑ 18%	549	↑ 47%	24%
HR2	328	402	↑ 23%	434	↑ 32%	8%
HR3	349	319	↓ 9%	362	↑ 4%	13%
HR4	423	483	↑ 14%	441	↑ 4%	-9%
HR5	1,638	1,489	↓ 9%	1,349	↓ 18%	-9%

9.4.4.2.2 Residential

The change in the extent of Residential zone land impacted by hydraulic risk under current and future climate conditions, was compared. Two climate change scenarios as discussed in Section 5.2 were applied to this analysis:

- CC5 – assumes 10% and 0.63m increase in rainfall intensity and sea level rise respectively, by 2090; and
- CC4 – assumes 20% and 0.8m increase in rainfall intensity and sea level rise respectively, by 2090.

Table 9-18 shows that the risk profile of residential land in HR1 and HR2 areas will increase more substantially under the CC5 and CC4 scenarios. For example, there is a projected 61% increase in the amount of residential land mapped as HR1 and HR2 under CC5 (from 733 Ha to 1,180 Ha). Under CC4, the amount of additional residential land affected in HR1 and HR2 areas is 121% (from 733 Ha to 1,621 Ha). The final column in Table 9-18 shows the change in the amount of residential land reassigned to a HR1 and HR2 category between CC5 and CC4 – 74% and 27% respectively.

Table 9-18 Residential zone land impacted under climate change scenarios

HR Category	Current residential land within floodplain (Ha)	Residential land impacted under CC5 (Ha)	% change between current & CC5 risk	Residential land impacted under CC4 (Ha)	% change between current & CC4 risk	% change between CC4 & CC5
HR1	178	255	↑ 43%	443	↑ 149%	74%
HR2	555	925	↑ 67%	1,178	↑ 112%	27%
HR3	1,146	1,079	↓ 6%	1,121	↓ 2%	4%
HR4	1,148	1,133	↓ 1%	1,170	↑ 2%	3%
HR5	5,122	4,837	↓ 6%	4,318	↓ 16%	-11%

9.4.4.3 *Implications of Future Urban Development*

The Future urban analysis identifies potential implications with the impact of climate change on the distribution of land use within the floodplain. This is seen in Table 9-19 below.

Table 9-19 Summary of future zoning exposure, including climate change

	Current Future Urban (Ha)	Future Urban under CC5 (Ha)	Future Urban under CC4 (Ha)	Current Residential (Ha)	Residential under CC5 (Ha)	Residential under CC4 (Ha)
Floodplain	3,112	3,134	3,135	8,149	8,229	8,230
HR1 & HR2	702	843	983	733	1,180	1,621
<12 hrs RTI	480			316		

Land use planning is the most effective mechanism to reduce flood risk to future development by avoiding high hydraulic risk areas (BMT WBM, Bewsher & Grech, 2014). Because future urban areas largely comprise large development opportunities and urban expansion areas, new development within these areas may have a pronounced, cumulative impact on flood behaviour regionally. This is particularly true of development relying on filling to achieve acceptable flood immunity. These impacts are also projected to be exacerbated over time with the impacts of climate change on flood hazard.

A Brisbane River regional cumulative impact assessment should be undertaken as a priority to support planning authorities in preparing and informing Phase 4 (LFMP) and the local risk assessment process. A strategic analysis of the cumulative impact of filling to achieve development assumptions should be undertaken across the Brisbane River floodplain to understand the implications of filling and land form change on flood risk. Section 9.5.4.2 discusses a recommended approach to this analysis.

It is recommended that the limit of acceptable hydraulic impact for filling should be less than 10mm (see Section9.5.4.2.2). However, it is known that filling in areas of the floodplain with extreme hydraulic risk (i.e. HR1) will result in the constriction of flood flows (see Section 5.1). Cumulative hydraulic impacts in these areas should therefore be managed by identifying filling as potentially intolerable (i.e. does not occur).

Planning instruments have historically used a range of flood risk treatment measures to achieve flood immunity up to a certain AEP event. Traditionally, these measures focus on minimising damage to property through the use of built form controls such as habitable floor levels and the location of non-habitable uses only below these levels, construction of buildings to withstand hydrodynamic and hydrostatic forces of flood waters, open undercroft design and balanced cut and fill to minimise filling implications and 'no worsening' of flood hazard conditions. However, the prevailing planning response to achieve acceptable flood immunity has generally been to fill up to the 1 in 100 AEP (as assumed in DS2 of Section 5.1). This approach is problematic for two reasons:

- First, parts of the floodplain are particularly sensitive to changes in landform. Table 9-20 shows that filling in DS2 will increase peak flood levels above the 1 in 100 AEP (e.g. 0.9m increase to peak flood levels in Ipswich). While the regional cumulative impact assessment will identify those more (and less) sensitive areas of the floodplain to land form change and filling, the Phase 3 (SFMP) sensitivity testing of future development scenarios shows noticeable increases in the severity of flood behaviour, by way of higher peak flood levels in some areas, when filling is relied on to achieve the 1 in 100 AEP design event.
- Secondly, a DFE up to the 1 in 100 AEP only accounts for approximately 29% of the total Average Annual Damages (AAD) incurred; the balance of damages (71%) results from floods greater than the 1 in 100 AEP, and these have the greatest economic impact in HR1 and HR2 areas (refer to Figure 9-15 and Figure 9-16).

Notwithstanding, the above two observations show that the prevailing land use planning response to flood risk – up to the 1 in 100 AEP – has yielded some positive results in damage reduction and economic recovery. However, these positives become less evident when accounting for climate change.

Table 9-20 Future development flood level impacts (Section 5.1 TER)

	Increase in Peak Flood Level from Base Case (m)			
AEP	Brisbane (City Gauge)		Ipswich (David Trumpy Bridge)	
1 in Y	DS1	DS2	DS1	DS2
10	0	0	0	0
20	0	0	0	0.1
50	0	0.1	0	0.4
100	0	0.1	0	0.9
500	0	0	0	0.4
2,000	0	0	0.2	0.3
100,000	-0.1	-0.1	0.4	0.5

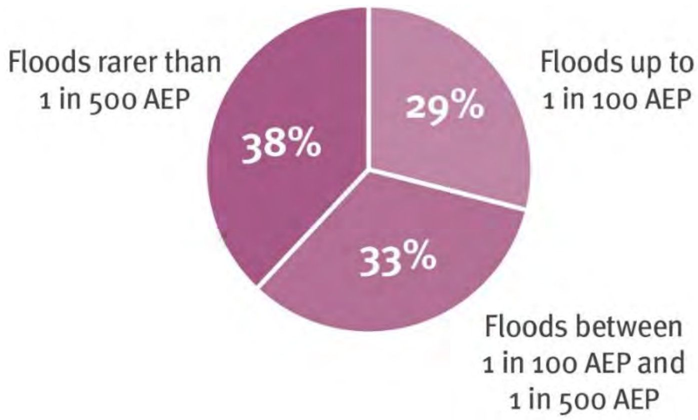


Figure 9-15 Proportion of flood damages by flood likelihood

Figure 9-16 Property damages by HR category

The effects of climate change will increase the amount of land within HR1 and HR2 areas; many of these areas would require even greater quantities of fill to reduce the level of risk to future development. Climate change therefore removes the net benefit of filling in future urban zones, with the peak flood levels in these areas already highly sensitive to filling up to the 1 in 100 AEP.

A co-ordinated, regional response to climate change adaptation is recommended to inform future flood hazard studies, local flood risk assessments, Phase 4 (LFMPs) and land use planning responses. This regional response should be informed by the senstivitiy analysis undertaken for this Phase 3 (SFMP) (see Section 5.2) and may be developed and implemented through the Queensland Climate Resilient Councils Program. Section 9.5.4.3 provides suggested guidance for incorporating climate change impacts into land use planning responses.

Land use planning and development policy should ensure that uses determined by the planning authority to be inappropriate to, or incompatible with, the flood risk do not occur in areas of the floodplain where an adverse increase in the hydraulic risk profile is expected to result from climate change over time, or where such development may potentially result in a material (future) risk of serious harm to persons or property on the premises from flooding (as intended by the feasible alternatives assessment process under the Minister's Guidelines and Rules). Notwithstanding, it will be the role of Phase 4 (LFMPs), local flood risk assessment and the outcomes of a regional climate change adaptation response to inform the: more detailed structure planning of future urban areas, land suitability and the development potential that exists in respect of this land, establishment of risk appropriate land uses and balancing of the flood constraint and future land use exposure with other locally relevant land use planning and development policy considerations.

9.5 Land Use Planning Responses

The analysis discussed in Section 9.4, although undertaken at a strategic, whole-of-floodplain level, indicates that refined or more nuanced land use planning responses to current and future flood risk within the Brisbane River floodplain are potentially warranted. The nature of the specific responses, however, requires further, more detailed investigation than has been possible within the scope of this analysis – to interrogate the adequacy of the existing planning arrangements to the treatment of flood risks and to identify any changes that may be required to planning instruments to refine existing approaches.

Ideally, a local flood risk assessment integrated with Phase 4 (LFMP), provides a logical pathway to enable these investigations to occur and to support with robust technical evidence any potential refinement to land use planning responses within the context of a broadly based and integrated local response to flood risk.

Preparing and implementing an integrated local flood risk assessment and LFMP is an important 'tool' to achieve a holistic and integrated response to flood risk management at the local level. It will provide the detailed evidence to ensure flood risk treatment measures, including land use planning responses, are suitably refined to respond to local circumstances. The Phase 4 (LFMPs) will assist planning authorities in meeting the requirements of the State Planning Policy and plan making process under the Minister's Guidelines and Rules (MGR), as discussed below (e.g. SPP flood risk assessment, natural hazards, risk and resilience evaluation report as part of the state interest review). However, to ensure regionally consistent outcomes for the identification and treatment of flood risk, the Phase 4 (LFMPs) should draw on, and be informed by, the following two approaches:

(1) Strategic planning actions recommended by, and emerging from, the SFMP aspirations, around which regional consistency is required – such as the preparation of a regional evacuation assessment, treatment of vulnerable uses involving vulnerable persons, incorporation of climate change factors into land use planning responses and regional cumulative impact assessment of filling and land form change across the full known extent of the floodplain; and

(2) Where (1) results in changes to the growth assumptions and settlement pattern (e.g. future urban areas) underpinning local planning instruments, the implications for regional land use, land supply and outcomes under the SEQ Regional Plan are investigated.

The Phase 4 (LFMP) approach will provide an important detailed evidence base to ensure responses are suitably refined to respond to local circumstance. However, this process, in order to achieve regionally consistent outcomes, must be integrated with two other responses including: (a) regionally consistent land use policy for a number of key policy areas influencing flood risk; and (b) a regional strategic planning response which, if required, calibrates the development directions provided by the Shaping SEQ Regional Plan with flood risk and other regional planning policies (informed by the detail of Phase 4 (LFMP)).

This iterative process enables knowledge developed through planning processes to feedback and inform the review of related planning instruments and floodplain management response.

Amendments to planning instruments – whether they be local planning schemes or Priority Development Area Development Schemes – must be undertaken following a statutory process that can require up to several years to execute in full. This timeframe could potentially be further extended with iterative associated local and regional planning processes. Opportunities to bring forward interim regulatory arrangements to address priority policy matters could be considered as part of the preparation of refined responses (if required) to provide direction to new development occurring within the floodplain. The need for, benefit and options for potential interim regulatory arrangements is a matter that should be considered further by the State Government in close consultation with local planning authorities; opportunely this is considered to best occur as part of the implementation, review and monitoring of the SFMP and its ongoing project governance.

The integrated response, discussed in detail in the sections below, and outlined in Figure 9-17**,** will support consistent land use planning outcomes in terms of Brisbane River flood risk.

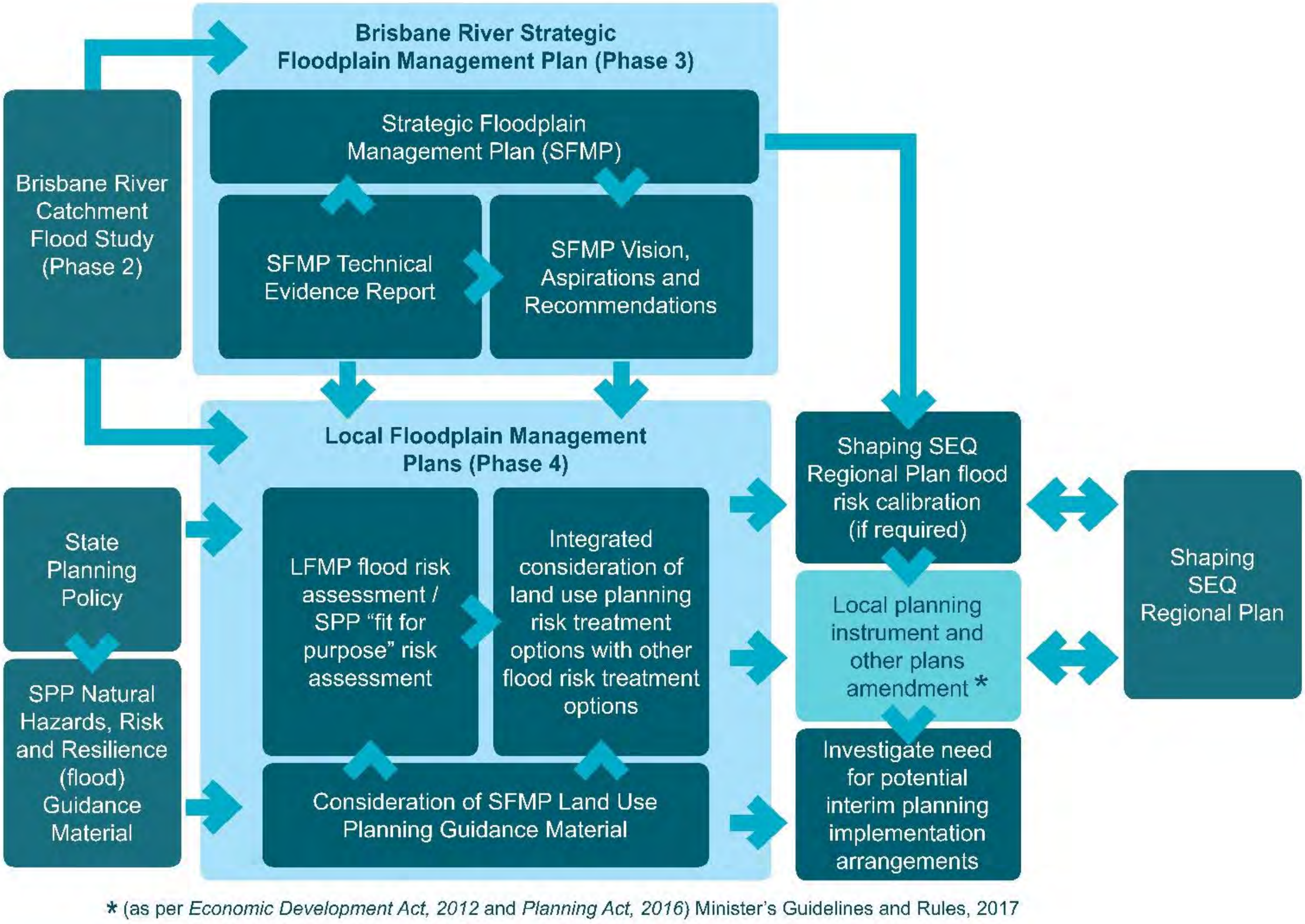


Figure 9-17 Land use planning response approach

9.5.1 Phase 4 (Local Floodplain Management Plans)

Section 13.8 provides guidance on the scope and approach recommended for the preparation of Phase 4 (LFMPs). That scope includes the consideration and inclusion of direction provided by Phase 3 (SFMP).

Specifically, with regard to land use planning, the preparation of a Phase 4 (LFMP), undertaken in accordance with the recommended direction, is complementary to the natural hazards (flood) risk assessment process prescribed by the State Planning Policy and the methodology and approach contained within the State Planning Policy Natural Hazards, Risk and Resilience – Flooding Guidance Material July 2017 (SPP Flood Guidance Material).

As such the preparation of Phase 4 (LFMP) is one way in which a local government may meet the requirements of the SPP natural hazards (flood) risk assessment process. Where a local government seeks to combine the requirements of Phase 4 (LFMP) and the SPP (flood) risk assessment, it is recommended that local authorities, have regard to and incorporate into the Phase 4 (LFMP) scope the requirements of the SPP, 'fit for purpose natural hazard (flood) risk assessment' and the requirements to prepare a 'Natural Hazards (flooding) Evaluation Report' and, in doing so, avoid duplication of processes and document preparation to support any proposed planning changes responding to flood risk.

It must be acknowledged that local planning authorities preparing planning instruments under the requirements of the SPP must consider the full suite of 17 state interests along with the SPP guiding principles and other applicable state planning instruments. The SPP acknowledges that the *'SPP does not give more weight to any particular state interest over another recognising that regional and local context must always be considered when integrating state interests at the regional and local level'*. In this context, the land use planning response to flood risk is a subset of one of those state interests and, as such, planning authorities will be challenged to establish land use planning responses which reflect a *'balance (of) state interests (as necessary)'* and '*best integrate these interests into a local planning instrument'*.

Phase 4 (LFMP) informed by community engagement will also establish the tolerability of different land uses, densities and built form to flooding, as well as the acceptability of the flood risk to local communities. This is an important input into establishing the necessary treatment responses to flood risks through the planning instrument.

The preparation of an integrated Phase 4 (LFMP) (including a risk assessment) will provide the framework and process through which flood risks can be assessed and evaluated and treatment options considered. The preparation of Phase 4 (LFMP) provides an opportunity for the land use exposure to flood risk (undertaken at a strategic level within Section 6 of this report) to be refined at a local scale in order for the adequacy of existing land use planning responses to be understood in detail and further refinements identified.

Through Phase 4 (LFMP), analysis of the intersection of the Potential Hydraulic Risk categories with specific planning instrument zones (rather than regionally aggregated zones), existing development approvals and existing land use activity, will – when coupled with an appreciation of other flood risk factors, such as evacuation capability, relative time to inundation, high and low island analysis etc. – provide a detailed local picture of land use exposure to flood risk. A detailed interrogation of the existing planning scheme responses, including strategic framework content, underlying land use zoning, zone purpose, applicable land uses, their level of assessment and the detailed zone, overlay and development code requirements/assessment benchmarks, will provide an evaluation of the adequacy of existing planning responses and the evidence base upon which the need to revise or refine planning responses can rely.

This analysis will be of particular importance in informing the content of a 'Feasible Alternatives Assessment Report' (See Minister's Rules and Guidelines , July 2017, Chapter 4) should the planning authority propose a 'planning change' to 'reduce a material risk of serious harm to persons or property' (*Planning Act 2016*, Section 30(4)(e)) as a result of flood risk.

The non-statutory LUP Guidance (Section 4.5.6) provides examples of possible circumstances where a planning change may be needed to reduce a risk of potential serious harm to people or property from flood hazard, and where these changes may be determined not to be an adverse planning change (where it is supported by a Feasible Alternatives Assessment Report (FAAR) prepared in accordance with the Minister's Rules and Guidelines).

The circumstances are drawn from the SFMP flood risk factor tools, particularly the potential hydraulic risk matrix and includes specific reference to the AIDR (2017) flood hazard classification and impacts on people, vehicles and buildings (See Figure 4-3 and Table 4-2 in Section 4.2.3 of the Technical Evidence Report). In summary, the recommended circumstances where a planning change may be considered appropriate to reduce a risk of potential serious harm to people or property include, but are not necessarily limited to:

- Potential Hydraulic Risk categories of HR1, HR2 or HR3, where defined at or more frequent than the 1 in 100 AEP and with flood hazard levels of H3 to H6 being potentially unsafe and intolerable for vulnerable people such as the elderly and children (at H3 or greater) and, being unsafe for adults and vehicles (at H4 or greater). Risk to life and property is also threatened because of potential for all buildings to be vulnerable to potential structural damage (at H5 or greater) and all building types considered vulnerable to structural failure (at H6);
- areas with limited relative time to inundation (being less than 24hrs for vulnerable uses and less than 12hrs for residential uses) and fast/high expected rates of rise/inundation making it difficult or impossible to evacuate;
- low immunity sections of an evacuation route;
- development controls (built form, DFEs, siting, design etc.) are unlikely to be effective in increasing flood resilience or treating flood risk to an acceptable or tolerable level, or the impacts associated with implementing the measures would be unacceptable;
- filling to the DFE as an option to mitigate flood risk is not possible because such filling will obstruct or alter flow in flow conveyance areas (HR1 or HR2), or filling is within HR3 or HR4 areas and will reduce flood storage volume resulting in impacts regionally or elsewhere in the floodplain (when considered on a cumulative basis).

Phase 4 (LFMPs) can be used as the technical evidence to inform the preparation of a FAAR and demonstrate to the State how a planning authority has made informed land use planning decisions based on a robust risk assessment within a broader LFMP process, including consideration of a range of options to respond to flood risk. Importantly, the LFMP will show how land use planning responses are working ‘in concert’ with other flood risk management measures to address risk to life and property and provide the evidence or rationale to justify the planning response. Hence, this strategic planning element of Phase 4 (LFMP) is an essential integrating component enabling land use planning responses to be modelled along with other floodplain management responses resulting in an optimum, integrated response to flood risk management where each floodplain management response ‘plays its part’. This modelling and analysis will provide clarity as to those risks that can be managed through non-land use planning responses and those that need to be treated by land use planning responses including potential ‘planning changes’ to local and state planning instruments if required.

Some of the inputs into this strategic planning process are already well defined, such as the SFMP vision, aspirations and recommendations and state planning interests through the State Planning Policy; others are emerging and will require further work – either locally or regionally – to inform these processes.

Brisbane River Strategic Floodplain Management Plan

The Phase 3 (SFMP) vision, aspirations and recommendations, upon finalisation, will provide direction to stakeholders on the integration of these elements into floodplain management initiatives. Importantly, the SFMP embeds considerations of Integrated Catchment Planning principles into the management of the Brisbane River floodplain. These considerations will provide an important context to land use planning initiatives in the floodplain which will require integration into the assessment of land use planning responses to flood risk.

State Planning Policy – State Interests and local strategic planning policy directions

As discussed above, Natural Hazard, Risk and Resilience (flood) is a subset of one state interest among 17 in total. Local planning authorities need to balance state interests to achieve locally relevant planning responses to the State Planning Policy. This balance will necessarily incorporate local policy considerations to inform local context to the application of the SPP. This balance may, for example, result in local planning instruments advancing development in an area of flood risk where those risks can be treated to an acceptable and tolerable level, whilst avoiding risk in areas of similar risk. This decision making will be informed by a wide array of land use planning considerations including (but not limited to) the:

- extent of flood risk on the site and comparable risk to alternate sites;
- extent of impact of filling or land form change on the site to achieve required flood immunity on local and regional flood risk;
- existing level of commitment to development;
- logic of expansion or consolidation of the site with surrounding areas;
- extent of existing infrastructure commitment;
- coincidence of flood risk with other site constraints and values such as biodiversity, waterways, cultural heritage etc.; and
- ‘weighing up’ the extent or magnitude of ‘need’ or other public benefits for various uses, with the potential consequences of risk to life and property from flood hazard.

Further action required to inform strategic planning

The Phase 3 (SFMP) Land Use Planning Guidance Material (see Addendum) incorporates a range of flood risk factor tools that are useful in assisting to define and inform the extent of flood risk. The completeness of regional datasets to support this consideration varies as follows:

- A cumulative impact assessment of fill and major development (including for example; filling, buildings and infrastructure) involving a holistic examination of the potential impacts that currently planned or future development may have on floodplain behaviour across the whole of the floodplain, is recommended. Given the known sensitivity of the Brisbane River floodplain to changes in landform, a regional cumulative impact assessment allows for the identification of cumulative impacts and provides one of the important ‘tools’ to informing a more complete understanding of flood risk. From a land use planning perspective, the cumulative impact assessment is a key strategic planning tool as it provides an input to allow flood risks to be considered fully as part of regional and local planning processes, together with the range of other planning factors required to considered, so that on 'balancing' competing issues and considerations, the best planning outcome for the community can be identified. It will also help to inform further consideration of regional flood mitigation options and evacuation capacity planning. It is recommended the cumulative impact assessment should be prepared for the whole of the Brisbane River floodplain and is one of the 'tools' or inputs to inform the preparation of Phase 4 (LFMPs), local flood risk assessments (as required by the SPP) and land use planning responses.

- Evacuation Capability Assessments and understanding the ability of people within the floodplain to evacuate safely during a flood event, is a critical input to flood risk management, informing flood risk and determining the risk appropriateness or suitability of land use and development in the floodplain. This assessment has not yet been comprehensively undertaken. It is recommended that a regional evacuation assessment be undertaken to understand current evacuation capability across the floodplain, the impacts of land use and new development on existing and future evacuation capability and identify prioritised actions to maintain or improve this capability. The regional evacuation assessment should be prepared to inform Phase 4 (LFMP) and land use planning responses. Furthermore, evacuation network plans are not yet comprehensively compiled identifying the extent of a preferred flood evacuation network and required flood immunity of each element of that network responding to flood risk, the current state of that network in terms of existing flood immunity and network upgrades required to achieve the required level of immunity. It is recommended that a Brisbane River Regional Evacuation Assessment be undertaken as a priority. (See Section 10.7.2.3.)

- Refined assessment of the potential structural options to support optimal regional flood risk mitigation, beyond the analysis undertaken as part of Section 8 of this report. Ideally, the suite of mitigation options should be identified and programmed for implementation to inform Phase 4 (LFMP) and other flood management responses. This analysis will inform the extent to which options provide both local and regional flood mitigation benefits.

- The feasibility of introducing flood resilient design of buildings to improve resilience of communities is emerging (Section 12.3) and further work is required to integrate these responses into the regulatory environment.

- Land management initiatives in the catchment to support modifications to flood flow inputs like the structural options, require further work to define a suite of initiatives that are feasible and will yield tangible flood risk benefits as per Section 6 of this report. Where relevant, consideration should be given to how planning schemes can influence and help achieve these outcomes in the context of new development. While a detailed review was outside the scope of this report, it is expected that most planning schemes will have existing provisions, such as biodiversity overlay and waterway overlay codes for example, that will partly contribute to land and catchment management responses to flood risk.

- Incorporating climate change factors and impacts into land use planning is critical and should form part of Phase 4 (LFMPs) and the local risk assessments. Understanding how current flood risk profiles will change and increase in the future (as identified in the sensitivity analysis described in Section 5.2), is essential to informing strategic planning and ensuring risk appropriate land use planning responses over the longer term. Understanding the extent of future flood risk within the floodplain and implications of climate change should, ideally, be considered in the context of a broader regional climate change adaptation response which should identify existing and future climate change risks associated with all natural hazards including flooding, coastal (erosion, storm tide inundation and sea level rise), bushfire, heatwave and drought etc. A whole of catchment and regional approach to climate change risk and adaptation provides a more holistic and integrated response to resilience at the regional level, including consideration of the interplay between various climate change risks. The benefits of a regional approach to climate change adaptation include:

  - providing a consistent approach to identifying climate change risks across the catchment (including consistency in methodology for any further localised or regional flood hazard or risk studies);
  - understanding the consequences of those impacts on tangible and intangible assets as well as risk to life and property;
  - understanding how these risks are expected to change or increase over time with future climate change;
  - prioritising the most urgent or pressing climate change risks across the catchment and sequencing actions over time;
  - identifying and evaluating adaptation actions to respond to risks;
  - identifying roles responsibilities, timing and funding sources for implementation.

- Further modelling of the impact of land filling and land form change in areas anticipated to support future growth is needed to inform comparative analysis of development of alternate future development areas. It is recommended that a Brisbane River regional cumulative impact assessment be undertaken as a priority to inform Phase 4 (LFMP) preparation through iterative modelling of settlement pattern options.
- From a community awareness perspective and to particularly assist in understanding and reducing flood risk for the establishment of new community infrastructure and vulnerable uses involving vulnerable people, it is recommended that planning schemes identify the full known extent of the Brisbane River floodplain in flood overlay mapping. Mapping the full known extent of the floodplain means that for the establishment of new development, particularly uses involving vulnerable people and community infrastructure, the consideration of flood risk will be 'triggered' in development assessment and planning authorities can ensure such uses are located and designed to be risk appropriate across the full known extent of the floodplain, as opposed to only being regulated in part of the floodplain. Furthermore, given the role of planning schemes in informing due diligence investigations for residents, business and industry in purchasing land and understanding potential development opportunities and constraints, the overlay map also has a role in helping to support community awareness about potential flood risk affecting land. (See Section 11.).

In combination, the consideration of these inputs into strategic planning will assist in ensuring that land use planning responses are both robust but also perform as an element of integrated floodplain management. It is critically important that the work needed for these matters to be useful and timely inputs into Phase 4 (LFMP), is advanced.

9.5.2 Land Use Planning Flood Risk Factor Support Tools

The SPP (Flood) Guidance Material, in conjunction with the Phase 3 (SFMP) Land Use Planning Guidance Material (see Addendum), are non-mandatory and non-statutory guidance resources intended to assist planning authorities to assess and treat flood risk through land use planning methods. These documents contain a range of processes and 'tools' that can be applied by planning authorities to inform Phase 4 (LFMP), local flood risk assessments and land use planning responses to flood risk.

The Phase 3 (SFMP) Land Use Planning Guidance Material (see Addendum) has been prepared as a resource to assist planning authorities to incorporate a risk-based planning approach in planning instruments and achieve the requirements of the SPP. The Guidance Material, specific to the Phase 3 (SFMP) Study Area, also explains how to apply and implement the SFMP land use planning strategies, where relevant. It also introduces other flood risk factor tools to support planning authorities in determining the level of flood risk and appropriate planning responses to treat the identified risk. These flood risk factor 'tools' are also provided in Appendix M and include:

- potential hydraulic risk category mapping;
- potential hydraulic risk cross-sections;
- relative time to inundation mapping;
- potential evacuation route immunity mapping;
- indicative flood function mapping;
- low and high flood islands mapping;
- vulnerability mapping;
- potential land use compatibility table; and
- flood risk factors decision support tool ('decision support tool').

Of the above, the flood risk factors decision support tool provides a risk-based decision framework that integrates and applies key regional flood risk factors, such as Potential Hydraulic Risk, relative time to inundation, indicative floodplain function and potential land use compatibility. This tool can be refined, as appropriate, by the relevant planning authority to account for those flood risk factors determined to be most relevant to the local government area in its Phase 4 (LFMP) / natural hazard flood risk assessment.

It should be acknowledged that there is a significant variance in the land use context across the Brisbane River floodplain, from rural and natural areas to the Brisbane CBD and Port, including long established urban areas and yet to be developed future urban areas. This differing context will influence the appropriateness of flood risk management responses including the applicability of land use planning response across the floodplain. By their nature, the responses in established urban areas will need to be different to those in 'greenfield' expansion areas. No single approach is appropriate in responding to this diverse context and directing the application of land use planning flood risk management tools. The guidance and examples provided are intended to illustrate the application of these tools as possible solutions, individually and in tandem, which can be tailored to local circumstances informed by the consideration of local and regional context.

Appendix M provides a more detailed description of the above regional flood risk factor tools, including how these come together in the decision support tool framework, and can be logically applied to land use planning, particularly in the evaluation and management of flood risk. Two hypothetical development scenarios – an expansion (greenfield) and consolidation (infill) example – have been worked up in Appendix M to demonstrate how the flood risk factor tools can be applied by local governments in evaluating risk as part of a Phase 4 (LFMP) and local risk assessment process.

Further to the above regional flood risk factors, an appreciation of an area's evacuation capability is a critically important consideration for determining flood risk. While it can be informed by insights provided by a number of the tools identified above, including relative time to inundation mapping, potential evacuation route immunity mapping and low and high flood islands mapping, it is recommended that a Brisbane River Regional Evacuation Assessment be undertaken to help inform Phase 4 (LFMP) and local evacuation route planning.

A methodology identified to understand evacuation capability and risk as an input into land use planning is the Evacuation Risk Classes (ERCs) established as part of the Tweed Valley Floodplain Risk Management Study (BMT WBM, Bewsher, Grech Planners, 2014). The Study states that the four graded ERCs were derived to provide advice to planners regarding evacuation risks of areas within the floodplain, and are based on a range of factors influencing evacuation constraints associated with development. These factors are dependent not only on the flood (hazard and hydraulic) characteristics of the site, but also the nature of the proposed development. The factors include:

- proposed land use and demographic characteristics of occupants;
- access to evacuation facility, including time available / required to evacuate;
- topographical constraints;
- availability of a refuge above the reach of flood waters; and
- availability of support facilities within the refuge.

The Evacuation Risk Classes established as part of that study are reproduced in Table 9-21.

Table 9-21 Tweed Valley Floodplain Risk Management Study Evacuation Risk Classes (ERCs)

Class A	**Risks are Minor – No Detailed Consideration is Required** Whilst potential for inundation and/or isolation exists, there are no significant evacuation constraints.
Class B	**Risks are Moderate – Detailed Consideration is Required** Evacuation constraints exist although in most situations these are not so severe as to significantly influence the planning decision.
Class C	**Risks are Serious – Very Detailed Consideration is Required** Serious evacuation risks exist. These may be close to the limit of community acceptance. Careful consideration of these risks must be undertaken when evaluating the appropriateness of the development having regard to all social, economic and environmental issues.
Class D	**Risks are Intolerable/Unacceptable – Development Should Not Proceed** Evacuation risks are so serious that irrespective of other considerations, the development should not proceed.

9.5.3 Land Use Planning Flood Risk Avoidance and Treatment Tools

The SPP (Flood) Guidance Material and the SFMP Land Use Planning Guidance Material provides detail on the scope and application of responses that a planning authority may apply within their planning instrument to avoid or treat flood risk. Table 9-22 provides an overview of the indicative application of the key tools to the treatment of risk as part of local plan making activity. Table 9-22 is not intended to be detailed guidance to planners in preparing land use plans; rather, it is intended to indicate that these tools can and should be tailored to achieve varying flood risk management outcomes of 'avoid', 'mitigate', 'accept', or 'retreat' responding to specific the land use planning context, local circumstances and the nature of the flood risk. This table also discusses the potential for these tools to be implemented at a whole of floodplain regional scale.

Table 9-22 Overview of land use planning, plan making and flood risk treatment tools

	Avoid	Mitigate	Accept	Retreat
Natural Hazards (flood) Evaluation Report	Identification of areas where future urban development or consolidation or sensitive uses will be avoided due to intolerable flood risk. This may also include identification of areas where a planning change is proposed to reduce a material risk of serious harm to persons or property from flooding, supported by a	Identification of areas where flood risk can be made tolerable for future development through specific planning instrument development requirements.	Identification of areas where land use is compatible with the extent of flood risk.	Identification of areas where a planning change is proposed to reduce a material risk of serious harm to persons or property from flooding, supported by a Feasible Alternatives Assessment Report.

<table>
<tr><th></th><th>Avoid</th><th>Mitigate</th><th>Accept</th><th>Retreat</th></tr>
<tr><td rowspan="2"></td><td>Feasible Alternatives Assessment Report.</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Potential for whole-of-floodplain implementation:
The Evaluation Report is intended to be a tool that summarises the hazard, risk and risk treatment approaches proposed within the planning area. By its nature, it requires detailed local consideration of available flood management options in treating flood risk including the role of land use planning, and the balance of land use planning flood management responses with other State Interests. As such the Evaluation Report documents the decision making and policy approach adopted by the planning authority.
Given the jurisdictional responsibility for local plan making across the floodplain resides with the various local planning authorities (albeit within a system where the state has a role in plan making), the preparation of the Evaluation Report is best implemented by each planning authority as a documentation of their plan making and policy rationale for responding to flood hazard and risk.
A single, whole of floodplain, Evaluation Report would not be able to efficiently or effectively respond to issues such as:
discrete community tolerance to flood risk
detailed local analysis of local flood risk factors informing localised planning responses
individual timeframes of local planning authorities in responding to flood risk through planning instrument reviews
the autonomous decision making of local planning authorities in responding to flood risk at the local level having regard to local and regional considerations, (even where common approaches to floodplain wide issues may be agreed)
As with application of many of the other tools, the SPP Natural Hazards, Risk and Resilience (flood) Guidance Material and the Phase 3 (SFMP) Land Use Planning Guidance Material (see Addendum) are non-statutory and non-mandatory resources that present potential approaches and recommended solutions to support local planning authorities to identify and evaluate flood risk, through a LFMP or a natural hazards risk assessment, building on the whole of floodplain assessment undertaken as part of Phase 2 (Flood Study) and Phase 3 (SFMP).</td></tr>
<tr><td rowspan="2">Strategic framework text</td><td>Settlement pattern where possible avoids areas of intolerable risk.
Strategic framework outcomes and provisions includes clear statements regarding the appropriateness of the settlement pattern and provides direction on locations in the floodplain where specific land uses (including vulnerable uses) should be avoided because of intolerable flood risk in line with SPP policy direction.</td><td>Acknowledge that flood risk is present within the plan area. Future compatible or risk appropriate land use can be regulated to mitigate risk to a tolerable extent. The strategic framework includes clear statements on where in the floodplain flood risk can be mitigated to a tolerable level.</td><td>Acknowledge that flood risk is present within the plan area. Existing land use within those areas is risk compatible. Future development will be regulated to ensure uses are risk compatible and appropriate for the location in the floodplain.</td><td>Statements that flood risk is incompatible with further development of the affected area for urban and other sensitive uses. Could include editorial note/s that identify the method by which retreat may occur where involving non-development related action.</td></tr>
<tr><td colspan="4">Potential for whole-of-floodplain implementation:
The Strategic framework is an expression of a local planning authority’s land use intents for the planning area. Local planning authorities have discretion under the planning system to express its intents in a form of their choosing albeit in a manner that reflects the state interests. As such, strategic framework content is a reflection of local policy direction and</td></tr>
</table>

<table>
<tr><th></th><th>Avoid</th><th>Mitigate</th><th>Accept</th><th>Retreat</th></tr>
<tr><td></td><td colspan="4">aspiration for the local area. Understanding the discretion and autonomy of local planning authorities in plan making, the SPP Natural Hazards, Risk and Resilience (flood) Guidance Material and the Phase 3 (SFMP) Land Use Planning Guidance Material (see Addendum) are non-mandatory resources that present potential approaches and recommended solutions to support local planning authorities to prepare strategic framework content in a manner that responds to the state interest for flood and the specific circumstances of the Brisbane River floodplain.

This material provides a suggested approach but does not mandate common content to be adopted across the planning instruments in the floodplain, acknowledging that common content across the floodplain could not reflect the detailed local nuances of local circumstances, and the autonomy of local planning authorities to express their responses in a way that is consistent with other strategic framework content.</td></tr>
<tr><td rowspan="2">Zone and land use allocation</td><td>Zoning provides for land uses that are risk compatible and appropriate for the location in the floodplain. In areas where risk cannot be mitigated to an acceptable or tolerable extent, the allocation of land to zones reflects the extent of this flood risk. Zones that encourage intensification and increased exposure of persons or property, in particular vulnerable uses, to intolerable flood risk, are avoided.</td><td>Where flood risk can be mitigated through assessment benchmarks, zone allocation that supports the location of risk compatible land use would be appropriate.</td><td>Zone purposes and uses within the zone are compatible with the extent of flood risk for the location in the floodplain.</td><td>Zone allocation through, a planning change, reduces the potential for incompatible land uses to establish in an area of flood risk where their establishment may have previously been possible.</td></tr>
<tr><td colspan="4">Potential for whole-of-floodplain implementation:
Zone and land use allocation is a key mechanism for setting land use expectations and development outcomes and should be informed by local flood risk assessment including an assessment of the local community's tolerance to flood risk. Whilst it is possible to propose potential land use tolerability to flood risk at the whole of floodplain level, acknowledging that some land uses are inherently more vulnerable to flood hazard and risk than others, while other uses are more suited to locating in flood risk areas (see Appendix M and Phase 3 (SFMP) Land Use Planning Guidance Material (Addendum)), it is essential that actual land use compatibility and zone allocation is risk appropriate for the location in the floodplain and determined at the local level with detailed local community engagement informing tolerability as part of plan making, led by a local planning authority. It is also recognised that planning authorities need to consider and balance a broad range of planning objectives and outcomes in the public interest (such as flood risk, biodiversity, heritage, employment, recreation etc). Through the LFMP process or local risk assessment, a planning authority may choose to accept that some risk might remain because the planning process determined that certain land uses are desirable in the floodplain due to other planning considerations. The planning authority needs to determine whether the benefits or extent of need for the land use 'outweighs' the extent of flood risk.

In this context, the application of zones such as the limited development zone in areas of significant flood risk needs to be considered in response to local circumstances given the potential that may arise from such a 'planning change'.

As such, local variation to zoning and land use allocation responding to flood hazard and risk could be expected where community tolerability and other local analysis and considerations informs that variation.</td></tr>
</table>

	Avoid	Mitigate	Accept	Retreat
	An exception to this local discretion may be through agreement of a regionally consistent approach to the allocation of vulnerable uses supporting vulnerable persons in response to flood risk. Such an agreement could limit local discretionary decision making for these uses to achieve a common approach across the whole floodplain that would avoid exposure of those people and property most at risk to the impacts of flooding (see Section 9.5.4.5).			
Level of assessment of land uses	Where zones span flood affected and unaffected areas, the Categories of development and assessment may vary the level of assessment of uses within the zone to increase the extent of regulation of areas affected by flood, and direct the assessment to the relevant Assessment Benchmarks. Uses sensitive to flood risk would unlikely be listed in the Categories of development and assessment table. All such use would be Impact assessable.	Where zones span flood affected and unaffected areas, the Categories of development and assessment may vary the level of assessment of uses within the zone to increase the extent of regulation of areas affected by flood, and direct the assessment to the relevant Assessment Benchmarks. Uses where development benchmarks may adequately mitigate flood risk will likely be listed in the Categories of development and assessment table as Code assessable.	Where zones span flood affected and unaffected areas, the Categories of development and assessment may vary the level of assessment of uses within the zone to increase the extent of regulation of areas affected by flood, and direct the assessment to the relevant Assessment Benchmarks. Uses likely to be able to accept flooding may be listed in the Categories of development and assessment table as Accepted development.	Land use incompatible with flood risk would unlikely be listed within the Categories of development and assessment table. All such use would be impact assessable.
	Potential for whole-of-floodplain implementation: Like the allocation of land use and zones, the establishment of the level of assessment responds to the specific flood risk conditions and tolerability. These considerations require detailed analysis and assessment at the local level. The LFMP and local risk assessment undertaken to inform the planning instrument will provide guidance on the appropriate level of assessment required and as such the level of assessment appropriate for development. The State Planning Policy Guiding Principle – Efficient, provides direction on determining the level of assessment, it encourages the lowest level of assessment appropriate based on potential impact of development. Balancing the risk and efficiency considerations is best undertaken at the local level to achieve risk appropriate levels of assessment and efficient local planning instruments. A whole of floodplain approach would not be able to achieve this degree of local consideration.			
Development assessment requirements including – assessment benchmarks (code purpose, overall outcomes and performance and acceptable outcomes) Note: To demonstrate compliance with performance	Assessment requirements can direct development to avoid areas or categories of flood risk.	Assessment requirements can direct development to mitigate flood risk to achieve performance thresholds that will mitigate risks to an acceptable or tolerable level. Development can also be required to demonstrate that mitigation solutions do not result in the	Assessment requirements may regulate development outcomes which may impact on flood behaviour.	Assessment requirements will be explicit in directing development incompatible with flood risk to avoid hazard areas; and regulate development outcomes which may impact on flood behaviour.

<table>
<tr><th></th><th>Avoid</th><th>Mitigate</th><th>Accept</th><th>Retreat</th></tr>
<tr><td rowspan="2">outcomes related to flooding, applicants will be encouraged (potentially through editor’s notes) to undertake site based assessments which incorporate consideration of the range of flood risk factors relevant to the site.
Specifications of the scope of site based assessments will likely be incorporated into Planning Scheme Policies</td><td></td><td>exacerbation of off-site flooding impacts.</td><td></td><td></td></tr>
<tr><td colspan="4">Potential for whole-of-floodplain implementation:
Development assessment requirements are the key regulatory mechanism directing development outcomes. These mechanisms must be crafted carefully to ensure that the outcomes anticipated by the planning instrument can be achieved and if needs be defended, through the statutory planning framework. The drafting approach for development requirements regulating development exposed to flood risk, must be integrated with the drafting approach of the balance of the planning instrument to ensure internal consistency of language and regulatory approach. Whole of floodplain ‘model provisions’ are unlikely to be able to be drafted to respond to the drafting requirements of discrete planning instruments.
Agreement of a regionally consistent approach to specific issues through the adoption of common administrative definitions such as for ‘no worsening’ of flood hazard and risk and a common approach to managing proposals for filling in the floodplain (see Section 9.5.4.2) could assist in driving common outcomes for development across the floodplain. Agreement and application of such common definitions and approaches could facilitate to the common consideration across the floodplain of cumulative and regional impacts of development on flood risk. The application of these ‘principles’ would however still require integration within the specific content of discrete planning instruments.
As with the Strategic framework discussion above, understanding the discretion and autonomy of local planning authorities in plan making, the SPP Natural Hazards, Risk and Resilience (flood) Guidance Material and the Phase 3 (SFMP) Land Use Planning Guidance Material (see Addendum) are non-mandatory resources that present potential approaches that local planning authorities may consider to prepare development assessment provisions.
This material provides a suggested approach but does not mandate common content to be adopted across the planning instruments in the floodplain, acknowledging that planning scheme content must reflect the detailed local nuances of local circumstances.</td></tr>
<tr><td rowspan="2">Mapping including overlay maps and supporting maps may provide an appreciation of Potential Hydraulic Risk and other flood risk factors included within planning scheme policy</td><td>Mapping will assist in triggering and interpreting the spatial application of assessment requirements</td><td>Mapping will assist in triggering and interpreting the spatial application of assessment requirements</td><td>Mapping will assist in triggering and interpreting the spatial application of assessment requirements</td><td>Mapping will assist in interpreting the spatial application of assessment requirements</td></tr>
<tr><td colspan="4">Potential for whole-of-floodplain implementation:
Planning scheme mapping assist in triggering the application and interpretation of the development requirements of the local planning instrument and as such, the approach to mapping and the use of mapping to describe flood risk is directly associated with the ‘architecture’ of how the planning scheme approaches the regulation of development exposed to flood risk. Were other planning scheme components required to adopt common approaches across the floodplain, it would likely be appropriate that common mapping approaches also be adopted, however such an approach would be inconsistent with the current, local planning authority led, plan making process supported under the Queensland planning system.
Maps assist in defining where a flood hazard and risk occurs within the plan area triggering the applicability of specific assessment requirements to development assessment (overlay maps). Mapping also plays an important part in describing flood hazard and risk including individual elements contributing to the definition of risk (for example mapping contained within overlays or planning scheme policy). Mapping can also play a role in triggering building code requirements for building work within the identified LGA Flood Hazard Area.
Aspirations for improved consistency of flood risk communication to the community need not specifically drive a regionally consistent approach to mapping or terminology within planning instruments as these maps play a specific regulatory role, used by a technical audience, which may require a different approach to that required for ‘risk communication’ through community awareness and resilience initiatives.</td></tr>
</table>

9.5.4 Achieving Regional Consistency of Land Use Planning Outcomes

Phase 4 (Local Floodplain Management Plans) provide a pathway for local land use planning refinements to be evaluated and considered within the context of other floodplain management responses. However, given there are four local planning schemes and a number of Priority Development Area Development Schemes within the floodplain, future refinements to these individual local planning responses should be guided by common approaches to addressing issues requiring 'region consistency'.

'Regional consistency' is defined and discussed in Section 9.1.1.1 as the achievement of consistent floodplain management outcomes across administrative boundaries in the floodplain. The issues considered to require regionally consistent outcomes include:

- a shared application of an agreed Potential Hydraulic Risk definition;
- the assessment of proposals for filling of land within the floodplain;
- the incorporation of climate change impacts into hazard and risk assessments and land use planning responses;
- the incorporation of evacuation capability and risk into flood risk assessment; and
- the tolerability of vulnerable land uses involving vulnerable persons in areas of increased flood risk.

9.5.4.1 A Shared Application of an Agreed Potential Hydraulic Risk Definition

Sections 4.2 and 9.1.1.3 discuss potential hydraulic risk and Figure 4-4 is the Potential Hydraulic Risk Matrix developed to inform Phase 3 (SFMP). This analysis of the hydraulic conditions and behaviour of the flood events at a whole-of-floodplain scale provides a consistent technical basis for Phase 4 (LFMP) flood risk assessments, incorporating other flood risk factors.

Section 9.1.1.3 discusses the role of consistently applied potential hydraulic risk definition in driving regionally consistent land use planning outcomes. It is essential in undertaking land use planning across the floodplain that the risk assessments undertaken by each planning authority informing their plans be based on a common definition of potential hydraulic risk. Without the shared application of an agreed Potential Hydraulic Risk Matrix, the same hydraulic conditions and flood behaviour in each administrative area may be defined differently. Different definitions of potential hydraulic risk may undermine regional consistency of land use planning responses, particularly the allocation of land use and regulation of new development across administrative boundaries leading to inconsistent floodplain management outcomes.

In applying an agreed potential hydraulic risk definition, all planning authorities within the floodplain will be working from the same baseline flood risk matrix conditions, and Phase 4 (LFMPs), local flood risk assessments and any future local flood studies will be underpinned by a consistent methodology and understanding of floodplain behaviour. This will assist planning authorities to plan the best location for land uses and determine their tolerability according to the same baseline hydraulic risk across the floodplain.

9.5.4.2 Assessment of Proposals for Filling of Land within the Floodplain

Section 5.1 explains how flood modelling was used to assess the sensitivity of flooding to filling of areas identified for future urban development. The results of the modelling confirm that cumulative impacts of filling and land form change across these areas can lead to substantial increases in flood levels across the floodplain.

Flood levels along the Bremer River, in particular, could increase substantially should further urban development result in filling in sensitive areas. Those areas most sensitive to filling include the defined Potential Hydraulic Risk categories, HR1 and HR2, as identified and described in Section 4.2. Section 5.1.4 discusses implications of filling within particularly sensitive areas of the floodplain; that is, HR1 and HR2 potential hydraulic risk categories.

In seeking to address the exacerbation of flood risk associated with future development, it is important that land use planning to accommodate future population growth, which relies upon an assumption of land filling or land form change to achieve a tolerable or acceptable level of flood risk, is examined both strategically (whole of floodplain and LGA levels) and at the development site level in order to respond to the catchment sensitivity to these changes.

Assessments should seek to determine 'no worsening' of flood risks.

9.5.4.2.1 'No Worsening' Principle

'No worsening' of flood risk is a key principle that is recommended to underpin the consideration of proposals for development within the floodplain. No worsening should be defined across a range of flooding characteristics and behaviours.

Moreton Bay Regional Council, in the Planning Scheme Policy Flood Hazard, Coastal Hazard and Overland Flow, requires Local Site Based (Localised) Flood Reports supporting development proposals to *"demonstrate that the proposed development, including filling (and excavation if included) of the site does not:*

a) cause an increase in flooding or drainage risks to surrounding properties or elsewhere on the floodplain;
b) does not impede the flow of floodwaters across the site causing worsening of flood or coastal hazards (levels, velocities, hazard categories) on neighbouring properties; and
c) does not change the timing of the flood wave or impact on flood warning times."

In the context of the Brisbane River floodplain and based on current industry best practice, it is recommended that no worsening be defined as follows:

Development including filling and land form change, when assessed against the full range of flood event AEPs considered in Phase 3 (SFMP):

- does not result in an increase in flood hazard conditions (flood levels, flood velocities, evacuation conditions and capability, flood hazard categories and potential hydraulic risk categories) for surrounding properties;
- does not increase the level of flood risk of surrounding properties;
- does not result in a total impact from cumulative filling across the floodplain of > 10mm;

- does not alter the flood hydrograph, and timing of the flood wave/s;
- does not impact on flood warning times.

9.5.4.2.2 Cumulative Impact

Given the known sensitivity of flood behaviour to changes in landform within the Brisbane River floodplain, it is recommended a regional cumulative impact assessment be undertaken to examine the impact that currently planned or possible future development might have on flood behaviour across the Brisbane River floodplain (extending the sensitivity analysis of DS1 and DS2 (see Section 5.1)). It will provide one of the key inputs to evaluating the consequences of alternate development, climate change and flood mitigation scenarios and informing the Phase 4 (LFPMs) and local flood risk assessments.

Undertaking a cumulative impact assessment at the regional level is best practice and the importance of considering cumulative impacts in strategic land use planning aligns with the Australian Disaster Resilience Handbook 7, viz:

> *An important consideration is the ability to assess the cumulative impacts of changes in development on flood behaviour and its impacts. Cumulative impact assessment enables more informed understanding on the broad effects of changing development patterns.* (page 52)

Handbook 7 also identifies the importance for studies and management plans to:

> *assess the cumulative impacts of potential future development on flood behaviour, emergency management and associated risk to the existing community.* (page 78)

Ideally, a cumulative impact assessment should be undertaken as part of the Phase 3 (SFMP) at the regional level, as it would not be reasonable to require individual planning authorities to undertake an assessment of cumulative impacts across the whole of the Brisbane River floodplain, or to defer such a study to the preparation of the Phase 4 (LFMPs) or to the assessment of individual development or infrastructure projects on a site-by-site basis. While it is recognised that planning authorities in the floodplain have development provisions that seek to assess cumulative impacts at the development assessment stage, the provisions vary across the floodplain, such that the outcomes of the assessment of cumulative impacts are also likely to vary and would not necessary result in a ‘zero impact’ on flood behaviour. At an individual site basis, a development may be able to demonstrate insignificant impacts, but when multiple developments across the whole-of-the-floodplain are considered cumulatively, these impacts can be significant. Furthermore, analysis using common methodology by each local authority to undertake their own cumulative impact assessment at the LGA level is not considered to be a feasible alternative to a whole-of-floodplain cumulative assessment, as disaggregated assessments will not be able to adequately consider cumulative impacts of proposals outside their local areas at the whole of floodplain scale. It is also considered impractical to require the consideration of cumulative impact assessment by individual development proponents and infrastructure projects.

A regional assessment allows for the identification of cumulative impacts that can be considered in the preparation of Phase 4 (LFMPs), local flood risk assessments and in the formulation and review of land use planning strategies and planning schemes, to provide flexibility in determination of the best planning outcome while identifying, publicly communicating, and pursuing, alternate flood risk management options to manage the consequences. Given the known sensitivity of Brisbane River flood behaviour to changes in landform, the hydraulic and land use planning benefits to undertaking a whole-of-floodplain cumulative impact assessment as part of the Phase 3 (SFMP) include the following:

Hydraulic Analysis

- Cumulative impact assessment is a standard approach in regions with significant amounts of ongoing development;
- Identifies areas and locations where loss of floodplain storage and conveyance have local and regional impacts;
- Determines if these impacts change with flood magnitude;
- Determines if slightly larger floods will have significantly larger impacts than the design flood event; and
- Realistic determination of climate change as future scenarios are a combination of climate change and development scenarios.

Planning

- A strategic tool, as part of a package of "tools", that provides an input to fully consider flood risks as part of the regional and local planning processes, together with the range of other planning factors required to be considered, so that on balancing competing considerations, the best planning outcome can be identified;
- To assist in the investigation of flood risk implications for regional land use, land supply and outcomes under the SEQ Regional Plan in a future review, which can provide better broad direction for planning schemes;
- Facilitates a more complete consideration of regional flood risk mitigation options and evacuation capacity planning with the implementation of the SFMP and at the stage of preparing Phase 4 (LFMPs);
- To provide a means to more fully address the State Planning Policy state interest for flood, including (but not limited to) the policy elements that require consideration of direct, indirect and cumulative impacts;
- To provide a means to test major developments, future urban areas and infrastructure projects with whole of catchment cumulative impacts considered;
- Can assist in guiding the location of major regional/state infrastructure (e.g. major public buildings, major recreation facilities, roads, rail, etc); and
- Allows for sensitivity analysis for different climate change scenarios together with the cumulative impact of possible development.

A regional cumulative impact assessment undertaken as part of the Phase 3 (SFMP) will help to inform the Phase 4 (LFMPs) and local flood risk assessments, including land use planning responses. In addition to this study being an important strategic planning tool, it can be used to test whether or not the assumptions about where and how development might occur across the whole floodplain can realistically be achieved within the limits of acceptable impact. This analysis will allow for development proposing filling or land form change to proceed with greater confidence in areas assessed as suitable; development expectations are not then created in areas where flood risk and filling would make development unlikely to be achieved or result in a worsening of flood risk elsewhere.

At the time of drafting this report, the scope of the cumulative impact assessment was still being developed. It is recommended that detailed iterative modelling of cumulative development across the floodplain be undertaken and ideally, also incorporate major infrastructure proposals. It is further recommended that modelling consider a full spectrum of events, with the 60 ensemble design events from Phase 2 (Flood Study) as a minimum. Consistent with industry practice, the target for total impact from cumulative filling and land form change across floodplain should be < 10mm. This analysis will effectively determine, at a whole-of-floodplain level, the filling or land form change ‘envelope’ for the floodplain. This analysis should inform planning instrument land use assumptions, provisions and local policy.

In principle, once the cumulative impacts of flooding have been examined and the extent of areas capable of filling determined, development controls for filling in these areas should not require a cumulative impact assessment where proposed filling is in line with the strategic study assumptions.

Where development proposes filling or land form change that exceeds the assumed filling or land form change, or is outside the ‘envelope’, it is reasonable that an assessment of cumulative impact, against the strategic analysis, be undertaken to demonstrate that the proposal will not result in a worsening of flood impact.

The following is recommended as a policy approach (to be adopted or maintained in planning instruments by all planning authorities, including the State and infrastructure providers) that will support regionally consistent consideration and treatment of proposed filling, land form change or the construction of buildings and other infrastructure that has the potential to result in any worsening of flood hazard conditions or flood risk to other properties within the floodplain:

A. Land use planning and infrastructure that proposes changes to land form or the construction of buildings and other infrastructure should not result in any worsening of flood hazard conditions or flood risk to other properties within the floodplain. Planning instruments and land use planning responses are informed by the outcomes of a regional cumulative impact assessment of filling and landform change across the floodplain within the context of the Phase 4 (LFMPs) and local flood risk assessments.

B. For planning instruments informed by the regional cumulative impact assessment as per A above, include provisions that ensure development proposing filling and land form change within the floodplain does not result in any worsening of flood hazard conditions or flood risk to other properties within the floodplain. Provisions should also include the requirement for an assessment of cumulative impacts across the floodplain for sites proposing filling or land form change exceeding filling or land form change assumptions, or are outside the regional fill ‘envelope’ areas, to demonstrate that the proposal will not result in a worsening of flood impact.

C. Planning instruments should include outcomes in the strategic framework and assessment benchmarks that recognise:

- land use and development avoids obstruction or alteration of flow in a flow conveyance area, which may be defined as HR1 or HR2 Potential Hydraulic Risk categories;
- filling is potentially intolerable in flow conveyance areas and should not occur in these areas. While filling to achieve a DFE in flow conveyance areas defined as HR2 is not preferred, it may potentially be tolerable where it is demonstrated through the Brisbane River regional cumulative impact assessment, a Phase 4 (LFMP) or local flood risk assessment that there is no impact or alteration to flow conveyance and no change to flood level (either increase or decrease) beyond property boundaries exceeding 10mm, when assessed against the 60 scenarios that make up the design event ensembles in Phase 2 (Flood Study); and
- filling is potentially tolerable in flood storage areas which may be defined as HR3 or HR4 Potential Hydraulic Risk categories, where it is demonstrated there is no reduction in flood storage volume in the floodplain when assessed for a range of AEPs relevant to the development site. Any proposed compensatory cut and fill is to be at the same flood level and not alter hydraulic behaviour.

D. Periodically (e.g. every 5 years to coincide with the review of Phase 3 (SFMP)), all developments which had been tested in the cumulative development scenario as part of the regional cumulative impact assessment, should be incorporated into the scenario and established as the new ‘base case’ used for future assessments.

E. Until the above proposed regional cumulative impact assessment is completed and the outcomes incorporated into planning instruments, it is recommended that planning instruments should maintain or include provisions which ensure that filling, landform change or the construction of buildings and infrastructure does not result in any worsening of flood risk to other properties in the floodplain. Until the outcomes of the regional cumulative impact assessment are understood, a suggested approach, as one solution to achieving a no worsening to flood hazard conditions or flood risk to other properties in the floodplain, is to ensure that filling, landform change or the construction of buildings and infrastructure in the floodplain:

- should be deemed to be potentially intolerable in flow conveyance areas (which may be defined as HR1 and HR2), but may be potentially tolerable if hydraulic modelling can demonstrate no alteration to (and maintenance of) flood flow behaviour and no change to flood level (either increase or decrease) beyond property boundaries exceeding 10mm;
- may be considered as potentially tolerable in flood storage areas (which may be defined as HR3 and HR4) where it is demonstrated there is no reduction in flood storage within the floodplain when assessed for a range of AEPs relevant to the development site. Any proposed compensatory cut and fill must be at the same flood level and must not alter hydraulic behaviour; and
- is considered potentially acceptable outside of flood storage areas or flow conveyance areas, subject to not creating local drainage and surface water issues.

9.5.4.3 Incorporation of Climate Change Impacts into Hazard and Risk Assessments and Land Use Planning Responses

The Brisbane River SFMP undertook a sensitivity analysis to understand the sensitivity of flooding to changes under future climate conditions, based on the hydrologic modelling undertaken as part of Phase 2 (Flood Study). This provided hydraulic model input files for rainfall increase scenarios of +10% and +20% which were combined with sea level rise increase. The adopted rainfall and sea level rise conditions and associated RCP scenarios used in the SFMP sensitivity analysis are shown (bolded) in Table 9-23.

Table 9-23 Scenarios adopted for SFMP sensitivity analysis of flooding to future climate conditions

	SFMP Adopted rainfall increase [ARR recommendations]	SFMP Sea level rise increase
RCP 8.5 by 2050	**10%** [8.8%]	**0.3m**
RCP 8.5 by 2090	**20%** [18.6%]	**0.8m**
RCP 4.5 by 2090	**10%** [9.1%]	**0.63m**

These scenarios are consistent with Australian Rainfall and Runoff latest guidance (2016), which recommends testing both RCP 4.5 and RCP 8.5 scenarios. The selected rainfall variables for the SFMP are marginally more conservative than the suggested rainfall increases provided in ARR (2016), shown in the table (unbolded) above. However, to derive the exact variables would require significant effort and time to re-run the hydrologic model.

The sensitivity testing demonstrates that the Brisbane River catchment is very sensitive to climatic changes. Sea level rise has impacts on the most downstream reaches of the Brisbane River; however, changes to rainfall and catchment runoff conditions have the potential to significantly alter flood behaviour in the floodplain, including notable increases in flood levels (and hence flood risks) across most of the floodplain. Increases in peak flood levels for a range of flood events are reproduced in Table 9-24 for the Brisbane City Gauge and David Trumpy Bridge (Ipswich).

Table 9-24 Increase (m) in peak flood level under climate change sensitivity scenarios

AEP	Brisbane City Gauge			David Trumpy Bridge (Ipswich)		
	RCP 8.5 by 2050	RCP 8.5 by 2090	RCP 4.5 by 2090	RCP 8.5 by 2050	RCP 8.5 by 2090	RCP 4.5 by 2090
1 in 20	0.5	1.1	0.7	0.8	1.5	0.8
1 in 50	0.7	1.3	0.9	0.8	1.5	0.8
1 in 100	1.2	2.5	1.4	0.9	2.4	0.9
1 in 500	1.5	2.9	1.6	1.3	2.5	1.3
1 in 2000	1.3	2.9	1.3	1.4	2.5	1.4

For much of the Brisbane River, the 1 in 100 AEP scenario for RCP 8.5 by 2050 produces similar peak levels to Base Case 1 in 200 AEP levels. That is, a 1 in 100 AEP flood which occurs in 2050 would be of similar magnitude to a present day 1 in 200 AEP flood.

Assuming no further development in the catchment, this would also nearly double the number of buildings which experience above floor level flooding. The number of buildings estimated to be inundated above floor level is provided in Table 9-25 below.

Table 9-25 Number of buildings estimated to be inundated above floor level, current day

AEP	BCC	ICC	SRC	LVRC	TOTAL
1 in 100	7,900	3,773	376	142	12,191
1 in 200	14,025	6,541	833	187	21,586

The extent of land identified as HR1 and HR2 is also expected to increase significantly under the higher RCP 8.5 scenario by 2090 (see Section 9.4.4.2). From a risk-based perspective, this increase in frequency and likelihood and increase in the extent of land identified as HR1 or HR2 increases the overall risk profile across most of the floodplain.

While the modelling work undertaken is a sensitivity analysis, it assumes that changes to rainfall and sea level rise occurs without other catchment changes, which can also influence flood behaviour (such as antecedent conditions), and it assumes no changes to Wivenhoe dam operations. Despite these assumptions, the work conclusively demonstrates that the catchment is very sensitive, and that development occurring now could be subjected to flood levels in 30 years that are more than a metre higher than current conditions.

Phase 3 (SFMP) has considered the full range of flood risk management measures for the Brisbane River SFMP Study Area, being structural mitigation options, land use planning, community awareness and resilience, disaster management and land management, to identify a regional framework for integrated flood risk management in the Brisbane River floodplain.

It is important that the consequences of a range of climate change probabilities are understood within the Brisbane River floodplain to test and plan for changes in flood risk over time. Land use planning has a central role in avoiding flood risk to future development and potentially intolerable consequences to communities. The effect of different flood futures on existing land use and development within the floodplain is important, particularly those uses that permanently 'establish' in the floodplain over their lifetime or have a key role in strategically shaping or influencing settlement patterns or how communities function (e.g. airports, hospitals, correctional facilities, transport infrastructure etc.) These uses are not readily relocatable or adaptable over time and are inherent to the strategic settlement pattern of an LGA and region.

Using land use planning as a mechanism to manage and reduce flood risk will improve resilience and provide greater community certainty than solely relying on potential structural mitigation options (e.g. Warrill Creek dry flood mitigation dam). While the Warrill Creek dry flood mitigation dam option shows some promising flood mitigation benefit, even if this option could be implemented in a short timeframe, Section 8 of this report explains that the net flood risk benefit accruing to these mitigation options – in terms of peak flood levels at a regional scale – have the potential to be completely eroded over time by the effect of climate change. Therefore, an understanding of how the current flood risk profile will change as a result of worsening flood futures should be used to inform Phase 4 (LFMPs) and local flood risk assessments and guide floodplain management decisions, including land use planning responses.

The sensitivity testing undertaken as part of Phase 3 (SFMP) supports action to respond to climate change and consider its effect on the current flood risk profile across the floodplain. It is recommended that there is regional consistency in the climate change assumptions used to inform mapping of the flood hazard area in planning schemes, and that a regional climate change adaptation response is coordinated across the Brisbane River catchment to provide a holistic approach to understanding and responding to broader climate change risks, including those associated with all natural hazards: flood, coastal hazards, bushfire etc.

As part of the response to climate change risk, planning authorities may choose to adopt the more conservative RCP 8.5 scenario (for 2050 and 2090), or take a more nuanced approach by applying different climate change scenarios as an input into Phase 4 (LFMPs) and local flood risk assessments. This can be achieved by either undertaking further testing and modelling of the impacts of a number of alternative planning horizons other than the 2050 and 2090 horizons considered in Phase 3 (SFMP), or use the Phase 3 (SFMP) modelled scenarios, which are considered fit-for-purpose. The outputs of such additional testing can be used to inform planning scheme provisions and development controls for specific land use and development.

Indicative climate change scenarios for land use activity ‘groups’ in the Phase 3 (SFMP) Study Area have been identified as a starting point in guiding how a more nuanced approach may potentially be applied to land uses (see Table 9-26). Further guidance on how this approach can be applied is provided in the SFMP (Phase 3) Land Use Planning Guidance (see addendum).

Other potential adaptation options to address climate change considerations may include:

- avoiding inappropriate uses in locations where known existing flood risk will increase or worsen with future climate change (e.g. areas where the existing hydraulic risk profile conditions for HR3 are likely to change and worsen to HR2 and may not be a risk appropriate location in the floodplain for vulnerable people etc).
- for tolerable uses in the floodplain, using a DFE that incorporates an additional climate change factor allowance or resilient building design to accommodate the risk. This could could be achieved through using a higher DFE and scaling up by event in parts of the floodplain where peak flood levels are expected to increase under the climate change scenario (e.g. scaling up the 1 in 100 AEP to a 1 in 200 AEP flood level).

Table 9-26 Indicative climate change scenarios for land use activity 'groups' in the Phase 3 (SFMP) Study Area

Land use activity	Scenario (model reference)	Climate change conditions	Planning horizon
Community infrastructure and critical services (Examples of such uses that are likely to permanently 'locate' in the floodplain up to 2090 and define the settlement pattern include: hospital, air service, major electricity infrastructure, emergency services)	CC4	RCP 8.5 – 20% and 0.8m	2090
Vulnerable uses (involving vulnerable people) (Examples of such uses that are likely to permanently 'locate' in the floodplain up to 2090 and define the settlement pattern include: hospital, community use, correctional facility, detention facility, educational establishment)	CC4	RCP 8.5 – 20% and 0.8m	2090
Filling	CC4	RCP 8.5 – 20% and 0.8m	2090
Subdivision	CC5	RCP 4.5 – 10% and 0.63m	2090
Residential and accommodation uses (Examples of such uses that are likely to permanently 'locate' in the floodplain up to 2090 and define the settlement pattern include: resort complex, hotel, tourist park)	CC5	RCP 4.5 – 10% and 0.63m	2090
Commercial and industrial uses	CC5	RCP 4.5 – 10% and 0.63m	2090
Non-urban and recreation uses	CC2	RCP 8.5 – 10% and 0.3m	2050

9.5.4.4 Incorporation of Evacuation Capability and Risk Into Flood Risk Assessment

Section 4.4 and the Supplementary Information to Support Evacuation Planning in the Brisbane River Region[24]) discusses isolation and the inundation of potential evacuation routes within the floodplain. The limitations of this analysis in relation to a comprehensive understanding of the flood evacuation network are identified. Sections 9.5.1 and 9.5.2 acknowledges that evacuation capability and isolation analysis are critical flood risk factors that must be incorporated into Phase 4 (LFMP) and flood risk assessments to inform risk appropriate land use planning responses.

A detailed understanding of the regional and local level evacuation capability, including the evacuation network, is a critical ingredient in risk-based land use planning as it will inform whether land uses are acceptable or tolerable within an area based on their ability to safely evacuate. A

[24] Supplementary information provided from BMT to QRA 12 February 2018

finding of Phase 3 (SFMP) has been that the evacuation route network is not comprehensively defined and documented at the regional scale and that further work is required to establish this information in a comprehensive and consistent manner.

The establishment of this dataset through collaboration between state and local stakeholders as part of a regional evacuation assessment across the floodplain should be undertaken as a priority, and is a critical input to Phase 4 (LFMPs), flood risk assessments and subsequently, to informing land use planning (and other floodplain management) responses.

In addition to an understanding of the evacuation network, it is essential that planning is also informed by an appreciation of an area's capability for safe evacuation. It is recommended that a Brisbane River Regional Evacuation Assessment be undertaken as a priority. A regional approach will identify priorities for the evacuation network and a consistent methodology to be applied in the assessment of evacuation risk to inform the preparation of Phase 4 (LFMPs) and local flood risk assessments. See Section 10.7.2.3 for further detail on a regional evacuation assessment.

9.5.4.5 Tolerability of Vulnerable Land Uses Involving Vulnerable Persons

The SPP, state interest policy 6 provides that '*community infrastructure is located and designed to maintain the required level of functionality during and immediately after a natural hazard event'* and the supporting SPP guidance talks to different types of 'community infrastructure', including those community infrastructure uses "*that are highly sensitive to flood risk because of the vulnerability of their occupants*". (SPP State Interest Guidance Material Natural Hazards, Risks and Resilience – Flood, pg 20).

While aligning with the SPP to provide guidance on 'community infrastructure', the SFMP LUP Guidance Material makes a distinction between 'community infrastructure and critical services' and 'vulnerable uses' for the purpose of providing a more nuanced response to considering flood risk and potential tolerability in the context of the Brisbane River floodplain.

Section 9.5.2, Appendix M, and the Phase 3 (SFMP) Land Use Planning Guidance Material (see Addendum), provides a potential land use tolerability table for consideration by planning authorities. It is non-statutory guidance and is intended to be used as a tool to inform Phase 4 (LFMP), flood risk assessments and ultimately, land use planning responses in planning instruments. It is important to note that the potential land use tolerability guidance is based on the relevant and currently available regional flood risk factors only, i.e. SFMP Potential Hydraulic Risk categories and relative time to inundation. Consideration should also be given to the outputs of the regional evacuation assessment once complete, and other locally relevant factors.

Hydraulic risk is one of the most important flood risk factors when considering risk to life from flood and determining if land use is risk appropriate for the location in the floodplain. Relative time to inundation and evacuation capability are also important risk to life considerations and key inputs to determining flood risk. It is intended that this tool be applied and varied as needed based on: local and regional circumstances, the consideration of other flood risk factors and importantly community expectations on tolerance or acceptance of flood risk.

The SFMP regional flood risk factor tools, particularly the potential hydraulic risk mapping and outcomes from both the regional evacuation assessment and regional cumulative impact assessment, will be important technical inputs to inform risk assessments and ensure land use planning responses are risk appropriate.

It is important to recognise that flood risk is only one of a number of issues and constraints that will need to be considered and balanced by planning authorities in determining the optimum plan for the community.

While it is also possible that some flood risk might remain because the planning process determined that certain land uses were desirable in the floodplain due to other planning considerations, vulnerable land uses supporting the most vulnerable people in the community warrants regional direction and special consideration.

The Land Use Planning Guidance Material discusses and describes vulnerable land uses and vulnerable people. These land uses are those most sensitive to flood risk and these people are those most at danger of, and least resilient to, the impacts associated with flood events.

Part A of the Land Use Planning Guidance material describes and provides examples of land uses involving different types of community infrastructure, including vulnerable uses, sensitive uses and critical services. In summary, the guidance material provides the following in respect of vulnerable uses:

> *Vulnerable uses comprise those uses or activities that accommodate vulnerable persons, the demographic or socio-economic characteristics (e.g. age, health, disability, need for assistance) of whom increase the severity of flood impact and the population's risk profile. The vulnerability of these uses' occupants creates a higher susceptibility to flood risk due to constraints on self-evacuation and self-assistance.*
>
> *Examples of vulnerable people include children, elderly, disabled, inmates and hospital patients. Vulnerability also exists for people who lack local knowledge or awareness of local conditions as they are visitors to an area and are not permanent residents. Uses involving vulnerable people means that managing risk to life is the highest priority when considering tolerability or acceptability of flood risk.*
>
> *Examples of vulnerable land uses include[25]:*
>
> - *child care centre*
> - *community care centre*
> - *community residence*
> - *correctional facility*
> - *detention facility*
> - *educational establishment*
> - *hospital (and health care service where supporting a hospital)*
> - *relocatable home park*

[25] Use terms are adopted from the suite of regulated requirements in Schedule 3 of the *Planning Regulation 2017*. The examples of uses identified are consistent with the SPP state interest guidance material – Natural hazards, risk and resilience (flood).

- *residential care facility*
- *retirement facility*
- *short term accommodation and other forms of tourist accommodation (e.g. resort complex, nature-based tourism)*
- *tourist park*

The Guidance Material also defines sensitive uses as those particularly sensitive to the impacts of flooding on property loss or damage, such as uses accommodating or storing sensitive content (e.g. precious or important documents, artefacts and cultural or historical records, animal refuges due to significant effort to organise evacuation). Managing risk to property is an important consideration when considering tolerability or acceptability of flood risk for these types of uses.

Examples of sensitive land uses include[25]*:*

- *cemetery*
- *community use (e.g. where for storage of culturally or historically significant artefacts, documents and records, such as in an art gallery, library or museum)*
- *crematorium*
- *funeral parlour*
- *veterinary service (animal refuges/hospitals)*

Other types of community infrastructure can be categorised as critical services. These have an active role in flood disaster management response and recovery and are required to operate during or immediately after a flood event to provide essential services to the community.

Examples of critical services include[25]*:*

- *air service*
- *emergency services (e.g. evacuation centre, disaster management, ambulance, fire and police stations)*
- *hospital*
- *major electricity infrastructure*
- *renewable energy facility*
- *substation (supporting other community infrastructure)*
- *telecommunications facility*
- *utility installation (for the supply of water, hydraulic power, gas, sewerage, waste management)*

Given the sophisticated understanding of flood behaviour, the SFMP and supporting non-statutory Land Use Planning Guidance Material can provide clear direction and guidance to implement State interest Policy 6 within the context of the Brisbane River floodplain. It is recommended that this group of vulnerable land uses be regulated consistently across the floodplain in accordance with the following principle:

> *Vulnerable land uses involving vulnerable persons should be avoided in areas of Potential Hydraulic Risk categories, HR1 and HR2, where evacuation risk is moderate, serious or intolerable (as defined through an evacuation risk assessment).*

9.5.5 Potential for Interim Land Use Planning Regulations

It is anticipated that refined land use planning arrangements within the floodplain's various local planning instruments will follow from the preparation of Phase 4 (LFMPs). Under the requirements of the Minister's Guidelines and Rules (under the *Planning Act 2016*) and the requirements of the *Economic Development Act 2012*, amendments to existing planning instruments must follow a statutory process which, under standard processes for local planning schemes, can take a minimum of two years from first proposing through to adoption and commencement (although flood mapping changes can be done more quickly as a minor amendment). Given that Phase 4 (LFMPs) are expected to commence in 2018 and may take perhaps a minimum of one year to complete before they are capable of informing changes to planning instruments, it is likely that adopted changes to planning instruments could not be expected within three-to-four years from early 2018 and indeed, may take longer given required process, level of community interest in changes, etc.

Consequently, the matters discussed in Section 9.5.4 as influencing development outcomes in the floodplain, will not be incorporated into regulation (such as planning schemes) and have statutory force and effect on development outcomes consistently across the floodplain until all the planning instruments have been amended.

The regulation of development which will increase existing and future flood risk, such as the regulation of filling and land form change, is considered to be a priority that warrants further consideration of interim regulation whilst either the statutory process of planning instrument amendment proceeds, or permanent planning changes emerging through the Phase 4 (LFMPs) take effect. The need for planning arrangement/s that may potentially be required in the interim is informed by the understanding of flood risk provided through the Phase 3 (SFMP) and should be determined through collaboration between the Department of State Development, Manufacturing, Infrastructure and Planning (DSDMIP) and local planning authorities. This collaborative process may also identify potential changes required to regional planning assumptions and can inform a future review of the ShapingSEQ Regional Plan. The ongoing governance arrangements for the implementation of the Phase 3 (SFMP), provides DSDMIP and local planning authorities with timely opportunity to investigate whether there is a need for planning implementation arrangement/s in the interim to address priority land use and development regulation issues in the floodplain.

The regulatory approaches discussed below are intended to identify potential options and are not intended to imply or presuppose a particular approach, which should be informed through detailed consideration and discussion with DSDMIP and planning authorities.

Interim land use regulation options may include one or more common Temporary Local Planning Instruments (TLPIs) under the *Planning Act 2016*, which may be adopted by each of the local governments.

Direction to prepare a TLPI or a planning scheme amendment may be given by the Minister under Section 26 of the Planning Act to 'protect, or give effect to, a State interest'. Should the Minister[26] form a view that a common approach across the floodplain is required, the provisions of the Act could allow for the Minister to give consistent direction to each local government to create a common TLPI or planning scheme amendments. It would be expected that prior to such a direction there would be consultation with the four local governments within the floodplain as the diversity of existing planning instruments in the floodplain would require careful consideration in the design of any 'single' interim planning response.

An approach that could 'bring forward' planning scheme responses (not necessarily interim responses), under the *Planning Act 2016* is for a Section 18 amendment process to be implemented under a process proposed by the local government and agreed by the Minister that 'streamlines' the plan making process. The Section 18 process has the benefit of moving more quickly through the amendment process by agreement of a tailored timeline unconstrained by prescribed amendment timeframes. The effectiveness of a Section 18 process in achieving a timely outcome relies on attentive, motivated collaboration of all parties to ensure the various interactions occur seamlessly and efficiently.

The above approaches would address development regulated under the four planning schemes but not that regulated under other planning instruments.

An option of amended Assessment Benchmarks under the SPP for Natural Hazards, Risk and Resilience is not proposed given these requirements would only apply to areas within the Brisbane River floodplain rather than the whole of the State.

9.5.6 ShapingSEQ Flood Risk Calibration

As each of the Phase 4 (LFMPs) are prepared, incorporating a review of the planning responses to flood risk it is possible, based on the indications of the analysis in Section 9.4, that amendments may be required to the land use planning assumptions and arrangements that underpin the various planning instruments in the floodplain. It may be the case that these amendments could influence regional planning assumptions regarding future growth of the SEQ region incorporated within ShapingSEQ. Any such implications will be identified by the local planning authorities, in conjunction with DSDMIP, as part of the LFMP and the framing of land use planning responses as part of that process.

Should it be required, it is recommended that local planning authorities within the floodplain, DSDMIP and QRA undertake an assessment that will calibrate the planning assumptions underpinning ShapingSEQ with Brisbane River flood risk to enable an integrated regional planning response to be identified. DSDMIP can investigate the assessment implications for regional land use, land supply and outcomes in a future review of the SEQ Regional Plan.

The scope and approach of any such assessment will need to be determined collaboratively with DSDMIP and the floodplain's local governments based on the scale and impact of any issues that may be identified.

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[26] It is understood that Ministerial decision making is discretionary, independent of DSDMIP and is based on individual circumstances at the time.

9.6 Land Use Planning Recommendations

Recommendations for the land use planning elements of the SFMP have been informed by the findings of Phase 2 (Flood Study) and Phase 3 (SFMP), together with feedback from the IPE, project partners and best practice review.

There are a number of key recommendations that are intended to support the evolution of risk-based land use planning within the Brisbane River floodplain. These recommendations should be considered in the context of the preparation of Phase 4 (LFMPs) and as part of the ongoing implementation and monitoring arrangements which will govern the implementation of the SFMP (as described in the SFMP) to facilitate regional consistency.

The SPP (Flood) Guidance Material and the SFMP Land Use Planning Guidance Material are non-statutory resources that will support the application of risk-based planning principles, tools and approaches to land use planning in the Brisbane River floodplain. Their application in the identification of flood hazard and flood risk and in the consideration of risk treatment are strongly recommended.

Specific recommendations which will drive regionally consistent floodplain management outcomes through land use planning responses to flood risk arise from the discussion in Section 9.5.4. and can be summarised as follows:

(1) An integrated Phase 4 (LFMP) and local flood risk assessment undertaken by each planning authority to inform the preparation of land use planning responses in planning instruments incorporate the agreed SFMP definition of potential hydraulic risk, and is consistently applied by other floodplain managers and planning authorities in the floodplain.

The Potential Hydraulic Risk matrix (see Figure 4-4) was prepared to inform Phase 3 (SFMP). This Potential Hydraulic Risk matrix is fit for purpose and should be used to inform the preparation of Phase 4 (LFMP) and flood risk assessments within the Brisbane River floodplain.

(2) A Brisbane River floodplain regional cumulative impact assessment should be undertaken as a priority to support regionally consistent consideration and treatment of proposed filling, land form change or the construction of buildings and other infrastructure that has the potential to result in any worsening of flood hazard conditions or flood risk in the floodplain. The regional cumulative impact assessment should involve a collaborative, whole-of-floodplain assessment of cumulative impacts of filling and land form change across the floodplain and the outputs support planning authorities in undertaking Phase 4 (LFMP) and local flood risk assessments and to inform planning instruments.

(3) Informed by the outcomes of a regional cumulative impact assessment referred to above, planning authorities within the floodplain should adopt or maintain land use and development policy outcomes in planning instruments that support regionally consistent consideration and treatment of proposed filling, land form change or the construction of buildings and other infrastructure that has the potential to result in any worsening of flood hazard conditions or flood risk to other properties within the floodplain. A suggested approach is as follows:

(a) Land use planning that proposes changes to land form or the construction of buildings and other infrastructure should not result in any worsening of flood hazard conditions or flood risk to other properties within the floodplain. Planning instruments are informed by the outcomes of a regional cumulative impact assessment of filling and land form change across the floodplain.

(b) For planning instruments informed by the regional cumulative impact assessment, as per 3(a), include provisions that ensure development proposing filling and land form change within the floodplain does not result in any worsening of flood hazard conditions or flood risk to other properties within the floodplain. Provisions should also include the requirement for an assessment of cumulative impacts across the floodplain for sites proposing filling or land form change exceeding filling or land form change assumptions in the regional cumulative impact assessment, or are outside the regional fill 'envelope' areas, to demonstrate that the proposal will not result in a worsening of flood impact.

(c) Planning instruments should include outcomes in the strategic framework and assessment benchmarks that recognise:

- land use and development avoids obstruction or alteration of flow in a flow conveyance area;
- filling is potentially intolerable in flow conveyance areas and should not occur in these areas. While filling to achieve a DFE in a flow conveyance area is not preferred, it may potentially be tolerable where it is demonstrated through the Brisbane River regional cumulative impact assessment, a Phase 4 (LFMP) and local flood risk assessment that there is no impact or alteration on flow conveyance and no change to flood level (either increase or decrease) beyond property boundaries exceeding 10mm, when assessed against the 60 scenarios that make up the design event ensembles in Phase 2 (Flood Study); and
- filling is potentially tolerable in flood storage areas where it is demonstrated there is no reduction in flood storage volume in the floodplain when assessed for a range of AEPs relevant to the development site. Any proposed compensatory cut and fill should be at the same flood level and not alter hydraulic behaviour.

(d) Periodically (e.g. every 5 years to coincide with the review of Phase 3 (SFMP)), all developments which had been tested in the cumulative development scenario as part of the regional cumulative impact assessment, should be incorporated into the scenario and established as the new 'base case' used for future assessments.

(e) Until the above proposed regional cumulative impact assessment is completed and the outcomes incorporated into planning instruments, it is recommended that planning instruments should maintain or include provisions which ensure that filling, land form change or the construction of buildings and infrastructure does not result in any worsening of flood risk to other properties in the floodplain. Until the outcomes of the regional cumulative impact assessment are understood, a suggested approach, as one solution to achieving a no worsening to flood hazard conditions or flood risk to other properties in the floodplain, is to ensure that filling, land form change or the construction of buildings and infrastructure in the floodplain:

- should be deemed to be potentially intolerable in flow conveyance areas, but may be potentially tolerable if hydraulic modelling can demonstrate no alteration to (and maintenance of) flood flow behaviour and no change to flood level (either increase or decrease) beyond property boundaries exceeding 10mm;
- may be considered as potentially tolerable in flood storage areas where it is demonstrated there is no reduction in flood storage within the floodplain when assessed for a range of AEPs relevant to the development site. Any proposed compensatory cut and fill must be at the same flood level and must not alter hydraulic behaviour; and
- is considered potentially acceptable outside of flood storage areas or flow conveyance areas, subject to not creating local drainage and surface water issues.

(4) In relation to the incorporation of the impacts of climate change in flood risk and land use planning responses:

(a) A regional climate change adaptation response is prepared for the Brisbane River catchment to provide an integrated and consistent approach to identifying, prioritising, evaluating and responding to a broad range of climate change risks, including flooding. This may be implemented via the Queensland Climate Resilient Councils Program (see Section 5.2.1). If required, Phase 4 (LFMPs), local risk assessments and planning instruments should be reviewed and updated to incorporate the outcomes of the proposed regional climate change adaptation response, once completed;

(b) The methodological approach proposed by AR&R (Ball et al., 2016) for climate change impact assessment should be followed in the preparation of any future flood hazard studies in the floodplain;

(c) The sensitivity analysis as detailed in Section 5.2 should be used to inform a whole-of-catchment regional assessment and climate change adaptation response to anticipated climate change impacts on future flood risk for land use planning (and other floodplain management activities);

(d) Planning authorities may choose to adopt the more conservative RCP 8.5 scenario (for 2050 and 2090), or take a more nuanced approach by applying different climate change scenarios to land use, appropriate to the longevity or resilience of the land use to changing flood risk exposure over time. In these circumstances, the SFMP modelled scenarios should be used;

(e) In the absence of a regional climate change adaptation response, planning authorities consider “no regrets” actions in planning instrument responses that will improve the resilience of local communities to future climate change related flood risks.

Potential adaptation options to address climate change considerations may include:

- avoiding inappropriate uses in locations where known existing flood risk will increase or worsen with future climate change (e.g. areas where the existing hydraulic risk profile conditions are likely to change and worsen and may not be a risk appropriate location in the floodplain for vulnerable people etc).
- for tolerable uses in the floodplain, using a DFE that incorporates an additional climate change factor allowance and/or in combination with resilient building design to accommodate the risk.
- using a greater DFE and scaling up by event in parts of the floodplain where peak flood levels are expected to increase under the climate change scenario (e.g. scaling up the 1 in 100 AEP to a 1 in 200 AEP flood immunity level).

(5) A regional evacuation assessment be prepared as a priority to inform Phase 4 (LFMPs), local flood risk assessments and subsequent land use planning responses.

(6) The application of the Evacuation Risk Classification methodology identified in Section 9.5.2 be encouraged in the assessment of evacuation risk to inform the preparation of Phase 4 (LFMPs), local flood risk assessments and subsequent land use planning responses.

(7) Vulnerable land uses involving vulnerable people should be regulated consistently across the floodplain in accordance with the following principle:

Vulnerable land uses involving vulnerable persons do not occur in areas of higher hydraulic risk and where evacuation risk is moderate, serious or intolerable (as defined through an evacuation risk assessment).

Planning scheme flood overlay mapping should be informed by the full known extent of the Brisbane River floodplain to trigger the assessment of flood risk and ensure the establishment of new vulnerable uses involving vulnerable people are located and designed to be risk appropriate.

(8) As part of the ongoing governance arrangements for the implementation of the SFMP, the Department of State Development, Manufacturing, Infrastructure and Planning (DSDMIP) in collaboration with the floodplain planning authorities, investigate whether there is a need for planning implementation arrangement/s that may potentially be required in the interim to address priority land use and development regulation issues, whilst Phase 4 (LFMPs) and planning instrument amendments proceed.

(9) Should it be required, DSDMIP, in conjunction with the region’s planning authorities and QRA, undertake an assessment that will calibrate the planning assumptions underpinning ShapingSEQ with Brisbane River flood risk to enable an integrated regional planning response to be identified and incorporated into the next iteration of the SEQ Regional Plan.

10 Disaster Management

10.1 Context

10.1.1 Overview

The Disaster Management Act 2003 defines disaster management as arrangements about managing the potential adverse effects of an event, including, for example, arrangements for mitigating, preventing, preparing for, responding to and recovering from a disaster. These arrangements are made tangible through a broad collection of actions, policies, documents, plans, strategies etc. (summarised in Section 10.1.5) which act to reduce loss of life and impact to people and properties during disasters. While there are key response agencies across government with responsibility for disaster management planning, effective disaster management requires input and action from the entire community. For this reason, disaster management is strongly linked with community awareness and resilience, which is addressed in Section 11 Community Awareness and Resilience.

Effective floodplain management requires the implementation of a suite of different measures; some of these seek to modify the flood behaviour (thereby removing flood risk for flood events of certain magnitudes), others to ensure that future development is not exposed to unacceptable levels of flood risk. Disaster management (along with community awareness and resilience) seeks to address flood risk to existing development. In general, disaster management has limited value for protection of property (though may have some small impact on building contents), but has particular focus on protection of human life.

Disaster management is typically described through the ‘PPRR’ cycle: prevention, preparedness, response and recovery. Prevention and preparedness stages occur in non-flood times, with the term prevention generally used to describe those actions or measures which can reduce the physical impacts of flooding (including other floodplain management measures such as building controls, land use planning and structural options), and preparedness relating more to arrangements and plans which are implemented to improve response and recovery. Response and recovery capture those actions which occur during and after floods, respectively, although the planning for these stages primarily occurs well before the onset of a flood.

10.1.2 Importance of Regional Approach

A regional approach is fundamental to all components of the Phase 3 (SFMP) to improve coordination and efficiency of floodplain management throughout the catchment (including across border and district boundaries – see Section 10.1.4). Within disaster management, it is important that planning and response are tailored to local conditions and communities, while ensuring a regionally-coordinated approach is used. Coordination improves efficiency of response in a situation where resources can be limited, and ensures that the community receives messaging and direction which is consistent, irrespective of where they live in the catchment.

With increased use of online materials and social media, community members are frequently exposed to materials and messaging from multiple council areas. Similarly, residents move about the catchment (and beyond) in their day-to-day activities and may not necessarily be within their own local government area during a flood. Some families also have members working across local government areas or attending education facilities in other areas. Consistency in approach and messaging, particularly warning and evacuation notices, is essential to avoid confusion. Project research has identified that residents seek information from multiple sources to have confidence in the action required (see Section 11.3.3.3).

In general, a regional approach to disaster management is promoted:

- For language / terminology, mapping, and symbology to assist understanding and interpretation;
- To improve efficiency in planning and execution of activities; and
- When coordination is required between councils and or state government agencies.

These regional considerations informed the development of disaster management measures included in the Phase 3 (SFMP).

Note that the term 'regional' has been adopted throughout the study to differentiate this study from a 'local' scale study (i.e. a study which is undertaken at the scale of a single council area). The study area addressed by this study covers the extreme flood extent plus a small additional area, and only includes that part of the catchment downstream of Wivenhoe dam. As discussed in Section 10.1.5.2, the study area does not align with the three disaster districts which intersect with the Brisbane River catchment.

10.1.3 All-Hazards Approach

The Queensland Prevention, Preparedness, Response and Recovery Disaster Management Guideline (QFES, 2018) outlines four main principles of disaster management which form the basis of the Queensland Disaster Management Act 2003:

(1) Comprehensive approach

(2) All hazards approach

(3) Local disaster management capability

(4) Support by the state group and district groups to local governments

Most disaster management organisations operate across all hazards (such as flooding, fire, land slide etc.) and utilise many of the same approaches to disaster management for each hazard. In particular, approaches which focus on making the community more resilient (rather than standard awareness activities) are likely to have benefits across all hazards, as well as broader community 'shocks and stressors'. While this study and document focus solely on flooding, it should be noted that it is important to continue this all hazards approach and to recognise that many of the recommendations stemming from this study can effectively deliver the flood component of an all-hazards approach or be all-hazards in nature.

10.1.4 Queensland Disaster Management Arrangements

Queensland's disaster management arrangements encompass a multi-tiered system of committees and coordination centres at state, district and local levels, as outlined at www.disaster.qld.gov.au and shown in Figure 10-1, below.

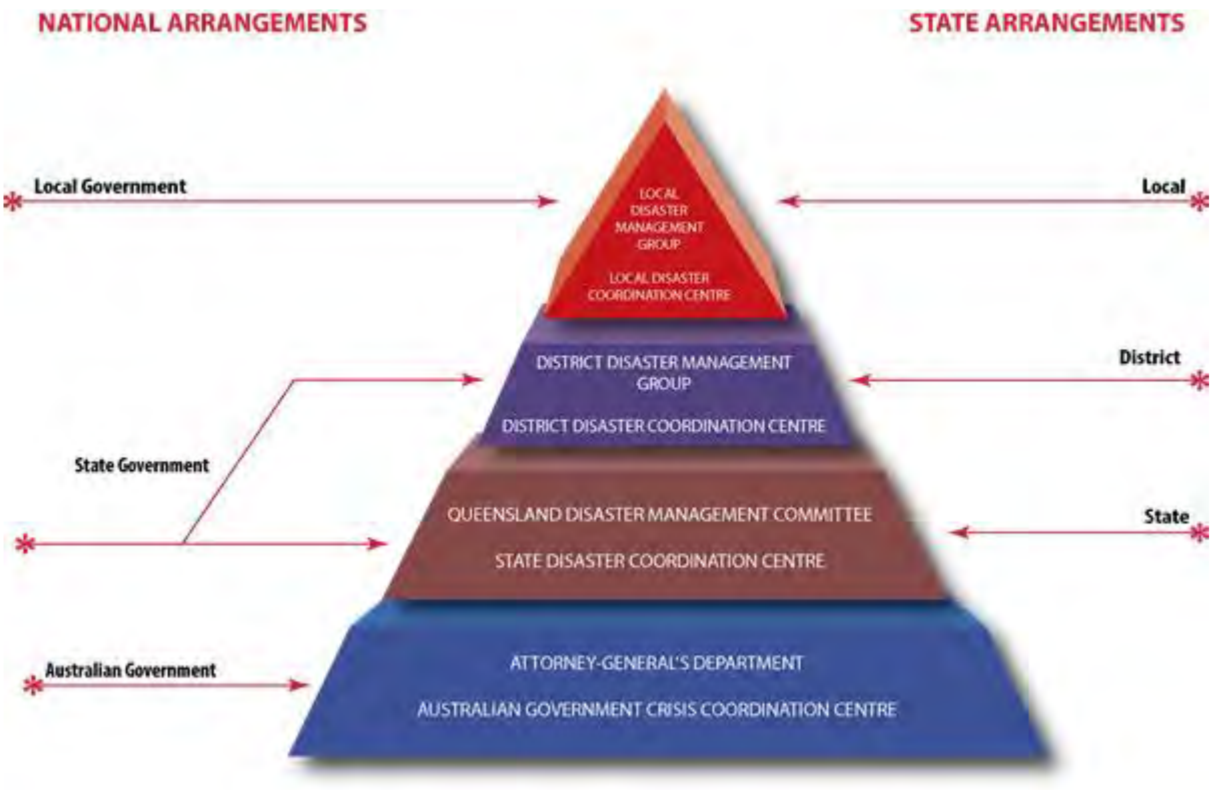

Figure 10-1 Queensland Disaster Management Arrangements[27]

As indicated in Figure 10-1, local disaster management groups are established based on local government areas, hence within the Brisbane River study area, there are local disaster management groups for each of Brisbane City Council, Ipswich City Council, Somerset Regional Council and Lockyer Valley Regional Council. District disaster management groups tend to encompass multiple local government areas. Three disaster districts are captured within this study area:

- **Brisbane Disaster District**, including Brisbane City Council (in the study) and Redlands City Council (not in the study);
- **Toowoomba Disaster District**, including Lockyer Valley Regional Council (in the study) and Toowoomba Regional Council (not in the study); and
- **Ipswich Disaster District**, including Ipswich City Council and Somerset Regional Council (both in the study).

Disaster districts and local disaster management groups address all hazards (i.e. not just flooding), and therefore do not necessarily align with catchment boundaries (which only relate to flood hazard). Therefore, where appropriate within this section (relating to disaster management), the terms 'local' or 'district' may be used, with the terms 'cross-boundary' and / or 'cross-district' used to capture the regional approach advocated in the broader study.

[27] Reproduced from http://www.disaster.qld.gov.au/About_disaster_management/Pages/Introduction-and-History.aspx

Further detail of the various disaster management groups, their interrelations and responsibilities is provided in the Disaster Management Regulation 2014. These arrangements were not reviewed or analysed within this study.

10.1.5 Legislation, Strategies, Frameworks, Studies

10.1.5.1 Overview

In Queensland, the Disaster Management Act 2003 and Disaster Management Regulation 2014 provide the definitions and legislative framework which underpin disaster management arrangements. Numerous other strategies, frameworks, and studies (etc.) also provide guidance on disaster management relating to riverine flood. Key documents are summarised below with emphasis on those aspects of the document which relate to the outcomes of this study. Refer to the original documents for full details.

10.1.5.2 Disaster Management Act 2003 and Disaster Management Regulation 2014

The Disaster Management Act 2003 identifies two key objectives of the Act: to help communities (through mitigating potential adverse impacts, preparing for management of effects, and responding and recovering from events or disasters), and providing effective disaster management for the State. These objectives are to be achieved through various arrangements (detailed in the Act) and according to the following principles:

- Disaster management should be planned across the four PPRR phases;
- All events (including natural disasters and flooding) should be managed via state-level strategic policy, the State disaster management plan, and any disaster management guidelines;
- Local governments are primarily responsible for events in their local government area; and
- District and State groups should provide local governments with appropriate resources and support to carry out disaster management operations [it is understood that local governments do not typically have a ‘trigger’ or ‘threshold’ to seek support from District and State groups, but rather support is sought when local governments are no longer able (or believe they will not be able) to manage an emerging situation on their own].

These principles recognise the multi-tiered management arrangements in place in Queensland, although ultimately place responsibility for disaster management with local governments.

Other aspects of the Act which are relevant to this study (recognising that the study does not address governance arrangements) include:

- Details of the Office of the Inspector-General Emergency Management, particularly the functions relating to reviewing and assessing the effectiveness of disaster management arrangements at all levels, and identifying opportunities for cooperative partnerships to improve disaster management outcomes;
- Details of the Queensland Disaster Management Committee, particularly the functions relating to ensuring effective disaster management is developed and implemented for the State and identifying resources that may be used for disaster operations;

- Temporary disaster districts can be established if a disaster has happened, is happening or is likely to happen in two or more adjoining districts; and
- Essential services providers must be consulted by relevant disaster management groups where it is considered that the provider can help the group perform its functions.

The Disaster Management Regulation 2014 provides further supporting information to the Disaster Management Act 2003.

10.1.5.3 Queensland Strategy for Disaster Resilience

The Queensland Strategy for Disaster Resilience (QG, 2017) (referred to as the 'Queensland Strategy') provides a framework and direction for the Queensland Government to support local governments and communities to identify resilience activities, and provides a cohesive approach to building resilience throughout the state. The Queensland Strategy complements the existing disaster management arrangements in Queensland, as specified in the Disaster Management Act 2003. It is also noted that the Queensland Strategy should be read in conjunction with the Queensland Disaster Management Strategic Policy Statement, the Queensland Disaster Management Plan, and the Emergency Management Assurance Framework.

The Queensland Strategy supports the approach that resilience is a shared responsibility, with the following stakeholders identified as central to the ultimate success of the Strategy:

- Queensland communities and individuals;
- Local Governments;
- Queensland businesses and service providers;
- State Government agencies;
- The Australian Government;
- Community-based organisations; and
- Non-government organisations.

The Queensland Strategy provides an overarching framework to empower Queenslanders to factor in resilience measures as they anticipate, respond, and adapt to the impacts of disaster events (including flooding). Each of these actions (anticipate / respond / adapt) is supported by a number of actions or abilities which characterise a resilient community. Further, the following guiding principles inform the Queensland Strategy:

- Shared responsibility;
- An integrated risk-based approach;
- Evidence-based decision making; and
- Continual learning.

10.1.5.4 Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience

The Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience (QRA, 2017) (referred to as the 'Riverine Flood Risk Framework') was developed to provide a consolidated and coordinated approach to the management of riverine flood risk in Queensland. The Riverine Flood Risk Framework clarifies roles and responsibilities of stakeholders and establishes a governance framework for implementing Queensland-specific flood risk management. It aligns with the Queensland Strategy and is consistent with relevant legislation.

The Riverine Flood Risk Framework seeks to provide direction for the entire flood risk management cycle and all related activities, although the stated vision of the Framework clearly emphasises community resilience:

> "Queenslanders understand flood risk, adapt to changing circumstances and take action to mitigate and build resilience." (p.3 QRA, 2017)

Underpinning the Riverine Flood Risk Framework are six guiding principles:

(1) Flooding is inevitable;

(2) Shared responsibility;

(3) Disaster risk management informs decision making;

(4) Multi-disciplinary catchment approach;

(5) Locally led initiatives for local communities; and

(6) Transparency in data and information sharing.

These principles are further supported by desired outcomes from the process. Outcomes emphasise a risk-based approach to flood management, shared and coordinated responsibility, and the empowerment of local communities through the provision of locally-specific flood risk management initiatives.

The Riverine Flood Risk Framework will be supported by an implementation plan, which will outline how the Framework's key objectives will be delivered.

10.1.5.5 Australian Disaster Resilience Handbook Collection

The Australian Disaster Resilience Handbook Collection (referred to as the Handbooks) capture nationally agreed principles, policies and practices to support the development of disaster resilience. The Handbooks are currently a series of 16 handbooks, each of which addresses a different aspect of disaster resilience, and are supported by additional technical guidance and other material. Prior to the development and publication of the Handbooks, similar material was provided in a series of 46 Manuals. The manuals have not been updated since 2011 or earlier and the material in the manuals is gradually being migrated across to the Handbooks, as the content is updated and reviewed.

Of most relevance to the management of flood risk is Handbook 7, Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR, 2017). This handbook is regarded as the national guidance for floodplain management and works in concert with the National Strategy for Disaster Resilience (COAG, 2011).

Handbook 7 outlines eight key principles for a best-practice approach to flood risk management:

(1) A cooperative approach to manage flood risk;

(2) A risk management approach;

(3) A proactive approach;

(4) A consultative approach;

(5) An informed approach;

(6) Supporting informed decisions;

(7) Recognition that all flood risk cannot be eliminated; and

(8) Recognition of individual responsibility.

Disaster management is primarily addressed through guidance for treating residual risk at the community scale. In particular, the following flood risk management treatments are identified:

- Flood forecasting and warning systems, which is discussed in detail in Australian Disaster Resilience Manual 21 Flood Warning (AIDR 2009); and
- Community-scale emergency response plans, which should be developed using flood intelligence, including detailed evacuation planning, identify infrastructure and critical services in the floodplain, and be directly linked with community awareness and resilience actions.

Community preparedness and community recovery plans are also identified as treatment options for residual risk. These are more directly addressed via community awareness and resilience actions, although closely linked with disaster management.

10.1.5.6 Queensland Floods Commission of Inquiry

The Queensland Floods Commission of Inquiry (referred to as the Inquiry) was established as an independent Commission of Inquiry to examine the 2010 / 2011 flood disaster that affected 70% of Queensland and resulted in the flood-related deaths of 33 people. The Inquiry took public submissions, held community meetings and consultations, and received input from nationally respected experts in their fields. An interim report (QFCoI, 2011) from the Inquiry was issued in August 2011, relating to matters associated with flood preparedness. The final report (QFCoI, 2012) was released in March 2012, and included recommendations for stakeholders.

Recommendations in the final report primarily focus on land use planning, dam operation, maintenance of essential services, structural measures etc. Where recommendations address disaster management, these primarily relate to issues of governance, responsibility, and communication between agencies.

By comparison, the interim report focussed on flood forecasts, warnings and information. Many of the recommendations in the interim report address issues related to disaster management, including:

- Disaster frameworks, preparation and planning. Of relevance to this scope of works:

  - Local Disaster Management Plans are consistent with the Disaster Management Act 2003, address local risks and circumstances, and can be easily used in a flood event.
  - Community education programs should be undertaken to help the community contribute to the PPRR cycle.
  - Consistent messaging should be provided to the public during all stages of flooding.
- Forecasts, warnings and information. Of relevance to this scope of works:
  - Councils should consider how to best convey information to the community about flood levels and local behaviour, including via social media.
  - Councils should ensure that residents and businesses understand the impact of predicted flood levels on their property, including via information that relates gauge heights with the level of flooding to be expected at a building.
- Emergency response. Of relevance to this scope of works:
  - Local governments should consider adopting uniform disaster management software, to enable inter-council assistance to be given more easily and effectively.
  - Councils should develop evacuation sub-plans in accordance with the Emergency Management Queensland Guidelines, including triggers in the form of those water level heights at which it is known that preparation for evacuation will be necessary, and identify areas at risk of isolation.

10.1.5.7 Queensland Emergency Risk Management Framework

Under the Queensland State Disaster Management Plan, Queensland Fire and Emergency Services (QFES) is responsible for the conduct of a State-level disaster risk assessment. The Queensland Emergency Risk Management Framework[28] (QERMF) provides a methodology to inform this risk-based planning across Queensland's Disaster Management Arrangements (QDMA). The QERMF is underpinned by a multidisciplinary approach, and uses operational geospatial intelligence to undertake exposure and vulnerability analysis which can directly inform the State's multitiered disaster management planning.

The aim of QERMF is to provide a consistent State-wide approach to assessing risk, which can in turn:

- Be operationalised;
- Facilitate greater stakeholder discussion and cooperation towards understanding and managing risk; and
- Directly support risk-based planning across all levels of the Queensland disaster management arrangements.

This framework was applied to the state of Queensland, addressing all natural hazard types, as captured in the Queensland State Natural Hazard Risk Assessment (QFES 2017). The State Natural Hazard Risk Assessment is a responsibility of QFES under the Queensland State Disaster

[28] http://www.disaster.qld.gov.au/Disaster-Resources/Pages/Emergency-Risk-mgmt.aspx

Management Plan. The assessment identified that tropical cyclones and flooding are equally the most destructive and damaging natural hazards within Queensland, with the potential to pose the most risk to life due to limitations to disaster operations during impact.

Data produced by the Phase 3 (SFMP) is available to be used by councils when undertaking their own emergency risk management in line with the framework. The data produced by the Phase 3 (SFMP) may also inform future revisions of wider risk assessments.

10.1.5.8 *Emergency Management Assurance Framework*

The Emergency Management Assurance Framework (EMAF) was developed by the Office of the Inspector-General Emergency Management in partnership with a range of disaster management practitioners from state government, local government, non-government, volunteer and government-owned corporations. The EMAF supports all levels of Queensland's disaster management arrangements to continually improve disaster management performance and empowers front-line disaster management service providers by outlining a standard which can be applied by all Queensland disaster management stakeholders. This ensures their legislative responsibilities are met and that disaster management programs are effective, aligned with good practice, and meet the needs of Queensland communities.

The EMAF identifies shared responsibilities across all sectors (including the community) over the key areas of:

- Hazard identification and risk assessment;
- Hazard mitigation and risk reduction;
- Preparedness and planning;
- Emergency communications;
- Response; and
- Relief and recovery.

Key outcomes and corresponding good practice attributes, indicators and accountabilities are provided for each of these shared responsibilities. Of particular relevance to this study and the disaster management component is the shared responsibility for hazard identification and risk assessment, which has the following key outcomes:

- Stakeholders have a shared understanding of, and ready access to, risk information for all types of events;
- Risk assessments are robust, replicable and authoritative; and
- Risk assessments are integral to the mitigation, preparedness, continuity, response and recovery planning processes and documentation.

Outcomes from this Phase 3 (SFMP) will inform the other shared responsibilities when applied at the regional and local scale.

10.1.5.9 Service Level Specification for Flood Forecasting and Warning Services for Queensland

The Service Level Specification for Flood Forecasting and Warning Services for Queensland (SLS) is prepared by the Bureau of Meteorology (Bureau) to document and describe the flood forecasting and warning services provided by the Bureau in Queensland. The SLS cross-references Manual 21 Flood Warning (part of the Australian Manual Series, Australian Government 2009), in particular through recognition of the total flood warning system and the Bureau's role in the system.

The SLS identifies forecast, observation and data locations, noting that the Bureau will develop and maintain prediction systems for forecast locations as provided. Within the Brisbane River study area (i.e. the area within the hydraulic model boundary), numerous forecast locations have been identified, as shown in Table 10-1.

Table 10-1 Forecast Gauge Locations within Study Area[29]

Gauge ID	Gauge Location	Gauge Type	Gauge Zero (m AHD)
040441	Lowood	Manual	23.68m AHD
040142 / 540199 / 040818	Mt Crosby	Automatic	0.0m AHD
540081 / 540504	Walloon	Automatic	16.46m AHD
540180	Amberley	Automatic	19.87m AHD
040101 / 040831	Ipswich	Automatic	0.0m AHD
540200	Moggill	Automatic	0.0m AHD
040713	Jindalee (Centenary Bridge)	Manual	0.0m AHD
540198	Brisbane City	Automatic	0.0m AHD

Note that the Bureau issues warnings for the Lowood, Walloon and Amberley gauges in a local datum, which is different to the Australian Height Datum (AHD) which was used in the Phase 2 (Flood Study). Disaster management officers using data from the Phase 2 (Flood Study) in the vicinity of the Lowood, Walloon and Amberley gauges should be cognisant of the difference between gauge datums and ensure that flood predictions are interpreted correctly.

10.1.5.10 Flood Warning Gauge Review

The QRA is responsible for coordinating whole-of-government flood risk management and resilience policy, and is leading the implementation of a best practice approach to the management of the flood warning gauge network in Queensland. The aim is to ensure people in flood-prone communities across Queensland have appropriate warning of flood events.

In 2015, a state-wide Performance Review of the Queensland Flood Warning Gauge Network was completed. The review and subsequent work with local councils identified that the Bureau of Meteorology uses data from more than 3,400 rainfall and river gauges owned and operated by 54 entities. It also identified priority locations for improved early flood warning infrastructure.

[29] Extracted from Schedule 2 from the SLS. See original schedule for full list of forecast locations and levels of service.

In conjunction with the Bureau, the QRA worked with councils including the councils in the Brisbane River catchment to identify and recommend improvements to flood warning systems and design improved networks. The key outcomes from the consideration and redesign of flood warning systems will be:

- An improved visibility of the data to relevant councils, the State Disaster Coordination Centre, and the Bureau
- Improvements to the flood warning gauge network to a standard approved by the Bureau
- The related transmission of data is suitable for use by the Bureau.

10.1.6 Summary

Disaster management, as outlined in the Disaster Management Act 2003 and the Queensland Strategy for Disaster Resilience is a shared responsibility across numerous stakeholders and levels of government. The relationships, roles, responsibilities and communication channels which extend across stakeholder groups are complex and important to clearly define. However, the aspects of legislation, policy, strategies, frameworks and studies are those which relate to two distinct aspects of disaster management:

- Understanding of flood behaviour and risk, used to inform a range of disaster management plans and decisions; and
- Information used to engage with the community to support development of personal flood plans, and to inform broader flood resilience.

Within these relevant aspects, forecast and observed rainfall and stream gauge data is a key input to many critical, real-time disaster management decisions. The gauge network is currently being reviewed by the Queensland Reconstruction Authority, with recommendations from the review to be provided to the Bureau and the Queensland Flood Warning Consultative Committee. Changes to the gauge network has the potential to significantly impact disaster management planning processes.

Disaster management recommendations from the Queensland Floods Commission of Inquiry emphasised the importance of providing flood information and maps to the community, including the provision of property-specific information which links stream gauge heights to expected impacts at buildings. This recommendation is strengthened by findings from the market research and other studies undertaken within the community flood awareness and resilience component of the Phase 3 (SFMP). That element identified the critical importance of empowering the community with locally-specific information to help residents make timely flood preparation and decisions.

10.2 Disaster Management Opportunities

10.2.1 Introduction

Disaster management includes all aspects of floodplain management, and involves many stakeholder organisations across all levels of government (as well as the community and non-governmental organisations). The systems, structures and policies in place which guide disaster management in Queensland have been developed and refined over many years, including through application in disasters and in response to review. Disaster management also applies beyond flooding, and beyond natural disasters to encompass all disaster types. As a result, review and analysis of governance arrangements relating to disaster management (including associated documents) was not included within this study.

However, governance is not the only aspect of disaster management: sound disaster management also relies on the availability of high-quality information, and the analysis of this information to understand the context and application. It is this aspect of disaster management, particularly as it relates to riverine flooding in the Brisbane River catchment, which was the focus of this Phase 3 (SFMP).

Development of the regional flood models as part of the Phase 2 (Flood Study) provides a trigger for improved coordination and consistency of disaster management information within the catchment. This Phase 3 (SFMP) focused on current challenges in (flood-related) disaster management, and how the flood models and associated analyses might help to address those challenges.

10.2.2 Existing Flood Risk

Section 4 Current Flood Risk described the flood risk within the catchment, including mapping of hydraulic flood risk (a prioritised intersection of flood hazard and likelihood), estimation of flood exposure to people and buildings, mapping of more vulnerable communities, sensitive institutions and critical infrastructure, and flood immunity assessment of state-controlled roads.

Information used to develop the critical infrastructure database was derived from land use classifications, and various primary data sources provided for this study. Note however that not all critical infrastructure datasets were made available for this study (some due to confidentiality issues), and hence the dataset does not provide a complete listing of all critical assets in the floodplain. Critical infrastructure types within the dataset include:

- Airports and associated infrastructure
- Emergency management facilities
- Water infrastructure
- Telecommunications infrastructure

The flood immunity of state controlled roads was also assessed.

Sensitive institutions were identified via the building database which included the following institution types:

- Hospital
- Child care
- Educational
- Community protection

Some sensitive institution types (such as aged care and other medical facilities) were not identified through the building database. Phase 4 (LFMPs) should seek to improve and verify the database.

This information provided essential disaster management information by understanding the impacts of flooding on the community.

10.2.3 Opportunity Identification Process

Opportunities to improve disaster management in the catchment, particularly by leveraging off the Phase 2 (Flood Study) models, were generally self-identified by stakeholders through a three-stage consultation process. Two workshop sessions focusing on disaster management were hosted during the study, supplemented by more personalised consultation with the primary stakeholders. Feedback received at these consultations and workshops shaped the identification of opportunities within this Phase 3 (SFMP).

10.2.3.1 Workshop 1

Workshop 1 of the Phase 3 (SFMP) was held on the 9th March 2017, and focussed on disaster management in conjunction with community awareness and resilience.

No pre-reading was provided for this workshop, and formal notes summarising discussion were not issued following the workshop. The workshop primarily comprised two group activity / discussion sessions asking stakeholders two key questions relating to disaster management:

- What's not working? (and)
- What can we do about it?

A full summary of all responses from the workshop is provided in Appendix J. From the discussion, four key themes emerged, as summarised in Table 10-2, below.

Table 10-2 Key Themes from Workshop 1 Feedback

Theme	Main Issues	Stakeholder Ideas to Address
Communication and evacuation infrastructure	Stakeholders are keen to better understand the flood immunity of critical infrastructure and how this might impact residents and dissemination of information	Establish standards for critical infrastructure
Community understanding	Particularly relating to translating flood warnings and gauge levels to 'on the ground' impacts	Provide personalised and translated information to the community, plus broader community awareness measures
Governance and collaboration	Issues relate particularly to information sharing and ensuring consistency of information, although there is some recognition of unclear division of responsibilities	Apply a cross-boundary / cross-district approach to disaster management. Improve collaboration between state and local agencies. Clarify accountabilities and responsibilities. Make mapping, messaging etc. consistent. Improve sharing of information
Resources, information, understanding	This relates to a broad range of issues including availability of gauged data, understanding of SOPs, and trigger points	Have a central hub for flood data, information and intelligence accessible for all agencies. Link live maps to flood predictions. Develop triggers from Phase 2 (Flood Study) and investigate recent developments in faster model software

10.2.3.2 Stakeholder Consultation

Consultation was undertaken with each of the following project stakeholders (separately) during July and August 2017:

- Bureau of Meteorology;
- Queensland Fire and Emergency Services;
- Queensland Reconstruction Authority;
- Seqwater;
- Brisbane City Council;
- Ipswich City Council;
- Somerset Regional Council; and
- Lockyer Valley Regional Council.

This consultation sought to clarify disaster management opportunities and better understand the needs of individual stakeholders. These sessions particularly focused on the following:

- Summary of work done to date (particularly the ‘existing risk’ profiling presented in Section 4 Current Flood Risk);
- Challenges faced by stakeholders in terms of tools, data and information; and
- Ideas for how the Phase 3 (SFMP) might help stakeholders improve disaster management outcomes.

A summary of the feedback received during consultation was provided as pre-reading briefing notes prior to Workshop 4 (provided in Appendix O). The feedback summarised current disaster management tools used by stakeholders, namely:

- Disaster management tool (DMT) – discussed further in Section 10.6.3.4;
- Disaster dashboard – a disaster-focused website primarily used for sharing information with the public and discussed further in Section 11 Community Awareness and Resilience;
- waterRIDE – proprietary software used for viewing flood model results, and understood to be under consideration in a project running parallel to the Phase 3 (SFMP);
- Incident management systems – such as Guardian / TAMS, Noggin and WebEOC.

The summary of feedback also captured desired outcomes from this component of the Phase 3 (SFMP) and current challenges, and used this information to develop draft objectives and goals. These objectives are:

- **Regional consistency** – project deliverables should support a consistent approach to disaster management in the region, while recognising the unique flood risks faced by each council area (via a cross-boundary / cross-district approach). Deliverables should particularly emphasise consistency in areas of language and messaging, with support provided to establish a single point of truth for regional-scale riverine flood information. Deliverables should acknowledge existing tools, arrangements and systems used by individual stakeholders, and build upon these where possible, rather than seek to replace.

- **Interface with other flood sources** – project deliverables should focus on regional-scale riverine flooding, while recognising that other flooding sources (creek, overland, storm tide) is a source of risk to the community. Deliverables should provide councils with guidance and tools for applying the same flood risk assessment and management processes to detailed / local scale flooding, where appropriate.
- **Interagency information sharing** - Project deliverables should identify the types of information needed to be shared across the region. Deliverables should provide a scope for the commissioning of a region-wide system capable of sharing flood information on a web-based platform, with a GIS focus.
- **Flood analysis** - Project deliverables should provide a range of regional-scale flood analysis which may include maps, charts, tables etc. Deliverables should provide guidance to Councils for creating similar flood analysis for other sources of flooding or detailed / local scale flooding.
- **Real-time modelling** - Project deliverables should compare the various options available to leverage existing data and models for the purposes of real-time modelling.
- **Interface with other studies** - Project deliverables will help Councils comply with the Inspector General of Emergency Management's Emergency Management Assurance Framework.

10.2.3.3 Workshop 4

Workshop 4 was held on the 14th August 2017, and focussed on disaster management during the afternoon session.

Pre-workshop reading included a range of proposed deliverables for this component of the Phase 3 (SFMP), which were developed following the stakeholder consultation sessions. The workshop sought to:

- Confirm the desired outcomes from this component of the Phase 3 (SFMP)
- Present the types of deliverables proposed for this component of the Phase 3 (SFMP)
- Provide an opportunity to discuss related issues, including challenges to implementation or other required guidance
- Explore the potential for real-time flood analysis (including modelling) through group discussion.

The workshop also provided the QRA with an opportunity to update stakeholders on the flood gauge review being undertaken concurrently with this study.

Key points of discussion from the workshop are provided below:

- Proposed deliverables have the same inherent limitations as the Phase 2 (Flood Study), i.e. they are based on the ensemble of 60 events and actual events will differ from these which were selected based on peak flood level;

- Stakeholders have difficulty categorising stream gauges (i.e. identifying minor / moderate / major levels) and would appreciate some guidance on this topic;
- Due to the relative uncertainty and precision of model results, information which links stream gauge levels to inundation / impact levels should be 'banded' to avoid overstating accuracy of relationship;
- The disaster management component of the Phase 3 (SFMP) is inter-related with, and should cross-reference, the community resilience and land use planning components; and
- There is a separate project being undertaken to establish a regional data sharing system. (See Section 10.2.4.1 for further discussion).

There was considerable discussion regarding options for real-time flood modelling systems. Feedback from this discussion is provided in Section 10.6.

10.2.3.4 Community Awareness and Resilience

Community flood awareness and resilience is strongly interconnected with disaster management. The analysis, summarised in Section 11, was captured via principles for resilience activities. Of particular relevance to disaster management, is the principle that 'local context is important to the effectiveness of resilience activities'. This principle was informed by literature review, but also responses received via market research undertaken within the Phase 3 (SFMP), which indicated that the community is more likely to respond to warning and evacuation notices which specifically name their local area. Further, greater specificity provided in the notice (i.e. street level rather than suburb level) leads to greater response rates.

10.2.4 Opportunities

Using feedback received at the two workshops and stakeholder consultations, shaped further by findings from the community awareness and resilience component of the Phase 3 (SFMP), a range of opportunities were identified which form the scope of the disaster management component's deliverables. These opportunities were initially tested with stakeholders at Workshop 4, and refined further with the QRA out of session. The remainder of this chapter delivers information, analysis and recommendations based on the identified opportunities. Opportunities have been grouped into the following categories:

- **Flood data** – information extracted from the Phase 2 (Flood Study) and other data sets. These opportunities are primarily delivered through digital data (e.g. GIS mapping), although a summary of the data derivation, purpose, caveats etc. is provided in Section 10.3.
- **Flood impact information** - information which builds upon the flood analysis to identify the impact of an event on people, buildings and critical infrastructure. As for flood analysis, these opportunities are primarily delivered through digital data (e.g. GIS mapping), although a summary of the data derivation, purpose, caveats etc. is provided in Section 10.3.
- **Flood analysis guidance** - advice for developing similar flood analysis at the local / detailed model scale, and guidance for additional studies to be undertaken at the local / detailed scale. Guidance is provided in Section 10.5.

- **Real-time flood analysis** - comparisons of real-time flood analysis options (including real-time modelling), and capturing stakeholder feedback on the topic. This discussion is provided in Section 10.6.
- **Additional disaster management recommendations** - capturing any additional considerations relating to regional disaster management for riverine flood risk.

10.2.4.1 Regional waterRIDE System

In direct response to opportunities identified through this study, a separate project has recently been commenced to upgrade, customise and unify the data within the waterRIDE software systems currently used by the four Local Government Authorities within the Brisbane River catchment.

The primary objective of the project is to set up a standardised version of the “Brisbane River Interpolation System” across the four Council areas. The system will interpolate flood surfaces using BoM issued forecast levels. The project also includes the addition of new functionality to use BoM issued forecast data in the execution of the hydraulic model, along with expanded functionality to provide more extensive flood intelligence.

Due to the limitations of hydrology models to capture the complexity of the perched creek systems in the upper and middle Lockyer and Laidley Creek systems during flood operations (in particular flood volumes, distribution and timing), stakeholders are investigating and implementing improvements to model representation of these systems. This will benefit the “Brisbane River Interpolation System” and any future real-time equivalent however, in the interim, care should be taken when using the existing models for flood intelligence.

10.3 Flood Data

10.3.1 Overview

Flood data provided for disaster management is derived from the detailed hydraulic model, and is additional to the maps provided in the Phase 2 (Flood Study). The data provided through the Phase 2 (Flood Study)was appropriate for a study which sought to understand flood behaviour. However, consultation undertaken throughout the course of this Phase 3 (SFMP) identified that additional data would be helpful when applying information from the Phase 2 (Flood Study)in a disaster management context. This data can be compiled in conjunction with other information to develop flood intelligence for a range of locations and potential flood outcomes.

10.3.1.1 Detailed Hydraulic Model

Although a full description of the detailed hydraulic model development will not be repeated here[30], there are some technical elements of the model which are important to highlight to ensure that flood model output (mapping) is used within its limitations and not misinterpreted or applied inappropriately.

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[30] A technical summary of the Flood Study hydrologic and hydraulic models is provided in Section 8, with a longer summary description provided in the BRCFS Technical Summary Report (Milestone 7) and a full description in the BRCFS Final Report (Section 8 Structural Options Assessment) prepared for that study (BMT WBM, 2017).

The hydraulic modelling was undertaken in two stages as part of the Phase 2 (Flood Study): a 'fast' hydraulic model was developed to allow thousands of flood events to be simulated quickly, with the model providing a simplified representation of the behaviour of floodwater; and a 'detailed' hydraulic model was developed to provide a more detailed representation of the complexity of flow in both channel and floodplain areas, but with a necessarily slower simulation time.

Many disaster management officers will be familiar with traditional flood models, which use a single flood event to represent each design flood size (e.g. a 1 in 100 annual exceedance probability (AEP), also called a 1 in 100 year event). These traditional approach models only capture one combination of catchment conditions (such as the relative timing of peaks in different waterways, whether the ground is saturated, how high the ocean levels are etc.), and only one pattern of storm (both how the storm evolves over time and how the storm pattern varies over the catchment). However, due to the large size and complexity of the Brisbane River catchment, in addition to the high flood risk in the catchment, it was determined that the Phase 2 (Flood Study) should use a more comprehensive approach to estimate design flood behaviour.

A large collection (11,340) of potential storm events of all sizes, combinations of conditions, timing and storm patterns was developed and tested in the fast hydraulic model. A statistical analysis was then undertaken of the peak (maximum) flood levels produced by the fast model at 26 key locations around the catchment. This analysis identified the peak flood level for each AEP flood event (e.g. 1 in 100 AEP) at each location and then selected one of the 11,340 events that provided the identified peak flood level at each reporting location. Because of the natural variability in the catchment, there was no single flood event from the 11,340 tested which appropriately represented a given design event for all of the reporting locations. As a result, it was necessary to select multiple flood events and combine the results from these events to form an overall representation of a design event. For instance, the 1 in 100 AEP comprises five separate events from the original 11,340. Those selected five events were simulated in the detailed hydraulic model and the results were combined to form an 'envelope' of results. It is these enveloped results which were mapped and provided in the Phase 2 (Flood Study). Envelopes were provided for each of the 11 AEP design events. In total, 60 events from the initial 11,340 were simulated in the detailed hydraulic model and used to map the 11 AEPs.

From this process, it is important to emphasise that the 60 events were selected based on peak heights at certain locations only. The 60 events are not considered 'representative' in other ways, and are not necessarily representative of typical flood timings or evolution. Further, the peak levels may have been generated through a collection of catchment conditions which are not 'typical' or don't tell the full story for all possible flood types.

The hydraulic models were focused on riverine flooding and, while the major creek systems are included in the model, they were not the focus of the modelling process. In general, this means that where flooding occurs around creek areas in the Phase 2 (Flood Study) maps, it is mostly caused by flood waters from the Brisbane River backing up the creeks, rather than the creeks themselves being in flood. For many floods and locations, this is a suitable representation, as creeks tend to reach peak levels before larger river systems and hence do not cause flooding at the same time as the rivers. However, users of the mapping should be aware that flooding may be worse than indicated in the Phase 2 (Flood Study) maps (or those provided from the Phase 2 (Flood Study) model) during creek flood events, or if there is coincident flooding in riverine and creek systems. Similarly, if local drainage structures become blocked or there is intense local rainfall, the flooding situation may be worse than the riverine flood maps indicate.

Finally, it is important to note that the detailed hydraulic model was developed on a 30m x 30m grid cell size. This cell size is appropriate for a regional-scale riverine model. Should flood behaviour at a local scale (smaller than the 30m grid) be of importance, a more refined model may be required to provide a better representation of smaller floodplain features, such as local drainage structures or small infill development.

10.3.1.2 Notion of Fit-For-Purpose

One of the greatest challenges faced by disaster management officers, particularly during flood times, is finding or developing data which describes the current or predicted event. All floods are different, with even the 11,340 different events simulated in the fast hydraulic model not sufficient to describe all the possible ways a flood might evolve throughout the Brisbane River catchment. As a result, floodplain management officers can become uncertain and feel reluctant to use design flood modelling for disaster management purposes as they need details relating to gauge heights and other information about the spatial and temporal evolution of the flood. However, worse than slightly incorrect or ill-fitting data is no data at all. Disaster management officers require information to make critical decisions and cannot let ‘perfect be the enemy of the good’.

It is the responsibility of all users of flood data to ensure that the data is the best available, most current, and is fit for the purpose for which it is intended. In the case of data from the Phase 2 (Flood Study) models, this may require users being more informed of model development and AEP event selection than they would otherwise. It is also the responsibility of stakeholders to continue to pursue refined and improved data, as new technologies and approaches become available (this is discussed further in Section 10.6).

10.3.1.3 Stream Gauge Reference Areas

One of the key processes in real-time disaster management is the translation of real-time and forecast river levels into flood inundation extents and impacts. To support this process, it is important to understand which stream gauges relate to which floodplain areas and if the behaviour observed at that gauge is generally representative of the flood behaviour in the surrounding areas. In many locations, the nearest gauge is likely to be most representative of flood behaviour, however the following additional factors may weaken the representation:

- Presence of hydraulic structures, such as dams, weirs etc;
- Confluences of additional water courses, particularly large waterways; and
- Steep hydraulic gradients, where water levels change rapidly.

To assist disaster management officers understand how stream gauge behaviour relates to flood behaviour in surrounding floodplain areas, stream gauge reference areas were established within this Phase 3 (SFMP). These reference areas are indicative only and may be subsequently refined based on local knowledge, more detailed hydraulic modelling, and / or inclusion of other flood sources (other than Brisbane River).

Stream gauge reference areas were used to inform development of flood impact information (which will inform local flood intelligence), and may also be used to help the community understand their local flood risk and where to find information relative to their location. It is recognised that stream gauges upstream of areas of interest are more suitable for use by emergency managers during real-time events. These reference gauge areas are primarily focused on the development of flood intelligence, and as communication tool for the community.

The stream gauge reference areas were developed using the following process:

- Thiessen polygons (based on nearest forecast gauge) were defined around each gauge (as identified in Section 10.1.5.9). Thiessen polygons define an area of influence around its sample points (i.e. forecast gauges), such that any location inside the polygon is closer to that point than any of the other sample points;
- The Thiessen Polygons were manually adjusted by considering the flood extents of the 1 in 100 AEP and the 1 in 100,000 AEP flood events to ensure hydraulic grade was consistently applied in each polygon. The reference area for the Lowood Pump Station gauge was also modified to reflect the hydraulic influence of Mt Crosby weir;
- Suburb boundaries were intersected with these modified Thiessen polygons and the suburbs assigned to a forecast gauge;
- Allocation of suburbs to reference gauges was reinspected and manually modified to reflect local hydraulic behaviour of the 1 in 100 AEP and the 1 in 100,000 AEP; and
- Buildings within each stream gauge reference area were assigned to that area (and correspondingly, that forecast stream gauge).

An overview map of the stream gauge reference areas is provided in Figure 10-2, with more detailed maps in Appendix P. Note that the majority of Somerset Regional Council area has not been assigned to a reference stream gauge, as these locations are best represented by the Gatton forecast gauge, which is beyond the Phase 2 (Flood Study) hydraulic model boundary. There is a gauge at Glenore Grove, however this is not currently specified as a forecast gauge location.

10.3.2 Increased Library of Riverine Flood Maps

10.3.2.1 Background

Maps of peak flood levels, depths, velocities and hazards for the design AEPs were provided as part of the Phase 2 (Flood Study). These maps provide information for 11 AEPs, which in some locations leaves large gaps between flood heights, limiting knowledge about flood extents at those heights.

10.3.2.2 Description

Digital maps of peak flood extents, levels and depths have been provided for all of the component 60 events simulated in the detailed hydraulic model (which were used to make up the 11 AEPs).

Peak levels, flow rates and velocities for each of the 60 events has also been provided (in Excel format), at the stream gauge forecasting locations.

10.3.2.3 Improvement to Current Situation

Additional flood maps will improve disaster management officers' understanding of flood behaviour and improve their ability to plan for flood events and estimate impacts during floods.

10.3.2.4 Considerations for Use

Users should be cognisant of the data source and decide for each application of the data whether it is 'fit-for-purpose' (per Section 10.3.1.2).

The following should be considered when using the increased library of riverine flood maps:

- Maps for the 60 component events have been provided for disaster management purposes and should not be used for land use planning.
- The maps indicate flood behaviour for those particular flood events (including initial conditions etc.) only. Maps do not necessarily represent 'typical' flood behaviour. In general, locations with more complex flood behaviour (e.g. where multiple waterways interact) will not be as well represented as locations with more predictable behaviour, such as the lower catchment.
- Flood maps of flood levels and extents are more reliably representative of flood behaviour at a given stream gauge height than flow rates, velocities and hazards. Caution should be exercised when using maps of flow rates, velocities and hazards from the 60 component events in a disaster management context.

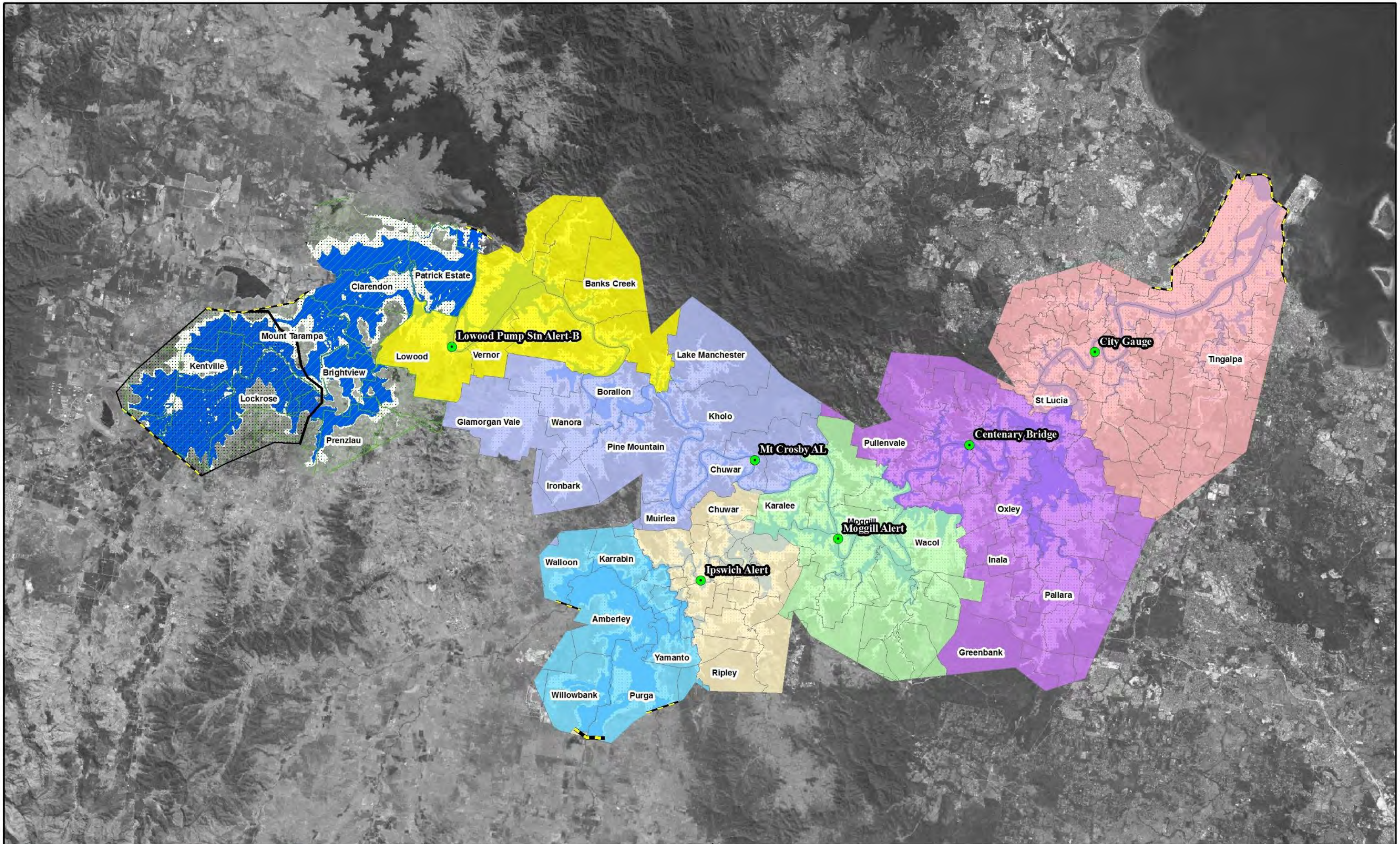
10.3.3 Forecast Location Diagrams

10.3.3.1 Background

The flood maps provided during the Phase 2 (Flood Study) provide important design flood information that can be used by disaster management officers during pre-flood planning and real-time response to estimate flood impacts. In general, these maps will be interpreted in conjunction with real-time or forecast values from the forecast stream gauge locations (identified in Section 10.1.5.9). Understanding the corresponding stream gauge value for each map, and how this compares with historic floods and flood gauge classification is an important interpretive step.

10.3.3.2 Description

The gauge 'totem' diagrams which are provided for all forecast stream gauge locations within the hydraulic model area have been used as a template for presenting the relative flood heights of the design flood maps. The newly created diagrams include current stream gauges classifications (minor / moderate / major), the 11 AEP flood levels, and historic events. An example forecast location diagram is provided in Figure 10-3, with the full set of diagrams for all forecast gauges within the TUFLOW model boundary provided in Appendix Q and digitally.



LEGEND

- Forecast Stream Gauges
- 1 in 100 AEP Extent
- 1 in 100,000 AEP Flood Extent
- Limit of Detailed Modelling
- Flooding in hatched area needs to be verified with the Local Council

Influence Zones of Flood Forecast Gauges

- Brisbane City
- Centenary Bridge
- Ipswich Alert
- Ipswich Upstream
- Lowood Pump Stn Alert-B
- Moggill Alert
- Mt Crosby AL
- Forecast Gauge Outside Model Boundary

*Refer to Councils for local flooding beyond limit

Brisbane River Catchment Flood Study
Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Zones of Influence to Forecast Gauge Locations

0 3 6 9 12
Kilometers

Map Grid of Australia 1994, Zone 56

Filepath : B:\B22374 BRCFMS\GIS\MXD\Forecast Gauges\FLD_006_Zones of Influence to Forecast Gauge.mxd

Fig 10-2 **A**

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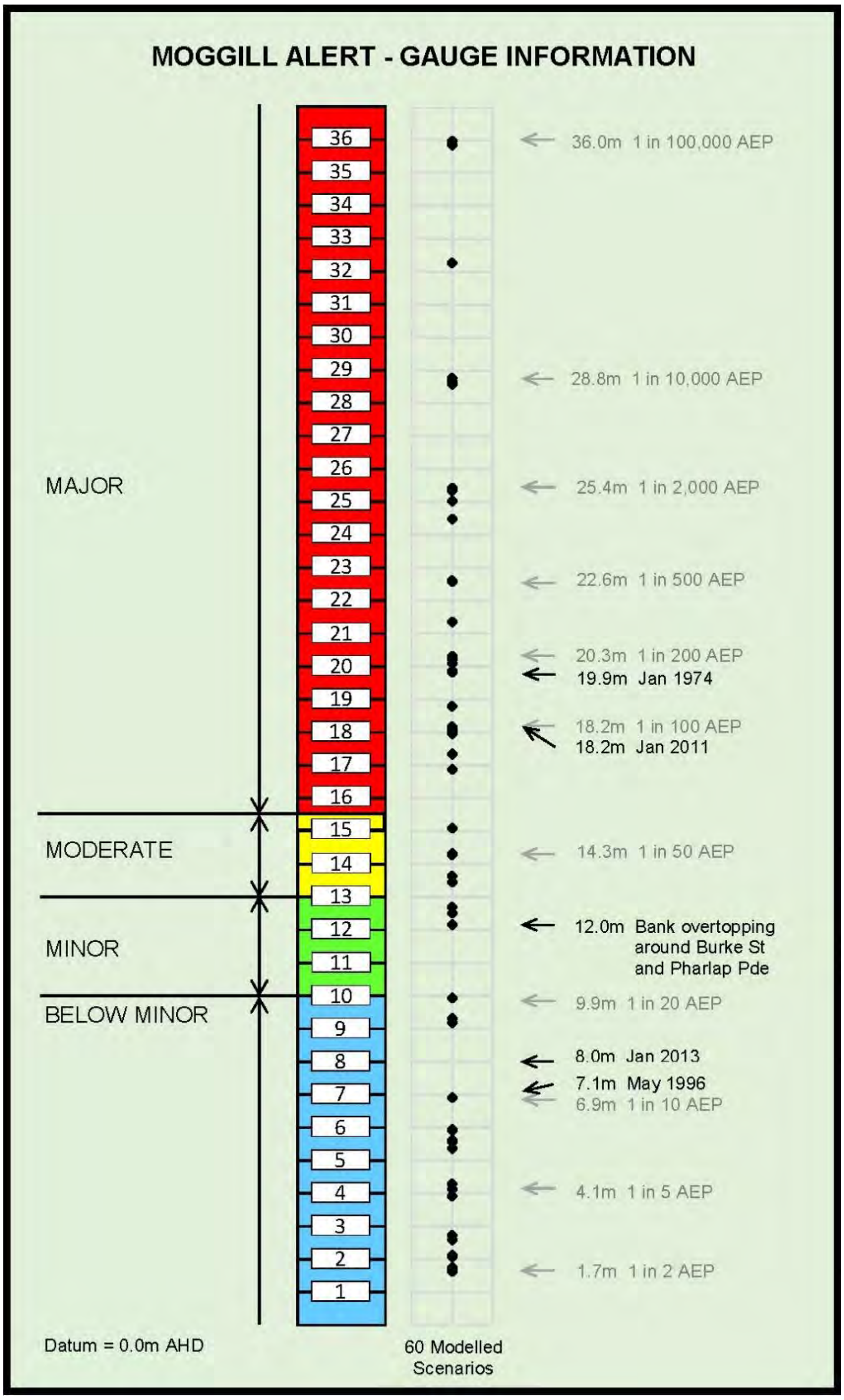


Figure 10-3 Example Forecast Location Diagram

10.3.3.3 Improvement to Current Situation

The supplied diagrams will help disaster management officers to understand the magnitude of the current and forecasted situations, and how to select appropriate flood maps from the provided library.

Outcomes from this process are also used to inform development of an enhanced gauge totem and subsequent gap analysis (discussed in Section 10.5.2). The diagrams identify gauge heights where there is little mapped data available to indicate potential flood extents. Disaster managers can use these diagrams to identify gaps in knowledge.

10.3.3.4 Considerations for Use

The diagrams provide a visual schematic of the flood heights of various historic and design flood events at each forecast stream gauge location. The same considerations for use that apply to the design flood mapping also apply to use of these diagrams (see Section 10.3.2.4).

10.3.4 Relative Time to Inundation

10.3.4.1 Background

Although the timing of flood inundation is highly variable from one event to the next, it is one of the most crucial elements of pre-flood planning. In particular, disaster management officers need to be aware of locations which may require pre-emptive evacuation due to early flood inundation or isolation, and how to best prioritise limited resources.

10.3.4.2 Description

Relative time to inundation mapping was developed to provide a high-level indication of relative flood inundation timing which may occur throughout the catchment. This mapping provides the time to inundation relative to the local reference gauge (as described in Section 10.3.1.3) and describes the duration between that gauge reaching ‘minor’ flood levels (per the gauge classification levels provided in the Service Level Specifications) and inundation occurring at that location. The process used to develop this mapping is provided below, with discussion of considerations for implementation (including caveats and limitations) provided in Section 10.3.4.3.

Digital maps have been provided for the 1 in 100, 1 in 500, 1 in 2,000, and 1 in 100,000 AEP events at each forecast gauge location (i.e. the enveloped events, not individual events). The following process was undertaken to develop the time to inundation mapping:

- Forecast stream gauge locations within the hydraulic model area were identified from the Bureau’s SLS document, as described in Section 10.1.5.9, including ‘minor’ flood classifications for each of those gauges.
- Stream gauge reference polygons were identified for the forecast stream gauges, as described in Section 10.3.1.3.
- The detailed hydraulic model was simulated to identify the time at which each cell in the model reaches a depth of 300mm, for each of the individual events in the four specified AEPs.
- Results from simulations were analysed to identify the time in each simulation when each forecast stream gauge first reached the minor flood level for each ensemble event.
- A relative time to inundation grid was created for each ensemble and each gauge location by subtracting the time to minor flood level at the reference gauge from the time to 300mm inundation at each output cell.

- Results from the relative time to inundation grids were 'enveloped' to create a grid for each gauge location for each AEP with the minimum / earliest time to inundation for each cell (this provides a conservative relative time to inundation estimate).
- Each 'enveloped' gauge location grid for each AEP was trimmed to the relevant stream gauge polygon.

Figure 10-4 demonstrates the parameter represented by the relative time to inundation mapping.

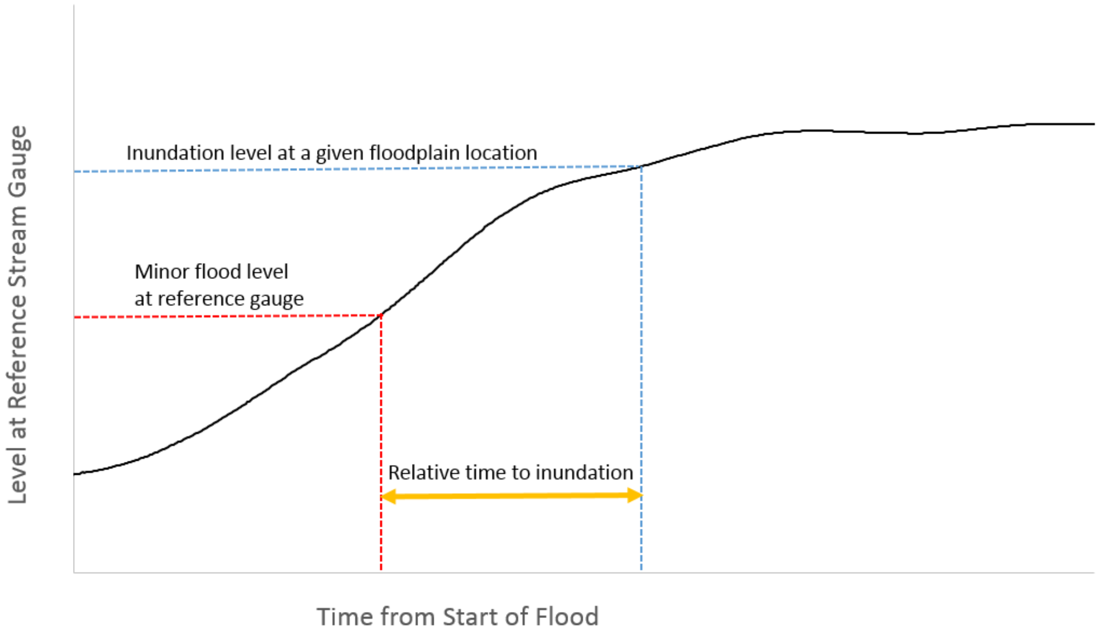
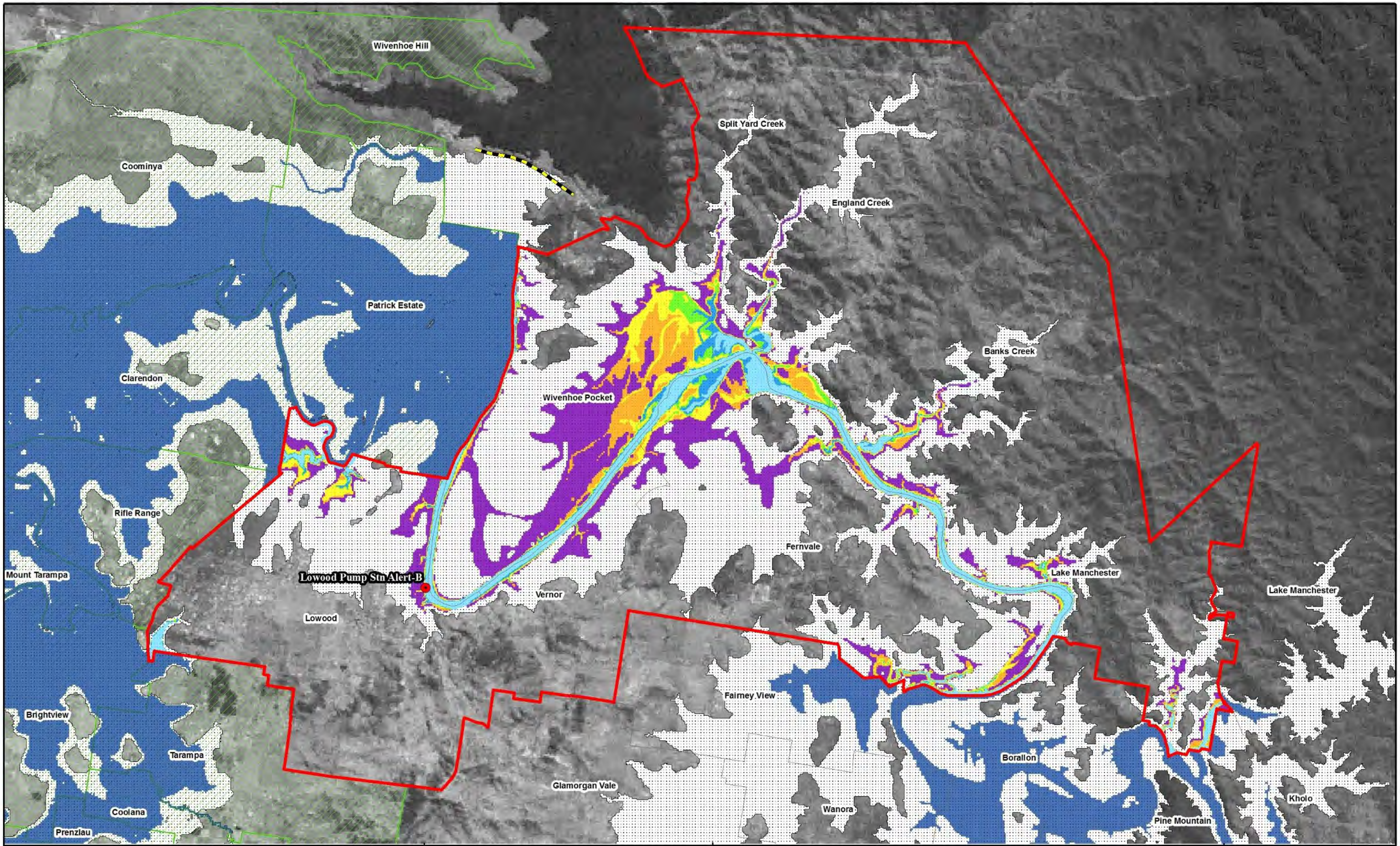


Figure 10-4 Example Relative Time to Inundation Hydrograph

Note that negative values indicate that the floodplain becomes inundated before the reference stream gauge reaches minor flood levels. The buildings in each reference area which may become inundated prior to the reference stream gauge reaching minor flood levels has been provided as digital GIS data. Note that data relating to the Jindalee gauge should be interpreted with caution. Many of the residential properties within the Jindalee gauge reference area are also subject to flooding from Oxley Creek. In the event of a large flood (above minor flood levels), flooding from Oxley Creek is likely to occur before flooding from the Brisbane River (due to the smaller catchment and hence shorter flood response time). It is therefore recommended that a similar investigation be undertaken during Phase 4 (LFMPs) to understand relative inundation timing between properties in this area and Oxley Creek gauges (such as the Oxley Mouth gauge).

An example relative time to inundation diagram is provided in Figure 10-5, with the full set of diagrams for all forecast gauges (within the TUFLOW model boundary) provided in Appendix R for the 1 in 100 AEP. Digital files are provided for all forecast gauges and all four AEPs assessed.



LEGEND

- Forecast Stream Gauges
- 1 in 100 AEP Extent
- 1 in 100,000 AEP Flood Extent
- Limit of Detailed Modelling

Time to Inundation From the Minor Classification

- <0
- 0.0 - 3.0
- 3.0 - 6.0
- 6.0 - 12.0
- 12.0 - 24.0
- >24.0

Influence Zones of Flood Forecast Gauges

- Lowood Pump Stn Alert-B
- Forecast Gauge Outside Model Boundary

Brisbane River Catchment Flood Study

Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Time to Inundation From the Minor Classification at Lowood Pump Station Alert B - 1 in 100 AEP

0 1 2 3
Kilometers

Map Grid of Australia 1994, Zone 56

Filepath : B:\B22374 BRCFMS\GIS\MXD\Forecast Gauges\FLD_007_Time to Inundation From the Minor Classification_Lowood.mxd

Fig 10-5 | A

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10.3.4.3 Improvement to Current Situation

Disaster management officers will have an improved understanding of potential relative flood timings. Identification of areas which are likely to flood earlier in an event can inform flood planning, leading to improved resourcing and sequencing of actions, such as evacuation. If, during pre-flood planning, locations are identified which are likely to become flooded earlier in an event, consideration might be given to communicating this additional risk to residents in those areas. For instance, residents might be informed that they might be warned or evacuated more often, or that they may be warned or evacuated earlier than other residents (or before widespread warnings or evacuations commence).

10.3.4.4 Considerations for Use

Timing (including relative timing) is one of the most variable aspects of flood behaviour and is extremely difficult to predict from design flood modelling, particularly in large and complex catchments, such as the Brisbane River catchment. The relative time to inundation mapping provides some information which may inform pre-event planning, but careful consideration should be used when adapting the output to a real-time event. This information is not intended to inform real-time response or replace timing predictions issued by the Bureau of Meteorology based on event modelling. Further, it is recognised that emergency response personnel will generally have more time available to respond to potential inundation, due to the additional lead-time provided by forecast modelling.

In addition to the variability inherent in riverine flood behaviour, other sources of flooding may cause earlier inundation. In addition, modelled scenarios which include dam release scenarios (from Wivenhoe) rely on simplified assumptions and do not necessarily reflect the relative timings that might be expected from real operations. See Section 10.3.1.2 for further discussion on ‘fit-for-purpose’ data.

As noted in Section 10.3.4.2, results are conservative based on the design events, and show the earliest time of inundation within the simulations that make up a given AEP. These results are specific to design events used in the analysis; other flood events can have different timing, peak levels and behaviour. Similarly, it should be noted that not every flood which exceeds minor flood level will reach levels sufficient to inundate all areas of the floodplain.

The timing is relative to the time when the minor flood level is reached at the reference gauge (as described in Section 10.3.4.2). If the level classified as ‘minor’ is revised, the mapping and information using the mapping will also require revision. [NB: minor flood levels relate to floodplain impacts and are not directly linked to AEPs].

Relative time to inundation data can be used in conjunction with the building database to identify buildings which are most likely to become inundated early in an event (or prior to minor flood levels being reached), and to provide targeted awareness material to these residents noting the potential for pre-emptive evacuation at those locations. Relative time to inundation mapping might also be used to help inform the update of stream gauge classifications (see Section 10.3.3.3 for further discussion).

10.4 Flood Impact Information

10.4.1 Overview

Flood impact information helps to describe the likely impacts of flooding on properties and infrastructure and can be used to inform all stages of the disaster management cycle, particularly planning and response. This information can be collated along with other flood data to develop flood intelligence for various locations and potential flood outcomes.

10.4.2 Buildings and Critical Infrastructure Data

10.4.2.1 Background

A detailed property survey was undertaken as part of this study which includes location, floor level, ground level and other attributes for all buildings in the floodplain (a full description of the derivation of the dataset is provided in Section 6 Flood Damages Assessment). Locations of critical infrastructure, such as utilities, were provided by stakeholders in the early stages of the study and collated for presentation in Section 4 Current Flood Risk.

Collation of these two data sets provide a valuable resource for disaster management operators to understand where the buildings and infrastructure are located within the floodplain, and the level of flood risk which these structures are exposed to.

10.4.2.2 Description

The property and critical infrastructure datasets developed in earlier stages of this study have been updated and tailored for disaster management applications with the following attributes:

Building database

- Location of building (latitude and longitude)
- Lot Description
- Postcode
- Peak flood levels from 11 AEP events
- Building floor level
- Building ground level
- Link to building photo (where available)
- Reference forecast stream gauge

Critical infrastructure database

- Location of asset (latitude and longitude)
- Infrastructure type
- Ground level
- Peak flood levels from 11 AEP events

- Reference forecast stream gauge

The building and critical infrastructure databases have been provided digitally.

10.4.2.3 Improvement to Current Situation

Building and critical infrastructure databases help to identify flood exposure and risk, for all phases of the disaster management cycle.

10.4.2.4 Considerations for Use

Users should be cognisant of the data source and decide for each application of the data whether it is 'fit-for-purpose' (per Section 10.3.1.2).

The building dataset was collected for the primary purpose of informing flood damages assessment at the regional scale. There are numerous caveats and considerations which accompany the dataset, which are discussed in detail in Section 6 Flood Damages Assessment. A slight modification has been made to the dataset used for the flood damages estimations, whereby multi-unit dwellings are listed as a single building in the disaster management dataset. This approach recognises that inundation at ground level of a building impacts all dwellings both directly and indirectly, even if higher levels are not inundated.

When applying the building dataset for disaster management purposes, and particularly where building-scale data (rather than, e.g. neighbourhood-scale data) is of critical importance, it is recommended that the data be verified with local knowledge or building inspections.

The critical infrastructure dataset was developed by compiling relevant data provided by stakeholders, supplemented with assumptions from zoning etc., as detailed in Section 4 Current Flood Risk. As for the building dataset, it is recommended that critical infrastructure data be verified through local knowledge and inspection, and / or through discussions with the infrastructure owner.

Both datasets have been updated with flood-related information from the detailed hydraulic model. Risk from additional sources of flooding, such as local, creek and storm tide have not been captured in these datasets.

Users may wish to establish pre-defined queries (or similar) in their local geographic information systems (GIS) for rapid assessment during flood events. For instance, a subset of the data may be created which only includes buildings within the zone of influence for a particular forecast gauge and within the flood extent for a certain AEP event.

10.4.3 Relationship Between Gauge Height, and Building and Critical Infrastructure Impacts

10.4.3.1 Background

A key finding from the investigations into community flood awareness and resilience component of the Phase 3 (SFMP), was the importance of providing locally-relevant flood awareness materials. Section 11 (discussing community flood awareness and resilience) includes a recommendation that members of the public be provided with building-scale information about flood risk at their building, including which stream gauge is relevant to their location (i.e. their reference forecast gauge), and information about what stream gauge height is associated with flooding at their building.

10.4.3.2 Description

The detailed hydraulic model was used to identify the relationship between stream gauge heights and inundation at buildings and critical infrastructure. This investigation used the building and critical infrastructure datasets described in Section 10.4.2 in conjunction with the stream gauge reference areas described in 10.3.1.3 via the following process:

- Each building and piece of critical infrastructure in the datasets were assigned to a single stream gauge, using the stream gauge reference areas.
- The detailed hydraulic model was simulated for the full range of component events in the 1 in 20, 1 in 100 and 1 in 100,000 AEP events (15 simulations total).
- The 'record gauge data' feature in TUFLOW[31] was used to monitor the ground level at the location of each building and critical infrastructure asset and identify the level at the reference stream gauge when a building or asset first becomes inundated above ground level. The stream gauge value corresponding to inundation at that building is then assigned back to the point.

As an example, a residential building in the South Brisbane area which has a ground level of 7.08m AHD and uses the Brisbane City gauge for reference, is estimated to become inundated when the Brisbane City gauge is between 5.56 and 6.13m AHD.

The digital building and critical infrastructure datasets include attributes for the minimum, maximum and average stream gauge value associated with ground level inundation for that building or critical infrastructure asset.

10.4.3.3 Improvement to Current Situation

Disaster management officers will be able to more clearly understand which buildings and critical infrastructure assets are likely to be inundated for a given stream gauge level. This will inform all stages of the disaster management cycle.

Building-scale information can be provided to the public (with relevant provisos and supporting information) to help the community understand the flood risk at their own building and how the Bureau's forecasts relate to their own flood situation. Empowering the community with the information to develop personal flood plans helps alleviate the disaster management burden.

10.4.3.4 Considerations for Use

Users should be cognisant of the data source and decide for each application of the data whether it is 'fit-for-purpose' (per Section 10.3.1.2).

Each item in the building and critical infrastructure dataset has been provided with four key attributes relating to this item:

[31] See section 9.8.1 of the TUFLOW manual for further information. https://www.tuflow.com/Download/TUFLOW/Releases/2016-03/AA/Doc/TUFLOW%20Manual.2016-03-AA.pdf

- Reference stream gauge
- Lowest level on stream gauge when item (building / asset) likely to become inundated
- Highest level on stream gauge when item likely to become inundated
- Average level on stream gauge when item likely to become inundated

As described in Section 10.4.3.2, these values were derived from the outputs from 3 AEPs (comprising 15 component events). Although these simulated events do not represent all possible permutations of flooding which may occur in the catchment, the outputs of this analysis do provide some indication of the variability in the relationship between stream gauge and building / infrastructure asset for a given location.

The data provided for these buildings / assets is for Brisbane River flooding only. Buildings and infrastructure may also be affected by other sources of flooding, including local, creek and storm tide. In addition, buildings may become isolated before they are inundated. During local / detailed studies, disaster management officers should seek to identify critical levels for buildings or neighbourhoods, and repeat this assessment using relevant hydraulic models (which may include the detailed hydraulic model in addition to other models).

Information can be used in flood planning (e.g. evacuation planning) and during actual flood events. The data can also be used to inform the community at which level their building will be inundated in relation to their closest gauge. Using this data in relation with a flood totem (per Section 10.3.3), would significantly improve the community's awareness of their flood risk and their building's relationship to stream gauge levels and flood warnings (particularly when gauge classifications such as minor / moderate / major are used).

Disaster management users may wish to establish pre-defined queries (or similar) in their local geographic information systems (GIS) for rapid assessment during flood events. For instance, a subset of the data may be created which only includes buildings within the zone of influence for a particular forecast gauge and which are likely to be inundated below a particular stream gauge influence. Then, if the Bureau issues a forecast that the relevant gauge is going to reach or exceed the gauge level used for the query, the dataset can immediately identify buildings which are likely to become inundated.

10.5 Flood Analysis Guidance

10.5.1 Overview

The following flood analysis guidance has been supplied to assist local governments and other stakeholders undertaking disaster management assessments at the local / detailed scale using outputs from the detailed hydraulic model and other models. Repeating the processes used for this regional, riverine study will ensure that disaster management information captures all sources of flooding and at the best resolution available.

When analyses are repeated for other sources of flooding, disaster management officers will need to consider how to integrate findings from those analyses with the outputs from this regional-scale study focused on riverine flooding. Many locations in the catchment are exposed to multiple sources of flooding, but the planning and response for each source will not always be the same. Considerations at planning stage should consider the source, timing, likely impacts, and response relevant to each type of flooding, and use that information to determine whether outputs from analyses should be combined or remain separate.

10.5.2 Forecast Location Analysis

10.5.2.1 Background

Forecast location diagrams (flood totem style) were developed for all forecast stream gauge locations within the hydraulic model area (as described in Section 10.3.3). These totems indicate key flood levels including flood classification, historical levels, and AEP levels based on the 11 flood surfaces. An additional 60 flood maps have also been provided as part of this Phase 3 (SFMP), which are the component events used to make up the 11 AEPs (described in Section 10.3.2). Mapping of these additional 60 events against the flood totem highlights that some locations have data gaps at key flood heights.

10.5.2.2 Description

Following the development of the flood location diagrams, a gap analysis was undertaken to estimate the number of additional flood maps that may be required to ensure that disaster management officers have sufficient resolution of data to inform planning at all flood heights. A risk-based approach was used in this analysis whereby more flood maps are suggested at lower heights (which are likely to be reached more often) and few maps for rarer / larger flood heights. The following assumptions were applied in the gap analysis:

- 60 design flood maps plus 3 historic flood maps are currently available
- Flood maps were suggested for levels that produce out of bank flooding
- For levels between the first level when out of bank flooding was observed in the reference area and the 1 in 500 AEP design event level, additional maps were suggested to provide maps every 0.25m on the gauge totem
- For levels greater than 1 in 500 AEP (i.e. up to 1 in 100,000 AEP peak level), additional maps were suggested to provide maps every 0.5m on the gauge totem.

Table 10-3 provides counts of the additional 'infill' flood maps that would be required to populate the gaps in gauge totems, per the assumptions provided above.

10.5.2.3 Improvement to Current Situation

The development of enhance forecast gauge diagrams helps disaster management officers identify appropriate flood maps to use in relation to forecast or real-time stream gauge readings and predictions.

The gap analysis highlights additional information which could be used to create a more complete library of surfaces for each forecast gauge location.

Table 10-3 Additional Flood Maps for Forecast Gauge Locations

Gauge ID	Gauge Location	Number of Additional Maps Required for Gap Infill
040441	Lowood	37
040142 / 540199 / 040818	Mt Crosby	42
540081 / 540504	Walloon	16
540180	Amberley	15
040101 / 040831	Ipswich	48
540200	Moggill	55
040713	Jindalee (Centenary Bridge)	44
540198	Brisbane City	39

10.5.2.4 Considerations for Use

If stakeholders wish to develop more flood maps to fill in gaps per the analysis above, these maps could be created by:

- Using intermediate (non-peak) values from the 60 events already simulated in the detailed hydraulic model, ensuring the time-step selected from the results has the required level at the relevant stream gauge location; and / or
- Simulate additional events from the fast hydraulic model in the detailed hydraulic model. It should be noted that numerous events from the fast model will produce the required peak at the gauge location. Therefore, consideration should be given to selection of events based on timing, initial conditions etc., as well as the peak level generated.

Stakeholders may wish to prioritise additional maps, rather than filling all gaps equally. For instance, locations may have critical levels relating to inundation or overtopping of key infrastructure; development of maps relating to these levels should be prioritised in future.

As noted in Section 10.3.2, flood levels are likely to be fairly representative of flood behaviour at a given stream gauge height, however flood velocities and flows vary significantly from one event to the next. Operators should exercise caution using maps of these attributes in a disaster management context.

Information may be used to enhance the regional waterRIDE system (Section 10.2.4.1) and / or the regional flood intelligence system (Section 10.7.2.2).

10.5.3 Road Inundation Assessment

10.5.3.1 Background

A road inundation assessment was undertaken as reported in Section 4 Current Flood Risk. This assessment identified time to inundation and duration of inundation for State controlled roads within the hydraulic model area, using the full suite of results from the fast hydraulic model (i.e. the 11,340 simulations).

Stakeholders noted that the outcomes of this assessment were highly valuable, however not sufficient to inform a detailed flood evacuation planning process, as is required by the Queensland Evacuation Guidelines for Disaster Management (see Section 10.5.4 for more detail).

10.5.3.2 Description

A script was developed as part of this study which assessed the model results and produced box-and-whisker plots for each road segment, highlighting inundation times and durations. It is recommended that additional roads are assessed during the local / detailed floodplain management studies to understand the inundation risks associated with local feeder roads, and due to other sources of flooding. Application of the script to other locations / roads and using the fast hydraulic model will produce the same type of box-and-whisker plots as are currently available for the State controlled roads, per examples in Figure 10-6 and Figure 10-7.

Details of the assessment process are provided in Section 4 Current Flood Risk.

Note that the script was developed using the Python programming language. Scripting files and a 'readme' text file with instructions for using the script is provided with digital data.

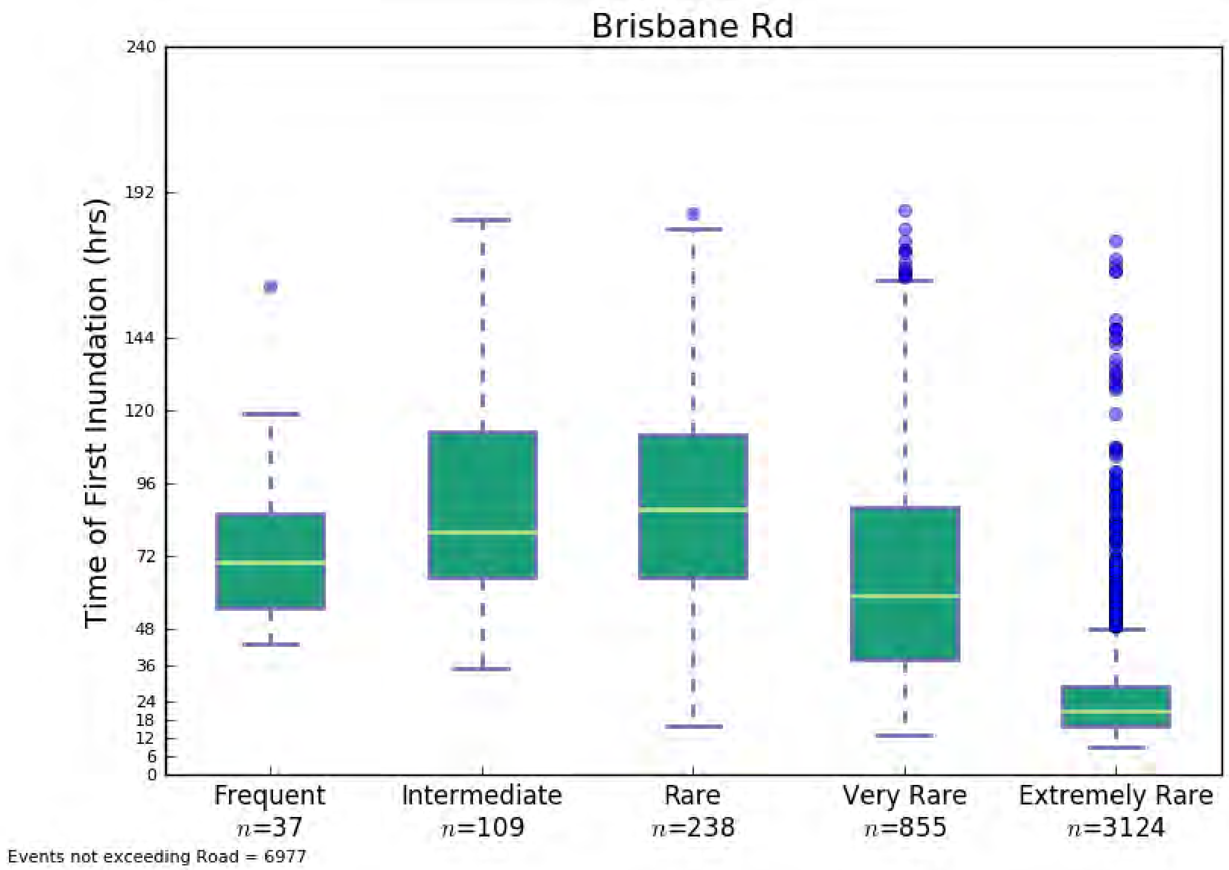


Figure 10-6 Example Time of First Inundation Plot

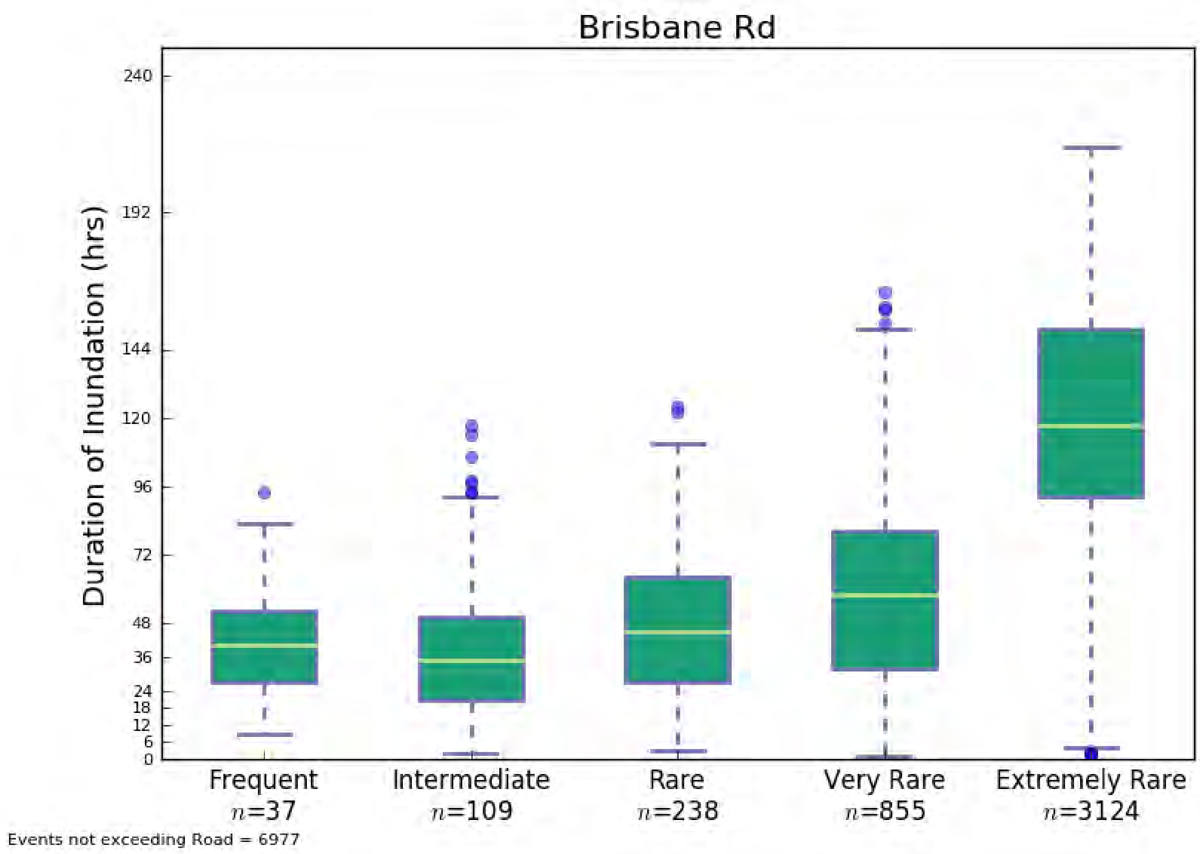


Figure 10-7 Example Duration of Inundation Plot

10.5.3.3 Improvement to Current Situation

Continuing the road inundation assessment at the local / detailed scale will improve understanding of the flood immunity of the entire road network, provide relevant information to inform evacuation planning, and highlight locations which are likely to become isolated early in a flood event. Undertaking a full analysis of evacuation routes on local roads will give a better understanding of which locations will require the most attention for evacuation, and whether road capacities and immunities are sufficient. Identifying evacuation routes will also provide disaster management officers with guidance needed to plan for evacuation, including the sheltering and return stages identified in Queensland Evacuation Guidelines for Disaster Management.

10.5.3.4 Considerations for Use

The script developed for this study and provided with the digital data package uses time-based evacuation route outputs from TUFLOW. Further, the script was developed to process results from the fast hydraulic model, and may require some minor modifications if applied to results from a different hydraulic model. The script was developed for technical users with an understanding of Python programming language.

While the use of results from the 11,340 simulations in the fast hydraulic model provides a good understanding in the variation and uncertainty in inundation behaviour at a particular location, it must be emphasised that this model is focused on riverine flooding. Separate assessments for other sources of flooding, such as creek, local and storm tide, should be undertaken separately. Similarly, disaster management officers should apply their knowledge of local areas and past flood behaviour to identify locations where e.g. blockages of culverts typically occur, and where the inundation risk may be higher than the model is able to predict.

The time to inundation values shown on the box-and-whisker plots reference ‘time zero’, which is the start of the main rainfall burst in the relevant flood design event. For real-time applications, this time will have no real world meaning. However, the plots do provide valuable information about relative timing, i.e. X section of road is likely to become inundated much earlier than Y section. Information from plots might therefore be used in pre-planning to estimate the relative sequencing of inundation, informing disaster managers of those areas which are likely to be isolated earlier in the event.

The challenges with ‘time zero’ can be reduced by identifying a new reference point for ‘time zero’. For instance, for a given location, the new ‘time zero’ might be set as the time that the local gauge reaches a certain level, or when some other observable impact occurs (such as the river breaking out of banks, or a bridge deck becoming overtopped). This approach could be applied during Phase 4 (LFMPs) using local information about impacts.

10.5.4 Evacuation Capability Assessment and Planning

10.5.4.1 Background

The Queensland Evacuation Guidelines for Disaster Management (QEGDM) (QFES, 2018) provide guidance to local / district disaster management groups (LDMG / DDMG) and local governments to prepare evacuation planning, and highlight the responsibilities for management of evacuation. QEGDM gives high level information on:

- Planning for evacuation including timelines and decision points;
- Decision to implement an evacuation and who can issue the evacuation;
- Warnings including messaging;
- Managing a withdrawal including evacuation routes and traffic strategy;
- Sheltering of evacuees; and
- Returning evacuees home after an evacuation.

Many of the requirements outlined in the QEGDM can be informed and partially populated using outputs from hydraulic models, such as the Phase 2 (Flood Study) models. Development of the models and modelling outputs (including those produced during this component and the Phase 3 (SFMP) more broadly) provide an opportunity to update evacuation planning.

10.5.4.2 Guidance

This guidance specifically relates to the application of outputs from the Phase 2 (Flood Study) models to evacuation planning, however the approaches can be applied to other sources of flooding and hydraulic models.

Evacuation comprises four key stages, as shown in Figure 10-8: decision, warning, withdrawal (the actual evacuation) and sheltering. Underpinning all of these stages, and occurring well in advance of a flood, is the planning stage. Information from flood models is most valuable for the pre-event planning and decision phases of evacuation; warning, withdrawal and sheltering phases are more likely to be informed by real-time, observed conditions.

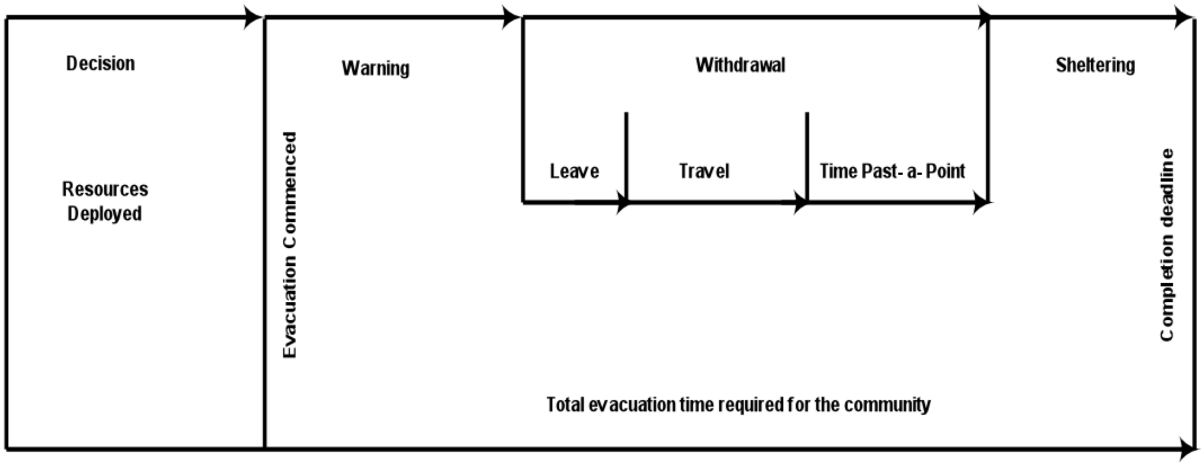


Figure 10-8 Compartmentalisation of Total Evacuation Time (QEGDM, 2011)

10.5.4.2.1 Planning Phase

Formalise Evacuation Routes and Identify Likely Road Inundation

State controlled roads were used as a proxy for evacuation routes for the regional-scale assessment undertaken in Section 4 Current Flood Risk. Additional assessment will be required by stakeholders to identify evacuation routes using local roads within each LGA. This can be undertaken by:

- Re-simulating the detailed hydraulic model using location and elevation data for local roads (and TUFLOW's evacuation route feature[32]) to identify which roads are inundated due to riverine flooding in events up to and including the extreme event (1 in 100,000 AEP).
- Application of the evacuation route assessment guidance provided in 10.5.4, using outputs from the additional simulations (above) to identify low-points in the road and the provided Python script to analyse road inundation times and durations. Outputs from the hydraulic modelling exercise should also be verified against local knowledge and experience, and be modified to include potential inundation from other flood sources, where relevant.
- Analysis of which route is the best option for evacuation – this will be informed by community size and ability to move the traffic through this route, using guidance provided in QEGDM and advice from traffic engineers.

The assessment of evacuation routes can be used in conjunction with the identification of isolated areas.

[32] See Section 9.8.2 of the TUFLOW manual for further information: https://www.tuflow.com/Download/TUFLOW/Releases/2016-03/AA/Doc/TUFLOW%20Manual.2016-03-AA.pdf

Formalise isolation areas

A regional-scale assessment of isolated areas was undertaken in Section 4 Current Flood Risk. This assessment identified flood islands using peak flood level mapping for each of the 11 AEPs, where a fully surrounded island was observed (i.e. a closed polygon / 'hole' in the flood mapping). It is recommended that a more detailed analysis be undertaken which uses inundated evacuation routes as an indicator of an isolated area or neighbourhood.

Analysis of the time-series floodplain mapping results for the detailed model will also help disaster management officers understand the general evolution of flooding in the area and how isolation areas may form. As described in Section 10.3.2.4, the 60 flood events selected for simulation in the detailed hydraulic model are not necessarily representative of all flood permutations, or indicative of the most common or likely flood behaviour. Disaster management officers should therefore use other information sources (including local knowledge and input from flood modelling experts) to build their understanding of flood evolution in their local area.

The identification of isolated areas will aid the evacuation process and assist the efficiency of emergency services.

Formalise Inundation Areas and Approximate Time to Inundation

Formalising inundations areas will help disaster management officers understand required flood warning and evacuation sequencing during a flood event. This information, particularly when used in conjunction with information about (relative) time to inundation, can also inform identification of areas which may require pre-emptive and / or directed evacuation, and in messaging to residents.

Inundation areas can be identified using the following inputs:

- Flood inundation maps, particularly when correlated with stream gauge heights for local locations
- Indicative time to inundation mapping, relative to forecast stream gauge locations
- The building dataset used for gauge relation will also highlight the first buildings inundated within each AEP flood surface.

Information regarding roads and / or suburbs could also be intersected with inundation areas to provide more direct messaging to support flood warning and evacuation notifications.

Identify Approximate Evacuation Times

Understanding approximate time to inundation across both the floodplain (Section 10.3.3.3) and for individual roads (Section 10.5.3) can be used in conjunction with other parameters such as inundation areas, the building dataset (Section 10.4.2) and population estimates to inform evacuation planning. This evacuation planning should consider how many people will require (and are likely to) evacuate, along which routes they may evacuate, the sequencing of evacuation, ability for those routes to convey traffic, warning methods (and time taken to distribute warnings) etc.

One of the outputs of this planning exercise will be the estimation of approximate evacuation times for various locations. Understanding these time-frames will help disaster management officers identify whether sufficient warning time is available to evacuate all at-risk locations, and to establish suitable triggers for issuing warnings and evacuation notices.

10.5.4.2.2 Decision Phase

Planning data, as described in Section 10.5.4.2.1, can be used during a flood event in conjunction with forecast levels and timing from the Bureau. This data will assist in issuing flood warnings, voluntary or directed evacuations, and mobilising flood response teams. Data can also be implemented in real-time flooding analysis tools which will aid the decision processes.

Real-time flood analysis options are discussed in Section 10.6. Should a real-time hydraulic modelling system be implemented, outputs from the modelling can be intersected with exposure data (such as buildings and critical infrastructure) to understand potential flood impacts. Systems may be further developed to populate ‘timeline’ approaches to real-time flood planning, which back-calculate the time when warnings should be issued etc.

10.5.4.3 Improvement to Current Situation

The information provided in the Phase 2 (Flood Study) and this Phase 3 (SFMP) can be used for analysis and identifying critical aspects for the evacuation process, including:

- Identification of isolated communities;
- Identification of evacuation routes and road inundation times;
- Identification of inundation areas; and
- Formalisation of evacuation procedures.

Much of the data should be used in the planning phase and support the decision phase during a flood. Detailed analysis of this nature will improve the allocation of disaster management resources and ultimately improve community safety.

10.5.4.4 Considerations for Use

It is recognised that most aspects of evacuation planning (e.g. flood behaviour, community response and traffic) are difficult to predict and introduce a high level of uncertainty in the estimations of a community’s evacuation capability. In addition, planning for evacuation of multiple areas concurrently is extremely complex, particularly if areas use shared resources (such as evacuation routes) and those resources have limited capacity. Nonetheless, the assessment forms a vital part of the flood risk management process and should not be avoided due to uncertainties and the risk of error. The flood information provided in the Phase 2 (Flood Study) and this Phase 3 (SFMP) help to identify constraints in the current evacuation capability, highlight the need for action and provide guidance on future evacuation decisions.

Evacuation planning should be informed by notions of reasonability and practicality when implementing values obtained from models. Although it is generally valuable to apply a conservative approach to disaster management planning, operators should be careful to not be overly conservative or use a compounding approach to conservative assumptions.

10.5.5 Gauge Classification Guidance

10.5.5.1 Background

Stream gauge classification (minor / moderate / major) is a critical element of understanding relative flood levels. Councils and Local Disaster Management Groups are responsible for establishing what those classification levels should be, and are supported by the Queensland Fire and Emergency Service when undertaking this process.

The Queensland Reconstruction Authority have recently undertaken a review of the gauge networks around Queensland, including forecast stream gauge locations, as described in Section 10.1.5.10. Outcomes from that review, in addition to new information delivered through the Phase 2 (Flood Study) and this Phase 3 (SFMP) provides an opportunity for disaster management officers to better understand flood behaviour and impacts, and whether gauge classifications should be updated.

10.5.5.2 Guidance

Stream gauge classifications are linked to flood impacts via the following definitions (provided by the Bureau):

- **Minor Flooding**: Causes inconvenience. Low-lying areas next to watercourses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.
- **Moderate Flooding**: In addition to the above, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required.
- **Major Flooding**: In addition to the above, extensive rural areas and/or urban areas are inundated. Many buildings may be affected above the floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation of flood affected areas may be required. Utility services may be impacted.

The following information provided in this Phase 3 (SFMP) can be used to inform the gauge classification review process:

- **Minor** flood levels can be established using the additional library of flood extents (described in Section 10.3.2) to identify when low-lying areas become inundated. Road inundation assessments (described in Section 10.5.3) can be used to identify when minor roads become inundated.
- **Moderate** flood levels can be established using the building and critical infrastructure datasets (described in Section 10.4.2), and particularly by examining the relationships between stream gauge height and inundation to identify when properties begin to be affected (described in Section 10.4.3).
- **Major** flood levels can be established using the same information applied to moderate flooding, supported further by outputs from evacuation planning (described in Section 10.5.4).

10.5.5.3 Improvement to Current Situation

Flood gauge classifications are important communication tools between the Bureau, Councils and the public. Improved classifications ensure that the definitions are meaningful, improving emergency planning and response, and improving the community's confidence in the classification forecasts.

10.5.5.4 Considerations for Use

Development of appropriate stream gauge classifications relies on sound underlying data. In particular, there should be high confidence in the following inputs:

- Hydraulic model – should provide a good representation of flood behaviour around the gauge, including in smaller and larger events.
- Stream gauge rating curve – should be reflective of current topography and bathymetry. If significant changes to the landscape and waterway has occurred since the rating curve was established (e.g. through significant channel erosion), the rating curve may need to be updated.
- Levels of major reference structures – where the gauge classifications are dependent on estimated inundation levels of infrastructure (e.g. roads, bridges etc.), ground survey may be required to ensure that the infrastructure is well represented in the hydraulic model, and that the level of the infrastructure is known relative to the stream gauge.
- Gauge datum – most forecast stream gauges in the Brisbane River catchment operate on the Australian Height Datum (AHD). If a gauge is not at AHD, there should be high confidence in the conversion value between the local datum and AHD.

Where gauge classifications are identified to provide insufficient information about flood impacts, particularly for levels significantly above 'major', additional information may need to be developed which links flood levels and impacts on the ground. The interpretation of flood levels to on-ground impacts is the responsibility of local authorities (not the Bureau), and hence development of information of this type should be undertaken by Councils.

10.6 Real-Time Flood Modelling and Analysis

10.6.1 Overview

As part of the Phase 2 (Flood Study), hydrologic and hydraulic models were developed and calibrated to better understand flood behaviour in the Brisbane River catchment; particularly the lower catchment downstream of Wivenhoe Dam. During consultation for the disaster management component of the subsequent Phase 3 (SFMP), stakeholders expressed an interest in exploring options for using one or more of these models to improve provision of real-time information during flood events.

10.6.2 Current Arrangements

Currently, the Bureau of Meteorology (Bureau) simulates the historic and forecast hydrology, and provides crucial flood information for extreme weather. It is understood that the Bureau simulates this information in the URBS software with hydrologic model(s) of the Brisbane River catchment. At the time of writing, it is unknown whether the URBS model developed for the Phase 2 (Flood Study) has been adopted by the Bureau.

From the simulation of extreme weather, the Bureau provides peak forecast water levels and associated timing for key river gauges, as described in the Service Level Specifications (see Section 10.1.5.9). This information is provided to local Councils and other government agencies via the Bureau website (with emails sent to pre-defined distribution lists for each basin affected). Councils then translate these levels to potential flood extents and impacts. There are numerous methods used by different government bodies to translate this information to potential flood extents, including: using knowledge of past events, mapping of selected flood events (historic, design and others), and tools to interpolate flood mapping (e.g. waterRIDE). Predicted flood extents are then used to estimate flood impacts, generally by intersecting GIS asset data sets with the flood extents.

10.6.3 Description of Models

A short summary is provided below of the current regional-scale hydrologic and hydraulic models of the Brisbane River catchment.

The Phase 2 (Flood Study) required the development of hydrologic and hydraulic models. The hydraulic models were developed in two stages: a 'fast' model, which could be run rapidly and provide preliminary hydraulic results, and a detailed model, which provides a more robust representation of flood behaviour but takes longer to simulate.

The Disaster Management Tool (DMT) uses a separate hydraulic model, which was developed to provide interim flood data, prior to the completion of the Phase 2 (Flood Study).

10.6.3.1 Hydrologic Model

The entire Brisbane River catchment is represented by a set of separate hydrologic models covering different sub-catchments. All hydrology models were built using URBS software, and it is understood that the models were developed in separate sections to capture and calibrate different rainfall events in different regions of the catchment. The URBS models used for the Phase 2 (Flood Study) were adapted from existing Seqwater models. For the Phase 2 (Flood Study), all hydrologic models were combined and simulated within a Delft-FEWS platform. It is understood that the Delft-FEWS software set-up also incorporates some simple dam release rules, suitable for use in design flood modelling, but not representative of the rules which would apply to most real-time applications. The Phase 2 (Flood Study) hydrologic models typically simulate a rainfall event in less than one minute.

The hydrologic models can input historic, design and forecast rainfall and the primary output is flow hydrographs (i.e. modelled flow over time). Secondary outputs are water levels at gauge locations, translated from flows using rating curves (which define the predicted relationship between flow and water level at a given location). Model parameters were adjusted during the model calibration process to obtain a best fit to recorded data at eight primary gauge sites for five historic rainfall events, and checked at other secondary gauges.

The calibrated model was then used to undertake a Monte Carlo simulation of more than 44 million combinations of rainfall depths, spatial and temporal distributions, losses and dam levels, of which 11,340 representative events were selected for hydraulic simulation.

A notable limitation of hydrologic models is the inability to simulate hydraulic interactions, such as the backwater influence of the Brisbane River on the Bremer River during large flood events, or downstream storm surge near the mouth of the Brisbane River (although backwater and tidal effects can be accounted for through other means, such as the use of dependent ratings).

10.6.3.2 Fast Hydraulic Model

The one-dimensional (1D) fast hydraulic model covers the lower Brisbane River floodplain, downstream of Wivenhoe Dam. It was developed using TUFLOW's 1D solver which is an explicit 2nd order solution of the full 1D equations and run on a central processing unit (CPU). The fast hydraulic model typically simulates a flood event in less than five minutes.

Development and schematisation of the model focussed on waterways and major breakout flowpaths. Topography and bathymetry in the model was represented via cross-sections of the stream bed and floodplain. In general, one-dimensional models do not well represent the behaviour of flood waters in complex floodplains, and are reliant on accurate identification of out-of-bank flowpaths to inform the development of the model.

The inputs to the fast hydraulic model are flows from the hydrologic models and downstream storm tide levels. The model was calibrated to river and creek water level gauges, available flow recordings, and flood marks along the river and creek banks for five historic rainfall events. Information about flood levels, depths, velocity, flow and hazard can be provided at all locations within the modelled extent. However, it should be noted that output from the fast model was not mapped in the Phase 2 (Flood Study), as results are interpolated between cross-sections and do not provide high confidence data, particularly in floodplain areas.

The calibrated fast hydraulic model was used to simulate 11,340 flood events from the hydrologic model. Peak levels at in-stream locations were then used to select 60 representative events for more detailed hydraulic simulation.

10.6.3.3 Detailed Hydraulic Model

The two-dimensional (2D) detailed hydraulic model (including coupled 1D elements) also covers the lower Brisbane River floodplain, downstream of Wivenhoe Dam (the same area as the fast hydraulic model). It was developed using TUFLOW's 2D solver which is an implicit 2nd order spatial finite difference solution of the full 2D equations and run on a CPU. The detailed hydraulic model has a 30 metre grid resolution and typically simulates a flood event in 24 hours.

The model was developed with the latest light detection and ranging (LiDAR) and bathymetry data to represent topography. Major topographic features (such as highway road crests or levees), and major waterway structures (such as bridges) were further embedded in the model using break lines, 1D structure representation, and other modelling features. The detailed model provides a robust representation of flood behaviour both in waterways and on the floodplain.

It uses the same inputs as the fast hydraulic model, flows from the hydrologic models and downstream storm tide levels. It was also calibrated to the same historical data, with the addition of overbank (floodplain) calibration data, for five historic rainfall events. Information about flood levels, depths, velocity, flow and hazard can be provided at all locations within the modelled extent, including within waterways, on the floodplain and (where relevant) within structures.

The calibrated detailed hydraulic model was used to simulate 60 flood events, representing 11 'annual exceedance probabilities' (AEPs).

10.6.3.4 Disaster Management Tool

The Disaster Management Tool (DMT) is a broad scale 2D (2-dimensional) hydraulic flood model that has was developed for the Queensland State Government for disaster management arrangements; specifically to produce a series of flood inundation maps for Somerset Regional Council (SRC), Ipswich City Council (ICC) and Brisbane City Council (BCC). The context for development of the DMT was the occurrence of the 2013 flood event, which identified the need for an interim disaster management project and deliverables, whilst awaiting the outcomes of the comprehensive Brisbane River Catchment Flood Study (BRCFS). The DMT was calibrated to three primary and two additional historic flood events (five in total). The primary objective of the DMT project was to deliver a set of disaster management maps prior to the 2013/2014 wet season. This objective was met with the completion of Brisbane River Catchment Flood Study Disaster Management Tool (DMT) Interim Calibration Report in October 2013 together with associated flood inundation map deliverables. The final DMT report and deliverables was completed in November 2014.

For the DMT project, the 1974 flood event was used to develop notional flood profiles of varying magnitude for the Lockyer Creek, Bremer River and Brisbane River systems in order to produce a range of notional flood profiles for the purpose of disaster management flood inundation extent mapping. The 1974 flood event was selected as the basis for the notional profile development due it being a single peaking voluminous hydrograph not impacted by dam operations, and so, for the purposes of generating disaster management flood inundation extents from the DMT hydraulic model this approximates steady state flow.

In total, 92 notional profile simulations were undertaken for the DMT project as follows:

- 36 for Somerset Regional Council (6 x 6 Lockyer Creek/Brisbane River coincident flooding scenarios)
- 36 for Ipswich City Council (6 x 6 Bremer River/Brisbane River coincident flooding scenarios)
- 20 for Brisbane City Council/SEQ region (20 notional profiles with varying storm conditions)

This has resulted in the production of maps as well as other information and data for the SEQ region which has been developed from the notional flood profiles.

The UDMT (Updated DMT) was used to assist with the development of the fast and detailed models during the Brisbane River Catchment Flood Study (BRCFS). This updated DMT (or UDMT) incorporated new bathymetry and refined land use categorisation, and uses the same inputs as the BRCFS (fast and detailed hydraulic) models, with flows from the hydrologic models and downstream storm tide levels. The UDMT was not calibrated, however it was simulated for three historic rainfall events to check results remained comparable to the original model. Information about flood levels, depths, velocity, flow and hazard can be provided at all locations within the modelled extent, including within waterways and on the floodplain.

In summary:

- The DMT is a hydraulic model developed for disaster management purposes with the project producing maps primarily and other deliverables for disaster management arrangements, and prior to completion of Phase 2 (BRCFS).
- The DMT was subject to a calibration process (5 events in total – 3 primary and 2 additional historical flood events) based on available information at the time of the study.
- BCC, SRC and ICC use the DMT, because it is a disaster management tool, with disaster management flood surface outputs, and so different to a flood study which produces AEP flood surface outputs.
- BCC currently utilises the 20 flood profiles produced from the DMT profiles as a 'library' of flood surfaces in its Brisbane River flood interpolation system or flood surface 'bending' system (waterRIDE – Flood Custom software). The library of flood surfaces are also used as a source of flood intelligence for pre-cooked situation reports, flood intelligence reports, powerpoint presentation and animations which were developed and produced after the completion of the DMT study in order to further enhance flood intelligence for the SEQ region, and particularly for BCC.
- As part of the Phase 3 (SFMP) waterRIDE upgrade project, BCC will be updating its flood bending software/system and evaluating the use of two library profiles sources, that is, the 20 flood profiles from the DMT, and 11 AEP ensembles from the Phase 2 (BRCFS), noting that each of these libraries of flood profiles has been produced specifically for different purposes, with the DMT flood surfaces being produced for disaster management purposes.
- The UDMT (Updated DMT) was used to assist with the development of the fast and detailed models during the Phase 2 (BRCFS).

Stakeholder feedback regarding the DMT is summarised in Appendix O (Section O.2.1). Note that this is based on the views of individuals and may not necessarily represent the views of the stakeholder agencies.

10.6.4 Consultation with Bureau of Meteorology

The Bureau of Meteorology (Bureau) is the lead national agency for flood forecasting in river catchments in Australia[33] and as such, any real-time hydraulic modelling of the Brisbane River catchment will need to be led by the Bureau. They are also advised by the Queensland Flood Warning Consultative Committee, whose role is to coordinate the development and operation of flood forecasting and warning services in Queensland. The Committee is a joint Commonwealth, State and local government advisory body comprising the Bureau, Seqwater, QRA, together with other relevant state and local agencies.

[33] From the Meteorology Act (1955), discussed further in National Arrangements for Flood Forecasting and Warning (Bureau of Meteorology 2013)

Based on consultation with the Bureau undertaken during this study, there are a number of recent and future developments in their flood forecasting services:

- The Bureau's current flood forecasting system for the lower Brisbane River is based on the Delft-FEWS platform running URBS hydrologic models. Seqwater operate a similar system, with both agencies' platforms interacting directly with each other. It is noted that the Bureau's system primarily relies on data from the Enviromon software, which only receives information from radio-telemetry gauges. Information from manual and telephone telemetry gauges are received via different routes.
- The Bureau's forecasts can be developed from a variety of options, however tend to use mostly gridded forecast rainfall data.
- A major refresh of the Bureau website is currently in progress which will enable better sharing of data.
- The Bureau will be providing forecast hydrographs this wet season, as opposed to just peak levels, via a 'registered users' page. It is understood that a separate registered users page provides gridded rainfall data which can be used e.g. for flash flood forecasting by Councils.
- As part of pre-flood planning, the Bureau simulate a number of rainfall forecast grids. They are planning to provide forecasts for a range of rainfall scenarios via the 'Flood Scenarios' product, which is scheduled for development this financial year, and national roll out next year. This will need to be carefully managed to minimise potential for confusion, e.g. if different scenarios conflict, or are accidentally released into the public domain.
- The Bureau is planning to provide probabilistic-type forecasts, and are considering the use of ensemble predictions.
- The Bureau's system currently has the capability to incorporate real-time hydraulic modelling, however this would require a relatively significant investment and lead time with implications for operations and resources due to the complexity of integrating hydraulic models into Delft-FEWS, and to ensure the high degree of robustness and reliability required.
- The Bureau would also consider providing data to Delft-FEWS systems operated by other agencies (e.g. Councils or State Government agencies).
- The Bureau also invite recommendations for the inclusion of additional gauges in their forecasts. (NB: There has been consultation between the QRA and stakeholders on this topic separate to the Phase 3 (SFMP).)

10.6.5 Workshop 4 Feedback

Workshop 4 was held on the 14th August 2017 and focussed on disaster management during the afternoon session (see Section 10.2.3.3) which included a group discussion on the potential for real-time flood analysis (including modelling). The following key points were discussed between the Phase 3 (SFMP) stakeholders, consultees and consultants in relation to real-time flood analysis.

All parties were in agreement that there should be no duplication of the Bureau's flood forecasting services, and that any real-time hydraulic modelling should be undertaken by the Bureau to avoid multiple or conflicting forecasts. Councils translate the Bureau's forecasts of peak flood levels into impacts for disaster management planning and response within their local government area. For large widespread events, disaster management coordination is escalated from a local to a district level, and state level as required. A view was put forward that data which is used for disaster management purposes should be made available to stakeholders (Councils) free-of-charge, e.g. via a dedicated funding stream for the Bureau.

In terms of the types of models available for real-time use, hydrologic models (as currently used by the Bureau) are typically more stable and run faster than hydraulic models, however the fast hydraulic model has been developed to be robust and stable for a wide range of events from frequent to extreme floods. Further testing would be required prior to implementation for real-time purposes. The fast hydraulic model can also be simplified if required for faster run times, e.g. by the omission of secondary flowpaths for extreme events. In terms of the detailed hydraulic model, run times can be reduced with recent developments in software (i.e. TUFLOW HPC) although the model would have to be recalibrated prior to use with a different numerical solver. However, run times would still be in the order of hours rather than minutes (like the fast hydraulic model) or seconds (like the hydrologic models) and therefore unlikely to be suitable for real-time purposes, particularly in the upper catchment areas.

In the 2011 flood event, one of the main issues in terms of disaster management was translating the forecast levels at gauges to building inundation. In general, there was very little response to the initial warnings until it was suggested that flooding could be worse than in 1974. Whilst there was a reasonable warning time available, the response time was hampered by the challenges of translating forecast levels to building inundation. This has directly led to the recommendation in the Queensland Floods Commission of Inquiry that the community be provided with information linking gauge levels with building inundation, and subsequently the output provided in Section 10.4.3. However, there is potential to further refine and improve this information via real-time hydraulic modelling, which will provide better estimates of event-specific flood levels across the floodplain, rather than relying on best-estimates or approximate relationships derived from design flood modelling.

Some stakeholders are currently interpolating design flood maps to estimate flood behaviour based on the Bureau's forecast peak level, however it was acknowledged that there are limitations in using design events to predict actual floods, and that real-time hydraulic modelling would improve disaster management planning through the provision of more accurate flood mapping, including more refined information on the evolution of the flood (i.e. not just the peak). Hydraulic modelling would also improve predictions of the backwater influence of the Brisbane River on the Bremer River in larger flood events, which is an inherent limitation of hydrologic modelling. Whilst there are some challenges to the implementation of real-time hydraulic modelling system(s), these challenges were not considered to be insurmountable.

The Bureau and Seqwater both currently use Delft-FEWS as their software platform for flood forecasting. This is a very flexible system which can accommodate a wide range of data formats and model software including those used in the lower Brisbane River (Enviromon, URBS and TUFLOW). Information can also be readily exchanged between Delft-FEWS systems, e.g. if Councils were to develop their own systems for other sources of flooding. Delft-FEWS requires a relatively significant investment in configuration and training to set up a system and can't be operated by untrained staff (time and cost depends on the system complexity).

There is also a need for a system for sharing flood analysis, including data and information arising from this study, to share flood analysis across the lower Brisbane River floodplain, which would include any outputs from real-time hydraulic modelling. Some stakeholders were of the view that Councils should each have their own system as their needs differ (e.g. in terms of functionality, complexity, experience and training) and so that they were not reliant on each other. It was however agreed that these systems should all be based on a 'single point of truth' to ensure consistency and accuracy. The QRA together with stakeholders are exploring potential systems for sharing flood analysis as part of a separate study and will take into account the outcomes and recommendations arising from this Phase 3 (SFMP).

In terms of an interim alternative to real-time hydraulic modelling, it is understood that the QRA are also exploring the implementation of a regional system using the waterRIDE software to enhance real-time flood analysis based on existing Bureau forecasts. This was identified as an option for translating Bureau forecasts to impacts that could be implemented by the end of the year. Depending on the outcomes of that study, the regional system (and interim disaster management planning in general) may benefit from using the detailed hydraulic model to simulate additional flood events and increase the 'library' of flood behaviour information available for use in the lead up to, and during, actual floods.

10.6.6 Additional Stakeholder Feedback

Following Workshop 4, additional (informal) meetings were held with the QRA, Seqwater and Brisbane City Council representatives. These meetings identified that many stakeholders share a longer-term goal to develop a 'world class' solution to support disaster management in the Brisbane River system. Scoping of this system may consider:

- Simulating hydraulic models in real-time using output hydrographs from the Bureau's hydrology models, and producing flood mapping in a suitable format for relevant stakeholders.
- Intersecting the flood maps produced by the system with information about the community (buildings, infrastructure, vulnerable communities, etc.) to provide real-time flood intelligence.

It was identified that development of a solution of this nature would require updated governance arrangements for the planning, development and implementation stages.

These discussions also recognised the importance of pursuing interim and long-term solutions concurrently.

10.6.7 Recommendations

It is recommended that real-time flood modelling options (beyond current systems) continue to be investigated, with the goal of improving the speed, accuracy and consistency of forecast flood behaviour. In particular, the generation of flood inundation maps from real-time modelling would greatly improve stakeholders' ability to understand the potential flood impacts, prepare and respond to those impacts, and to use this information to support communication with the community. This would bring notable benefits to disaster management planning and response for the lower Brisbane River floodplain. The following actions are recommended:

- Relevant stakeholders continue to meet and plan options for future real-time modelling approaches or systems.
- Stakeholders develop a scope of the desired system, i.e. identifying functions, capabilities, requirements etc., ensuring that consideration is given to issues such as interoperability, 'future-proofing', data-sharing, governance etc.
- Stakeholders develop a 'road map' to identify what further actions need to be undertaken to realise the desired system. Particular focus should be given to sequencing actions to deliver intermediate products or systems, not just the ultimate end-goal.
- Stakeholders continue to engage with the Bureau of Meteorology (as the lead flood forecast agency) to ensure that proposed actions and systems align with the Bureau's future plans (to avoid inefficiency and maximising available resources).

The following are the key considerations in the establishment of such a system based on a review of existing flood forecasting arrangements, the Phase 2 (Flood Study) models available, and feedback from stakeholder consultation:

- The fast hydraulic model is considered the most suitable hydraulic model to simulate a range of scenarios in real time (i.e. under 5 minutes per simulation). The detailed hydraulic model (which could be upgraded to the faster TUFLOW HPC software but would still take a number of hours per simulation) is not currently considered suitable for real-time modelling, but could be used to expand the 'library' of information available for use in the lead up to, and during, actual floods.
- Real-time hydraulic modelling should be implemented via a platform which is compatible with the Bureau and Seqwater's existing flood forecasting systems. The platform should also provide sufficient flexibility for Councils who may wish to develop compatible systems in future that can integrate flood forecasting for other sources of inundation, e.g. creeks and overland flow. Depending on the nature and complexity of the adopted platform, this may require significant time and financial investment.
- The proposed solution will need to be flexible to cater to the needs of the different users and Councils, but should be based on a 'single point of truth', i.e. the Phase 2 (Flood Study) for historic and design flood information, and Bureau forecasts during flood events. A separate project being led by QFES is investigating options for cataloguing and sharing disaster data, both before and during flood events.
- As an interim step during development of more advanced approaches, the detailed hydraulic model might be used to improve the Bureau's hydrologic models, i.e. by using detailed model results to better understand flood behaviour in the floodplain.
- Future systems may seek to include the ability to intersect flood maps from real-time models with exposure data, such as buildings, people, linear infrastructure etc. and produce reports and mapping to support emergency response decision making. A system of this nature may also

support more complex functions such as undertaking rapid damage assessments using forecast flood results, and sharing information / interpretation between agencies.

10.7 Disaster Management Recommendations

10.7.1 Structure of Recommendations

In addition to the information and guidance provided within the scope of this component of the Phase 3 (SFMP), a number of other recommendations emerged from feedback received during stakeholder consultation. These recommendations have been grouped into the following categories, informed by the degree of regional implementation required:

- Regionally-coordinated activities (which will require a cross-boundary / cross-district approach); and
- Local activities with regionally consistent elements (i.e. requires local interpretation of regional information, development of local data, incorporation of other flood sources etc).

Linkages between disaster management and other components of the Phase 3 (SFMP) have also been highlighted.

10.7.2 Regional Recommendations

10.7.2.1 Disaster Management Working Group

Ongoing collaboration between all stakeholders is key for effective management of flood risk in the Brisbane River catchment. At present, numerous organisations are involved and meet in various groups, including multiple local and district disaster management groups.

Although this study does not address governance relating to disaster management, it is recommended that the disaster management issues identified in this study are provided to the disaster groups (which may include existing and new groups) to implement the recommendations in a considered and regionally consistent manner.

10.7.2.2 Regional Flood Intelligence System

As noted in Section 10.2.4.1, a regional waterRIDE system is being developed which will unify the waterRIDE systems currently being used by individual councils for viewing of flood mapping. This is a crucial first step in better coordinating flood response in the catchment. However, flood response is informed by more than just mapping or data; it requires flood intelligence. Flood intelligence (discussed further in Section 10.7.2.2) includes information about inundation, isolation and disruption to communities. A regional flood intelligence system would ideally include information about flood impact (see Section 10.4) and flood analysis (see Section 10.5). It might also be dynamic to include live data, particularly if real-time flood modelling and analysis is implemented (see Section 10.6).

A review of available flood intelligence systems has not been undertaken as part of this study, however the selected system should ensure that all relevant stakeholders have access to the same information, and that this information represents the most up-to-date information. Potential flood intelligence systems range from simple systems (e.g. basic web-mapping / online GIS systems) to more complex systems (such as FloodIntel, waterRIDE and Delft-FEWS). When selecting a system, priority should be given to addressing the most basic and essential functions first, while building flexibility in the system to ensure it can grow to include more complex functions (such as inclusion of real-time hydraulic modelling).

Note that a flood intelligence system is distinct from 'tasking' software such as Guardian and Noggin, although most flood intelligence systems should be able to communicate with tasking software.

10.7.2.3 Undertake Regional Evacuation Assessment

Evacuation assessments consider the ability of people within the floodplain to evacuate safely during a flood event. Assessments of this type describe the current evacuation capability of the region as well as determine the benefit of potential floodplain management measures and / or impacts of future floodplain development on evacuation capability. Evacuation capability assessments are not detailed evacuation plans, although much of the information and output from the assessments can be used to inform response planning. (See Section 10.7.3.5 for recommendation addressing local evacuation planning.)

It is recommended that information and data provided in this study (particularly from Section 4 Current Flood Risk, as well as this chapter and the Supplementary Information to Support Evacuation Planning in the Brisbane River Region[34]) be used in conjunction with the guidance in Section 10.5.4 and the Queensland Evacuation Guidelines for Disaster Management (QEGDM) (QFES, 2018) to undertake a regional evacuation assessment. Undertaking the assessment at a regional scale supports efficiencies in the assessment process, and provides opportunities to improve evacuation logistics across the region. Similarly, where the evacuation assessment informs other flood management responses (such as strategic land use planning), it is important to have a regionally consistent understanding of evacuation capability.

Key inputs to the assessment should include (but not be limited to):

- Dynamic flood results (i.e. time-based outputs, not just peak flood maps). These are currently available for the 60 flood events assessed in the detailed model, however these may be supplemented by additional events from the fast model.
- Collation of evacuation infrastructure including road locations, road levels, road capacity (how many lanes), other traffic impediments (e.g. concrete barriers preventing contraflow of traffic), and locations of evacuation centres.
- Understanding of existing flood warning and evacuation processes, including triggers for evacuation, and available data to inform the decision to evacuate.
- Spatially distributed population data, including information about more vulnerable residents.

Key actions to be undertaken should include (but not be limited to):

- Assessment of the flood immunity of evacuation infrastructure, including roads and evacuation centres. [Note: it is understood that Councils do not generally identify evacuation routes in advance of a flood event, due to the many different ways that flood may present and evolve (including interactions with local flooding). However, identification of routes which are likely to be

[34] Supplementary information provided from BMT to QRA 12 February 2018

used in an evacuation can help to identify if those roads have sufficient flood immunity and carrying capacity.]

- Assessment of the potential and probable timing of road inundation for various flood event sizes. This assessment can be informed by the road inundation assessment ('box-and-whiskers' plots) for State controlled roads, however will require assessment for other roads. During the assessment, consideration should also be given to other factors which may influence road inundation, such as potential for cross-drainage structures to be blocked and local flooding. Local / historical knowledge may supplement modelled data in these cases, and prioritisation should be given to better understanding locations which are critical for evacuation.
- Identification of flood evacuation triggers. These triggers will primarily be based on recorded stream gauge, however might also be supplemented with recorded rainfall and forecast information (particularly in the upper catchment areas).
- Identification of 'clusters' of properties which would be evacuated at the same time and advised to evacuate to the same place (on the same roads). [For this regional assessment, an option might be considered where only those clusters which are likely to use inter-Council infrastructure are included in the assessment.]
- Creation of a simplified representation of regional evacuation infrastructure which identifies key roads, clusters of properties, and where those properties join the roads. Roads should terminate in an evacuation centre or other suitable and safe location.
- Undertake a timeline analysis to understand how an evacuation might proceed from first prediction and commencement of evacuation, through to either successful evacuation or failed evacuation due to inundation occurring. Standard parameters should be used for traffic flow rates, time for public to understand and respond to warnings, impediments for bad weather etc. [The timeline analysis does not need to be agent-based traffic modelling, however some consideration will need to be given to the dynamics of intersecting roads.]
- Analysis of evacuation centre capacity to identify if sufficient for the number of people being directed to the centre. Key considerations for selecting / assessing suitable evacuation centres are provided in the Queensland Evacuation Guidelines[35], and might be supplemented with resources such as the Design Guidelines for Queensland Public Cyclone Shelters[36].

The assessment should also consider broader aspects of evacuation such as human behaviour, effectiveness of messaging, and the integration and testing of plans.

Key outputs to be delivered should include (but not be limited to):

- Identification of evacuation capability and constraints in the system, including location and nature of constraints and whether management of the constraints require regional coordination. This should include identification of what parameters in the timeline are limiting the process, e.g. insufficient road capacity, delayed warning etc.

[35] http://www.disaster.qld.gov.au/dmp/Archive/Documents/2907EMQ_SDMG_QLD_Evac%20Guide_web.pdf
[36] http://www.hpw.qld.gov.au/SiteCollectionDocuments/DesignGuidelinesQueenslandPublicCycloneShelters.pdf

- Supporting materials to communicate the findings of the assessment, including thematic maps of the floodplain including evacuation infrastructure, clusters of properties, and areas which are represented by those clusters. The map(s) should highlight constrained locations such as roads which become inundated prior to completion of evacuation, and those clusters of properties which are not able to successfully complete evacuation. Locations where evacuation is possible with a small time margin should also be highlighted. Summary tables, reporting and digital GIS information should also be supplied.
- Establishment of an ongoing maintenance and review program which ensures the regional evacuation capability assessment remains current and reflects current development and infrastructure conditions, and the extent to which plans covering relevant aspects of the points above are integrated.

Other considerations when scoping the regional evacuation assessment should include (but not be limited to):

- Inclusion of QFES on the project team to ensure consistency with the Queensland Evacuation Guidelines for Disaster Management and any emerging work as a result of the ongoing IGEM review into evacuation management arrangements.
- Identification of next steps, including any actions which are planned to address identified constraints. These actions might include improving road immunity (through road raising or improved cross-drainage), improve carrying capacity (through planned contra-flow or road widening), or changed evacuation response such as pre-emptive evacuation or re-routed evacuation.
- Ensuring that the outputs are delivered in a suitable form and to an appropriate level of detail to inform local-scale evacuation planning.

Note that outcomes from the recommendation in Section 10.7.2.9 Evacuation Route Infrastructure Design Immunity may inform the future road raising activities or the design of new roads.

10.7.2.4 Seasonally Updated Reporting Templates

During stakeholder consultation, numerous stakeholders identified that the requirement to provide regular briefing reports to other stakeholders (such as the State Disaster Coordination Centre and Queensland Reconstruction Authority) was onerous and time-consuming. It was further identified that one of the challenges historically with this reporting responsibility is that reporting requirements change from one event to the next. It is understood that these changes are likely driven by the availability of new data, collection approaches, funding and governance arrangements etc.

In response to this feedback from Councils, QFES provided the following information:

- When activated, the SDCC is under the control of the State Disaster Coordinator and is a whole of Government coordination centre.
- It is acknowledged that reporting requirements can change from one season to the next (or one event to the next) depending on various departmental requirements, new data availability etc.

- The additional requests for information is driven by a number of areas including Media, Political inquiries, conflicting information, inadequate information in reports, critical issue updates i.e. missing persons update. Contacts are made directly in times of critical timings either from the district or SDCC.
- For each event, the local impacts and community consequences will change, hence contextualised reporting will be required for every event and reporting will need to be adjusted to suit the event.
- It is acknowledged that this poses an impost on the local level.
- The SDCC staff will continue to explore strategies that will hopefully negate or reduce the contacts in the future but there will probably never be an incident where is a zero total of contacts for time critical issues.
- A new local disaster management group reporting template has been created. The new template aligns in structure and content to be consistent with the state agency reporting practices.

The issue of reporting demands during events was also addressed in IGEM's Cyclone Debbie Review. The review recommended that:

> "A strategy should be developed to improve the availability of information to decision-makers and other audiences. Information should be searchable, more specific, timely, and allow stakeholders to find what they want."

A response, led by QFES, was supported in the Queensland Government action plan that followed. It is understood that updates have been made to reporting templates in response to the Cyclone Debbie Review findings, and the new templates will be used for the first time next disaster season.

Informed by the response from QFES and recent changes as a result of the Cyclone Debbie Review, it is recommended that relevant parties (including Councils, QFES, QRA etc.) continue to monitor the reporting processes in the interest of continuous improvement. Where possible, opportunities to semi-automate the population of reports should be sought out, while recognising the necessary 'human' element in contextualising raw data and information.

10.7.2.5 Review Forecast Gauges

The Service Level Specification for Flood Forecasting and Warning Services for Queensland (SLS) is prepared by the Bureau of Meteorology (Bureau) to document and describe the flood forecasting and warning services provided by the Bureau in Queensland, as described in Section 10.1.5.9. As a separate piece of work, the QRA has recently been undertaking a review of the flood warning gauge network (Section 10.1.5.10). It is recommended that findings from the QRA gauge network review be used to inform possible updates to the SLS.

10.7.2.6 Additional Forecast Gauges

Based on feedback received from stakeholders during this study, there is particular interest in the gauges at Savages Crossing and Glenore Grove being elevated from Schedule 3 (Information locations with flood class level defined) to Schedule 2 (Forecast locations and level of service). If these gauges are included in Schedule 2, the Bureau would provide official forecasts for these locations.

Gauges have not been reviewed within this study for suitability as forecast gauges, however Milestone Report 5 of the Phase 2 (Flood Study) examined stream gauges within the hydraulic model area to determine suitability for use in the hydraulic modelling assessment. This discussion includes observations for both Glenore Grove (Section 6.2 of that report) and Savages Crossing (Section 6.7 of that report) which may be of value, if these gauges are considered for use as forecast gauges. [It is noted in particular that Glenore Grove is located on a perched section of Lockyer Creek and may only be suitable as a forecast location for levels up to approximately 81mAHD].

10.7.2.7 Revised Forecast Gauge Locations

Stakeholder feedback also indicated interest in better aligning forecast gauge locations (between Seqwater and the Bureau) at the Jindalee and Lowood gauge sites. The following information was provided by the Bureau about these gauges:

Jindalee

- There are three separate stations at this location. All have been installed for different reasons but the historic location is the 040713 Jindalee (Centenary Bridge) manual station. This is the forecast location and the point at which the Bureau provides forecasts.
- There is an ALERT station installed by Seqwater (Jindalee AL 540192) on the left bank in the direction of flow.
- More recently Brisbane City Council installed another ALERT station (Jindalee (Boat Ramp Park) Alert-B on the right bank in the direction of flow.

Lowood

- Four stations at this location but only one manual station (Lowood 040441) is located at the forecast location right on the bend.
- There is a co-located Seqwater ALERT (540183)/BoM TM (040706) site at the Lowood Pump Station.
- There is another Seqwater ALERT station (540182) located slightly downstream.
- This location is in a current state of flux and the historic Lowood station has changed locations several times which can make it challenging to compare historic heights.

10.7.2.8 Updated Gauge-Related Flood Information

Should any additional gauges be added to the list of gauges used by the Bureau for flood forecasting (i.e. communication of forecasts), it is recommended that data and information which relates to gauges be updated. Updates relating to data, information and recommendations within this chapter include:

- Stream gauge reference areas (Section 10.3.1.3). These areas should be modified to include any new gauges (this may have the effect of reducing the size of adjacent areas, and subsequently improving the strength of the relationship between flood behaviour at the gauge and within the reference area);

- Forecast location diagrams (Section 10.3.3). New diagrams should be produced for the additional forecast gauge locations. These diagrams will help to identify if any additional flood maps would be helpful to better predict potential flood behaviour at that location.
- Time to inundation mapping (Section 10.3.3.3). These maps relate to the time to inundation relative to minor flood levels being reached at those gauges. If additional forecast gauges are introduced, revised time to inundation mapping should be produced to better link gauge information and floodplain behaviour.

10.7.2.9 Evacuation Route Infrastructure Design Immunity

During stakeholder consultation (Workshop 1, Section 10.2.3.1), it was identified that additional flood immunity requirements (which exceed standard design requirements) should be applied to designated evacuation routes. For instance, a local road may not require high flood immunity according to standard design requirements, but if this local road is the single egress for a flood exposed town, there may be justification to increase the flood immunity beyond normal standards.

The Department of Transport and Main Roads (TMR) is the authority responsible for establishing road immunity standards. Consultation with TMR is recommended to raise this issue on behalf of stakeholders.

10.7.3 Local Recommendations

10.7.3.1 Undertake Local-Scale Assessments

A range of data and analysis has been provided within this regional-scale study using regional-scale information. It is recommended that councils use this information as a starting point for local-scale assessments. In particular, it is recommended that local-scale disaster management assessments consider:

- Where additional (local) flood modelling is being undertaken to support Phase 4 (LFMPs), councils should ensure that model outputs are sufficient to inform disaster management planning (e.g. information about inundation timing, hazards, isolation, road inundation etc.).
- Inclusion of other flood sources, such as creek and local flooding, and storm tide inundation (where relevant). Consideration should be given to the potential for multiple flood sources to cause inundation concurrently (and the likelihood of that happening, i.e. joint probability analysis), the types of response triggered by the various flood sources (and potential overlaps), and the likely scale / extent of impacts caused by each of the flood sources.
- Local disaster management plans (including evacuation planning) should be updated to reflect best available data from regional-scale and / or local flood information (depending on data availability and priority).
- Evacuation capability assessments should be undertaken to identify constraints in the evacuation process including flood warning, warning dissemination, active evacuation and shelter (see Section 10.7.3.5 for further information).

- Use outputs from evacuation capability assessment to inform isolation assessment and consider options to manage isolation risk, including pre-emptive evacuation.
- Where assessments indicate the potential for fast-onset flooding, consider implementation of flash flood warning systems, informed by best-practice guidance via the Bureau of Meteorology's FLARE resource / forum.
- Ensure that local / district / state disaster management systems and databases etc. are maintained with refined or new data developed during the Phase 4 (LFMP).

10.7.3.2 Update Local Flood Intelligence

Local authorities play an important role in interpreting the Bureau's flood forecasts into potential flood impacts and communicating these potential impacts to the community. Development of flood intelligence in advance of an event helps emergency managers quickly determine the actual or likely effects of flooding on a community, and shapes decision making. A conference paper (Morgan et. al 2013) on the types of information typically included in flood intelligence lists:

- Inundation (requiring evacuation, building protection and/or rescue);
- Isolation (creating risk to life and the need for resupply and/or rescue); and
- Disruption to community activities (e.g. due to the loss of electricity supply or transport routes)

Information of this nature should be developed / updated to incorporate new information provided through the regional study and additional information developed in local / detailed floodplain management studies.

One of the benefits of flood intelligence is the ability to translate flood levels / flows and rainfall intensities / depths into real-world outcomes. This also becomes a valuable communication tool when sharing flood warning information with the community, particularly when local landmarks are used as reference points (e.g. noting that water is likely to reach the top step of the post office etc.).

10.7.3.3 Adoption of New Bureau of Meteorology Products

Consultation undertaken with the Bureau of Meteorology during the study identified that the Bureau will soon be releasing or updating a number of new products and services which will assist councils better understand flood forecasts and provide more information to inform interpretation of those forecasts. In particular, the Bureau noted that:

- Their website is currently being updated, which will enable better sharing of data
- Probabilistic forecasts will be provided in the future, which will help councils to prioritise their resources and undertake contingency planning, i.e. resources can be prioritised to address those locations where there is highest confidence of flooding occurring. Conversely, councils will be better able to understand the upper limit of likely flooding, and plan their response and resources accordingly.

It is recommended that councils remain in close contact with the Bureau (via the Disaster Management Working Group, Section 10.7.2.1, district disaster groups, or the Queensland Flood

Warning Consultative Committee) to remain current with new products and services, and update disaster management processes to fully utilise these new inputs.

10.7.3.4 Review Gauge Classifications

It is recommended that councils use findings from QRA's recent review of the flood warning gauge network to identify gauges in their system which may require updated flood classification levels (minor / moderate / major). If gauge classifications require review, guidance is provided in this document (Section 10.5.5). It is understood that QFES also provide support to undertake this process.

10.7.3.5 Undertake or Update Local Evacuation Planning

A large amount of data and information has been created through Phase 2 (Flood Study) and Phase 3 (SFMP) including information about flood size, behaviour and timing; population characteristics; identification of vulnerable institutions and critical assets; and areas likely to become isolated by flooding. This information, in conjunction with outputs from the regional evacuation capability assessment (Section 10.7.2.3), can be used to undertake local-scale evacuation planning (or update existing evacuation plans). These plans typically build upon results from evacuation capability assessments to identify resources needed to support safe evacuation (including rescue and recover phases) and detail a range of supporting logistics.

10.7.4 Links with Other Components of the Phase 3 (SFMP)

Effective floodplain management requires integration across all disciplines (or work packages). Disaster management has particularly strong links with community flood awareness and resilience, land use planning, and structural modification options.

10.7.4.1 Community Flood Awareness and Resilience (Section 11)

Disaster management and community flood awareness and resilience actions should work hand in hand for maximum effectiveness. Empowering the community with the skills, knowledge and information to manage their own flood risk reduces the disaster management burden on response agencies and ultimately improves flood safety for the community.

The following key links between the disaster management, and community awareness and resilience components are highlighted:

- The disaster management chapter provides a range of flood data which can be used to inform the community of their flood risk, including explaining flood behaviour and the potential for floods to be worse than observed in the past.
- The disaster management chapter provides building-specific information, including flood immunity and relationship to forecast stream gauges, which can help the community understand personal flood risk and develop personal flood action plans.
- The disaster management chapter provides information to help stakeholder's review stream gauge classifications. If stream gauge classifications are modified, these changes should be clearly communicated to the community to ensure they understand that changes have occurred,

what those changes are, and how the changes will impact their understanding of flood risk and flood warnings.

- The community flood awareness and resilience chapter recommends the establishment of regionally consistent language and messaging. Adoption of this consistency will inform disaster management actions such as issuing flood warnings and evacuation notices.
- The community flood awareness and resilience chapter recommends improved use, sharing and coordination of location-based data including, but not limited to emergency alert polygons. Findings from this chapter, Section 4 Current Flood Risk, and Phase 4 (LFMPs) can all be used to identify Emergency Alert polygons. [The Emergency Alert system does not operate on an opt-in basis, it targets both location and service addresses, and operates across carrier networks. Emergency Alerts are requested by local government and are actionable through the State Disaster Coordination Centre.]
- The community flood awareness and resilience component of this Phase 3 (SFMP) recommends the development of a communication and engagement framework to ensure consistent use of terminology related to flooding in the catchment, as well as establishing governance structure and processes for managing communication during and after an event (including use of social media). It is recognised that there is a distinction between awareness messaging and disaster management messaging, however it is intended that the scope of the framework will be sufficiently broad to address both. The communications framework is intended to be informed the compendium of resilience activities (recommended within Section 11 Community Awareness and Resilience), which describes examples of best-practice resilience activities from within the catchment (and potentially the State), which may include effective disaster messaging. Similarly, the recommendation from Community Awareness and Resilience to undertake a research project evaluating the effectiveness of activities might spend some focus on evaluating the effectiveness of disaster management messaging (e.g. evacuation warnings) and how this might be improved for improved community response.
- The community flood awareness and resilience component of this Phase 3 (SFMP) provides two key recommendations to improve volunteer response during floods (thereby reducing demand on disaster management resources), although provides many recommendations to improve community awareness and resilience. It is understood that Queensland Fire and Emergency Services are currently developing a volunteerism strategy to help develop more flexible strategies to support volunteering; Community Awareness and Resilience provides some suggestions for future investigations to facilitate, expand and better utilise volunteers. The second, more structured recommendation addressing volunteers, recommends that community champion programs be considered, similar to programs already in place to assist with the management of fire risk. Implementation of these two recommendations, in conjunction with numerous other awareness and resilience activities, will better empower residents with the skills and knowledge they need to better manage their own response and evacuation.

10.7.4.2 Land Use Planning and Building Controls (Sections 9 and 12.3)

Land use planning (including building controls) can support the implementation of disaster management practices by ensuring that land use and development is risk appropriate for the location in the floodplain, which includes an evaluation of whether safe evacuation is possible. Evacuation planning is one of the key flood risk factors in determining land use tolerability and needs to be considered upfront in strategic planning to achieve a flood responsive settlement pattern. Evacuation and access design are also key considerations for development assessment decisions. Section 9 Land Use Planning provides advice and recommendations for local planning schemes to include evacuation considerations for both development assessments and strategic planning. Section 12.3 Building Controls outlines how resilient design principles (such as those outlined in the Queensland Development Code MP3.5 – *Construction of Buildings in Flood Hazard Areas*) can minimise both the damage and impact caused by the inundation of buildings in the floodplain.

The information provided in this study and chapter, including time to inundation mapping, road inundation information and guidance, and evacuation planning guidance can all be used to support future land use planning decisions.

10.7.4.3 Structural Modification Measures (Section 8)

The implementation of measures which modify flood behaviour can significantly alter flood risk for the regions impacted by the measure, and correspondingly change the disaster management requirements for that area.

Structural modification measures were assessed using a multi-criteria assessment which considered the impact the measure would have on buildings in terms of the change in flood level / risk at the building, and the change in warning and evacuation time. Should any of the measures assessed in this study be implemented, relevant LDMGs should update LDMPs, including evacuation planning, to reflect the modified risk profile.

11 Community Awareness and Resilience

11.1 Context

11.1.1 Overview

The community's awareness of and resilience to flooding is one of the most crucial considerations for floodplain management. Historical land use planning has resulted in some communities being exposed to flood risks that are higher than we would generally tolerate for new developments today. Notwithstanding, land use planning cannot entirely avoid areas that are flood affected, and as such, the community must be informed of the risks and be able to respond accordingly to manage risks to an acceptable level.

Traditionally, floodplain management efforts have focused on community awareness, however there is growing recognition of the importance of building resilience in the community (of which awareness is just one component). The importance of community resilience for improving disaster outcomes is highlighted in the recent publication of the Queensland Strategy for Disaster Resilience (QRA, 2017). The Strategy notes that:

> *"Current research in the field of resilience informs us that it is at the community level that the most powerful action can be taken to address disaster risk. Communities play an active and central role in disaster risk prevention and preparedness, and are the first to experience the rapid changes brought on by disasters that call for the adaptation required to survive and thrive.*
>
> *Resilience should be realised as tangible improvements in the capacity and capability of a community to prepare, respond and recover from a disaster event. This includes the effectiveness of engagement and support of agencies, entities and individuals who serve the community within the context of Queensland's disaster management arrangements."*
>
> *(p.7, QRA, 2017)*

This component of the Phase 3 (SFMP) focuses on community resilience to riverine flooding in the lower Brisbane River catchment, recognising that resilience to one type of disaster can also improve broader resilience to a range of disasters and societal shocks (see also Section 11.1.4 which explains the all hazards approach).

11.1.2 Importance of Regional Approach

A regional approach is fundamental to all components of the Phase 3 (SFMP) and is particularly relevant for community awareness and resilience activities. With increased use of online materials and social media, community members are frequently exposed to materials and messaging from multiple council areas. Similarly, residents move about the catchment (and beyond) in their day-to-day activities and may not necessarily be within their own local government area during a flood. Some families also have members working across local government areas or attending education facilities in other areas. Consistency in approach and messaging is essential to avoid confusion.

Communities in different areas may have had different experiences, exhibit different characteristics and focus on different priorities. Community awareness and resilience activities should be cognisant of these differences, and tailored to suit each section of the community. These sections of the community might be similar across local government boundaries and it may be possible to engage with these groups regionally.

In general, a regional approach to community awareness and resilience is promoted:

- For language / terminology, mapping, and symbology to assist understanding and interpretation;
- To improve efficiency in planning and execution of activities; and
- When coordination is required between councils and or state government organisations.

These regional considerations will inform selection of the community awareness and resilience activities included in the Phase 3 (SFMP), noting that measures:

- May require regionally coordinated implementation;
- May require local implementation, with regionally consistent elements such as communication or messaging; and
- May require state government coordination or implementation, including commissioning of new work and advocacy.

Application of recommendations made in this document to other flood sources (e.g. creeks, overland flow, storm tide), will be addressed in Phase 4 (LFMPs).

11.1.3 Guidance, Strategies and Frameworks

The assessments undertaken within this component of the Phase 3 (SFMP), as well as the community awareness and resilience activities recommended herein, are guided by and consistent with a number of resilience-focused guidelines at the international, national and state level. A brief summary of each of these guidelines is provided below, with emphasis placed on aspects of the guidelines that relate to community awareness and resilience to riverine flooding in Queensland.

11.1.3.1 Sendai Framework for Disaster Risk Reduction 2015 – 2030

The Sendai Framework for Disaster Risk Reduction 2015 – 2030 (UNISDR, 2015) (referred to as the 'Sendai Framework') is an international, voluntary and non-binding agreement which was endorsed by the UN General Assembly following the 2015 Third UN World Conference on Disaster Risk Reduction. The Sendai Framework is the successor instrument to the Hyogo Framework for Action (HFA) 2005 – 2015: Building the Resilience of Nations and Communities to Disasters (UNISDR, 2005), and recognises that the State[37] has the primary role to reduce disaster risk, but that responsibility should be shared with other stakeholders, including local government, the private sector and other stakeholders.

Four priorities for action are identified under the Sendai Framework:

(1) Understanding disaster risk;

(2) Strengthening disaster risk governance to manage disaster risk;

(3) Investing in disaster risk reduction for resilience; and

[37] 'State' used here denotes relevant government authority, rather than the State of Queensland

(4) Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction.

Of these priorities, the first and fourth are most relevant to this component of the Phase 3 (SFMP), although the other priorities will be addressed in broader implementation of the SFMP. Beneath each priority is a list of achievements which help deliver the priorities at both national / local and global / regional levels.

Importantly, the Sendai Framework discusses the role of stakeholders in the disaster risk reduction for resilience process, and highlights that community groups typically identified as vulnerable to disasters (e.g. children, older people, migrants etc.) are critical considerations to the disaster risk reduction process and can act as agents of change in their communities.

11.1.3.2 National Strategy for Disaster Resilience

The National Strategy for Disaster Resilience (COAG, 2011) (referred to as the 'National Strategy') was developed by the National Emergency Management Committee through the Council of Australian Governments (COAG) to create a framework for national, coordinated and cooperative enhancement of Australia's capacity to withstand and recover from emergencies and disasters.

The National Strategy echoes the message provided in the Sendai Framework that disaster resilience is a shared responsibility for individuals, households, business and communities, as well as governments. This focus on resilience calls for an integrated, whole-of-nation effort encompassing enhanced partnerships, shared responsibility, a better understanding of the risk environment and disaster impacts, and an adaptive and empowered community that acts on this understanding. Moving beyond traditional emergency management planning, the National Strategy emphasises the need for action-based resilience planning to strengthen local capacity, through increased community engagement and improved understanding of the diversity, needs, strengths and vulnerabilities within communities.

The National Strategy asks two clear questions of emergency managers and other readers:

(1) What does a resilient community look like?

(2) What action can we take? [The 'we' refers to all sections of the community, through the shared responsibility model].

Understanding what a resilient community looks like is used in place of a disaster resilience definition, and focuses on the common characteristics of disaster resilient communities, individuals and governments. These characteristics are identified as:

- Function well while under stress;
- Successful adaptation;
- Self-reliance; and
- Social capacity.

The actions which can be taken to support the development, enhancement and maintenance of a resilient community are grouped under seven themes, each of which identifies several priority outcomes. These themes are:

(1) Leading change and coordinating effort;

(2) Understanding risks;

(3) Communicating with and educating people about risks;

(4) Partnering with those who effect change;

(5) Empowering individuals and communities to exercise choice and take responsibility;

(6) Reducing risks in the built environment; and

(7) Supporting capabilities for disaster resilience.

As for the Sendai Framework, some of these themes (e.g. reducing risks in the built environment) are better addressed in other components of this Phase 3 (SFMP), but all actions ultimately contribute to a resilient community.

11.1.3.3 Queensland Strategy for Disaster Resilience

The Queensland Strategy for Disaster Resilience (QG, 2017) (referred to as the 'Queensland Strategy') provides a framework and direction for the Queensland Government to support local governments and communities to identify resilience activities, and provides a cohesive approach to building resilience throughout the state. The Queensland Strategy sits beneath and is consistent with the National Strategy, interpreting the national framework for Queensland's unique disaster risk profile, governance arrangements and community characteristics. In addition, the Queensland Strategy complements the existing disaster management arrangements in Queensland, as specified in the *Disaster Management Act 2003*.

As seen in both the National Strategy and the Sendai Framework, the Queensland Strategy supports the approach that resilience is a shared responsibility, with the following stakeholders identified as central to the ultimate success of the Strategy:

- Queensland communities and individuals;
- Local Governments;
- Queensland businesses and service providers;
- State Government departments and organisations;
- The Australian Government;
- Community-based organisations; and
- Non-government organisations.

Consistent with the National Strategy, is the Queensland Strategy's use of a resilient community to define what resilience 'looks like'. The Queensland Strategy identifies that the following elements contribute to a resilient organisation or community:

- Risk-informed and appropriately prepared individuals;
- The capacity to adapt; and
- Healthy levels of community connectedness, trust and cooperation.

The Queensland Strategy provides an overarching framework to empower Queenslanders to factor in resilience measures activities as they anticipate, respond, and adapt to the impacts of flooding. Each of these actions (anticipate / respond / adapt) is supported by a number of actions or abilities which characterise a resilient community. Further, the following guiding principles inform the Queensland Strategy:

- Shared responsibility;
- An integrated risk-based approach;
- Evidence-based decision making; and
- Continual learning.

11.1.3.4 Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience

The Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience (QRA, 2017) (referred to as the 'Riverine Flood Risk Framework') was developed to provide a consolidated and coordinated approach to the management of riverine flood risk in Queensland. The Riverine Flood Risk Framework clarifies roles and responsibilities of stakeholders and establishes a governance framework for implementing Queensland-specific flood risk management. It aligns with the Queensland Strategy and is consistent with relevant legislation.

The Riverine Flood Risk Framework seeks to provide direction for the entire flood risk management cycle and all related activities, although the stated vision of the Framework clearly emphasises community resilience:

> "Queenslanders understand flood risk, adapt to changing circumstances and take action to mitigate and build resilience." (p.3 QRA, 2017)

Underpinning the Riverine Flood Risk Framework are six guiding principles:

(1) Flooding is inevitable;

(2) Shared responsibility;

(3) Disaster risk management informs decision making;

(4) Multi-disciplinary catchment approach;

(5) Locally led initiatives for local communities; and

(6) Transparency in data and information sharing.

These principles are further supported by desired outcomes from the process. Outcomes emphasise a risk-based approach to flood management, shared and coordinated responsibility, and the empowerment of local communities through the provision of locally-specific flood risk management initiatives.

Note that the Riverine Flood Risk Framework will be supported by an implementation plan, which will outline how the Framework's key objectives will be delivered (not yet published).

11.1.3.5 Australian Disaster Resilience Handbook Collection

The Australian Disaster Resilience Handbook Collection (referred to as the Handbooks) capture nationally agreed principles, policies and practices to support the development of disaster resilience. The Handbooks are currently a series of 16 handbooks, each of which addresses a different aspect of disaster resilience, and are supported by additional technical guidance and other material. Prior to the development and publication of the Handbooks, similar material was provided in a series of 46 Manuals. The manuals have not been updated since 2011 or earlier and the material in the manuals is gradually being migrated across to the Handbooks, as the content is updated and reviewed.

Of most relevance to the management of flood risk is Handbook 7, Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR, 2017). This handbook is regarded as the national guidance for floodplain management and works in concert with the National Strategy.

Handbook 7 outlines eight key principles for a best-practice approach to flood risk management, all of which can directly guide and inform community awareness and resilience actions:

(1) A cooperative approach to manage flood risk;

(2) A risk management approach;

(3) A proactive approach;

(4) A consultative approach;

(5) An informed approach;

(6) Supporting informed decisions;

(7) Recognition that all flood risk cannot be eliminated; and

(8) Recognition of individual responsibility.

Community preparedness is addressed briefly (as a means to treat residual flood risk at a community scale), with further advice on this topic provided in two of the Manuals: Manual 20 – Flood Preparedness, and Manual 45 – Guidelines for the Development of Community Education, Awareness and Engagement Programs. As noted above, the Manuals are not currently up to date and therefore cannot be used reliably to represent current best-practice approaches.

11.1.3.6 Queensland Floods Commission of Inquiry

The Queensland Floods Commission of Inquiry (referred to as the Inquiry) was established as an independent Commission of Inquiry to examine the 2010 / 2011 flood disaster that affected 70% of Queensland. The Inquiry took public submissions, held community meetings and consultations, and received input from nationally respected experts in their fields. An interim report (QFCoI, 2011) from the inquiry was issued in August 2011, relating to matters associated with flood preparedness. The final report (QFCoI, 2012) was released in March 2012, and included recommendations for stakeholders.

Recommendations in the final report do not directly address community flood awareness and resilience, and instead focus more on land use planning, dam operation, structural measures etc. The two recommendations with direct linkages to community resilience are:

- Recommendations 2.16 – 2.17, that councils and the Queensland Government should display on their websites all flood mapping they have commissioned or adopted; and
- Recommendations 15.1 – 15.2 that councils should support and encourage business owners to develop private flood evacuation plans by providing relevant and location-specific information to support the development of those plans.

By comparison, the interim report focussed on flood forecasts, warnings and information. Although most of the recommendations in the interim report address issues relating to the Disaster Management component of this study, the following issues (addressed over numerous recommendations) more directly relate to community awareness and resilience:

- Flood warnings should be issued using a range of methods, including SMS, radio, social media, door knocking, 'bush telegraph', and sirens (for flash flood prone locations);
- Individuals and businesses should be made aware of the importance of battery operated radios for receipt of emergency information during power outages;
- Councils should ensure that residents and businesses clearly understand the impact of predicted flood levels on their property, including knowing the location of their nearest prediction river gauge, and how levels at that gauge relate to inundation at the property. Options for conveying this information include:
  - Information on rates notices;
  - Mapping showing inundation at a range of river heights;
  - Flood markers;
  - Property flooding reports;
  - Colour coded maps; and
  - Information relating gauge heights with the level of flooding expected at a property.
- In rural and remote areas where telecommunications are not effective, measures that do not rely on internet and mobile phone service should be implemented to inform the travelling public of road conditions, e.g. signs with detailed information or providing information to tourist information centres and radio stations.

11.1.3.7 Victorian Bushfires Royal Commission

The Victorian Bushfires Royal Commission (referred to as the Commission) was established to better understand the 'Black Saturday' bushfires of February 2009, including how to reduce the risk and impacts of fire and minimise fire-related loss of life in future. The final report comprises four volumes; the second volume contains lessons learnt (VBRC, 2009). Some of those same lessons learnt, particularly regarding community resilience measures, can also apply to flood risk.

The Commission recognises and promotes the notion of shared responsibility, though goes further than other guidance materials and notes two important qualifications:

(1) Shared responsibility means increased responsibilities for all; and

(2) Share responsibility does not mean equal responsibility. In some aspects of risk identification and management, and particularly where vulnerable people are involved, the State, councils and emergency management authorities should assume greater responsibility.

The report provided 67 recommendations for improvement of fire risk management. Of these, the below recommendations are also applicable to community awareness and resilience to flood risk:

- Enhance the role of warnings –providing for timely and informative advice about the predicted passage of a fire and the actions to be taken by people in areas potentially in its path;
- Emphasise that all fires are different in ways that require an awareness of fire conditions, local circumstances and personal capacity;
- Ensure that local solutions are tailored and known to communities through local bushfire planning;
- Ensure that bushfire safety education content and delivery is flexible enough to engage individuals, households and communities and to accommodate their needs and circumstances;
- Regularly evaluate the effectiveness of community education programs and amend them as necessary;
- Document in municipal emergency management plans and other relevant plans facilities where vulnerable people are likely to be situated—for example, aged care facilities, hospitals, schools and child care centres; and
- Compile and maintain a list of vulnerable residents who need tailored advice of a recommendation to evacuate and provide this list to local police and anyone else with pre-arranged responsibility for helping vulnerable residents evacuate.

11.1.4 Summary

The guidelines, strategies and frameworks summarised above were developed to align with related documents, per the following:

- The National Strategy for Disaster Resilience was developed to align with the Sendai Framework for Disaster Risk Reduction 2015 – 2030, and adapt the principles of the Sendai Framework to an Australian context;
- The Queensland Strategy for Disaster Resilience was developed to align with the National Strategy for Disaster Resilience (and by default, the Sendai Framework), and adapt the National Strategy to a Queensland context;
- The Australian Disaster Resilience Handbook Collection, as national guidelines, were also prepared in accordance with the National Strategy;
- The Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience were informed by the Queensland Strategy for Disaster Resilience and Managing the Floodplain: a guide to best practice in flood risk management in Australian (Handbook 7), one of the Handbook Collection documents;

- Recommendations provided in the Queensland Floods Commission of Inquiry were generally provided by independent experts, however these recommendations (and the nationally accepted notion of 'best practice' in the field of floodplain management) is informed by Handbook 7; and
- Recommendations provided in the Victorian Bushfires Royal Commission helped shape the development of the National Strategy for Disaster Resilience.

Each of these documents apply to a distinct geographic region (internationally / nationally / state-wide) and are relevant for either all disaster types, or specific hazards, Nonetheless, common themes are evident throughout most documents:

- The notion of shared responsibility and decision making across all sectors (not just a top-down approach);
- The approach of considering a resilient community, rather than defining resilient as a standalone attribute; and
- The importance of evidence-based decision making, including through the provision of locally relevant information to end-users (including the community).

11.2 Community Flood Resilience Aspirations

11.2.1 Introduction

One of the key outcomes from this study is the development of a shared vision of flood resilience for the Brisbane River catchment. A shared vision ensures that all stakeholders, including the community, can work collaboratively towards a common goal, with a clear understanding of what that goal looks like and what actions should be taken to reach it.

Community flood resilience aspirations have been developed within this study and for application to riverine flooding in the Brisbane River catchment, however they may also be applied to other sources of flooding or locations, with minor modifications, during Phase 4 (LFMPs).

11.2.2 Development of Aspirations

11.2.2.1 Overview

The community flood resilience aspirations were developed through a multi-stage process, informed by formal guidance, strategies and frameworks, and by stakeholder input sought at multiple points during the study.

The notion of defining resilience by identifying the characteristics of a resilient community is strongly advocated in both the National Strategy for Disaster Resilience and the Queensland Strategy for Disaster Resilience, and has been adopted for use in this study. Defining resilience in this way ensures that resilience moves from a theoretical concept, to a real-world attribute that can be developed through real-world actions.

At the commencement of the study, a workshop was held focusing on community awareness and resilience which asked the stakeholders: *what does a flood resilient community look like?* Responses from this workshop, combined with structure from guidance material (particularly the Queensland

Strategy for Disaster Resilience) was used to develop draft community flood resilience aspirations. These aspirations were presented to stakeholders at a subsequent workshop for their comment and input. Stakeholder input was used to refine the aspirations further. In particular, it was noted that it's not sufficient to identify what 'good looks like' in terms of community resilience; it's also necessary to identify what 'good looks like' from the perspective of stakeholders who support the community.

Further detail about the development process is provided below.

11.2.2.2 Stakeholder Input (Workshop 1)

During Workshop 1 of this study (held 9th March 2017), stakeholders were asked to identify what they believed were components or aspects of flood resilience. A full list of these responses is provided in Appendix S, however the main attributes of a resilient community were identified as follows:

A resilient community …

- Has strong community networks, built on trust and cooperation;
- Is self-reliant and highly responsive at the individual level;
- Is aware of local hazards;
- Has a good understanding of personal flood risk;
- Has a flood response plan in place;
- Has an understanding of flood notifications and warnings;
- Is empowered to drive local resilience activities;
- Can make evidence-based decisions;
- Has capacity to adapt to consequences, not just impacts;
- Is financially able to recover from floods (not solely reliant on insurance);
- Can learn from past events; and
- Accepts the potential for future disasters.

11.2.2.3 Stakeholder Input (Phase 3 (SFMP) Workshop 3)

During Workshop 3 of this study (held 23rd June 2017), stakeholders were presented with preliminary community resilience aspirations and asked to provide their feedback and comments on the aspirations. The following feedback was received, summarised here in themes:

Geographic context

- Should have a catchment focus, e.g. where you live is not just your city, it is your whole catchment. People need to understand that they live in a catchment and how a catchment behaves.

Role of community / stakeholder engagement

- Residents need to be part of the discussion and involved in the journey;
- Residents proactively seek information about potential risk and warnings;

- Promote self-management on the basis of understanding the risk, accepting risk and mitigating risk;
- Residents / businesses need a financial buffer to mitigate against temporary loss of income stream;
- Community empowered / confident to ask for help;
- Community empowered to act for themselves, not (totally) reliant on outside services / organisations;
- Property regularly valued for insurance purposes;
- Community understands their vulnerabilities and what action to take;
- What are the trusted sources of information, e.g. news, social alliances;
- Community understands impacts (inundation and isolation);
- Use local and historical knowledge. Identify / empower responsible community members / champions;
- Be adaptable to changes in technology, urban development, social aspects etc. (e.g. working from home if business or access is inundated);
- Capacity for new community members to adapt (become resilient) between events. Maintain awareness between events.

Communication / messaging

- Find ways to communicate with transient communities;
- Promote living with water, i.e. flooding does not just have negative impacts (positive marketing). Change the idea that living in a floodplain is a negative, when in fact it has value;
- Move away from "1 in 100 year" terminology;
- Manage expectations around flood modelling;
- Accept flood risk is an issue / overcome denial;
- Consider effective approaches of other campaigns, e.g. water efficiency during the drought, bushfire etc.;
- Undertake longer-term awareness campaigns which are ongoing rather than reactive to an emergency;
- Residents need to know their own personal flood risk (not just generalised information).

Council / state government responsibilities

- Apply prevention, preparedness, response and recovery (PPRR) model for all aspects;
- Provision of timely, reliable, trusted information as an event unfolds (i.e. "single point of truth");
- Prominent flood markers are effective in maintaining community awareness (particularly between events);

- Simple property level flood resilience measures are required;
- Need to address risks for vulnerable groups and how to identify and understand the vulnerabilities;
- Utilise existing groups (e.g. Meals on Wheels etc.) to improve resilience;
- Understand what gauge levels mean for the community;
- Consider housing affordability, house prices (immediately post-flood vs later), insurance availability and affordability, rental market, job stability;
- Resilient cities require a resilient community, i.e. an empowered community with ownership of risk that takes proactive action. How do we achieve this? Support with built form and infrastructure;
- Provide support to vulnerable groups, e.g. vulnerable persons' framework.

General

- Regarding terminology, be clear about who we are talking about in aspirations, i.e. are these aspirations the community should have, or actions the community should take? What is meant by an 'event'?
- Can these be applied to any community, anywhere?

Group discussions also identified that the aspirations for a flood resilient community might be more practical if matched by aspirations for the stakeholders, in terms of the type of support they should provide to foster a resilient community.

11.2.3 Structure of Aspirations

The community flood resilience aspirations adopted for use in this study are divided into three broad headings, which capture the essential elements of a resilient community.

A flood resilient community is:

(1) Risk informed;

(2) Appropriately prepared; and

(3) Adaptable.

For each of these elements, a number of aspirations are identified, which generally recognise the strength and capabilities of resilient communities. Matching each of the community aspirations are one or more indicators of what these aspirations mean from the stakeholders' perspective. For instance, under the element of 'risk informed', one of the community aspirations is:

- Understands that everyone is responsible for working together to reduce flood risk.

Complementing this aspiration, are indicators which stakeholders should consider when supporting and empowering the community in this aspiration:

- Is clear on responsibilities for governance and action;
- Empowers the community to manage their own flood risk; and

- Promotes stakeholder and community participation in the decision-making process.

These indicators inform and shape the recommendations in this chapter by identifying means for stakeholders to e.g. empower the community to manage their own flood risk.

Through this stepped process, a nebulous term such as ‘resilience’ is translated to tangible actions.

11.2.4 Community Flood Resilience Aspirations

The community flood resilience aspirations adopted for this study are provided below in Table 11-1 to Table 11-3, divided into the elements of ***risk informed***, ***appropriately prepared*** and ***adaptable***.

Table 11-1 Community Resilience Aspirations: A Risk Informed Community

Risk informed, appropriately prepared and adaptable communities	What this means for councils, state governments and organisations
• Assesses flood risk by seeking comprehensive and local information from trusted sources, and personal or shared lived experience.	• Undertakes comprehensive flood risk assessments. • Translates flood risk to a community, neighbourhood or household scale. • Provides flood risk information using: ○ Easy to understand language. ○ Formats and media channels which are readily accessible to the entire community (including vulnerable or hard to reach communities). ○ Consistency in language, terminology and approach with other organisations providing information for the same community. • Communicates risk and uncertainty. • Captures and promotes the sharing of past flood experiences.
• Acknowledges that they live in a floodplain, and not all risk can be eliminated.	• Assesses the full range of flood risk, up to and including extremely rare events. • Provides information on the full range of flood risk, emphasising that the future will be different from the past. • Promotes some flooding as desirable.
• Assesses strengths, capabilities, vulnerabilities and capacity to respond to flood risk.	• Involves the community in planning for flood resilience to build capabilities and capacity to respond. • Identifies strengths, capabilities, vulnerabilities and capacity of community to respond to flood risk. • Provides tailored support, information and capacity building for communities which are vulnerable to flooding or do not have sufficient capacity to respond appropriately.
• Understands that everyone is responsible for working together to reduce flood risk.	• Is clear on responsibilities for governance and action. • Empowers the community to manage their own flood risk. • Promotes stakeholder and community participation in the decision-making process.

Table 11-2 Community Resilience Aspirations: An Appropriately Prepared Community

Risk informed, appropriately prepared and adaptable communities	What this means for councils, state governments and organisations
• Has the capacity, skills and knowledge to prepare, safely respond to and recover from a flood.	• Contributes to a risk informed community (see above). • Provides ongoing and effective flood awareness and education programs and activities. • Builds networks of community leaders/champions with in-depth capacity, skills and knowledge. • Develops systems for appropriate community response (such as coordinating volunteers).
• Has strong social alliances and networks, including with local leaders and partnerships with emergency services, local authorities and other relevant organisations, and existing connections. Knows who they can help, and who can help them.	• Incorporates community development approaches in resilience building activities wherever possible. • Delivers community resilience building information and activities through existing social networks to reinforce and strengthen these networks. • Supports social alliances and networks as a component of various government functions, wherever possible (invests in community development approaches beyond direct flood applications).
• Makes informed decisions and takes appropriate measures to reduce exposure to floods including to potential loss of life, assets, and livelihoods. • Appropriately modifies these measures as risks evolve (including considering changing conditions during a flood, future climate, impacts of development or infrastructure, and changing demographics in the community).	• Provides timely and relevant information about changing circumstances (hazard, exposure, vulnerabilty). • Invests in communication systems to provide information to the community, and for the community to communicate with each other and authorities as risks evolve. • Facilitates flood resilient urban and rural planning. • Facilitates flood resilient built form outcomes. • Supports the community in preparation and response measures, including provision of aids (such as sandbags).
• Plans for continuity (households, businesses and community organisations and institutions), including investing in measures to lesson impacts, being appropriately insured, and developing plans in advance.	• Provides templates and guidance materials to assist with planning for continuity, based on research of effective strategies and tailored for specific users such as households, businesses, community groups, and other institutions. • Engages with representatives and peak bodies for businesses and insurance to facilitate provision of relevant information and support.
• Prepares psychologically for potentially traumatic events.	• Supports the community to prepare psychologically for potentially traumatic events, informed by research and tailored to suit local community characteristics and past flood experience.

Table 11-3 Community Resilience Aspirations: An Adaptable Community

Risk informed, appropriately prepared and adaptable communities	What this means for councils, state governments and organisations
• Adjusts response in rapidly changing circumstances including changing flood conditions, infrastructure conditions and availability of support.	• Provides timely and relevant information during floods, including flood warning, identification of potential impacts and recommended response measures. • Provides information across a range of media to ensure system redundancy in changing circumstances.
• Draws on community alliances and networks for rapid and effective disaster response.	• Establishes communication protocols and clarifies responsibilities for engaging community alliances and networks during flood events. • Includes community leaders/champions in formal disaster management response planning.
• Reassesses and reorganises approaches based on evaluation and learnings.	• Undertakes evaluations of resilience building activities and evaluations of flood event response, shares the outcomes of these evaluations, and modifies future activities based on learnings.
• Identifies and introduces new resources, tools, technology, and courses of action to improve resilience over time.	• Identifies gaps in current activities and develops resources, tools, technologies and courses of action based on best-practice and current research.

11.3 Current Community Resilience Snapshot

11.3.1 Introduction

A ‘snapshot’ of the current state of community awareness and resilience in the catchment was developed using information from numerous sources, including:

- Demographic analysis of vulnerable communities, and mapping of sensitive infrastructure, such as schools, undertaken as part of Section 4 Current Flood Risk;
- Community surveys of residents in the Brisbane River floodplain, undertaken by Geoscience Australia following the 2011 and 2013 floods;
- Market research of residents living in the Brisbane River floodplain, undertaken as part of this component of the Phase 3 (SFMP) (Appendix S and Appendix U); and
- Community survey of residents living in the Brisbane River floodplain, undertaken as part of this component of the Phase 3 (SFMP) (Appendix V).

The demographic analysis and mapping of sensitive infrastructure provides a spatial context to the resilience snapshot, while the Geoscience Australia surveys (and to a lesser extent the market research) provide some temporal data, showing how attitudes and responses change over time.

Resilience is a challenging and nebulous concept which can mean different things to different people. Understanding what resilience looks like in a community (as advocated in the National Strategy for Disaster Resilience and the Queensland Strategy for Disaster Resilience) is a practical way to assess resilience. Information from surveys and market research supports our understanding of the community’s current resilience.

11.3.2 Vulnerable Communities

Residential communities can be more or less vulnerable to the potential impacts of flooding depending on the socio-economic and demographic characteristics of the communities within and surrounding the floodplain. Vulnerability to flood exposure is an important metric in the consideration of flood risk and the management measures used to address it. Vulnerable communities are impacted by flooding more than non-vulnerable communities due to the inherent characteristics of the community.

An assessment of vulnerable persons was undertaken in Section 4 Current Flood Risk. The assessment considered community-scale socio-economic and demographic characteristics that can magnify the effects of flood exposure, over and above physical impacts such as property damage.

A recent meta-analysis (Rufat *et al.*, 2015) of 67 flood disaster case studies undertaken between 1997 and 2013 sought to identify the key drivers of social vulnerability to floods. The meta-analysis recognised that demographic characteristics (particularly age), socio-economic status, and health (particularly in relation to mobility) are the social attributes most strongly related to vulnerability to floods. Assessment of these attributes was undertaken in this study using information derived from Australian Bureau of Statistics census data, collected in 2016.

Relative community vulnerability was assessed within the Brisbane River study area by considering four different vulnerability indices. Each vulnerability index comprises three or four specific vulnerability characteristics, as available through the 2016 census data, and mapped at the Statistical Area 1 (SA1) scale, which is the finest resolution available for census data.

11.3.2.1 Vulnerability Indices

Four vulnerability indices were developed to describe the social vulnerability to flooding of communities in the floodplain. These indices generally seek to capture those attributes identified by Rufat *et al.* (2015), with an additional index to capture vulnerability due to potential low flood awareness. Each index describes a different type of vulnerability: physical vulnerability; social and economic vulnerability; mobility vulnerability; and awareness vulnerability. By understanding these different types of vulnerabilities, it is intended that flood management measures can be suitably targeted.

Each vulnerability index comprises three or four vulnerability characteristics, as available through the census data. There is not sufficient research available to indicate whether certain characteristics are more strongly related to vulnerability than others (e.g. whether older people are more vulnerable than children), hence each characteristic has been given equal weighting within the index. The composition of the adopted vulnerability indices is provided below. Further detail about the derivation of these indices, and mapping of the relative vulnerability, is provided in Section 4 Current Flood Risk.

Physical Vulnerability

The physical vulnerability index seeks to describe those communities with heightened vulnerability due to age and disability. It was calculated using the following attributes:

- Percentage of population under 5 years
- Percentage of population 65 years and over
- Percentage of population 65 years and over, and living alone
- Percentage of population who require assistance with everyday living.

Social and Economic Vulnerability

The social and economic vulnerability index seeks to describe those communities with heightened vulnerability due to limited financial capacity to recover from the impact of flooding. It was calculated using the following attributes:

- Percentage of population living in rental accommodation
- Percentage of households with low household incomes (less than $600/week)
- Percentage of population who are unemployed.

Mobility Vulnerability

The mobility vulnerability index seeks to identify those communities where households or families may have difficulty evacuating during a flood. It was calculated using the following attributes:

- Percentage of households with no private vehicles
- Percentage of single parent households
- Percentage of households with three or more dependent children.

Awareness Vulnerability

The awareness vulnerability index seeks to identify those communities that may have a low level of awareness, or difficulties accessing and understanding flood warning messages. It was calculated using the following attributes:

- Percentage of population who are new to the area
- Percentage of population with little or no English skills (speaks language other than English at home and speaks English 'not well' or 'not at all')
- Percentage of population with limited or no access to the internet.

11.3.2.2 Limitations of Approach

There are numerous factors which may increase a community's vulnerability which could not be assessed as part of this study, such as primarily levels of household insurance and community resilience, which can influence a resident's ability to withstand and recover from flooding. Insurance information is not available for this study, though it might be assumed there is a correlation with the social and economic vulnerability index.

The vulnerability assessment undertaken in Section 4 Current Flood Risk sought to identify vulnerabilities due to inherent community characteristics. These characteristics were limited to data which is captured in the Census and therefore does not describe residents or sections of the community who are not well described in the census, such as homeless people and travellers.

Some vulnerability characteristics, such as age, are not necessarily clear indicators of community vulnerability. Rufat *et al.* (2015) note that although young children are generally considered to be more vulnerable than adults, children can also "serve as resilience drivers by bringing together community networks through their schooling, or by providing assistance to the household during recovery processes".

The approach used to represent aspects of vulnerability via the indices (which combine multiple vulnerability characteristics) provides indicative and relative results only.

11.3.2.3 Summary of Assessment

The assessment identified that many highly vulnerable residents live in the inner Brisbane suburbs, such as West End, St Lucia, and within the Oxley Creek floodplain, such as Rocklea and Oxley. These residents were identified as highly vulnerable due to a combination of the high proportion of renters, people without cars, new residents and / or limited or no English. There are also residents in suburbs such as Brassall, Goodna, One Mile, East Ipswich, North Booval, North Ipswich, and Somerset who were identified to be highly vulnerable due to a combination of indices. In the Lockyer Valley local government area, residents in suburbs such as Lockrose are considered vulnerable, primarily due to physical and socio-economic factors. It is noted that many residents in areas adjacent to the upstream reaches of the Lockyer Valley, such as Forest Hill, Murphy's Creek, Helidon and Gatton may also be highly vulnerable, but are outside the present study area boundaries.

11.3.2.4 Sensitive Infrastructure

Certain land uses are more sensitive to the impacts of flooding due to the nature of the communities who live or spend large amounts of time in those locations. These land uses include (but are not limited to): schools, child care centres, hospitals, aged care facilities, caravan parks and gaols/detention centres.

A preliminary identification and assessment of sensitive infrastructure in the floodplain was undertaken in Section 4 Current Flood Risk.

11.3.2.5 Further Studies

Assessment of community vulnerability at a regional-scale is the first step in identifying more vulnerable residents or communities. Councils and other local authorities will have a greater understanding of the nature of their own communities and should undertake a more thorough analysis of vulnerabilities in detailed Strategic Floodplain Management Plans (see Section 11.6.4.1 for further details).

11.3.3 Community Surveys (Geoscience Australia)

11.3.3.1 Background

Geoscience Australia undertook two, paired social surveys titled 'Household experiences of flooding in Brisbane and Ipswich, Queensland' to investigate the impacts on households from the 2011 and 2013 floods. The first survey (undertaken April – May 2012) invited 5,000 households to participate, with 1,267 households responding. All respondents that expressed a willingness to participate in further research were approached for a second survey in October – November 2014. Of the 772 households that were contacted, 440 participated. All households were within the 2011 flood extent, and therefore directly affected by flooding in the recent past. Both surveys were undertaken as postal surveys.

11.3.3.2 Structure of Questions

Questions in the survey were grouped into the following key themes or categories:

- Warnings and risk perception:
  - Warnings, warning relevance and sources;
  - Interpreting warnings;
  - Risk perception;
- Preparation, evacuation and moving back home:
  - Preparing for the floods;
  - Evacuation and relocation;

  - Returning home;
- Damage and repair;
- Flood damage;
  - Disruption to the household;
  - Repair and rebuild;
  - Deterioration after repair;
  - Mitigating against future flooding;
- Financial implications;
  - Extra costs and finance;
  - Working following the flood;
  - Property values;
- Medical impacts, mental health and support;
  - Medical impacts;
  - Subjective well-being;
  - Mental health; and
  - Support.

A full list of questions was not made available for this study.

11.3.3.3 Findings

Key findings from the surveys has been summarised below into the themes of risk perception, preparedness, capacity to adapt and community connections (with a few additional points captured under 'other'). The Geoscience Australia report on these two surveys can be accessed online [does not include the survey questions]: http://www.ga.gov.au/scientific-topics/hazards/flood/reports.html.

Risk Perception

- Risk perception must be appropriate before a flood is imminent;
- Many households had a poor perception or incorrect assessment of flood risk / likelihood of impact, and therefore disregarded warnings as not relevant to their household;
- 46% of households did not know that their house was at risk of flooding before the 2011 floods;
- Lack of understanding that flood levels can change with new modelling and analysis, and changes upstream contributed to a poor perception or incorrect assessment of risk / likelihood of impact;
- Respondents who received warnings from multiple sources were more likely to consider the warnings to be relevant to them. Some might suggest this is about households not understanding or taking seriously the warnings, however could also be households gathering data (from multiple sources) to assess their own risk. Households generally looked to television, radio, websites and

friends, family and neighbours to 'triangulate' warnings and assess their relevance for the individual household.

Preparedness

- Prior to the 2011 flood, 71% of households thought their insurance covered flooding. However, 32% of households had their claim fully paid, with 13% partially paid (45% total);
- The median time to return back home after the 2011 flood was three weeks, with a mean /average of three months;
- Various other financial costs were incurred, even for insured households including: temporary accommodation, high utility costs (mainly from water used to clean up), cleaning and transport costs. In addition, various assets were often excluded from insurance coverage, such as swimming pools, gardens and fences. Some households also required out of pocket expenses, even if they were later reimbursed;
- On average, household incomes were reduced for six months after the 2011 flood, and 19 days following the 2013 flood.

Capacity to Adapt

- Preparatory behaviour of households changed from the 2011 to 2013 floods. For instance, residents who sandbagged or lifted items for the 2011 flood, instead lifted items or removed them from the premises completely for the 2013 flood;
- 60% of households repaired like for like after being flooded in 2011. 19% replaced flooring with water resistant materials, 12% changed the use of lower level rooms, 11% installed water resistant linings, 8% raised electrical outlets, and 5% elevated the homes. The reasons for not building back better included inflexible insurance companies, lack of money, or timing (for example, some households would consider raising the house at a later date, but their immediate priority was to move back in);
- Mental health issues were reported by many respondents, with some respondents indicating that mental health issues had a greater impact on their life than damage to their homes. Some respondents are receiving treatment for depression and suicide. A high proportion continue to get nervous or anxious when it rains.

Community Connections

- Friends, family and neighbours provided a common thread throughout the surveys, and had a vital role in many aspects of community flood resilience;
- Friends, family and neighbours assisted in warning households and encouraging households to undertake an assessment of risk and actions;
- Households where someone volunteered in any organisation moved back home faster;
- Respondents had mixed feelings about the 'mud army'. In general, respondents were grateful for help, but it was noted that some volunteers were over-enthusiastic and threw out items indiscriminately;

- Reconstruction and repair work was most often undertaken by insurance companies and private contractors, however friends and family also contributed in around 40% of households;
- After the 2011 flood, there was a bump in the proportions of respondents who felt they could ask for support in times of crisis from friends (change from 73% in 2011, to 87% in 2013), neighbours (change from 56% in 2011, to 69% in 2013) and work colleagues (change from 33% in 2011, to 48% in 2013). This supports the idea that social capital is not depleted when it is used, rather it is enhanced.

Other

- One quarter of respondents reported that at least one member of the household required medical treatment following the 2011 flood, with some acquiring long term health conditions; and
- 88% of households expected councils to provide information on flood risk, 54% from State Governments.

11.3.4 Market Research

11.3.4.1 Background

Market research was undertaken by the Queensland Government as part of the Phase 3 (SFMP) to further develop an understanding of the community's flood awareness and resilience within the catchment. The research was undertaken by a market research company as an online survey of approximately 800 residents with respondents being sought for each postcode within the four council areas of Brisbane, Ipswich, Somerset and Lockyer Valley. The online survey method returned only limited responses for Somerset and Lockyer Valley residents, and as a result a 55 further telephone surveys were undertaken for these areas. Selection of respondents sought to capture people who lived in the study area (lower Brisbane River floodplain), with approximately half of respondents within the 2011 flood extent.

The initial phase of the market research was undertaken between 8th and 22nd May 2017, with the subsequent phone survey undertaken between 5th and 10th July 2017.

11.3.4.2 Structure of Questions

The questions used in the market research sought to repeat some of the themes addressed in the Geoscience Australia surveys where possible. To facilitate a high response and completion rate, the survey was deliberately brief with only a few optional free text questions. The market research questions were grouped into the high-level topics of:

- Risk perception and preparedness;
- Information;
- Social capital; and
- Economic resources.

The market research report is provided in Appendix T with further analysis at the local government area scale undertaken by the QRA, provided in Appendix U.

11.3.4.3 Findings

Key findings and statistics from the market research are summarised below (this includes both online survey and phone survey).

- Direct and indirect impacts to businesses have been substantial with 32% respondents expecting flooding to their workplace during a major flood. Around 68% of respondents noted that they needed to take time off work during recovery;
- Evacuation was identified as a major issue, with most respondents indicating they don't have a planned evacuation route if a flood event occurred today;
- Residents are prepared to help each other evacuate if needed, with 67% responding they could help with transport;
- Councils are relied upon to provide flood risk information, with 86% of residents expecting to receive this information from their local council. Other nominated sources include professional bodies, such as real estate agents, insurers and lawyers, and in their rates notices;
- Personalised / tailored warning information is highly valued by residents, with 84% of respondents more likely to take action (e.g. evacuation) if their suburb or street is named in an alert. 50% of respondents noted they would need to hear a warning from an official source, such as council or the SES, before taking action;
- Respondents are prepared to help each other, even if they don't know it yet. 95% of respondents indicated they'd be in a position to help others during a flood event, but 30% of respondents feel they wouldn't have any family, friends or neighbours to call upon if they needed help with e.g. sandbagging, lifting furnishings, cleaning up, emotional support etc.;
- Respondents have a sense of personal responsibility, with 93% noting that individuals are primarily responsible for their own safety during flood events;
- Older residents are generally more prepared with basic preparations such as torches, radios and evacuation kits;
- Respondents continue to be confused about flood insurance coverage, with 25% of respondents unsure whether their home building or car would be covered, and 20% unsure about contents insurance. Large numbers of residents believe they don't have enough insurance;
- A large proportion of the community would struggle to handle a major flood event, with 20% of respondents indicating that they would be in some or extreme financial distress if they were unable to work for two weeks due to flood impacts; and
- A notable proportion of the respondents (14%) have insufficient networks to support them for a few days if they were forced to evacuate in an emergency situation (increasing to 33%, if respondents were out of home for a few weeks).

Respondents were asked in a free text question: *What else could the Queensland Government do to help?* A selection of responses reflecting key themes by respondents is provided below:

- Provide regular and consistent information via a variety of communication channels;

- Be clear about what is known and what is not known;
- Avoid generic warnings; provide specific warnings;
- Centralised source of information and consistent messaging;
- Release likely flood maps in lead-up to events;
- Greater communication to households around future planned evacuation centres;
- Teach children in primary and high school flood safety; and
- Use different road closed signage for inundation than construction works.

11.3.5 Community Survey

11.3.5.1 Background

An online community survey was undertaken by the QRA between 14th August and 15th September, supported by promotional stands at various community events around the catchment. This survey had two separate sections:

(1) Community acceptance of structural options; and

(2) Community sourcing of flood information.

186 responses to the survey were collected, from the following local government areas:

- 49% from Brisbane City Council
- 23% from Somerset Regional Council
- 12% from Ipswich City Council
- 8% from Lockyer Valley Regional Council
- 9% from other council areas

11.3.5.2 Structure of Questions

The questions relating to community awareness and resilience sought to identify:

- The types of information that residents need before, during and after floods;
- Which council areas information is typically needed for;
- Trusted information sources, and whether conflicting information is an issue;
- Whether community networks and organisations could be used to help inform and prepare residents for flooding; and
- Whether community champion programs are perceived to be of value in preparing for flooding.

11.3.5.3 Findings

Findings which relate to community awareness and resilience measures, or broader floodplain management principles and priorities are provided below:

- More than 1/3 of the respondents work in a different council area to where they live, and more still would seek information from numerous council areas during flood events.
- Nearly ¾ of respondents believe that ‘increasing community safety during floods’ is the most important priority when selecting flood management options, followed by ‘reducing the cost of flood damages’ (66%).
- 20% of respondents have been at their current address for less than five years (although this does not necessarily imply that residents are new to the broader area).
- Community awareness initiatives were identified to be the second most important type of measure for managing flood risk (behind land use planning and development controls).
- More than half (58%) of respondents had checked flood mapping online, with 18% noting that they weren’t aware council provided maps.
- The information perceived to be most important during floods is road closure information and safe travel routes, how the predicted flooding compares to historic floods, the timing of flooding, and impacts to properties. Many other types of information were also seen to be valuable.
- Respondents were also interested in flood information for council areas beyond the Brisbane River catchment, particularly for adjacent council areas (e.g. Moreton Bay Regional Council, Logan City Council), but also state-wide.
- The information sources identified to be most accurate and timely were the Bureau of Meteorology, Queensland Police Service and Queensland Fire and Emergency Service, and local councils (in that order).
- Nearly 1/3 of respondents indicated they have been involved with community groups which have the potential to get involved with flood preparation and recovery. These groups include church groups, rural fire brigade, rotary clubs etc. Support for a community champions group was relatively high, with around half of respondents prepared to support such an initiative, and less than 20% against.

[The full set of Phase 3 (SFMP) community survey results is provided in Appendix V. Note that 185 responses is a relatively low response rate compared to the population who potentially live, work and recreate in the floodplain. Information received in the survey may therefore not be representative of all viewpoints and should be cross-checked via other information sources.]

11.4 Review of Resilience Activities Literature and Case Studies

11.4.1 Literature and Case Studies Reviewed

A review of available literature and case studies on resilience activities was also undertaken to identify best-practice principles, and successful implementations of resilience activities. The literature review of resilience activities covered:

- Australian Institute of Disaster Resilience Guidelines for the Development of Community Education, Awareness and Engagement Programs (Commonwealth of Australia 2010) – one of the most comprehensive reviews of the effectiveness of community resilience activities available in Australia;

- Australian Institute of Disaster Resilience Handbook 6: National Strategy for Disaster Resilience: Community Engagement Framework (2013);
- State of Victoria (2012) Victorian Emergency Management Reform: White Paper response to the Black Saturday bushfires in 2009 in Victoria; and
- Various journal articles including by Neil Dufty, Steven Molino and others, on the effectiveness of various activities and interventions, including flood education, emergency plans, connected communities and flood resilience, social capital in community resilience and post-disaster recovery, effectiveness of warnings, flood memories, behaviour change models and social influences on readiness.

Case studies investigated ranged from small-scale local interventions to regional activities and strategies. The case studies are generally from the Australian context, however, some international examples were included, and relate to various hazards, including flooding, cyclone, bushfire, and heatwaves.

Case studies used to inform this study were identified based on the knowledge of the project team on effective programs, programs recognised with state-based and / or national resilience awards, and the availability of detailed information and formal evaluations on the programs. A smaller number of case studies were then selected to cover the breadth of resilience activity types (from awareness campaigns through to community-led initiatives), and ensuring a balance between national and international examples, and flood specific, single hazard and multi-hazard programs.

The following case studies were reviewed:

- Woronora Flood Preparedness Strategy awareness activities;
- Hunter Valley awareness and education activities;
- City of Yarra Keep Cool / Stay Healthy in the Heat program (Resilient Australia National Award - Highly Commended 2016);
- Operation Bushfire Blitz / Fire Ready Victoria street meetings;
- Street FireWise program;
- Angelsea ‘Survive and Thrive’ schools program (Resilient Australia National Award - School Award 2016);
- Psychological preparedness trial;
- Coffs Harbour floodplain management community engagement;
- Lake Macquarie Marks Point and Belmont South Local Adaptation Plan community engagement;
- Victorian community-based resilience building case studies compendium;
- Managers of spontaneous emergency volunteers pilot program;

- Mansfield community planning and resilience leadership program (Resilience Australia National Award – Highly Commended 2015);
- ACOSS Resilient Community Organisations toolkit;
- Emerald Community House as Centre of Resilience (Resilience Australia Victoria Award – Community Award Highly Commended 2016);
- BOCO Strong: Community Powered Resilience;
- Resilient Melbourne (Resilience Australia Victoria Award – Government Award Highly Commended 2016); and
- One New York Resilience Strategy.

Only a select number of case studies have been included in Appendix W that relate to the recommendations of the study. The full bibliography of reviewed literature is included in the reference list.

11.4.2 Findings of Review and Principles for Resilience Activities

Findings from the review of literature and case studies on specific resilience building activities are outlined below.

- **Local context is important to the effectiveness of resilience activities.**

  Local context – including the history of previous resilience activities, the history and recentness of disaster events in the local area, the vulnerabilities and capabilities of target groups and existing community networks – is important in determining program success. There is therefore no one 'best-practice approach' to resilience activities, and highly effective resilience activities in one local context may have a different level of effectiveness elsewhere.

  Local context elements include:

  - Geographic context of the locality (inner city, urban fringe, rural township, rural);
  - Livelihoods and lifestyles of the community;
  - Community characteristics, vulnerabilities and networks;
  - The nature of past and present events;
  - Past engagement and interest in the issue;
  - Relationships with organisations during planning and implementation; and
  - Availability of funding.

  Despite differing local contexts, there continues to be value in developing regional approaches and coordination of resilience activities at a regional level. A regional approach to community awareness and resilience can contribute to developing consistent language / terminology, mapping and symbology to aid understanding and interpretation; improve efficiency in planning and execution of activities; and when coordination is required between councils and / or state government departments and organisations.

Flexible adaptation of regional resources to local contexts may be more effective in achieving community preparedness and resilience, including incorporating local planning knowledge and expertise, and local implementation. For example, a regional information factsheet and workbook could be developed regionally with consistent language and terminology, but adapted with locally relevant examples and mapping, and utilised in locally planned and organised workshops and events.

- **Suites of activities should be implemented which target different steps on the pathway from hazard awareness to preparedness.**

  A range of resilience building activities are available from multi-hazard, community-wide information dissemination campaigns to hazard-specific, neighbourhood-scale events and individual empowerment activities. Resilience activities can vary on at least three characteristics:

  - <u>Information specificity</u>: A multi-hazard, multi-organisation approach may be useful to distil information into common actions which limits the number of voices communicating with the community. Awareness and preparedness information focusing on a specific hazard is also useful.
  - <u>Audience targeting:</u> Community-wide awareness campaigns can be cost efficient to provide information and raise awareness. Neighbourhood-scale awareness campaigns are also useful to target specific communities with relevant local information or particularly vulnerable groups. Specific segments of the community may also require tailored messages, including in languages other than English, in sign language, etc.
  - <u>Level of engagement / participation</u>: Awareness and knowledge do not necessarily lead to behaviour change but are an important step in the process. A deeper level of engagement can assist in influencing attitude and behaviour change including activities recognising the importance of emotion as well as cognitive processes.

  Activities across these spectra of targeting, information specificity and participation can all have a place in contributing to community resilience when relevant to the community context and identified community needs, and focused on progressing target audiences along the pathway from hazard awareness, to attitude change, to behavioural change / preparedness.

  Suites of activities which deliberately respond to the community context and needs, and target pathways to behaviour change, should be implemented. These suites should include activities from across the spectra of audience targeting, information specificity and level of engagement as appropriate to achieving project outcomes.

  In addition, it is recognised that resilience building strategies need to be ongoing and long-term but the specific activities used within the strategy may change over time and be refreshed based on appraisal and changing information/context.

- **Social networks are important to resilience outcomes.**

  Social networks have been found in multiple studies to improve community resilience, and can contribute to better mental health outcomes. Social networks can be strengthened through a variety of implementation approaches:

  - Community-based planning / participatory planning: Involve the community in developing local resilience plans / all-hazard disaster management plans etc. potentially via avenues such as community resilience committees. The process of developing the plan builds resilience and increases community ownership of the plan and outcomes. A suite of tools is useful to encourage involvement by participants from all backgrounds, development must be community-led and supported by emergency services, and may require efforts from emergency services or other stakeholders to build capacity and sustain community involvement.
  - Integrate risk assessment and planning into existing community development programs: This approach builds on transferrable community skills developed through existing community planning activities and social action groups, and mobilises these skills towards hazard and risk management. This approach also provides a 'return on investment' in everyday community life, not just in the event of a future disaster. There are multiple approaches for implementation of this strategy:
    - Inviting representatives of existing community groups to participate in hazard / risk management planning;
    - Training community leaders in hazard / risk management which they can then build into their community work;
    - Work with volunteers involved in existing community groups who can then act as community leaders; and
    - Emergency management organisations act as consultants to work within community groups – including as facilitators, mentors, advocates, change agents, coordinators – to help identify needs, provide information and resources, think about integrating in vision / goals etc.
  - Social media networks: Promotion of involvement in social media networks before, during and after events.
- **Deeper engagement approaches are required, including emotional and social involvement.**

  Information dissemination is important to raise awareness of new information and resources, and to assist the community to incorporate new information in their assessments of risk. However, reliance on information dissemination only has been found to be inadequate to achieve community resilience. More work is required to develop approaches to guide programs that create attitude and behavioural change before, during and after an emergency, not just increase awareness.

  A deeper level of engagement is important to influence behaviour including a participatory approach to strategy development, and including emotional and social appeals/elements in resilience activities. For example, memories of past experiences can be powerful emotional triggers.

  The following aspects of community participation should be incorporated in resilience building:

  - Community members actively participate in planning and preparation to enhance their own safety;
  - Community members are involved in programs, for example, identification of community champions and supporting them with resources and training; and
  - Community members are involved in program initiation, design, implementation and management (community-based planning / participatory planning).
- **Evaluations of implemented resilience building activities are an important part of building community resilience to improve effectiveness.**

  Evaluations of the effectiveness of community awareness and resilience activities were undertaken irregularly in the reviewed case studies. Evaluations often relied on one source of information, and information put together by the organisation implementing the program, rather than an independent third-party.

  Where evaluations were undertaken, they often did not clearly describe how the activities implemented were expected to improve preparedness (a program theory model). As a result, evaluations focused on measuring the awareness of the information campaign itself, interaction with the materials provided, and concern about the hazard, rather than an indicator of preparedness that was the target of the activity.

  To assist with implementing the most effective resilience building activities, activities should include a clear program theory model before implementation and a proportion should be evaluated for effectiveness during and after implementation.
- **Communication materials should adopt clear language, consistent terminology, visually attractive design, and diagrammatic and simple presentation.**

The principles outlined in these findings shape the approach to recommendations outlined in Section 11.6.

11.5 Review of Current Resilience Activities

11.5.1 Introduction

Project stakeholders, including councils, state government departments and organisations, and community organisations are currently undertaking numerous activities to improve the community's flood resilience and awareness. A review of community awareness and resilience activities currently being undertaken by project stakeholders in the region was undertaken during the study, which sought to better understand what activities are being undertaken and which activities are working well, as identified by stakeholders. Project stakeholders consulted through this process were:

- Seqwater;
- Queensland Fire and Emergency Service;
- Department of Communities;
- Department of Environment and Heritage Protection;

- Ipswich City Council;
- Lockyer Valley Regional Council;
- Brisbane City Council; and
- Somerset Regional Council.

It is recognised that there are other stakeholders who may be engaged in community flood resilience and awareness activities in the region, however, it is assumed that the consulted project stakeholders undertake most activities in the region and are aware of other activities that may be undertaken by other groups or organisations. Where project stakeholders referred to resources provided by other groups and organisations these were also considered in the review of activities.

A summary of the review is provided below, reported in categories of whole of community, property-scale, business, vulnerable communities, and community partnerships. Note that this summary is guided by information provided directly by project stakeholders. The process did not review the content, with efficacy of activities self-identified by stakeholders.

11.5.2 Community-Wide Activities

11.5.2.1 Overview

Community-wide activities are broad-scale measures for the whole community. They are not targeted or customised to smaller groups or neighbourhoods in the community.

11.5.2.2 Warnings and Alerts

11.5.2.2.1 Early Warning Alerts

Early warning alert services are used by all four councils in the catchment (Lockyer Valley Regional Council; Somerset Regional Council; Ipswich City Council; and Brisbane City Council) and Seqwater (for dam release notifications) to send alerts to the community.

These are managed by private companies (Early Warning Network and Weather Zone), which offer a number of services related to weather and hazards. The warnings can be issued from systems directly or via an API which interacts with other systems, and can be geographically targeted by e.g. drawing a polygon in GIS to identify an area of interest. Individual organisations (such as councils) generally generate their own alerts through the system and distribute alerts to individuals who have opted-in to the service with that particular organisation.

A representative from Ipswich City Council noted that Council chose a relatively high threshold for when notifications were sent out in order to avoid community members receiving too many alerts, which might be ignored.

It was suggested by one stakeholder that the uptake for the EWN service could be higher as it does not yet include all households in the community.

11.5.2.2.2 Emergency Management Dashboards

Ipswich City Council, Lockyer Valley Regional Council and Somerset Regional Council have implemented similar emergency management dashboards (marketed by QITPlus) which republish dynamic information on road conditions (from Queensland Traffic), weather warnings and fires (from the Bureau of Meteorology and QFES), and power outages (from Energex), and provides links to river height data (from the Bureau of Meteorology) on a single online interface. Some dashboards also republish council website posts related to a disaster event, and show council social media feeds.

Information republished on the dashboard is sourced from other organisations (as noted above) through published data feeds, and through social media providers. The organisations and social media providers (Facebook and Twitter generally) allow this integration by providing their data formatted in a way that can be accessed and interpreted by a computer (that is, the dashboard server). The computer accesses this data automatically based on a set refresh timeframe (every 10 minutes, for example)[38]. The data can then be stored in a database (so it can be displayed between refreshes), combined with other data, and displayed in different ways on a single interface.

Currently the emergency management dashboards provide information for the specific local government area only, and do not provide links to dashboards for surrounding local government areas. This could be a simple addition to assist people looking for information for multiple government areas.

A representative of Ipswich City Council noted that the implementation of the dashboard has led to a reduction in phone calls to Council during storm events, which has freed up telephone lines for people without access to the internet, people who don’t use the internet, and vulnerable people who need specific information. It was also noted that media organisations use the dashboard to access information to share with their audiences so the information has a broader reach than just visitors to the website portal.

11.5.2.2.3 Other Alert Websites / Systems

In addition to the warning and alert websites and systems noted above, other websites and systems identified in the review included:

- The Queensland Government’s disasters and alerts website (qldalert.com) which republishes the social media feeds of a variety of organisations that publish alerts, including:
  - Biosecurity Queensland (Twitter);
  - Bureau of Meteorology (data feed);
  - Department of Communities, Child Safety and Disability Services Community Recovery (Twitter);
  - Department of Transport and Main Roads – Metro; North and South Coast; Darling Downs and South West; Far North and North; Central and North West; and Mackay, Fitzroy and Wide Bay (Twitter);

[38] The data cannot be updated each time a visitor to the website accesses the page as this can place pressure on the provider websites and result in access being blocked.

    - Electrical Safety Queensland (Twitter);
    - Energex (Twitter);
    - Ergon Energy (Twitter);
    - Fisheries Queensland (Twitter);
    - Queensland Education and Training (Twitter);
    - Queensland Fire and Emergency Services (Twitter);
    - Queensland Health (Twitter);
    - Queensland Park Alerts (Twitter);
    - Queensland Police (Twitter);
    - Queensland Rail (Twitter);
    - Queensland Rural Fire Service - Rural Fire Map (Google Maps feed);
    - Queensland Urban Utilities (Twitter);
    - Seqwater (Twitter);
    - Sunwater (Twitter);
    - Translink (Twitter and service status data feed);
    - Various councils (including all four councils in the catchment) (Twitter or Facebook);
    - Water Queensland (Twitter);

  Most of these social media feeds are from Twitter. The social media feeds are published without filters so not all of the shared content are alerts or provide emergency information.

- Queensland Fire and Emergency Service (QFES) provides updates on their newsroom page (newsroom.psba.qld.gov.au) which is a website for dissemination of warnings and messages from the state government primarily for use by media organisations (includes videos and images to include with reports).
- Seqwater provides a free-call phone number offering an automated message about the status of dams in the region which is updated during emergency events. Seqwater also provides a mobile phone application that provides dam release notifications and alerts.
- Somerset Regional Council has installed sirens at Fernvale and Lowood to provide flooding alerts. Warning sirens are installed at Schmidt Road, Fernvale and Lindemans Road, Lowood and have been designed to activate and issue a loud alarm shortly before a flood to notify residents there may be a need to evacuate.

11.5.2.2.4 Targeting of Alerts

The targeting of warnings and alerts was mentioned in the review of activities. For example, one stakeholder noted that it did not matter if community members received the same notification from multiple organisations as long as the content is consistent, while others suggested that targeting information and messages to particular communities and making warnings more relevant to them rather than region-wide messaging is preferable.

One stakeholder representative noted that there are a variety of alert services provided in the region, including by different councils and different services, and therefore people who are visiting other council areas, or who live and work in different council areas, would need to register with multiple services to get alerts relevant to their location. This is a limitation of delivering alerts through local government based systems.

11.5.2.3 Information Campaigns – Website, Newsletters, Brochures etc.

11.5.2.3.1 Get Ready Queensland Program

The Queensland Government's Get Ready program provides state-wide guidance on how to prepare for all hazards, which are then used by organisations, councils, businesses, and industry in their messages to the community. An advantage of this approach is that it helps deliver a consistent message to the community throughout Queensland. For example, even external organisations, such as Telstra and Queensland Urban Utilities, use the Get Ready guidelines / messaging as the basis of their awareness campaigns.

Get Ready Week is an annual event that is used to raise awareness about disaster preparedness in the lead up to the annual storm and cyclone season. Various organisations and councils coordinate events and programs around this time to further the messages of the Get Ready campaign.

The program also funds a range of locally implemented activities. For example, Ipswich City Council developed a series of three small videos to educate the community which were funded through the Get Ready program. The videos were popular on social media, and have been used by local schools. The videos were seen to be successful because they were made locally, in and for Ipswich, and therefore resonated with the community.

11.5.2.3.2 Other Information Campaigns

QFES provide information brochures for all-hazards, because it is recognised that much of the same preparation is needed for multiple hazards, and that these preparedness actions assist in other emergency situations that are difficult to plan for (e.g. a security or terrorism incident).

In addition to organisation and council provided information, third-party providers are also supported, including for example, Green Cross Australia’s Harden Up website, which provides information and links to awareness and preparedness actions.

Volunteering Queensland provides many resources online for use with community education and engagement activities such as Disaster Readiness Index (to self-assess level of readiness, supported by actions to increase personal resilience), and Business Readiness Index. Numerous other resources and materials are provided to support community preparedness.

11.5.2.4 Mobile Phone Applications

Stakeholders provide or support the following mobile phone applications identified in the review:

- Emergency+: provides shortcuts for calling Triple Zero, SES and police, as well as current GPS coordinates of the user to share with emergency services. This application had been downloaded between 100,000-500,000 times for Android-based phones at September 2017.
- Self-Recovery (Department of Communities): Provides information on preparing and recovering from events including information on insurance, accessing personal and family support, business support, how to volunteer, how to donate goods and service and how to make a financial contribution to the recovery efforts.
- Ready Qld (iOS only): Developed by Volunteering Queensland to provide information to Queenslanders about preparing for disasters, and provide updates on emergency volunteering news and opportunities.
- SES Assistance QLD: Allows users to request assistance from the SES.
- Seqwater public safety app: Provides information on dam levels, dam release notifications and alerts, and recreation and safety notices, and can be used to request assistance. This application had been downloaded between 500-1,000 times for Android-based phones at September 2017.

11.5.2.5 Social Media

Social media are commonly used to disseminate information by councils, and state departments and organisations on a range of issues. Facebook and Twitter are the most widely used social media platforms. Social media accounts are often corporate agency or council social media accounts that are used to share a variety of content, not just warnings and emergency information.

The following social media accounts were identified in the review (recognising that numerous other accounts exist which were not directly identified by stakeholders during the review process):

- Get Ready Queensland (Facebook and Twitter)
- Queensland Fire and Emergency Services (Facebook and Twitter)
- SES Brisbane (Facebook and Twitter), SES Ipswich City (Facebook and Twitter), SES Woodford (Facebook)
- Rural Fire Brigade Brookfield (Facebook), Rural Fire Brigade Chambers Flat (Facebook)
- Seqwater (Facebook and Twitter)
- Queensland Traffic (Twitter)
- Queensland Police (Facebook and Twitter)
- Community Recovery – Department of Communities (Twitter)
- Bureau of Meteorology (Facebook, Twitter (Australia, and Queensland), YouTube)

- Brisbane City Council (Facebook and Twitter), Ipswich City Council (Facebook and Twitter), Lockyer Valley Regional Council (Facebook and Twitter), and Somerset Regional Council (Facebook and Twitter).

The SES has a number of localised social media channels for different SES groups, and some Rural Fire Brigades also have their own social media presence. However, the capacity and extent to which these social media accounts are used to share awareness and preparedness information, particularly alerts and warnings, differs.

Emergency management dashboards used by some councils (discussed in Section 11.5.2.2.2) connect with social media platforms to provide a single website with posts from a variety of social media accounts (for example, Facebook posts from Ipswich City Council and QPS are shown on the Ipswich City Council Emergency Management Dashboard).

Stakeholders suggested that social media can be useful for delivering real-time information to audiences when they are looking for information before, during and after disaster events. Stakeholders noted that social media use in the lead up to weather events was used effectively to refer audiences to organisation and council websites to gain more detailed information. Videos shared through social media were also suggested as being well received by the community.

Stakeholders however did express some confusion with social media protocols required to maintain a single point of truth for information shared online. For example, knowing which organisation is the single point of truth for different information and therefore sharing that information from the original source rather than through other sources.

Further challenging the management of social media messaging are 'unofficial' voices, such as Higgins Storm Chasing, a social media channel that repeats / reposts official messages and introduces new information about weather conditions, natural hazards, impacts etc. Higgins attracts almost 700,000 members to its Queensland-centric Facebook page, with an active posting schedule and highly engaged users. Although Higgins is the most well-known unofficial channel, other local voices were also identified by stakeholders. In general, it was noted that the community appreciated these unofficial channels providing highly local information (e.g. translating broad warnings to possible local impacts), but it was recognised that there was a high risk of unofficial channels introducing conflicting information (from official channels), or providing incorrect information.

11.5.2.6 Promotional Materials

Various stakeholders used promotional materials to raise awareness with a broad audience including through television, newspapers, radio, digital outdoor, online, and social media advertising. Promotional materials related to flood awareness and preparedness was generally targeted to storm season and during the period leading up to storm season (Get Ready Queensland, Brisbane Ready for Summer, campaigns) or the promotion of new services (new online flood mapping services, new mobile phone application, etc.).

Real-time advertising is often used to direct audiences to specific information sources when storms or heavy rainfall are predicted – for example, through digital billboards and advertising on the Bureau of Meteorology website. Radio advertising also has been used in this way. Social media advertising was considered useful to communicate in a timely way with residents and visitors before, during and after events.

At least one stakeholder suggested that real-time advertising, radio and television commercials worked well for larger severe weather campaigns in terms of marketing metrics. It was noted that newspaper advertising is not as effective as it once was as people are shifting away from newspapers to online news.

11.5.2.7 Signage

A representative of Seqwater noted that the use of digital signage at key creek / river crossings impacted by dam releases were working well to encourage uptake of / registration for digital services such as the Seqwater phone application, especially at North Pine Dam / Dayboro Rd.

11.5.3 Local Activities

11.5.3.1 Overview

Local activities are more targeted initiatives providing more specific information on hazards, targeting specific neighbourhoods or communities, or interacting with smaller groups of people in more engaging ways.

11.5.3.2 Flood Hazard Property Reports and Flood Awareness Maps

Brisbane City Council provides Floodwise Property Reports for all properties in the local government area through their website. These reports provide a comparison of ground levels for the particular lot and flood levels for various flood events (20%, 5%, 2% and 1% AEP, 2011 flood level, new Phase 2 (Flood Study) 1% AEP). However, these reports are generally related to planning and development (although separate to planning scheme maps and information), and contain limited information, or links to information, aimed at increasing flood awareness or preparedness.

Separately, Brisbane City Council provides Flood Awareness Mapping which provides an interactive flood map for the whole of the local government area. It provides information for all types of flooding (river, creek, storm tide and overland flow), and for various event likelihoods (5%, 1%, 0.2% and 0.05% AEP). This website also provides links to learn more about flood likelihood.

11.5.3.3 Direct Mail / Information in Rates Notices / Newsletters

Many councils used direct mail or information in newsletters and publications delivered to households to share flood awareness and preparedness information. For example:

- Brisbane City Council included ‘Be Prepared’ articles and inserts in rates notices and monthly newsletters.
- Brisbane City Council has used direct mail to inform individual households that there has been a change to their level of flood risk when new information on flood risk becomes available.
- Somerset Regional Council includes messages in quarterly newsletters.

- Ipswich included flood preparedness messages in multiple newsletters, and issued messages in rates notices regularly.

Some councils noted that they lacked the resources to use direct mail to target individual households with specific household-scale flood information.

11.5.3.4 Household Emergency Plans and Emergency Kits

Online resources were identified in the review which provide guidance on emergency planning and emergency kits, including:

- Brisbane City Council has information on their website and a factsheet (*Flooding in Brisbane: A Guide for Residents*) which includes guidance on preparing an emergency plan and a checklist for emergency kit contents.
- Ipswich City Council refers visitors to their website to Get Ready guides.
- Lockyer Regional Council promotes the Get Ready information on their website as well, and at events.
- Somerset Regional Council makes use of the QFES and Get Ready guides.

11.5.3.5 Business Continuity Planning

Brisbane City Council provides online resources targeting businesses to improve their resilience to flood. These resources include:

- A short video explaining suggested flood preparedness activities for businesses;
- *Flooding in Brisbane: A guide for businesses* provides introductory information to prompt businesses to think about:
    - Appropriate insurance, including for business interruption;
    - Business continuity planning, covering storing stock and equipment, backup of electronic files, alternative locations for work, needs for ongoing accounting / financial requirements (paying staff and suppliers, and billing clients), etc.
    - Information needed to contact employees, suppliers and customers;
    - Emergency and evacuation plans;
    - Storing hazardous material and leaving an evacuated workplace safe and secured;
    - Emergency kit contents; and
    - Emergency contact details.
- A Severe Weather Business Continuity Plan template is also provided which steps through the various stages of the risk assessment and plan development process.

Ipswich City Council and Lockyer Valley Regional Council refer businesses to:

- The Get Ready Queensland series of fact sheets on preparations for businesses; and

- The Business Queensland (Queensland Government) website which includes a range of resources for business continuity planning including videos explaining business continuity planning, a business continuity plan template, checklists, and strategies for business continuity plan management.

Evaluation on the effectiveness of these resources were not available.

The Department of Communities, Child Safety and Disability Services also advised it is preparing a toolkit to assist community organisation prepare for disasters and establish effective continuity plans and strategies.

11.5.3.6 Activities Targeting Vulnerable Communities

A range of activities were undertaken throughout the catchment targeting vulnerable communities, including:

- Targeting neighbourhoods with high flood risk:
  - ‘Street meets’ / small events in areas that are at risk of being isolated by flooding.
- Targeting cultural and linguistically diverse (CALD) communities:
  - Translating website content and information provided into other languages. For example, some Brisbane City Council information is simplified and translated into five languages, and Get Ready factsheets for flooding are available in more than 20 languages (these are hosted on the general Queensland Government website – qld.gov.au).
  - Emergency Management Australia (EMA) (Australian Government) provides handbooks, guides and communication materials for councils. Ipswich City Council teamed up with EMA to produce pictorial fact sheets about floods and other hazards for use with non-English speaking and residents with low literacy levels.
- Targeting aged people:
  - Ipswich City Council used Get Ready funding to hold disaster preparedness workshops targeting residential aged care providers and home care providers.
  - Brisbane City Council provides preparedness information in senior’s guide brochures.
- Targeting people with a disability:
  - Department of Communities has developed easy-English and symbolic representation resources for people with a learning disability or reading impairment. This resource includes various factsheets for different grants and support services available through Community Recovery and different disaster-specific factsheets.
  - Red Cross RediPlan is a planning resource for all-hazards and includes guidance on getting prepared for disasters in four steps: get in the know, get connected, get organised and get packing. These are available as online content and PDF guides (both on the Red Cross website), Auslan videos stepping through the sections of the guides (accessible from the general Queensland Government website – qld.gov.au), and an Auslan version and easy

English version of the booklet (available on the SES website however these could not be accessed and may have been removed).

- Targeting people experiencing homelessness:
    - Participation in Homeless Connect events sharing information on being prepared for severe weather and disasters with people experiencing homelessness.
- Targeting new residents / workers (migrants, temporary visitors (backpackers) and itinerant workers):
    - Lockyer Valley Regional Council participates in monthly welcome events targeting temporary workers (backpackers) and itinerant workers (where a range of information is provided including information on workers' rights, disaster awareness and other messages that are topical at the time e.g. biosecurity awareness of fire ants). Workshops tailored to newly settled migrants have also been provided.

11.5.3.7 Community Events

Organisations and local governments participate in an extensive range of local community events and displays throughout the year to promote flood risk and disaster management awareness and preparedness.

Local governments generally participated in local shows to share information about disaster preparedness, for example:

- Brisbane City Council participates in local events such as Green Heart Fair and Get Ready for Summer events.
- Ipswich Regional Council participates in the local show, as well as landowners' workshops, environment forums, etc.
- Lockyer Valley Regional Council participates in events including shows, and emergency services days held every two years.
- Somerset Regional Council participates in rural shows in Esk, Lowood, Toogoolawah and Kilcoy.

Stakeholders noted that stalls at local rural shows give councils the opportunity to promote disaster management in the region.

Various information campaigns have launch events including Get Ready, 'If it's flooded, forget it', etc. Get Ready Week includes community events that involve state departments and organisations, and councils.

11.5.3.8 School Programs

All councils, and some state departments and organisations undertake school-focused activities relating to flooding, or broader disaster preparedness, including:

- Somerset Regional Council noted that Council staff, SES and Queensland Rural Fire representatives attend various schools each year to discuss disaster management. These events are popular and well received. However, it was identified that attending all schools within the region for disaster management discussions would be very difficult from a time / resourcing perspective.

- Lockyer Valley Regional Council representatives noted that a school program is available to schools in the area.
- Brisbane City Council has developed a pilot 'My Resilient School' program, aimed at building resilience and disaster preparedness for grades five and six (developed by BCC with support from SES and QFES).
- Ipswich City Council contribute to school newsletters, visit schools and make presentations on disaster management, including flood awareness and preparedness. Ipswich City Council are also currently developing a program for primary schools which aligns with the curriculum, that can be booked in and attended by schools in the area for 2018. In addition to this, they are also developing teacher resources for use in the classroom if they are not able to have an excursion.
- Seqwater delivers a comprehensive schools education program, including site visits to dams, water treatment plants etc.

11.5.3.9 Records of Past Events

Flood markers indicating the flood water heights reached in past events are located at strategic locations throughout the catchment, including for example, New Farm park, the Brisbane Botanical Gardens, and Goodna.

Somerset Regional Council and Lockyer Valley Regional Council representatives both noted that books on past flood events are available for their areas.

Brisbane City Council's Flood Awareness Maps also provided information for historical events including the 2011 and 1974 events.

However, representatives from Ipswich City Council noted that a focus on past flood events might limit the community's preparedness response for potentially worse flooding than has previously occurred. Communities should prepare for all possible scenarios, rather than for past events to reoccur.

11.5.3.10 Community Development Approaches

Stakeholders noted that the Local Government Association of Queensland (LGAQ) coordinated a Community Development Engagement Initiative (CDEI) which included funding for community development workers to help communities recover from the 2011 and 2013 flood events as a community development approach. It was noted that this was the first time that some councils in Queensland had community development officers on their staff.

It was noted by at least one stakeholder that with increased emphasis on building community resilience it is evident that greater funding is needed in the community / social space to improve capacity to deliver prevention measures.

11.5.4 Evaluation of Activities

Evaluation is an important component in any communication activity. Understanding how effective an activity was in achieving its intent (exposure, uptake, changed behaviour etc.) is critical for identifying how resources might be best used in future. The stakeholder review asked respondents to identify if their organisation undertakes any evaluation of the effectiveness and uptake of resilience activities, and if they evaluate community attitudes to flood risk.

It is understood that most stakeholders do use some evaluation methods, however these are most likely to be informal evaluations measuring indicators of participation, such as number of queries received, website hits, or community interactions rather than formal evaluations of effectiveness at changing attitudes to risk and changing behaviour in terms of taking preparedness action. Formal evaluation processes captured by the review include:

- Queensland Fire and Emergency Services (QFES) have undertaken data collection and analysis which aim to link interventions with long-term behavioural change;
- Seqwater worked with the Queensland University of Technology (QUT) to undertake social research on dam release messaging in 2016;
- Brisbane City Council includes question about making preparations for flooding and disaster readiness in their annual community survey.

11.5.5 Other Stakeholder Feedback on Activities

Through the review of activities, stakeholders also provided feedback on approaches to resilience building activities generally, including:

- There is an opportunity to undertake market research and research on community engagement that all organisations can draw on;
- Clearly outlining state and local government communication responsibilities might assist in supporting a coordinated approach to information dissemination;
- Residents appear to be somewhat fatigued with years of flooding talk;
- Consistent messaging from various stakeholders increases credibility of organisations and councils in the community (including from elected representatives for example);
- Disaster management officers in the region are sharing information via three key mechanisms / channels:
  - The IGEM Collaboration Zone is a secure, online portal that provides access to the broader sector (all stage-agencies, as well as councils). The portal is generally used to share ‘client in confidence’ classified documents with councils. Some stakeholders indicated that the Collaboration Zone was somewhat underutilised at present. The Office of the Inspector-General Emergency Management have identified that there are plans to address this under-utilisation in the future
  - The DMO Network is a peer-driven group of local disaster management practitioners based in councils. The network uses Basecamp (an online platform) to support collaboration across

councils. The network has regular teleconferences (at least once per quarter), and conduct an annual three day face-to-face forum.

  - Disaster management engagement group. This group is more catchment / region-based and includes disaster management officers from councils across South-East Queensland. This group was identified as a valuable resource for supporting community awareness and resilience activities, and;

- More guidance around managing volunteers is needed. Insurance is a key issue. Should the message be: help people you know first, then if you want to help your wider community, volunteer as a secondary measure?

11.5.6 Summary of Current Resilience Activities

The review of current activities in the catchment found that stakeholders are implementing a range of programs to promote flood awareness and resilience. This review of activities has attempted to capture the range of current activities being implemented in the catchment, however it may not comprehensively capture all activities that stakeholders are undertaking that contribute to flood resilience (for example, community development programs are likely to not be covered by the review given these workers are generally in other sections of councils).

The range of activities captured in the review are briefly summarised below:

Community-Wide Activities:

- All four councils use the Early Warning Network system as well as Seqwater to send alerts to the community.
- Three out of four councils have implemented a similar emergency management dashboard which republishes information on road closures, weather warnings, power outages etc. on a single online interface. Information is sourced from other organisations (through published data feeds) and through social media accounts.
- The Queensland Government's disasters and alerts website (qldalert.com) also republishes the social media feeds of a variety of organisations that publish alerts, including state departments and organisations, and councils.
- The State Government's Get Ready program provides:
  - Useful guidance and factsheets on preparedness actions for a variety of hazards that are then shared by a range of organisations and councils to promote consistent messaging.
  - Factsheets in more than 20 languages making them some of the most accessible resources for people who speak a language other than English.
  - The Get Ready week initiative provides a focal point each year to launch events and programs to provide 'cut through' and benefit from the broader campaign.
  - Funding for localisation of messaging, including for the production of local videos, programs targeting vulnerable groups, etc.

- Multiple social media accounts provide information and warnings. These are mostly Facebook and Twitter accounts. These are generally considered successful in engaging with the community as they provide real-time communication when people are looking for information before, during and after an event.
- Television and radio advertising was considered useful for reaching large audiences, and digital outdoor, radio, online and social media advertising were useful for referred audiences to useful information in real-time in the lead up to storms / disaster events.

Local Activities:

- Individual property-scale information is available online from Brisbane City Council (Flood Awareness Maps). Most councils noted that sending this information to individual properties through direct mail would not be achievable given available resources. However, most of the councils noted that they include flood awareness information in regular newsletters and other notices sent to households and businesses.
- All of the councils provided information on emergency planning and preparing emergency kits for households or referred community members to guides produced by other organisations (mainly the Get Ready guides).
- Brisbane City Council had developed information for businesses on continuity planning, and the other councils referred organisations to Get Ready and Business Queensland resources.
- It was noted that the Department of Communities is developing a toolkit to assist community organisations to undertake continuity planning.
- Some stakeholders provided activities promoting business / community organisations continuity planning or preparedness plans.
- A variety of activities were identified targeting vulnerable or hard to reach people in the communities, including people in high flood risk neighbourhoods, aged people, people with a disability of some kind, people experiencing homelessness, and targeting new residents / workers to the area.
- Organisations and local governments participate in an extensive range of local community events and displays throughout the year to promote flood risk and disaster management awareness and preparedness.
- Only a limited number of community empowerment / community development approaches to resilience building were identified in the review, however this could have been due to a focus on gathering data from disaster management officers in councils. The review may not have captured activities undertaken by community development workers in other sections of councils.

Evaluation of Activities:

- Evaluations of the effectiveness of activities could be improved and shared to benefit others in the region.

11.5.7 Gaps and Opportunities identified in Current Resilience Activities

A gap analysis was undertaken to cross-check current resilience activities with the community flood resilience aspirations. This analysis helped to identify opportunities for future actions, shaped by the best-practice principles identified in Section 11.4. The identified gaps and opportunities were then used to inform the recommendations provided in Section 11.6. Full findings of the gap analysis are provided in Appendix W, with a summary of the findings provided below, grouped by the key aspiration headings of:

- A risk informed community;
- An appropriately prepared community; and
- An adaptable community.

A risk informed community

The following gaps and opportunities were identified relating to the community flood resilience aspirations for a *risk informed community*:

- New flood risk information: Detailed flood hazard information is not publicly available to the same level of detail throughout the catchment. The Brisbane River Catchment Flood Studies will provide more detailed flood hazard information for a variety of events / likelihoods including nature of flooding at a regional scale. This additional information will assist councils, organisations, residents, businesses and communities to undertake assessments of flood risk. There is an opportunity to share the outputs of the flood studies broadly throughout the catchment to improve awareness of this new flood risk information.
- Property-scale flood risk information: Property-scale flood risk information will help households and businesses to understand and assess their level of flood risk and consider appropriate preparedness actions. Brisbane City Council provides useful property-scale information, and the underlying data and systems could be expanded to other parts of the catchment and enhanced to deliver targeted preparedness messages. The outputs of the Phase 2 (Flood Study) will assist in providing regional-scale flood risk information, assessed at the property-scale, which will be important for assessments of flooding risk for households (and communities broadly), businesses and community organisations.
- Consistent communication: Consistency of communication was a gap / opportunity identified in the review in terms of:
  - Consistent categories of flood risk throughout the catchment and descriptions of these categories using easy to understand language and visual explanations;
  - Consistent flood risk language throughout the catchment;
  - Easy to understand explanation of key flood risk concepts.

  The Get Ready program provides a useful Queensland-wide approach to awareness and resilience activities, and the Get Ready website and resources are well utilised by stakeholders in the catchment. There are opportunities to build on this success by utilising the Get Ready program and / or the Get Ready approach to deliver consistent explanations of key concepts and flood categories, and regional flood awareness resources which are then referenced or tailored by local councils and organisations.

- Communication responsibilities and protocols: Responsibilities for organisations and council to communicate with the community during events (especially through social media), and the role of community organisations / community groups / communities in disaster preparedness / response are not clearly identified. Clear roles for communication with the community, and clear explanation of the role of the community itself, in a flood event should be considered.
- Social media strategy: Stakeholders suggested some confusion in sharing consistent and accurate information into the many social media networks managed by stakeholders. For example, sharing alerts and warnings on different hazards from large organisations down to local SES and fire brigade branches. A coordinated approach to social media may assist.
- Communication materials for vulnerable / hard to reach groups: Communication resources were sometimes translated into other languages however these were mostly the state-wide, all-hazard Get Ready resources, and information provided by Brisbane City Council. Any new communication materials developed as part of the recommendations should be provided in common languages other than English, and in Auslan (Australian Sign Language) where appropriate, to support use with communities that use these languages. There may also be an opportunity for an organisation to provide translation of resources as a service to other organisations and local governments and this could be investigated further.
- Innovative communication formats and channels: There is an opportunity to investigate methods to communicate flood risk that may more effectively trigger attitude and behaviour change such as images of house showing flood heights, 3D visualisations, and augmented reality. Numerous stakeholders noted they have found video materials have a high uptake / viewing rate by the public.
- Increased community involvement: Community involvement in risk assessment and disaster management planning before an event, and decision making during and after an event was limited in the review. This is considered a gap given that involvement in the process of assessment, planning and recovery would help build the community's knowledge and capabilities. Involving the community in developing local / detailed Flood Risk Management Strategies, Local Disaster Management Plans and other planning efforts through appropriate engagement methods is an opportunity to build community resilience. Additional community involvement can also be encouraged by supporting community-led initiatives that share flood risk information, assess flood risk at a community level and / or contribute to building community resilience, and investigating a community champions program (described below).
- Acknowledging that some flooding is desirable: No resources were identified in the catchment that acknowledged that some flooding is desirable. There are opportunities to include some promotion of this in a variety of activities.
- Sharing flood memories: Although past flood experiences were captured and shared in the catchment through events, public installations and resources, there may be an opportunity to

share flood memories which emphasise the whole of catchment nature of flooding, and recognise the natural processes and benefits associated with flooding.

An appropriately prepared community:

The following gaps and opportunities were identified relating to the community flood resilience aspirations for *an appropriately prepared community*:

- Move beyond awareness campaigns to deeper engagement to trigger preparedness actions: Pure awareness campaigns have been found to be less effective than activities which include deeper engagement methods. However, few activities using deeper engagement methods were identified in the review. This may be because of the limitations of the review, however there are opportunities to support and encourage deeper engagement and the evaluation of these activities throughout the catchment. Deeper engagement here includes:
    - Involvement of the community in planning and decision making with regard to flood risks;
    - Utilising existing community networks to share information and implement programs (community networks include online networks, social media networks, workplace networks, school and university networks, and not just networks based on a geography / neighbourhood);
    - Use community development approaches to support community-led initiatives.
- Investigate network of community leaders / champions: There may be an opportunity to upskill a network of community leaders / champions to share their skills with the broader community, or use community groups / organisations to operate as resilience centres.
- Coordinate effective community response: There may be an opportunity to build on the work of Volunteering Queensland to develop systems to coordinate community response.
- Continue to improve warnings and alert messages: Different services available in different local government areas mean that users need to register / visit multiple services to access information for multiple local government areas. There is an opportunity to build on the success of the emergency management dashboard and Early Warning Network service to link alerts / warnings throughout the catchment to wherever the person is located. Specifically, each emergency management dashboard could provide links to dashboards for neighbouring local government areas to provide quick access, and these dashboards can continue to be developed by adding new data sources. More broadly, data sharing (including geographically referenced information), could be developed to enable multiple online and mobile applications.
- Business and community organisation continuity planning: Continuity planning resources are available online from the Get Ready website (which have been adapted by Brisbane City Council), Business Queensland, and the Australian Council of Social Services (ACOSS), and the Department of Communities, Child Safety and Disability Services is preparing a toolkit to assist community organisations with continuity planning. There may be an opportunity to develop a program, based on these resources, which offers additional support and assistance to organisations to undertake continuity planning (for example, with workshops and meetings), and to fulfil a more significant role in sharing information, preparedness advice, warnings and alerts.

- Engagement with business, community, real estate and insurance bodies: Engagement with representatives and peak bodies including business / community sector, real estate and insurance bodies to facilitate collaboration was identified as a gap / opportunity.
- Further research on psychological preparedness: Psychological preparedness can help to encourage physical preparedness, however, was not identified in the activities reviewed. Research on the applicability of psychological preparedness to flooding is needed, however broad psychological preparedness information could be integrated into a range of awareness campaigns to support action before further research is undertaken.

An adaptable community:

The following gaps and opportunities were identified relating to the community flood resilience aspirations for *an adaptable community*:

- Undertake evaluations of effectiveness: The review found that formal effectiveness evaluations were rarely undertaken in the catchment, and it is presumed that funding to undertake evaluations is an issue. Evaluations should focus on the effectiveness of programs in terms of influencing preparedness attitudes and behaviours, rather than measuring campaign awareness.
- There are opportunities to undertake more formal evaluations of the effectiveness of activities to identify effective activities, share the learnings of these evaluations with all stakeholders regionally to continually improve the activities being undertaken and ensure the most effective activities are supported.

The Inspector-General Emergency Management DMO Network (including the annual forum) was identified as a useful mechanism for sharing information throughout the catchment, and may be leveraged to share evaluations of the effectiveness of activities implemented throughout the catchment. In addition to broader, all-hazards sharing, there may be value in having focused discussions (either on Basecamp or at the in-person forums) which are flood specific and support sharing approaches to community awareness and resilience building activities. Stakeholder feedback also noted that the Collaboration Zone is currently under-utilised (although IGEM has intentions to address this).

11.6 Recommendations

11.6.1 Overview

11.6.1.1 Identification Process

The community awareness and resilience recommendations provided in this report were identified using the following process:

- Development of a shared vision for riverine flood resilience in the catchment, articulated as community flood resilience aspirations, and what these aspirations mean for stakeholders (outlined in Section 11.2.4).

- Understanding current community flood awareness and resilience, informed by identification of vulnerable regions and sensitive infrastructure, and by information provided by the community through surveys and market research (outlined in Section 11.3).
- Identification of principles for resilience activities, informed by a literature review and case study assessment (outlined in Section 11.4).
- Identification of resilience activities currently being undertaken in the catchment, including evaluation of those activities, self-identified by councils and other stakeholders through an activity review; and a subsequent gap and opportunity analysis which cross-referenced those activities with the community flood resilience aspirations (outlined in Section 11.5).

The identification process sought to identify a suite of recommendations which help stakeholders to realise the community flood resilience aspirations across the region, building on current activities, and tailoring recommendations to meet the needs of the community.

Draft recommendations were presented to the Working Group at Workshop 5 (3rd October 2017) for stakeholders' consideration and comment. Feedback received at that workshop, in conjunction with stakeholder comments on the draft version of this document further shaped recommendations.

11.6.1.2 Links with Other Components of the Phase 3 (SFMP)

Community flood awareness and resilience is not a standalone floodplain management solution; it is fully integrated and supports all other aspects of floodplain management, including disaster management, land use planning, structural mitigation, and integrated catchment management. Improved flood resilience leads to a safer community, but also reflects the philosophy of shared responsibility for floodplain management.

Many of the recommendations provided in this chapter require information from other components of the Phase 3 (SFMP), such as mapping from Section 10 Disaster Management. Similarly, recommendations made in other chapters require community awareness and resilience measures to support the implementation of those measures. Linkages are noted within the recommendation descriptions, as relevant.

11.6.2 Summary of Recommendations

11.6.2.1 Structure of Recommendations

Recommendations to support improved community flood awareness and resilience at the regional scale have been grouped into the following categories, informed by the degree of regional implementation required:

- Regionally-coordinated activities;
- Local activities with regionally consistent elements; and
- Evaluation, research and advocacy activities.

In addition, the following broad types of recommendations have been identified, and noted in the description for each provided recommendation:

- Supports an approach to regional-scale resilience through coordination, facilitation, and governance;
- Expands, extends or modifies an existing activity being undertaken in the catchment;
- A new activity to be undertaken in the catchment; and
- Requires new research or additional work.

Recommendations were also categorised to note which aspects of the prevention, preparedness, response and recovery (PPRR) cycle, the recommendation contributes to.

Section 11.6.6 presents logical groupings or suites of recommendations for implementation

11.6.2.2 Summary of Recommendations

A summary of the recommendations relating primarily to community flood awareness and resilience, is provided in Table 11-4. These recommendations are grouped in the reporting categories described in the previous section, and are cross-matched with the stakeholder responsibilities for supporting the community flood awareness and resilience aspirations.

Note that implementation considerations, such as funding and resources, are addressed in the Strategic Floodplain Management Plan.

Table 11-4 Summary of Recommendations

Aspirations:	A risk informed community:															An appropriately prepared community:															An adaptable community:					
& Recommendations:	Undertakes comprehensive flood risk assessments.	Translates flood risk to a community, neighbourhood or household scale.	Easy to understand language. Consistency in language, terminology and approach with other organisations providing information to the same community.	Formats and media channels which are readily accessible to the entire community (including vulnerable or hard to reach communities).	Communicates risk and uncertainty.	Captures and promotes the sharing of past flood experiences.	Assesses the full range of flood risk, up to and including extremely rare events.	Provides information on the full range of flood risk, emphasising that the future will be different from the past.	Promotes some flooding as desirable.	Involves the community in planning for flood resilience to build capabilities and capacity to respond.	Identifies strengths, capabilities, vulnerabilities and capacity of community to respond to flood risk.	Provides tailored support, information and capacity building to communities vulnerable to flooding or do not have sufficient capacity to respond appropriately.	Is clear on responsibilities for governance and action.	Empower the community to manage their own flood risk.	Promotes stakeholder, community participation in the decision-making process.	Contributes to a risk informed community (all measures to left).	Provides ongoing and effective flood awareness and education programs and activities.	Builds networks of community leaders/champions with in-depth capacity, skills and knowledge.	Develops systems for appropriate community response (eg. volunteer coordination).	Incorporates community development approaches in resilience building activities wherever possible.	Delivers community resilience building information and activities through existing social networks to reinforce and strengthen these networks.	Supports social alliances and networks as a component of various government functions, wherever possible.	Provides timely and relevant information about changing circumstances (eg. hazard, exposure, vulnerability).	Invests in communication systems to provide information to the community, and for the community to communicate with each other and authorities as risks evolve.	Facilitates flood resilient urban and rural planning.	Facilitates flood resilient built form outcomes.	Supports the community in preparation and response measures, including provision of aids (such as sandbags).	Provides templates and guidance materials to assist with planning for continuity, based on research of effective strategies and tailored for specific users such as households, businesses, community groups, and other institutions.	Engages with representatives and peak bodies for businesses and insurance to facilitate provision of relevant information and support.	Supports the community to prepare psychologically for potentially traumatic events, informed by research and tailored to suit local community characteristics and past flood experience.	Provides timely and relevant information during floods, including flood warning, identification of potential impacts and recommended response measures.	Provides information across a range of media to ensure system redundancy in changing circumstances.	Establishes communication protocols and clarifies responsibilities for engaging community alliances and networks during flood events.	Includes community leaders/champions in formal disaster management response planning.	Undertakes evaluations of resilience building activities and evaluations of flood event response, shares the outcomes of these evaluations, and modifies future activities based on learnings.	Identifies gaps in current activities and develops resources, tools, technologies and courses of action based on best-practice and current research.
11.3 Regionally-Coordinated Activities																																				
11.3.1 Establish or use a regional group for coordinated flood awareness and resilience													■																						■	■
11.3.2 Summarise current resilience activities in a compendium																																			■	■
11.3.3 Develop resilience toolkit to guide local implementations of priority regional resilience activities										■																									■	■
11.3.4 Develop framework for communication and engagement for use by organisations			■	■	■				■	■			■		■																■	■	■	■		
11.3.5 Develop a region-wide information and awareness campaign to share the results of Brisbane River Flood Studies	■							■	■								■																			
11.3.6 Provide online mapping for flood awareness purposes	■	■									■			■			■						■ [39]					■								
11.3.7 Provide property-scale information to households and organisations	■	■		■													■											■								
11.3.8 Investigate options for sharing location-based data across the region																	■		■				■	■							■					■

[39] If can be updated before and during specific events.

BMT

Aspirations:	A risk informed community:															An appropriately prepared community:															An adaptable community:					
& Recommendations:	Undertakes comprehensive flood risk assessments.	Translates flood risk to a community, neighbourhood or household scale.	Easy to understand language. Consistency in language, terminology and approach with other organisations providing information to the same community.	Formats and media channels which are readily accessible to the entire community (including vulnerable or hard to reach communities).	Communicates risk and uncertainty.	Captures and promotes the sharing of past flood experiences.	Assesses the full range of flood risk, up to and including extremely rare events.	Provides information on the full range of flood risk, emphasising that the future will be different from the past.	Promotes some flooding as desirable.	Involves the community in planning for flood resilience to build capabilities and capacity to respond.	Identifies strengths, capabilities, vulnerabilities and capacity of community to respond to flood risk.	Provides tailored support, information and capacity building to communities vulnerable to flooding or do not have sufficient capacity to respond appropriately.	Is clear on responsibilities for governance and action.	Empower the community to manage their own flood risk.	Promotes stakeholder, community participation in the decision-making process.	Contributes to a risk informed community (all measures to left).	Provides ongoing and effective flood awareness and education programs and activities.	Builds networks of community leaders/champions with in-depth capacity, skills and knowledge.	Develops systems for appropriate community response (eg. volunteer coordination).	Incorporates community development approaches in resilience building activities wherever possible.	Delivers community resilience building information and activities through existing social networks to reinforce and strengthen these networks.	Supports social alliances and networks as a component of various government functions, wherever possible.	Provides timely and relevant information about changing circumstances (eg. hazard, exposure, vulnerability).	Invests in communication systems to provide information to the community, and for the community to communicate with each other and authorities as risks evolve.	Facilitates flood resilient urban and rural planning.	Facilitates flood resilient built form outcomes.	Supports the community in preparation and response measures, including provision of aids (such as sandbags).	Provides templates and guidance materials to assist with planning for continuity, based on research of effective strategies and tailored for specific users such as households, businesses, community groups, and other institutions.	Engages with representatives and peak bodies for businesses and insurance to facilitate provision of relevant information and support.	Supports the community to prepare psychologically for potentially traumatic events, informed by research and tailored to suit local community characteristics and past flood experience.	Provides timely and relevant information during floods, including flood warning, identification of potential impacts and recommended response measures.	Provides information across a range of media to ensure system redundancy in changing circumstances.	Establishes communication protocols and clarifies responsibilities for engaging community alliances and networks during flood events.	Includes community leaders/champions in formal disaster management response planning.	Undertakes evaluations of resilience building activities and evaluations of flood event response, shares the outcomes of these evaluations, and modifies future activities based on learnings.	Identifies gaps in current activities and develops resources, tools, technologies and courses of action based on best-practice and current research.
11.4 Local Activities with Regionally Consistent Elements																																				
11.4.1 Extending/embedding approach to community resilience in local / detailed Flood Risk Management Strategies	■						■	■		■	■		■		■					■		■													■	
11.4.2 Continue implementation of suite of activities targeting vulnerable communities at a local level	■										■	■					■											■								
11.4.3 Investigate options for facilitating / expanding / utilising volunteer connection and coordination strategies by organisations and councils at a regional level														■					■																	
11.4.4 Utilise existing community events / networks to support community resilience														■			■			■	■															
11.4.5 Investigate options for sharing flood histories through place-based installations and regional / local community events						■											■																			
11.4.6 Support community -led initiatives using community development approaches and community development training for organisation / council disaster management officers										■	■			■	■		■			■	■												■			
11.4.7 Build on existing continuity planning resources with a local program assisting	■										■						■											■								

Aspirations:	A risk informed community:															An appropriately prepared community:															An adaptable community:					
& Recommendations:	Undertakes comprehensive flood risk assessments.	Translates flood risk to a community, neighbourhood or household scale.	Easy to understand language. Consistency in language, terminology and approach with other organisations providing information to the same community.	Formats and media channels which are readily accessible to the entire community (including vulnerable or hard to reach communities).	Communicates risk and uncertainty.	Captures and promotes the sharing of past flood experiences.	Assesses the full range of flood risk, up to and including extremely rare events.	Provides information on the full range of flood risk, emphasising that the future will be different from the past.	Promotes some flooding as desirable.	Involves the community in planning for flood resilience to build capabilities and capacity to respond.	Identifies strengths, capabilities, vulnerabilities and capacity of community to respond to flood risk.	Provides tailored support, information and capacity building to communities vulnerable to flooding or do not have sufficient capacity to respond appropriately.	Is clear on responsibilities for governance and action.	Empower the community to manage their own flood risk.	Promotes stakeholder, community participation in the decision-making process.	Contributes to a risk informed community (all measures to left).	Provides ongoing and effective flood awareness and education programs and activities.	Builds networks of community leaders/champions with in-depth capacity, skills and knowledge.	Develops systems for appropriate community response (eg. volunteer coordination).	Incorporates community development approaches in resilience building activities wherever possible.	Delivers community resilience building information and activities through existing social networks to reinforce and strengthen these networks.	Supports social alliances and networks as a component of various government functions, wherever possible.	Provides timely and relevant information about changing circumstances (eg. hazard, exposure, vulnerability).	Invests in communication systems to provide information to the community, and for the community to communicate with each other and authorities as risks evolve.	Facilitates flood resilient urban and rural planning.	Facilitates flood resilient built form outcomes.	Supports the community in preparation and response measures, including provision of aids (such as sandbags).	Provides templates and guidance materials to assist with planning for continuity, based on research of effective strategies and tailored for specific users such as households, businesses, community groups, and other institutions.	Engages with representatives and peak bodies for businesses and insurance to facilitate provision of relevant information and support.	Supports the community to prepare psychologically for potentially traumatic events, informed by research and tailored to suit local community characteristics and past flood experience.	Provides timely and relevant information during floods, including flood warning, identification of potential impacts and recommended response measures.	Provides information across a range of media to ensure system redundancy in changing circumstances.	Establishes communication protocols and clarifies responsibilities for engaging community alliances and networks during flood events.	Includes community leaders/champions in formal disaster management response planning.	Undertakes evaluations of resilience building activities and evaluations of flood event response, shares the outcomes of these evaluations, and modifies future activities based on learnings.	Identifies gaps in current activities and develops resources, tools, technologies and courses of action based on best-practice and current research.
businesses, organisations and community groups																																				
11.4.8 Develop guidance for a community champion program to be implemented locally										■	■			■			■	■			■						■	■					■	■		
11.4.9 Investigate development of education program on flood awareness that aligns with the school curriculum outcomes														■			■				■							■								
11.5 Evaluation, Research and Advocacy																																				
11.5.1 Evaluate resilience activities and share learnings																	■																		■	■
11.5.2 Continue to learn from and share best-practice research findings on community resilience activities from around Australia and internationally																																			■	■
11.5.3 Further research on incorporating psychological preparedness into awareness and resilience campaigns including applicability to flood hazards																														■						■
11.5.4 Engage with representatives of peak business / community sector, real estate and insurance bodies to facilitate collaboration																	■												■							

11.6.3 Regionally-Coordinated Activities

11.6.3.1 Establish or use a Regional Group for Coordinated Flood Awareness and Resilience

Recommendation type:

Supports an approach to regional-scale resilience through coordination, facilitation and governance.

Contribution to PPRR:

- *Contributes across entire PPRR cycle: Information sharing and collaboration amongst organisations implementing awareness and resilience activities, and supporting regionally consistent elements in awareness and resilience activities, contributes to more effective and efficient activities being implemented and higher levels of prevention and preparedness action (which then improves disaster response and recovery).*

Background:

Best-practice community resilience building embraces the notion of shared responsibility and decision making across all sectors, and numerous government and non-government organisations are involved in supporting community flood awareness and resilience in the Brisbane River catchment. However, the planning and implementation of resilience activities can sometimes be undertaken in a fragmented way, leading to duplication of effort and potential for inconsistency of messaging. Additionally, with so many different organisations and disciplines involved in community resilience, it can be challenging for stakeholders to stay abreast of relevant programs and activities, potentially leading to duplication of effort.

There are numerous groups and forums for disaster management officers (DMOs) to meet and exchange information, however an opportunity was identified to establish a catchment-wide group which includes representatives from a range of organisations and disciplines to support the implementation of community awareness and resilience activities across all sectors.

Description:

It is recommended that a regional group be established, which meets regularly to share information and collaborate on resilience building activities amongst stakeholders and support implementation of regionally consistent elements in activities. The purpose of this group would be to:

- Raise awareness of services and resources that can be utilised and implemented by local governments and others; and
- Encourage collaboration on the planning, development and implementation of resilience building resources, particularly mobile applications and online resources, which are readily accessed by all communities in the catchment.
- Support the development of relationships and collaboration across sectors, to work towards shared responsibility and decision making in the resilience space.

Considerations for implementation:

The following considerations should inform the establishment of the group:

- The regional group should include a diversity of specialists in the area of community resilience such as disaster management workers, community development workers, and communication and engagement teams. Consideration should be given to the make-up of the group to ensure it is not a duplication of existing groups and provides avenues for resilience activities to be embedded across all sectors. The group might consist (as a minimum) of stakeholders involved in the Community Awareness and Resilience Working Group for this study. Other relevant stakeholders might be invited to join the group on a regular basis, or to provide periodic updates on new research, programs or similar;
- While recognising the all-hazards approach which is embedded in Queensland disaster management, consideration should be given to focussing the group on flooding, and Brisbane River flooding in particular, given the nature and magnitude of the risk; and
- The group should seek to support all stakeholders in implementing the community flood awareness and resilience aspirations, in a regionally consistent manner which avoids duplication and inconsistency.

Related resources / examples:

- Example (within the catchment): The Brisbane Community Engagement Working Group facilitates a coordinated process across multi-agencies for collaborative prioritising, planning and delivery of bushfire and severe weather event community engagement activities within the Brisbane Region. The group has the following stated objectives (from the Terms of Reference):
    - Review, plan and implement the bushfire and severe weather event community engagement needs of the region in a systematic and timely manner.
    - Conduct all operations and activities in accordance with the working group annual calendar.
    - Record all community engagement activities conducted by the working group.
    - Foster collaboration within QFES, Local Government and other relevant stakeholders in relation to community engagement activities.
- Example (within the catchment): The Disaster Management Engagement Group (DMEG) consists mainly of councils in the South-East Queensland area, meets quarterly and is mostly attended by the Disaster Management Officers of relevant councils.

11.6.3.2 Summarise Current Resilience Activities in a Compendium

Recommendation type:
A new activity to be undertaken in the catchment
Requires new research or additional work.

Contribution to PPRR:

- *Contributes across entire PPRR cycle: A Compendium of Resilience Activities provides a resource of activities with learnings that contribute to the implementation of more effective and efficient activities across the PPRR cycle. Ultimately, more effective and efficient activities increase prevention and preparedness for future shocks and stressors, which subsequently improve response and recovery.*

Background:

A review of activities was undertaken as part of the resilience project, with responses summarised in Section 6. This review identified a large number of resilience activities being undertaken in the catchment, however it did not capture all resilience activities, for example, activities undertaken by community and non-profit organisations. The review also did not identify or undertake evaluations of effectiveness of the resilience activities identified.

Description:

It is recommended that a Compendium of Resilience Activities is developed to provide a concise resource outlining learnings from the implementation of resilience activities in the catchment. The Compendium might include a summary of around 20 activities including formal evaluations of the effectiveness of these activities in influencing attitudes and preparedness behaviours, as well as feedback / input from people involved in the activities (from various stakeholder groups including the community). This Compendium would therefore provide a more robust evidence base to inform the development of a Resilience Toolkit (Section 11.6.3.3) consisting of a small number of activities to be implemented across the catchment (with flexibility to adjust activities to respond to the local contexts).

The compendium can build on work undertaken in this review and use the audit of activities undertaken to select activities to evaluate, but should be expanded to include resilience activities organised by businesses, and community and non-profit organisations and other activities offering useful learnings.

Activities should be assessed to determine whether they are best implemented at a regional-scale, or at a local-scale following adaptation to local context.

Considerations for implementation:

- Activities described in this chapter relate only to the Brisbane River catchment, however the scope of the Compendium could be expanded to include activities from across the State. If this recommendation is implemented as a State-wide activity, stakeholders in the Brisbane River catchment would contribute examples from their own region, but have the opportunity to learn from examples gathered from around the state.
- The Compendium of Resilience Activities, Resilience Toolkit (Section 11.6.3.3) and Communication and Engagement Framework (Section 11.6.3.4) form a set of three resources useful for workers in community awareness and resilience. These could be a single combined resource with three sections or separate, but related resources.
- Partnerships with universities or other research institutions may assist in undertaking evaluations of the effectiveness of identified activities, particularly utilising the expertise of research staff in social programs evaluation.
- This chapter provides a base of information that could be used for the Compendium, however this content should be expanded to include resilience activities organised by businesses, and community and non-profit organisations and other activities offering useful learnings not covered in this report. The resource should also present information in a more concise and accessible format.

Related resources / examples:

- Case Study (outside the catchment): Emergency Management Victoria (EMV) and Monash University compendium of community-based resilience building case studies.
- Resource (outside the catchment): Australian Institute of Disaster Resilience Guidelines for the Development of Community Education, Awareness and Engagement Programs (Commonwealth of Australia 2010) includes effectiveness evaluations for a variety of activities, and provides recommendations for evaluation methodologies.

11.6.3.3 Resilience Toolkit Developed to Guide Local Implementations of Priority Regional Resilience Activities

Recommendation type:

A new activity to be undertaken in the catchment
Requires new research or additional work

Contribution to PPRR:

- *Contributes across entire PPRR cycle: A Resilience Toolkit assists with the practical implementation of a number of key awareness and resilience building activities (and evaluations of these activities) across the PPRR cycle. Ultimately, more effective and efficient activities increase prevention and preparedness for future shocks and stressors, which subsequently improve response and recovery.*

Background:

The Compendium (Section 11.6.3.2) will help to identify important resilience activities which are effective and may be suitable for implementation at the local level by councils and other relevant stakeholders.

Description:

It is recommended that the research findings from the Compendium of Resilience Activities are used to develop a practical toolkit for planning and implementing a small number of key activities that are considered relevant across the region. The toolkit can include:

- Practical guidance for implementing a small number of key activities at the local level that are considered relevant across the region, including principles for implementing the activity, how to adapt the programs to the local context, useful templates to aid implementation, etc.; and
- Guidance on undertaking evaluations of programs including the use of a program theory model consisting of descriptions of: the context (people and settings), the nature of the problem and causes, the outcomes to be achieved and the causal process that will be activated by the activities, and the implemented activities or program. Templates should be provided for undertaking evaluations, or for data gathering which will then be analysed at the regional scale.

Considerations for implementation:

- The Compendium of Resilience Activities (Section 11.6.3.2), Resilience Toolkit and Communication and Engagement Framework (Section 11.6.3.4) form a set of three resources useful for workers in community awareness and resilience. These could be a single combined resource with three sections or separate resources.

- The Resilience Toolkit would be an effective activity at a State-wide scale, providing advice to all stakeholders throughout the State. If the Toolkit is implemented at a State scale, the Compendium (Section 11.6.3.2) should also be implemented at that scale, to ensure the best-practice tools draw on learnings from across the State.
- Investigate option of providing funding to support implementation and evaluation of activities included in the toolkit, potentially linking funding to a requirement that implementation of those activities is evaluated and shared across relevant stakeholders; and
- Sharing of local implementation and evaluation outcomes could be undertaken through the Basecamp platform and / or the Emergency Management Collaboration Zone / DMO Network online forum (depending on confidentiality of material). This forum was specifically setup for councils in Queensland to share their learnings in the area of emergency management. Participants in this forum also meet in person each year.

Related resources / examples:

- Case Study (outside the catchment): BC Climate Action Toolkit, which provides a range of resources for knowledge sharing, collaboration, best-practice and strategic guidance to local governments in British Columbia Canada to strengthen their communities.

11.6.3.4 Develop Framework for Communication and Engagement for use by Organisations

Recommendation type:

A new activity to be undertaken in the catchment

Contribution to PPRR:

- *Preparedness: The Communication and Engagement Framework establishes a shared language and approach to communication and engagement resulting in regionally consistent messages.*
- *Response: Alerts and warning messages utilise shared language and consistent messaging to reduce confusion and link alerts and warnings to preparedness messages and rehearsed response.*

Background:

Consistency in language and messaging has been identified by project stakeholders and in the literature and case-study review as a priority outcome for the region. The importance of this issue was further emphasised by key findings from market research and community survey such as:

- Residents often work and live in multiple regions across the catchment, and are therefore exposed to information from multiple councils;
- Residents often seek flood information online, and will therefore be exposed to information from councils other than their local councils; and

- Residents seek to ‘triangulate’ or validate information (particularly during flood events) between multiple flood sources.

Description:

It is recommended that a Communication and Engagement Framework be developed to ensure consistent use of terminology related to flooding in the catchment as well as to establish governance structure and processes for managing communication during and after an event, including use of social media. The Framework can also promote appropriate engagement approaches to encourage community involvement and empowerment.

Considerations for implementation:

- The Office of the Inspector-General Emergency Management (IGEM) is currently undertaking a project to develop a sector-wide lexicon, supporting a common understanding and consistency of language, contextualised to Queensland disaster management arrangements (discussed further below under ‘related resources / examples’). This work is currently under development; however, it is anticipated that formal adoption of the lexicon in the Standard for Disaster Management in Queensland may occur in late 2018. Development of the framework for communication and engagement should be undertaken in close consultation with the working group responsible for the IGEM lexicon to ensure consistency and avoid duplication of effort.
- The framework might be developed at a State level, providing support and resources to regions across Queensland, including the Brisbane River catchment. If developed at a State level, stakeholders within the catchment may need to decide on consistent local implementation of the framework.
- The Compendium of Resilience Activities (Section 11.6.3.2), Resilience Toolkit (Section 11.6.3.3) and Communication and Engagement Framework form a set of three resources useful for workers in community awareness and resilience. These could be a single combined resource with three sections or separate resources.
- Consistency is required at the catchment-scale to describe the riverine flooding which affects the entire catchment community. However, the recommendation may be broadened to a State-wide Communication and Engagement Framework, focusing on riverine flooding. In this instance, stakeholders in the Brisbane River catchment may still need to modify aspects of the guidance to reflect other regionally consistent aspects of regional floodplain management, e.g. the hazard and risk categories informing the Strategic Floodplain Management Plan, and the nature of flooding in the Brisbane River catchment.
- Irrespective of whether the Communication and Engagement Framework is developed at the regional level (coordinated by the Regional Group for Coordinated Flood Awareness and Resilience) or at a State level, the Framework should include clear advice on the following topics:
    - Descriptions of flooding categories. These descriptions should align with the language used by the Bureau of Meteorology, to avoid confusion with the lead forecasting agency. It should also provide advice on developing extensions or value-add statements to complement the official warnings from the Bureau, particularly in terms of relating the warnings to local impacts and capturing other aspects of flood behaviour, such as timing;

- How to explain challenging concepts such as:
  - Flood variability (every flood is different);
  - Flood characteristics (such as volume, level, duration, rate of rise, and extent);
  - Catchment characteristics which influence flooding (such as topography, land use / development, water storage operation, downstream water levels etc.);
  - Flood risk, particularly elements of flood likelihood, providing examples to relate flood likelihoods to familiar probability-based examples (e.g. describing the chance of a particular flood occurring in a lifetime, or comparing to the probability of winning the lottery);
- Responsibilities of key organisations to communicate as the authority on components of flood event preparation and response. This will provide guidance to communication teams within organisations and councils on sharing information into their networks from the authoritative source and providing links back to the source to obtain the most up-to-date information;
- Social media guidance, particularly relating to sharing of messages from other organisations (see above for discussion relating to Bureau of Meteorology warnings), maintaining consistency between social media channels and organisations, and guidance on engaging with unofficial social media voices (e.g. Higgins Storm Chasing and others);
- Communication and engagement protocols for communicating with community leaders and their networks before, during and after an event. Community leaders may be involved in local SES branches or community organisations or be recognised 'community champions' who have undertaken additional training and upskilling (see Section 11.6.4.8); and
- Communication materials developed as part of the recommendations should be provided in common languages other than English, and in Auslan (Australian Sign Language) where appropriate, to support use with communities that use these languages. There may also be an opportunity for an organisation to provide translation of resources as a service to other organisations and local governments (requires further investigation and consideration).

Related resources / examples:

- Resource: The disaster management lexicon project is being undertaken by a working group comprising State, local and non-government agency representatives and overseen by the IGEM Advisory panel. It is the intent of this project to formally enshrine words from the lexicon as part of the Standard for Disaster Management in Queensland in 2018. Phase 1 of the project has seen 115 initial words finalised and approved by the Panel. The approach and format being applied to development of the lexicon is being adopted at a national level by the Australian Institute for Disaster Resilience (AIDR). It is understood that the working group has been working with Griffith University on sheltering terms; with AIDR on the national review; and will continue to develop and expand the Queensland lexicon in subsequent phases.
- Resource: Following IGEM's reviews of cyclone and storm tide sheltering arrangements (CTSA) and local government's emergency warning capability (LGEWC), QFES released a fact sheet which provides information on recommendations 5 and 9 from the two reviews, respectively. In

particular, this factsheet summarises 18 good practices which should be applied when developing warning messages and communications.

- Resource: The public facing document “Understanding floods: Questions & Answers” produced by the Queensland Chief Scientist (2011) provides plain English explanations of technical flood concepts such as causes of floods, flood estimation and likelihood, flood forecasting and future flood risk. Language used throughout the document is accurate and definitive, but accessible for an average educated reader. Content from the document may be used by stakeholder as a basis for standardising language and terminology; and

- Resource: The “Australian Emergency Management Thesaurus”, part of the Australian Disaster Resilience Handbook Collection (Australian Institute for Disaster Resilience 1998), was developed to capture a number of emergency management terms which would form a common understanding of definitions, to encourage use of common nomenclature. Although the Thesaurus is now somewhat out of date and not Queensland of flood specific, it does provide an example of a similar communication guideline.

11.6.3.5 Develop a Region-Wide Information and Awareness Campaign to Share the Results of Brisbane River Flood Studies

Recommendation type:

Expands, extends or modifies and existing activity being undertaken in the catchment

Contribution to PPRR:

- *Preparedness: Sharing the results of the Brisbane River flood studies will increase awareness of flood behaviour and flood risk, and encourage communities to assess their risk and act on flood warnings and alerts.*

- *Response: Understanding of flood risk can assist with understanding warnings and alerts and appropriate response actions.*

Background:

The Phase 2 (Flood Study) and Phase 3 (SFMP) have greatly increased our collective knowledge of flood behaviour and flood risk in the lower Brisbane River catchment, through the production of numerous reports, maps and other types of data. Some measures have commenced to make the community aware of the study (e.g. publishing reports from the Phase 2 (Flood Study) online, and hosting information booths at community events).

Description:

It is recommended that a region-wide information and awareness campaign is planned and delivered to:

- Share the results of the study with the community, including new online mapping for the whole catchment and property-scale information (as outlined in Sections 11.6.3.6 and 11.6.3.7);

- Promote consistent terminology / language and concepts (as described in Section 11.6.3.4);

- Promote the idea of the Brisbane River catchment as a regional community (rather than LGA-based messaging), and promote a catchment-wide or regional approach to flood management; and
- Promote the lifestyle benefits of living in the catchment, promote some flooding as desirable and spread the message that flooding will continue to be a feature of living in the catchment.

Note that this action is currently being undertaken by the Community and Engagement Working Group as part of the project delivery.

Considerations for implementation:

- This work could be coordinated by a 'regional group' as outlined in Section 11.6.3.1;
- The campaign should include QFES;
- A suite of activities should be included in this information and awareness campaign, including but not limited to:
  - Extension of online media advertising, outdoor and radio as these have been noted as being successful by project stakeholders;
  - Direct mail factsheet or brochure for particular geographic areas where changes to understanding of flood risk are most evident;
  - Involvement in community events such as River Festival, etc.;
  - Activities implemented at the local level;
- The effectiveness of this recommended activity (and sub-activities) should be evaluated during and after implementation; and
- Consider the inclusion of psychological preparedness principles / elements in region-wide campaign.

Related resources / examples:

- None identified

11.6.3.6 Provide Online Mapping for Flood Awareness Purposes

Recommendation type:
Expands, extends or modifies and existing activity being undertaken in the catchment

Contribution to PPRR:

- *Preparedness: Online mapping increases awareness of flood risk and concepts, and encourages communities to assess their risk and act on flood warnings and alerts.*
- *Response: Understanding of flood risk can assist with understanding warnings and alerts and appropriate response actions during an event.*

Background:

The Phase 2 (Flood Study) and this Phase 3 (SFMP) (in particular Section 4 Current Flood Risk, Section 5 Future Flood Risk and Section 10 Disaster Management) has produced a range of new mapping and other data which the community require access to for general flood awareness, and to populate their personal and business flood plans.

Description:

It is recommended that new information which is developed as part of this project (including the Phase 2 (Flood Study)) be disseminated through a whole of catchment online mapping tool or individual online mapping tools for each local government area with similar functionality and consistent categories of flood, terminology and colours. The online mapping tool/s should be capable of:

- Being updated to include the outputs of local flood modelling;
- Providing an interface to create a property-scale report targeting households and organisations (see Section 11.6.3.7);
- Providing easy to understand information to explain key concepts (flood variability, flood characteristics, catchment characteristics, flood risk etc. as appropriate / relevant to users);
- Providing links to key online resources to learn more about preparedness actions.

Considerations for implementation:

- It is suggested that this mapping is shared as a customisable online portal in order to explain key concepts (as above) and maximise the opportunity to provide visitors to this portal with links to other existing resources and information. A review of available products and platforms will be required to identify suitable delivery mechanisms based on stakeholder and community needs.
- If individual online mapping portals are created for each local government area, functionality should be consistent, and consistent categories of flood, terminology and colours should be used. Links to neighbouring local government mapping portals should be provided within maps to aid access to neighbouring local government information. Interoperability (at least to some degree) is desirable with existing map systems used by relevant agencies.
- Consideration should be given to whether additional flood sources should be included in the system (to make the system more 'complete') or, if the system should focus on Brisbane River flooding only (for the sake of clarity / streamlined governance etc.).
- This recommendation relates to flood mapping for the purpose of awareness. However, it is recognised that alternative mapping is often used in place of awareness mapping during (or in the immediate lead-up to) flood events. That alternative mapping generally has less focus on 'design' flood events, and more focus on linkages with gauge levels, or predicted flood extents. Consideration should therefore be given to establishing a regionally-consistent protocol to displaying (and removing) awareness mapping, and replacing with flood-specific mapping during disasters. Alternative mapping is also used for planning purposes, such as flood hazard overlays in planning schemes, and as a communication resources by the Insurance Council of Australia.
- A range of data and information has been generated through this study which can be used in an online mapping system for flood awareness purposes (supported by relevant explanatory information or caveats etc.). Resources that might be used include design flood mapping (from

the Phase 2 (Flood Study)), flood risk mapping (Section 4 Current Flood Risk and Section 5 Future Flood Risk), and property-related information (from Section 10 Disaster Management).

- QFES should be involved in the planning and implementation of the mapping resource.

Related resources / examples:

- Example (within the catchment): Ipswich City Council, Lockyer Valley Regional Council and Somerset Regional Council all provide ‘Disaster Dashboard’ websites designed to act as ‘one stop shops’ for the community’s disaster information needs. In their present form, these websites provide static mapping of flood extents, text-based awareness and preparedness information (e.g. templates for home flood plans) and some live data (such as CCTV feeds or links to the Bureau of Meteorology’s website). However, none of the websites show bands of flood risk or hazard, nor is there sufficient information for a resident or business to understand how flood risk relates to their property; the type of information needed to populate a personal flood plan;
- Example (within the catchment): Brisbane City Council provides flood awareness mapping, distinct from Council’s land-use planning based mapping. The flood awareness mapping can be downloaded (PDF) for a particular property location, which includes the mapping and resources about how to prepare for flooding. A FloodWise Property Report can be accessed via a personalised link from the flood awareness mapping, or by accessing the FloodWise service directly. The FloodWise Property Reports provide relative flood levels for historic and design flood events, and the site ground levels;
- Example (outside the catchment): Sunshine Coast Council provide flood hazard mapping for riverine and storm tide inundation (as well as other hazard sources) via the Disaster Hub website. The accompanying information on the site provides descriptors for the hazard categories (the likelihood of that event occurring in any given year, and the likelihood of that event occurring in a lifetime / 70 year period), and provides examples of historic floods which are similar in magnitude. The mapping does not provide information about levels or depths, nor any way for residents to relate flood levels to their property. As for the disaster dashboards, Disaster Hub provides a range of live and static information about disaster preparedness and response.

11.6.3.7 Provide Property-Scale Information to Households and Organisations

Recommendation type:
Expands, extends or modifies and existing activity being undertaken in the catchment

Contribution to PPRR:

- *Preparedness: Specific property-scale information increases awareness of flood behaviour and flood risk for at-risk communities, and encourages communities to assess their risk, take preparedness actions and act on flood warnings and alerts.*
- *Response: Understanding of flood risk can assist with understanding warnings and alerts and appropriate response actions.*

Background:
Numerous sources indicate that residents and businesses are most likely to respond to flood risk if they are able to identify the likely impact of the disaster at their property. The literature and case-review principles clearly identified the importance of localised information, and responses in market research indicated that residents are most likely to respond to warnings and evacuation notices that relate directly to their street. The Queensland Floods Commission of Inquiry also recommended in the Interim report (QFCoI 2011) that property-specific information be made available to residents.

Some information is available to residents about flood extents and / or levels at their property location (such as Brisbane City Council's property flood reports or Insurance Council of Australia's flood exposure mapping). However, this information in itself may not be sufficient for residents and businesses to understand the characteristics of flood behaviour, and the likely impacts at the property.

Description:
It is recommended that flood modelling outputs are provided at the property-scale to inform household and business / organisation flood risk assessments. This information should include a comparison of lot topography and floor height levels to gauge heights at key or reference stream gauges in the catchment, which is provided as a key output from Section 10 Disaster Management. This information would be most beneficial if combined with other flooding information (creek / waterway and overland flow) to provide a comprehensive comparison of floor level to flood gauge height for all flood types.

Description of hazards / risks (not just flood water levels) and factors important for households and businesses/organisations to undertake risk assessments and resilience planning are vital to support and help interpret flood model output. For example, information about the nature of flooding in an area (e.g. speed of onset, rate of rise etc.) and the extent to which the property can become isolated, is useful information to assist households and businesses/organisations to understand and assess risks, and undertake relevant preparedness actions.

Information on recommended preparedness actions based on property risk profile, and links to relevant resources to gain more information should also be provided. For example, automatically generated PDF reports might be appended with fact sheets on psychological preparedness, important preparedness actions to take, where to get more information online, how to reach out to get more specific help if particularly vulnerable etc.

Considerations for implementation:

- Property risk levels and other hydraulic data is being provided through Section 10 Disaster Management and can be used to inform communication with the community. This information includes description of design flood levels at the property, ground levels, reference stream gauge, relationship between the reference stream gauge and flooding at the property, etc. Information relating to the implementation and limitations of this data is provided in Section 10 Disaster Management and should be considered when determining how best to provide the data to the community;
- Consider distribution methods to ensure information is provided to renters as well as home owners, particularly in high flood risk areas, and vulnerable neighbourhoods. Approaches such

as stickers in household electricity or water meter boxes might be trialled to distribute the information;

- Property-scale information should be accessible online and could be provided to households and businesses / organisations through direct mail particularly where risks have changed based on new information (e.g. new flood studies);
- Consideration may be given to using the property photos captured during the property survey process (e.g. by superimposing flood lines against the photograph to indicate flood levels), however anecdotal evidence suggests that this approach can invoke strong reactions from the public. If this approach is pursued, it is recommended that small-group testing be undertaken to gauge community response.

Related resources / examples:

- Example (within the catchment): Brisbane City Council provides FloodWise Property Reports which provide flood level information compared to the ground level of the lot and the minimum habitable floor level. These are provided for the purposes of building and development and therefore do not contain information assisting households to undertake risk assessments and preparedness planning. (See Section 11.6.3.6 for further discussion about online mapping).
- Case Study (outside the catchment): Flood signage from Woronora Flood Preparedness Strategy

11.6.3.8 Investigate Options for Sharing Location-Based Data Across the Region

Recommendation type:
Requires new research or additional work

Contribution to PPRR:

- Response: Specific location-based alerts and warnings increase the relevance of messages to individuals and support appropriate response actions.
- Recovery: Similarly, specific location-based recovery information increases the relevance of messages to individuals, and supports access to recovery services.

Background:

As identified in the review of current resilience activities, numerous systems exist within the catchment to create, present and share location-based alerts / warning data, and recovery information. These include the emergency management dashboards used by Ipswich City Council, Lockyer Valley Regional Council and Somerset Council; the Queensland Government's disaster and alerts website; and a range of social media channels and mobile phone applications. These systems have some similarities and often rely on the same source data (e.g. repeating warnings or social media messages), however are generally not directly coordinated.

Results from the market research and community survey indicate that residents frequently move throughout the catchment (i.e. between council areas) for work and family reasons and may therefore need to access flood information for numerous LGAs.

Description:

It is recommended that further investigations are undertaken around options for sharing location-based alerts / warning data and recovery information by state departments and organisations, and councils. Sharing and repeating data across multiple channels minimises the chance of conflicting information and increases the likelihood that users will find the data, without having to search across multiple sources. Investigations should consider:

- Data sharing protocols for publishing / sharing alerts / warning data and recovery information from a variety of organisations in a standard format so that it can be integrated into a variety of applications for dissemination to the community;
- Geographically referencing all shared data so that applications can target information to specific geographic areas based on pre-set locations of interest and commonly used travel routes, travel times and methods;
- Prioritising the sharing of road closure information within the catchment and into neighbouring areas. The Department of Transport and Main Roads' "If it's flooded, forget it" awareness campaign includes the "Flooded Roads Map", which uses real-time data and user reports (from the public) to help drivers plan safe routes. Data sharing protocols should prioritise the integration of information from this site with other products, such as the emergency dashboards.;
- Promotion of catchment-wide information to residents and other users of the catchment (if shared or sharing system implemented).

Considerations for implementation:

As an interim / immediate response, relevant councils might consider providing links to the emergency dashboards of neighbouring councils (even those beyond the catchment area, such as Logan City Council). Similarly, links to these dashboards (or similar websites) might be collated for all relevant council areas in a common location, such as https://www.qld.gov.au/emergency and / or a non-government website, such as RACQ's trip planner (https://www.racq.com.au/travel/trip-planner).

Emergency management dashboard should also continue to be updated with new data sources, and capabilities improved to provide geographically targeted information during events.

Pre-determined polygons of high risk areas (similar to Brisbane City Council's creek flood alert polygons) might be developed using information about known areas of high flood risk, as identified in Section 4 Current Flood Risk and Section 10 Disaster Management.

Related resources / examples:

- Recommendation (state-wide): The Cyclone Debbie Review Action Plan (IGEM 2017) identifies a series of recommendations (6a to 6c) which relate to warnings and emergency alerts. Broadly, the recommendations relate to improved timeliness, accuracy and targeting of Emergency Alert messaging, and promotes the use of e.g. pre-populated warning polygons.

11.6.4 Local Activities with Regionally Consistent Elements

11.6.4.1 Extend Approach to Community Resilience in Local / Detailed Flood Risk Management Strategies

Recommendation type:

Supports an approach to regional-scale resilience through coordination, facilitation and governance.

Contribution to PPRR:

- *Contributes across entire PPRR cycle: Local flood risk management strategies embed and extend approach to resilience and therefore may contribute to all parts of the PPRR cycle.*

Background:

Following the completion of this Phase 3 (SFMP), Phase 4 (LFMPs) will be undertaken which extend the regional approach and findings to local or detailed scale assessments.

Description:

It is recommended that local flood risk management strategies in Phase 4 (LFMPs) include local community resilience actions which build on identified actions at the catchment scale as well as responding to local contexts within the region. These local strategies can embed and extend the approach to community resilience established here to develop locally relevant action plans to contribute to the resilience of the whole Brisbane River Catchment community. Strategies should continue to support the community flood awareness and resilience aspirations developed in this regional study, with modifications to the implementation to provide greater detail and ensure activities are tailored to local flood risk and community characteristics.

Considerations for implementation:

The scope of the Detailed / Local Strategic Floodplain Management Plans are yet to be defined, however, as a minimum, the community awareness and resilience aspects of the Plans should:

- Be informed by more detailed vulnerability assessments for local communities;
- Consider ‘gaps’ in community resilience based on the aspirations set at the regional scale and assessments of local community resilience;
- Develop strategies and actions to implement community resilience activities that are locally relevant, including tailoring recommendations to the nature of local communities and particularly vulnerable communities. Other considerations may include broader community characteristics (urban / rural, long-term residents / new residents, etc.), and for residents living behind or affected by flood management structures, such as behind backflow prevention devices and downstream of dams;
- Include stakeholders and the community in the development of local risk management strategies and evaluation of options including capacity building and upskilling, and engagement with vulnerable groups to ensure that stakeholders and the community have the opportunity to participate in the planning and decision-making process;

- Recommend utilisation of regional coordination frameworks to share learning from evaluation of activities with other stakeholders in the region.

Related resources / examples:

- None identified

11.6.4.2 Continue Implementation of a Suite of Activities Targeting Vulnerable Communities at the Local Level

Recommendation type:
Expands, extends or modifies an existing activity being undertaken in the catchment

Contribution to PPRR:

- *Contributes across entire PPRR cycle: Locally implemented suites of activities targeting vulnerable communities continue to contribute to appropriate prevention, preparedness and response actions, and recovery.*

Background:

A range of activities are currently being implemented within the catchment targeting vulnerable communities including for people who speak languages other than English; older, frail and people requiring assistance at home; homeless people; backpacker / itinerant workers, etc. These activities have been developed to respond to vulnerable groups within communities, and generally respond to local community demographics and needs.

Description:

It is recommended that suites of activities targeting vulnerable communities continue to be implemented based on identified local vulnerabilities and needs. These are most appropriately undertaken at the local level responding to local vulnerabilities and needs, with learnings from successful activities shared at the regional scale. Activities targeting vulnerable communities identified in the catchment have included:

- Provision of information in languages other than English, including Auslan, and simple English, including in traditional, online and social media;
- Information and programs delivered through existing social support networks such as Meals on Wheels;
- Backpacker / itinerant worker meet ups offering free food and drinks and provision of information on a variety of topics specifically targeted to this group;
- Information for people experiencing homelessness through targeted events;
- Activities offering tailored information and support to residential aged care providers, and older, frail and people requiring assistance through home care support/respite providers.

Activities targeting neighbourhoods newly identified (in this study) with high relative vulnerability should be implemented including:

- University students, and other young people generally with low socio-economic status;

- People with mobility issues including older people, people with pets, etc.

However, more detailed analysis of vulnerability should also be undertaken as part of local flood risk management strategies in order to develop activities targeting these neighbourhood areas.

Considerations for implementation:

- Regional-scale vulnerability mapping has been undertaken as part of this study and is provided in Section 4 Current Flood Risk. This mapping helps to identify the location of more vulnerable communities, although additional 'ground-truthing' should be undertaken as part of Phase 4 (LFMPs) to refine this information using local knowledge of the community.
- Consider the inclusion of psychological preparedness principles / elements in planning for resilience activities targeting vulnerable groups.
- Although focused on vulnerable communities, implementation programs should recognise and build on existing capabilities, rather than focus on the limitations or vulnerabilities of people and groups.
- Current activities might be evaluated (if sufficient / appropriate evaluation information available), and used within the compendium.

Related resources / examples:

- Example (within the catchment): Lockyer Valley Regional Council: Backpacker / itinerant worker meet ups
- Case Study (outside the catchment): Keep Cool / Stay Healthy in the Heat - City of Yarra
- Case Study (outside the catchment): Emergency Volunteering's Youth Looking Beyond Disasters Forums

11.6.4.3 Investigate Options for Enhancing Volunteer Connection and Coordination Strategies at a Regional Level

Recommendation type:
Expands, extends or modifies an existing activity being undertaken in the catchment

Contribution to PPRR:

- *Contributes across entire PPRR cycle (particularly response and recovery, but can be expanded into prevention and preparedness): Investigating options for enhancing volunteer connection and coordination may contribute to resilience across the entire PPRR cycle, for example, utilising volunteers for awareness building, to assist communities undertake prevention and preparedness actions, managing evacuation centres during response and helping with recovery efforts.*

Background:

Volunteers are a valuable resource for disaster response. There was significant volunteer support after recent flood and disaster events, however in some cases, the volunteer response was difficult to coordinate and manage. A system for coordination of volunteers developed before an event, would help effectively utilise volunteers before, during and after events.

Emergency Volunteering CREW is an initiative of Volunteering Queensland and involves collating a database of volunteer registrations that can be utilised by organisations needing volunteers during an event.

A recent review by the Office of the Inspector-General Emergency Management following Tropical Cyclone Debbie found that volunteers played a vital role during Debbie. The review recommended that “continued support and advocacy of informal and non-traditional volunteering through organisations such as Volunteering Queensland and the social sector ensure the community is rapidly supported following an event”.

Description:

It is recommended that options for facilitating, expanding and / or better utilising volunteer connections and coordination strategies are investigated for use by organisations and councils at a regional level. This might involve investigating:

- How third-party provided services such as the Emergency Volunteering CREW initiative could be supported / expanded and utilised by organisations and councils to coordinate volunteers before, during and after events;
- Governance frameworks (for example, which organisation would be responsible for coordinating volunteer involvement) and integration with emergency management protocols (for example, can volunteer involvement form a significant component of planning and response efforts) to utilise volunteers in recovery efforts;
- If volunteers can be effectively utilised in awareness and resilience building activities before an event;
- Training and upskilling interested volunteers who identify interest in specific tasks so that volunteers have improved capabilities to undertake specific roles before, during and after events, including potentially managing other volunteers, communicating through social media networks, etc.

Considerations for implementation:

Implementation requires consideration of all of the points described above, particularly the governance arrangements and communication / organisation channels.

Queensland Fire and Emergency Services is currently developing the QFES Volunteerism Strategy. To shape this framework, a volunteerism strategy discussion paper is currently in circulation highlighting the challenges facing traditional volunteerism, establishing QFES’s vision for volunteerism, and providing a roadmap and next steps.

Related resources / examples:

- Resource: Emergency Volunteering CREW (initiative of Volunteering Queensland, supported by Volunteering ACT, Volunteering Victoria and Volunteering Tasmania) refers potential volunteers to organisation when they request volunteer support.
- Case study (outside the catchment): Managers of spontaneous emergency volunteers pilot program.

- Resource: AIDR is currently developing a new handbook in the emergency management handbook series, *Communities Responding to Disasters: Planning for Spontaneous Volunteers – Handbook 12*. Although not available at the time of writing this document, Handbook 12 is understood to provide a link between the National Spontaneous Volunteer Strategy (2015) and the Spontaneous Volunteer Management Resource Kit (Australian Red Cross, 2010), which is in itself going to be updated.

11.6.4.4 Utilise Existing Community Events / Networks to Support Community Resilience

Recommendation type:

Expands, extends or modifies an existing activity being undertaken in the catchment

Contribution to PPRR:

- *Prevention / Preparedness: Community events and networks are utilised in awareness and resilience building activities to encourage deeper social engagement which encourages prevention and preparedness actions.*
- *Response / Recovery: Better prepared communities recover more quickly. Social engagement contributes to stronger social networks which can be activated during response and support recovery.*

Background:

It was noted in the literature and case study review of resilience activities that information dissemination campaigns undertaken in isolation may be ineffective at altering attitudes and behaviours. Deeper engagement with preparedness messages is required to inspire action, and this may be achieved through engagement with the messages in a social environment, and using social / community expectations to persuade. For example, households in a community making a commitment to each other to prepare a simple emergency kit (and checking in later) may be more effective than reading information on the need to prepare an emergency kit and what it should contain.

Strong social networks are an important contributor to community resilience (various sources, see Aldrich 2012; Paton and McClure 2013; Dufty 2013; Gibbs et al 2016). Delivering resilience messages through social networks may also reinforce and strengthen existing social networks which then contributes further to community resilience.

Description:

It is recommended that existing community groups and community events are utilised to discuss and undertake resilience planning (including disaster preparedness and response) in order to reinforce and strengthen existing social networks.

This may include community groups and events based around special interests and online social networks, rather than necessarily being around specific neighbourhoods or geographic communities.

Considerations for implementation:

- Guidance for implementation at the local scale may be provided in the Resilience Toolkit (Section 11.6.3.3).

- Likely to be implemented through local resilience activities adapted to the specific context.
- Consideration should be given to historically hard to reach groups, such as dual working households and people with accessibility issues (e.g. language and transport).
- Evaluation of this recommendation should be undertaken during and after implementation of programs, especially around how social relationships / community expectations can contribute to attitude and behaviour change, and how existing community groups and community events can be best utilised.

Related resources / examples:

- Case Study (outside the catchment): Keep Cool / Stay Healthy in the Heat - City of Yarra

11.6.4.5 Investigate Options for Sharing Flood Histories through Place-Based Installations and Regional / Local Community Events

Recommendation type:

Expands, extends or modifies an existing activity being undertaken in the catchment

Contribution to PPRR:

- *Prevention / Preparedness: Place-based installations and community events increase awareness of flood behaviour and flood risk and encourage communities to assess their risk. Reminders of flood histories with personal stories create an emotional connection which may encourage prevention and preparedness actions.*
- *Preparedness / Response: Understanding of flood risk in local areas can assist with interpreting warnings and alerts and appropriate preparedness and response actions during an event.*

Background:

Personal experiences of past floods are strong influencers on attitude and preparedness behaviours. In the absence of personal experiences, the sharing of local histories can be a strong motivation for action. Resilience activities which share stories and remind communities of past flood events may lengthen the period of time that histories are remembered. Historical accounts or records also provide a stronger emotional connection to flooding than outputs from computer models of 'theoretical floods'. This emotional connection can increase the likelihood that communities will change their behaviours.

Description:

It is recommended that the sharing of flood histories is supported through resources (books, videos, photographs, websites, etc.), installations and community events that prolong the period of time histories are remembered between significant flood events. These should include consideration of:

- Collecting oral histories / stories of people impacted by flood events and adding these to public library collections;
- Collecting photographs and video and incorporating these into public places such as recreation areas, public building foyers and museums;

- Developing community events that celebrate our rivers and waterways, including sharing stories of flood and / or incorporating stories of past floods in existing events (such as River Festival in Brisbane).

Considerations for implementation:

- Although individual markers or installations may be located within a single local government area, the markers should recognise that place's position within the broader catchment, e.g. by identifying the Brisbane River catchment, referring to the extent of impacts elsewhere in the catchment, or providing a broader history of flooding in the wider-area;
- Installations and events need not be limited to the dangerous aspects of flooding, but might embrace and promote all aspects of living in a floodplain, including amenity and environmental benefits;
- Augmented reality options might be explored to demonstrate how flooding might impact a particular location;
- Installations and events may be implemented as a suite of options, linked through common elements, such as style and appearance, such that the community recognises the suite and understands the connections between individual installations or events.

Related resources / examples:

- Case Study (outside of catchment): Series of installations, signs etc. by Public Utility Board of Singapore.
- Recommendation (state-wide): Recommendation 2b from The Cyclone Debbie Review Action Plan (IGEM 2017) promotes the use of markers in prominent public places to highlight storm tide risk. The recommendation is supported by an action to investigate a develop a standard for storm tide markers and complementary public-facing interactive mapping technology. This standard might also be used to inform design and implementation of flood markers.
- Example (within catchment): Brisbane's River Festival is a joint initiative of the Queensland Government and Brisbane City Council which utilises many of the city's riverside spaces to host cultural and entertainment events. Despite the river focus, the event does not currently extend up river to recognise other council areas within the same river basin, nor does it generally include discussion or recognition of the floodplain function.

11.6.4.6 Support Community-led Initiatives using Community Development Approaches and Community Development Training for Disaster Management Officers

Recommendation type:
Expands, extends or modifies an existing activity being undertaken in the catchment

Contribution to PPRR:

- *Contributes across entire PPRR cycle: Community-led initiatives can themselves be part of the PPRR cycle – for example, awareness raising activities, volunteers helping vulnerable people to prevent impacts and prepare for flooding, management of evacuation centres, or helping with* *recovery efforts. Supporting community-led initiatives encourages empowerment and ownership of resilience, and builds the capacity of the community which contributes across the PPRR cycle.*

Community-led initiatives also build and strengthen social networks which encourage prevention and preparedness actions through social engagement (which improve response and recovery), but can also be activated during response and recovery (even if this is not part of the initiative).

Background:

Strong community networks contribute to community resilience generally (various sources, see Aldrich 2012; Paton and McClure 2013; Dufty 2013; Gibbs et al 2016), and, in some cases, strong community networks can lead initiatives aimed at building community resilience broadly, and disaster resilience specifically (see related examples below).

Description:

It is recommended that where community-led initiatives are identified that support community resilience and, particularly disaster preparedness, these are supported using community development approaches.

Community development approaches support community members to identify issues and work together to take collective action to improve the community's resilience, without requiring support from community development practitioners to drive the process or outcomes. Community development approaches redistribute power away from organisations and towards communities. The role of disaster management personnel, organisations and local governments in these activities is to support community-directed processes with the resources and expertise they need to undertake their work. This may include assessments of capabilities / vulnerabilities and risk, and planning support to address identified gaps in awareness and preparedness.

While it is understood that shared responsibility is a commonly understood principle in councils and other emergency management organisations, it may be less understood that an implication of this approach is that community development approaches will need to become more of 'business as usual' activity for organisations and council emergency management teams. Further investigation may be required to develop education and training to emergency management teams on community development principles to support the required change in institution culture needed to support this approach.

Considerations for implementation:

- An awards program for community-led initiatives would assist in first identifying, and secondly recognising / supporting initiatives. There are existing community resilience awards in Queensland and Australia. These awards are organised into categories based on the organisation primarily responsible for the activity (Business, Community, Government, School) and may assist in identifying community-led activities.
- Employment of community development practitioners within council and associated emergency management organisations and / or support for professional development in community development approaches could assist in providing additional support for community-led initiatives, and assist cultural change within organisations to recognise this as an implication of the shared responsibility model.

- Learn from independent evaluations of the LGAQ's implementation of the Community Development Engagement Initiative (CDEI) program to assist with the implementation of community development approaches.
- Program to identify and recognise community groups / community centres as 'Resilience Centres'. These identified Resilience Centres could provide resources / information, provide risk assessment training to others, provide support for undertaking continuity planning, build up resources to distribute after an event (similar to the Community Support Centres following the 2011 flood event), etc.
- People involved in community-led initiatives related to community resilience will develop expertise in flooding concepts, and a program to share this expertise with other community networks (where requested) would assist in sharing learnings and potentially short-cutting processes.
- Consideration should be given to historically hard to reach groups, such as dual working households and people with accessibility issues (e.g. language and transport). Engagement should consider non-traditional communities, such as online communities.

Related resources / examples:

- Case Study (outside the catchment): Emerald Community House as Centre of Resilience
- Case Study (outside the catchment): BOCO Strong: Community Powered Resilience

11.6.4.7 Build on Existing Continuity Planning Resources with a Local Program Assisting Businesses, Organisations and Community Groups

Recommendation type:

Expands, extends or modifies an existing activity being undertaken in the catchment

Contribution to PPRR:

- *Contributes across entire PPRR cycle: Continuity planning for businesses, organisations and community groups is an activity undertaken as part of preparation, however actions in the plan are implemented across the entire PPRR cycle. The continuity plan can include actions for the business, organisation or group to undertake, but can also contribute to broader outcomes for workers / members by distributing awareness materials that support prevention and preparedness, disseminating warnings and alerts to staff, providing financial support, and counselling services.*

Background:

Flood resilience and continuity planning for businesses is often forgotten in resilience planning. However, if local businesses bounce back quickly following a disaster, the community as a whole responds positively as well. Conversely, the longer a business is disrupted following a disaster, the more difficult it will be to re-establish a customer base when they return.

IGEM's Cyclone Debbie Review (2017) highlighted 'visible gaps' in business and organisational continuity planning despite sound guidance provided by Business Queensland, and found that 'enhanced business continuity planning within state agencies, businesses and communities will help all to be more resilient to the impact of events'. The review particularly noted the need for continuity planning to be a permanent feature in disaster management planning, and the need for more collaborative and integrated continuity planning – including between Council / disaster management groups, local critical infrastructure providers, and important supply chain businesses, and similarly, between businesses / community organisations and their supply chains and others on which they rely.

The Queensland Government provides information and resources for businesses to undertake business continuity planning through Business Queensland, with these services promoted and extended by Brisbane City Council. The Australia Council of Social Services also provides continuity planning resources for community organisations.

Description:

It is recommended that a program is implemented to assist businesses, organisations and community groups to assess risks and vulnerabilities, and plan for continuity of operations during flooding and other disaster events. The program can build on existing resources, supplemented by new information from the Brisbane River Catchment Flood Studies, such as the property-specific information (see Section 11.6.3.7).

One-on-one support for businesses / organisations and workshops for community groups are considered to be appropriate methods for providing this program. The program should focus on collaborative and integrated continuity planning involving networks of suppliers. As business continuity planning is a commercial activity that provides benefits to the business beyond disaster events, assistance or support from government should be provided with specific limitations, such as making the business continuity plan available online, sharing it with other businesses through business events / conferences, or focusing on the network components of continuity planning (those elements requiring coordination between suppliers).

Considerations for implementation:

- Further research should be undertaken to inform the implementation of this recommendation, and effectiveness should be evaluated during and after implementation given no engagement with businesses / organisations and evaluation of this activity was identified before making this recommendation.
- The program is recommended to be delivered through: one-to-one support for businesses interested in undertaking risk assessment and planning; and one-to-one support or workshops for community organisations or community groups (for example, neighbourhood centres) to:
  - Assist organisations better utilise the resources / templates available; and
  - Allow those implementing the program to evaluate the benefits and issues with the resources/ templates in an effort to continually improve relevance and effectiveness.
- The Department of Communities' program targeting community organisations currently being developed may have guidance for the implementation of this recommendation for not-for-profit / community organisations.
- This program should be targeted to large employers and not-for-profit / social organisations, and community groups (for example, neighbourhood centres) in the first instance, to maximise

coverage of the program and efficiency given resourcing required to deliver one-on-one support and workshops. Linkages with existing business networks, such as chambers of commerce, may also help with information distribution and awareness.

- Business-focused materials may wish to highlight information that aligns with business drivers, such as emphasising the economic disruption which may be experienced due to flooding.
- As well as planning continuity of operations, the program should consider opportunities for organisations to take a more active role in sharing awareness and preparedness messages with staff, including for example, disseminating information on warnings and alerts to staff, or providing guidance on travel to work / home from work arrangements that would assist emergency services.

Related resources / examples:

- Resource: Business Queensland – Business Continuity Planning website
- Resource / Case Study (within the catchment): ACOSS Resilient Community Organisations Toolkit

11.6.4.8 Develop Guidance for a Community Champions Program

Recommendation type:

Expands, extends or modifies an existing activity being undertaken in the catchment

Contribution to PPRR:

- *Contributes across entire PPRR cycle: Community champions can contribute to resilience across the entire PPRR cycle, for example, to share awareness materials, run awareness and resilience building activities, coordinate prevention and preparedness actions, manage evacuation centres during response, and helping with recovery efforts.*

Background:

The literature and case-study review highlighted the importance of community-led activities in the shared responsibility model.

From a practical perspective, resources to improve community resilience and support community response and recovery can be limited. Improving the skills and knowledge of key community members can help to distribute this responsibility throughout the community.

The idea of a community champions program was tested through the community survey (without details of what such a program might encompass). There was high level support for a program of this nature, with some concern that champions may not have appropriate knowledge or skills to undertake relevant tasks.

Description:

It is recommended that guidance materials are developed to support a program of identifying and upskilling a number of community leaders / community champions. In the long term, community leaders / community champions might:

- Assist with disseminating information to their networks and filter questions from the community back to authorities;

- Be involved in community resilience planning and implementation of other activities;
- Communicate with emergency service authorities regarding conditions in the local area.

Considerations for implementation:

- Existing engagement activities taking place in the catchment within neighbourhoods susceptible to flood hazards provide a local example of how the community champions program could be implemented. These engagement activities assist in identifying interested and active individuals in the local area, and could potentially be run by identified community champions on an ongoing basis.
- Community champions do not necessarily need to be leaders of a geographic area or neighbourhood, but rather could be active participants of online / specific interest communities, and could deliver messages through a variety of networks. For example, a community champion involved in social networks around their workplace, online forum, special interest group (cycling group, photography group, storm chasers group), or school community (for example, school P&C).
- Feedback from the community survey (as well as learnings from community champion programs elsewhere) should be used to shape the scope and nature of the program.
- Engagement with the community champions should commence at the flood planning stage to ensure that locally relevant information is used to shape planning and preparedness actions.

The effectiveness of this recommended activity requires further evaluation before implementation, and should also be evaluated during and after implementation.

Related resources / examples:

- Example (outside the catchment): Southern Moreton Bay Islands (SMBI) Community Champions program – network of people nominated by residents to work with Council to raise disaster awareness and preparedness.
- Example (within the catchment): ‘street meets’ within neighbourhoods susceptible to flood hazards occurring within the catchment.
- Case Study (outside the catchment): Operation Bushfire Blitz / Fire Ready Victoria street meetings.
- Case Study (outside the catchment): Mansfield community planning and resilience leadership program.

11.6.4.9 Investigate Development of Education Program on Flood Awareness and Preparedness that Aligns with the School Curriculum Outcomes

Recommendation type:

Expands, extends or modifies an existing activity being undertaken in the catchment

Contribution to PPRR:

- *Contributes across entire PPRR cycle, particularly preparedness: School education programs increase awareness of flood behaviour and flood risks, and encourage students to assess their risk with their families and broader networks. Social engagement encourages prevention and preparedness actions (which then improves response and recovery).*

Background:

Education campaigns delivered through schools can have wider impacts on the preparedness of their families and broader school communities.

Numerous school-related activities are occurring throughout the catchment area, as identified in the current activities review. Although flood education programs are supported by state organisations such as QFES, it is understood that the activities being implemented are not consistent between council areas / throughout the catchment.

Description:

It is recommended that an education program that can be integrated into the school curriculum be investigated. This should involve:

- Engagement with schools and teachers to understand learning outcomes required and thoughts on how to implement.
- Engagement with Queensland Education and Training to discuss implementation.
- Evaluation of the existing Queensland Fire and Emergency Services school program to assess effectiveness and learnings for potential wider implementation and learnings that may be relevant to flood risks.

It is expected that this action can build upon existing programs (such as Brisbane City Council's 'My Resilient Schools' program), with an emphasis on providing consistency throughout the catchment, supported by continuous evaluation and refinement.

Considerations for implementation:

- A participatory approach to education is useful in creating ownership of the issue and therefore is more likely to filter into the broader school community. For example, a pilot project in Angelsea Victoria related to bushfires involved a participatory approach to learning where students decided what they wanted to learn, researched issues supported by teachers, local and state emergency management personnel, and involved presenting learnings to the school community and other nearby schools through workshops and presentations;
- This recommendation requires further investigation into current school-focused activities being undertaken throughout the catchment, with a focus on developing consistency in messaging and content throughout the catchment.
- The effectiveness of this recommended activity requires further evaluation before implementation, and should also be evaluated during and after implementation.

Related resources / examples:

- Example (within the catchment): Brisbane City Council has developed a pilot 'My Resilient School' program, aimed at building resilience and disaster preparedness for grades five and six (developed by BCC with support from SES and QFES).
- Example (within the catchment): Ipswich City Council are currently developing a program for primary schools which aligns with the curriculum for 2018, that can be booked in and attended by schools in the area. In addition, a teacher resource is being developed for use in the classroom if not able to provide an excursion.
- Case Study (outside the catchment): Angelsea 'Survive and Thrive' schools program

11.6.5 Evaluation, Research and Advocacy Activities

11.6.5.1 Evaluate Resilience Activities and Share Learnings

Recommendation type:

New research or additional work.

Contribution to PPRR:

- *Contributes across entire PPRR cycle: Sharing learnings and evaluation findings contributes to the implementation of more effective and efficient activities across the PPRR cycle. Ultimately, more effective and efficient activities increase prevention and preparedness for future shocks and stressors, which subsequently improve response and recovery.*

Background:

Robust evaluations of community awareness and resilience activities are not undertaken enough in Australia and overseas, nor are their results published widely (Commonwealth of Australia 2010), most likely due to limitations of funding and limited understanding of evaluation methodologies. A larger evidence base of effective activities in a range of context would assist in achieving community awareness and resilience aspirations in the catchment and with regard to the broader disaster resilience field.

Description:

It is recommended that:

- A funding source for evaluation of resilience activities be investigated. This might include State Government funding and / or a partnership with a university to undertake program evaluations. It is understood that the Office of the Inspector-General Emergency Management has undertaken preliminary discussions with local government and researchers about a project through the Disaster Management Research Framework to evaluate community engagement strategies and techniques used to build community resilience;
- Robust evaluation methodology for resilience activities should be developed, including templates/ guidance materials for local governments and organisations to assist with implementation. This methodology should recommend the use of a program logic approach and therefore advocate the measuring of success in terms of indicators related to attitude change or behavioural change (not indicators of interactions/participation such as visits to a website, views on social media, letters sent, etc.);

- Evaluation results (or resultant learnings from evaluations) should be shared regionally, at the least, through established stakeholder collaboration groups, for example, the Regional Group for Coordinated Flood Awareness and Resilience working group recommended in this report, the Basecamp platform (for public documents), Inspector-General Emergency Management Collaboration Zone online forum (for 'client in confidence' documents), and ideally publicly.

Considerations for implementation:

Evaluation research suggests the following considerations for implementation:

- Evaluations should be simply written, comprehensive, theory-based and describe the program processes and contexts to be most useful (Commonwealth of Australia 2010).
- Evaluation findings should be robust, valid and compelling, seeking to contribute to the body of knowledge.
- More scientific evaluations using randomised experiments can be useful, however mixed-method (quantitative and qualitative) evaluations can be just as robust and useful, particularly when focused on improving the underlying theory of the program for a range of contexts (Commonwealth of Australia 2010).
- Evaluation methods should be included in the design of future resilience activities, to ensure that funding and resources continue to be directed to activities which are most effective.

Related resources / examples:

- Resource: Australian Institute of Disaster Resilience Guidelines for the Development of Community Education, Awareness and Engagement Programs (Manual 45) (Commonwealth of Australia 2010) evaluates a number of community resilience activities and provides recommendations relating to evaluation (as well as recommendations for resilience activities based on these evaluations).

11.6.5.2 Continue to Learn from and Share Best-Practice Research Findings on Community Resilience Activities from around Australia and Internationally

Recommendation type:
New research or additional work.
Expands, extends or modifies an existing activity being undertaken in the catchment

Contribution to PPRR:

- *Contributes across entire PPRR cycle: Sharing research findings contributes to the implementation of more effective and efficient activities across the PPRR cycle. Ultimately, more effective and efficient activities increase prevention and preparedness for future shocks and stressors, which subsequently improves response and recovery.*

Background:
Improved and increased evaluation of activities undertaken within the catchment (Section 11.6.5.1) will help stakeholders to understand what past, local activities have worked well. However, the field of community flood awareness and resilience is constantly evolving, with new research being undertaken by a range of organisations within Australia and around the world. It is important for

stakeholders in the Brisbane River catchment to look beyond the local area to identify examples and research from other regions which may be applicable in the Brisbane River catchment.

Description:
It is recommended that responsibility and communication pathways be established to ensure that all stakeholders have access to best-practice research findings on community resilience activities from around Australia and internationally. It is likely that the Queensland Reconstruction Authority, as the state's lead resilience organisation, would take the lead on the identification and synthesis of new information.

Considerations for implementation:

- Best-practice and new research may emerge from areas such as formal guidelines, journal articles, conferences, research networks, and informal sources;
- Existing communication forums, such as the Basecamp platform (for public documents), Inspector-General Emergency Management Collaboration Zone online forum (for 'client in confidence' documents) and / or the regional group for coordinated flood awareness and resilience (Section 11.6.3.1);
- Where new approaches are identified which are suitable for local-scale implementation, the Resilience Toolkit (Section 11.6.3.3) should be updated accordingly, supported by appropriate, regionally-specific guidance;
- Where new information about communication is identified, the Communication and Engagement Framework (Section 11.6.3.4) should be updated accordingly.

Related resources / examples:

- Resource: AIDR Knowledge Hub https://knowledge.aidr.org.au/

11.6.5.3 Further Research on Incorporating Psychological Preparedness into Awareness and Resilience Campaigns including Applicability to Flood Hazards

Recommendation type:
New research or additional work

Contribution to PPRR:

- *Contributes across entire PPRR cycle, particularly preparedness: Psychological preparedness is part of preparedness, however contributes to all of the PPRR cycle stages. It contributes to physical prevention and preparedness actions by reducing psychological barriers to action, improves response by reducing anxiety and negative thinking (and therefore better decision making), and longer term mental health in recovery.*

Background:

Psychological preparedness has been found to contribute to individual resilience after disaster events. Psychological preparedness can also assist in reducing barriers to preparedness action, where people might otherwise reject discussions of preparedness due to anxiety and / or past trauma.

Description:

It is recommended that further research is undertaken to understand the applicability of current research on psychological preparedness to flood hazards. This research should include how to best fill any identified gaps in understanding flood-specific psychological preparedness, and how psychological preparedness can best be incorporated into flood awareness and resilience campaigns.

Some guidance on psychological preparedness may be useful for almost all communities / households / businesses / individuals. This guidance can help communities to undertake risk assessments, and develop plans to improve their resilience, reduce flood-related anxiety, and support productive engagement in the resilience building process.

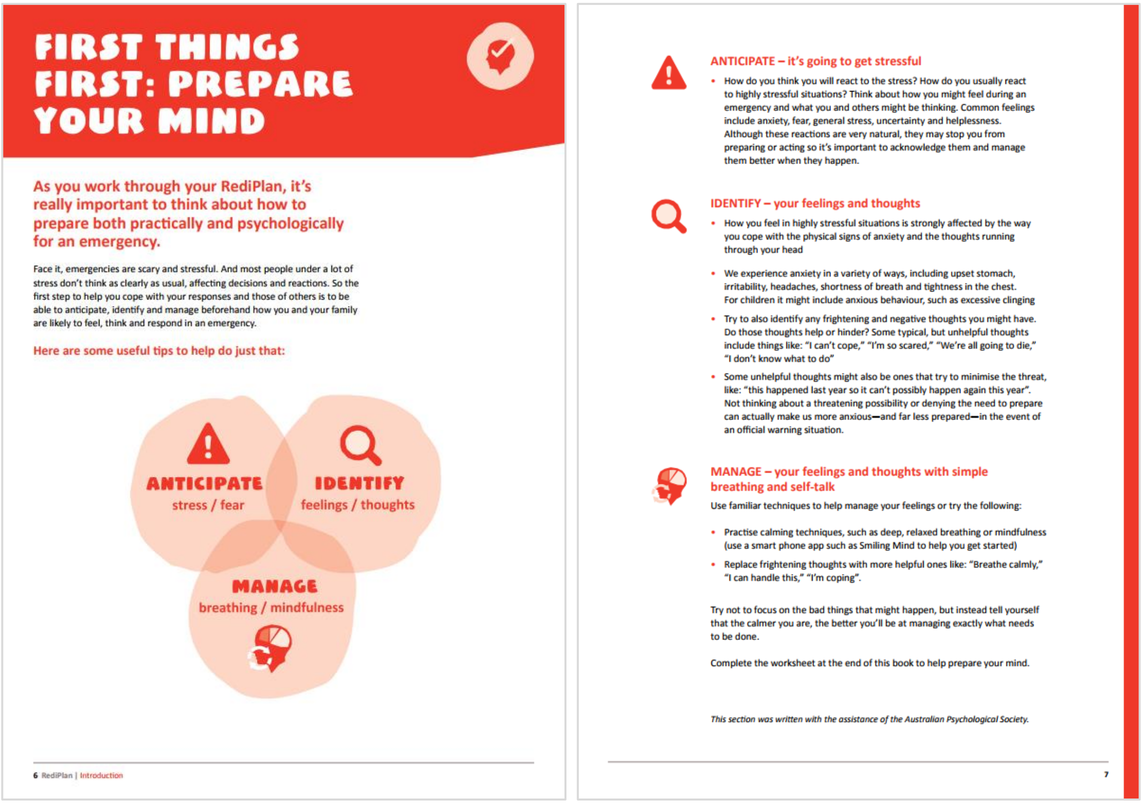
Implementation might include incorporating psychological preparedness elements in activities from flood preparedness checklists for households, to business continuity plans, to community education workshops. Psychological preparedness information may impact people differently who have experienced traumatic events in the past, and this may require special consideration during planning, implementation and evaluation.

Considerations for implementation:

- The Australian Psychological Society has been involved in developing materials for psychological preparedness relating to climate change and disaster preparedness more broadly, and might be considered as a partner for undertaking further research.

Related resources / examples:

- Resource: Red Cross RediPlan Emergency Planning Resource includes advice on psychological preparedness before working through the emergency planning process. This is in the form of two-pages of information asking users to anticipate stress / fear, identify feelings and thoughts, and manage breathing and mindfulness (see figure below). This guidance was prepared with assistance from the Australian Psychological Society.
- Case study (outside the catchment): Psychological preparedness trial in Cairns relating to cyclone warnings.



FIRST THINGS FIRST: PREPARE YOUR MIND

As you work through your RediPlan, it's really important to think about how to prepare both practically and psychologically for an emergency.

Face it, emergencies are scary and stressful. And most people under a lot of stress don't think as clearly as usual, affecting decisions and reactions. So the first step to help you cope with your responses and those of others is to be able to anticipate, identify and manage beforehand how you and your family are likely to feel, think and respond in an emergency.

Here are some useful tips to help do just that:

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ANTICIPATE – it's going to get stressful

- How do you think you will react to the stress? How do you usually react to highly stressful situations? Think about how you might feel during an emergency and what you and others might be thinking. Common feelings include anxiety, fear, general stress, uncertainty and helplessness. Although these reactions are very natural, they may stop you from preparing or acting so it's important to acknowledge them and manage them better when they happen.

IDENTIFY – your feelings and thoughts

- How you feel in highly stressful situations is strongly affected by the way you cope with the physical signs of anxiety and the thoughts running through your head
- We experience anxiety in a variety of ways, including upset stomach, irritability, headaches, shortness of breath and tightness in the chest. For children it might include anxious behaviour, such as excessive clinging
- Try to also identify any frightening and negative thoughts you might have. Do those thoughts help or hinder? Some typical, but unhelpful thoughts include things like: "I can't cope," "I'm so scared," "We're all going to die," "I don't know what to do"
- Some unhelpful thoughts might also be ones that try to minimise the threat, like: "this happened last year so it can't possibly happen again this year". Not thinking about a threatening possibility or denying the need to prepare can actually make us more anxious—and far less prepared—in the event of an official warning situation.

MANAGE – your feelings and thoughts with simple breathing and self-talk

Use familiar techniques to help manage your feelings or try the following:

- Practise calming techniques, such as deep, relaxed breathing or mindfulness (use a smart phone app such as Smiling Mind to help you get started)
- Replace frightening thoughts with more helpful ones like: "Breathe calmly," "I can handle this," "I'm coping".

Try not to focus on the bad things that might happen, but instead tell yourself that the calmer you are, the better you'll be at managing exactly what needs to be done.

Complete the worksheet at the end of this book to help prepare your mind.

This section was written with the assistance of the Australian Psychological Society.

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Figure 11-1 Psychological Preparedness in Your Emergency RediPlan

11.6.5.4 Engage with Representatives of Peak Business / Community Sector, Real Estate and Insurance Bodies to Facilitate Collaboration

Recommendation type:

New activity being undertaken in the catchment.

New research or additional work.

Contribution to PPRR:

- *Particularly supports preparedness: Ongoing collaboration with peak bodies could contribute across the PPRR cycle, however this recommendation is more focused on improving preparedness through continuity planning and provision of consistent and easy to understand information.*

Background:

Following the 2010 / 2011 Queensland floods, a number of reviews into flood insurance were undertaken, including:

- The Queensland Floods Commission of Inquiry examination of the performance of the insurers in meeting their claims responsibilities;
- The Commonwealth Natural Disaster Insurance Review;
- The House of Representatives Standing Committee Inquiry into the operation of the insurance industry during disaster events;

- The Commonwealth Treasury consideration of proposed reforms to insurance policies.

As a result of these reviews, a number of insurance reforms were undertaken, including the type of insurance cover provided and the way that insurance cover was communicated with the customer. Nonetheless, results from the market research indicates that much of the community remains confused about their flood insurance cover.

Market research suggested relatively high proportion of residents still did not know if they had sufficient insurance to meet their needs (approximately 20% of respondents). Insurance cover is a key component in financial resilience, and supports faster recovery.

Market research also found that many respondents expected to get information about flood risks from real estate agents, lawyers or banks (37% of respondents).

Description:
It is recommended that organisations and councils continue to engage with peak bodies for business / community sector, real estate agents, and insurance providers to identify opportunities to improve community flood preparedness and resilience collaboratively. Discussions could facilitate:

- Businesses / community organisations:
  - Ongoing engagement with businesses and community organisations to identify partnership opportunities;
- Real estate agents:
  - Inclusion of property-scale flood information factsheets when providing information to potential property purchasers;
- Insurance providers:
  - Clearer language in home and contents insurance policies around the inclusion or exclusion of different types of flooding events to improve property owners' understanding of their cover.
  - Messages to property owners about the type of information insurers need to process claims more quickly after an event (for example advice around scanning and uploading key documents and receipts to an online storage service).

Considerations for implementation:

- Annual conference / workshops to share new information / approaches to flood resilience, and identify opportunities for collaboration.

Related examples:

- Resource: Insurance Council of Australia (ICA) has recently released the latest version of its Simplified Hazard Exposure Map[40]. This mapping seeks to assist members of the ICA to discuss exposures to natural hazards at a local level (the data is also publicly available).
- Example (outside the catchment): Representatives from the ICA attended public consultations on flood studies hosted by Toowoomba Regional Council, allowing the community to address their

[40] http://dataglobe.maps.arcgis.com/apps/webappviewer/index.html?id=3688b4af97e248048cddc565804f5cb0

insurance-related questions directly to insurance professionals. The ICA has expressed willingness to be involved in broader floodplain management processes, including cost-benefit-assessment of structural modification measures (i.e. providing advice to help estimate the impact of e.g. a levee on insurance premiums for houses behind a levee).

11.6.6 Suites of Recommendations

Recommended activities have been grouped into logical suites of actions, based on natural groupings and the intent of the outcomes or process. In addition, suites of actions have been noted as being suitable for short-term or medium-term implementation. Those suites identified for short-term implementation are generally foundational to subsequent recommendations or the evolution of resilience building, of high or critical importance to the improvement of community resilience, and / or being delivered or supported through other components within this study (or the Phase 4 (LFMPs)).

The Strategic Plan document provides further details on the implementation of measures, including responsibilities, time-frames, and review triggers.

11.6.6.1 Short-Term Actions to Support Continuation of Study

These actions are either being currently undertaken or will be undertaken as part of this broader suite of studies (including the local / detailed flood risk management strategies).

- Develop a region-wide information and awareness campaign to share the results of Brisbane River Flood Studies (Section 11.6.3.5)
- Extend approach to community resilience in local / detailed flood risk management strategies (Section 11.6.4.1).

11.6.6.2 Short-Term Actions to Facilitate Coordination

This action is critical to facilitate regional coordination across relevant stakeholders and implement other, regionally-coordinated activities.

- Establish a regional group for coordinated flood awareness and resilience (Section 11.6.3.1).

11.6.6.3 Short-Term Actions to Support State-Wide Flood Resilience

These actions have been identified as relevant for the Brisbane River catchment, but will have relevant outcomes for the entire state.

- Develop framework for communication for use by organisations (Section 11.6.3.4)
- Summarise current resilience activities in a compendium (Section 11.6.3.2)
- Develop a resilience toolkit to guide local implementations of priority regional resilience activities (Section 11.6.3.3).

11.6.6.4 Short-Term Actions to Address Flood Awareness

These actions help to address ‘involuntary risk’ by providing targeted, relevant flood information to the community, to improve flood awareness.

- Provide online mapping for flood awareness purposes (Section 11.6.3.6)
- Provide property-scale information to households and organisations (Section 11.6.3.7)
- Investigate options for sharing location-based data across the region (Section 11.6.3.8).
- Continue implementation of a suite of activities targeting vulnerable communities at the local level (Section 11.6.4.2)
- Engage with representatives of peak business / community sector, real estate and insurance bodies to facilitate collaboration (Section 11.6.5.4).

11.6.6.5 Medium-Term Actions to Improve Delivery of Resilience Activities

These actions help to improve the delivery of resilience activities by better understanding the effectiveness of actions, and sharing learnings.

- Evaluate resilience activities and share learnings (Section 11.6.5.1)
- Continue to learn from and share best-practice research findings on community resilience activities from around Australia and internationally (Section 11.6.5.2).

11.6.6.6 Medium-Term Actions to Investigate Deeper Resilience (Beyond Awareness)

These actions seek to better understand options for improving deeper level flood resilience and require additional investigation or optioneering.

- Investigate options for facilitating / expanding / utilising volunteer connection and coordination strategies by organisations and councils at a regional level (Section 11.6.4.3)
- Investigate options for sharing flood histories through place-based installations and regional / local community events (Section 11.6.4.5)
- Investigate development of education program on flood awareness and preparedness that aligns with the school curriculum outcomes (Section 11.6.4.9)
- Further research on incorporating psychological preparedness into awareness and resilience campaigns including applicability to flood hazards (Section 11.6.5.3).

11.6.6.7 Medium-Term Actions to Facilitate Deeper Resilience (Beyond Awareness)

These actions seek to move beyond straightforward awareness activities and develop a deeper level of flood resilience in the community, particularly through community development approaches.

- Utilise existing community events / networks to support community resilience (Section 11.6.4.4)
- Support community-led initiatives using community development approaches and community development training for organisation / Council Disaster Management Officers (Section 11.6.4.6)
- Build on existing continuity planning resources with a local program assisting businesses, organisations and community groups (Section 11.6.4.7)
- Develop guidance for a community champions program to be implemented locally (Section 11.6.4.8).

12 Property Specific Flood Risk Management

Property modification measures seek to reduce flood risk to existing development by improving the resilience of buildings, raising houses, or removing properties from the flood prone location altogether.[41] Property scale measures were not in scope of this regional study, but are described here for further investigation in the Phase 4 (LFMPs), including consideration of the social and economic costs and benefits of each option relative to alternative measures.

12.1 Residential Property Buyback

For the highest risk properties in the floodplain, structural, awareness, resilience and disaster management measures may not be viable or able to sufficiently reduce flood risk, and Phase 4 (LFMPs) may include consideration of purchase options as a means of encouraging these owners to relocate away from the danger. Property buyback schemes, as referred to in Handbook 7 (AIDR, 2017), also known as voluntary purchase schemes, remove people and properties from the highest flood risk areas and enables the land to be rezoned to support a more flood-responsive settlement pattern. An alternative option is to implement a 'Right of First Refusal' or 'Option to Purchase' approach, which allows LGAs to consider purchase of specific properties in higher risk locations under particular circumstances over time. Based on the level of risk and available budget in any given year, this approach could be enacted on an as-needed basis without articulating a specific LGA policy of purchase, or setting a precedent. If implemented, legal advice should be sought on the most appropriate mechanism.

The highest priority properties based on potential hydraulic risk are categories HR1 and HR2 are those where the degree of hazard poses a safety risk to people (hazard categories H3 to H6). For an explanation of potential hydraulic risk and hazard categories, refer to Section 4.2.

Table 12-1 Residential properties based on potential hydraulic risk and higher hazard

HR category	Residential properties where hazard poses a safety risk to people, H3 to H6
HR1	860
HR2	6,300

The above property estimates are based on existing risk, and do not take account of areas where risk could be reduced through structural mitigation measures identified as part of this Phase 3 (SFMP) (Section 8 Structural Options Assessment). If considering potential buyback schemes during Phase 4 (LFMPs), properties should be reviewed in terms of their appropriateness and priority for inclusion, for example:

- Review of risk, hazard and priority of properties based on the local flood risk assessment
- Economic, social and environmental costs and benefits
- Viability of the scope and scale of the scheme

[41] Flood Resilient Building Guidance for Queensland Homes (2018) Brisbane River Catchment Flood Studies

- Identification of properties and the residential buildings on them
- Community consultation on the support (or otherwise) for a potential buyback scheme
- The impact of removal on neighbourhoods (communities and streetscapes)
- Any regional or local mitigation measures planned for implementation that will reduce (or increase) flood risk
- Any other feasible flood risk management options to address the risk to life.

Property buyback is an expensive measure, particularly in South East Queensland. Based on the preliminary estimates above, it would be prohibitively expensive to include all HR1 and HR2 properties in a buyback scheme. If introduced, it would be reserved for only the highest risk residential properties where risk can not be managed via alternative measures, or where properties are required to be resumed for the construction of flood mitigation infrastructure.

Pending QRA commentary re State position on funding.

12.2 Improving Building Resilience

For residential properties located in areas of lower hazard, as well as other types of properties (e.g. commercial, industrial etc.), there are a range of options for improving the resilience of buildings and contents to flooding, which are of most benefit to properties that are inundated relatively regularly. This may include the use of materials that are more resistant to inundation damage, installation of barrier systems, or house raising. LGAs do not necessarily need to fund these works, but can play a role by supporting and encouraging owners to improve the resilience of their buildings, either as a standalone initiative, or when undertaking renovations or extensions. This will also enable insurance companies to be leveraged to recognise resilience measures and reduce premiums accordingly. This role may include promotional campaigns targeted at suitable properties to incorporate resilience measures, and the provision of relevant flood behaviour information (depths, velocities, levels etc.) and / or small subsidies to undertake appropriate structural investigations.

In terms of house raising, houses must be of suitable construction (i.e. low-set timber, not slab on ground) and located in the lower hazard areas of the floodplain, where the degree of hazard does not pose a risk of structural damage (hazard categories H1 to H4). The building database was used to estimate the number of houses that are potentially suitable for raising by potential hydraulic risk category. For an explanation of potential hydraulic risk and hazard categories, refer to Section 4.2.

Table 12-2 Residential properties based on potential hydraulic risk and lower hazard

HR category	Low-set, timber residential properties where hazard does not pose a risk of structural damage, H1 to H4
HR1	30
HR2	590
HR3	750
HR4	1,480

The above property estimates are based on existing risk, and do not take account of areas where risk could be reduced through structural mitigation measures (Section 8 Structural Options Assessment) recommended as part of this Phase 3 (SFMP) or residential property buyback (Section 12.1). If considering potential house raising schemes during Phase 4 (LFMPs), properties should be reviewed in terms of their appropriateness and priority for inclusion in any program for improving building resilience via house raising, including consideration of design AEP and any regional or local mitigation measures planned for implementation.

Given the incised nature of much of the lower Brisbane River floodplain, the economic benefits of house raising may be limited compared to broader floodplains, due to the significant difference in flood height between events of different magnitude (Section 4 Current Flood Risk). Irrespective of whether the investment is to be publicly or privately funded, support for this measure should be informed by cost-benefit assessments to be undertaken as part of the Phase 4 (LFMPs), based on the building database (Section 4.3.2) and stage-damage curves (Section 6.6) output from this Phase 3 (SFMP).

12.3 Building Controls

Following the 2011 floods, large numbers of homes and businesses were inundated requiring significant re-construction work and in some cases total rebuilding. This event, and others, have highlighted the need for a considered and comprehensive approach to building works in areas subject to flooding to improve the resilience of buildings.

Consequentially, and in response to the QFCoI, amendments were made in 2012 to the *Building Act* 1975, and the Queensland Development Code MP3.5 – *Construction of Buildings in Flood Hazard Areas* was introduced. The purpose of these changes is to ensure the structural integrity of buildings location in flood hazard areas safeguard people against illness and injury caused by flood water affecting buildings, and that utilities are protected from the effects of floodwaters. Whilst these arrangements do not prevent consideration of other resilient design principles to reduce property damage and the time to recover, it does not provide specific guidance on wider flood resilient design principles to achieve these aims.

There are considerable benefits obtained by adopting flood resilient design principles, including reducing the tangible costs of flooding (building and possession damage), as well as the intangible costs (such as stress and emotional distress). It means that homes and businesses that would otherwise be affected by flooding, sometimes severely, are more able to function continuously or be brought back to full functionality with minimal disruption, thereby achieving the highest and best use of land possible. Design solutions where non-habitable rooms on the ground floor of a house are treated as sacrificial (and washable) in being constructed of waterproof materials and resilient construction detailing, can be easily cleaned and allow occupants to quickly move back in after flood events with minimal long-term disruption. While the upper levels, above the DFE, enable belongings to be safely stored prior to a flood event, reducing the damages to possessions.

13 Recommendations

The following recommendations of the SFMP Technical Evidence Report have been developed in response to the identified current and future risks, shaped by qualitative and quantitative analysis, together with additional recommendations identified during the preparation of the Strategic Plan document, and stakeholder consultation process. The suite of recommendations seeks to achieve the strategic aims for management of flooding in the lower Brisbane River (presented in Section 3.4).

13.1 Governance

- The BRCFS steering committee and technical working groups (or other appropriate groups) should continue to maintain a formal means of communication between the stakeholders for implementation and review of the SFMP, and the development of the Phase 4 (LFMPs).
- The SFMP should be reviewed every 5 years (or in response to other relevant triggers, e.g. a flood event or significant changes in the catchment, such as a change in the height and / or operational rules of Somerset and Wivenhoe Dams) considering all issues addressed in the original SFMP and identifying any emerging issues, new data or guidance.
- To ensure continuing relevance and useability of the Brisbane River flood models, ongoing maintenance and custodianship of the models should be managed by appropriate experienced professional(s). This should include the integration of any updates of significance to the regional flood models.
- Establish a state policy on the assessment, prioritisation and funding of flood mitigation works.
- Extend the economic framework established in this Phase 3 (SFMP) to include community awareness and resilience, disaster management, and land use planning.
- Use the climate change sensitivity analysis approach applied in this Phase 3 (SFMP) to support the implementation of the SFMP and the development of Phase 4 (LFMPs).
- Develop a coordinated, regional response to climate change and future flood risk in the Brisbane River catchment.

13.2 Data and Models

- Pre-plan the collection of regionally-consistent post-flood data, including requirements, specifications, approaches, and the development of templates.
- Collaborate with the insurance industry, QFES, QRA, GA and universities to co-ordinate post-flood surveys. Ensure future post-flood surveys collect information about property type and estimates of flood damage, as well as indirect and intangible damages, across a range of flood magnitudes. Ensure future post-flood data collection includes the collation of post-flood damage to public and community owned assets.
- Collaborate with the insurance industry to share the most current floodplain risk management information.

- Consider a program of research to establish the consequential effects of large flood events on business output, focusing on economic (rather than financial) losses in 'services' economies (particularly SEQ) and export-oriented regions including mining, agriculture and tourism.

13.3 Section 6 Landscape Management

- Co-ordinate and share landscape management information within a consistent regional framework.
- Co-ordinate, conduct and share landscape management research, in particular the relationship between broad-scale revegetation and catchment hydrology in the local catchment and climate.
- Undertake further local geomorphological studies as required to identify key catchment processes and issues, and assess current conditions and pressures, to help effectively prioritise locations for landscape management actions.
- Based on the outcomes of the research, undertake hydrologic and hydraulic modelling to assess landscape management actions in the upper catchment, including potential implications for the operation of dams in the catchment.
- Include potential landscape management actions within flood assessments for waterways within the upper catchment areas.
- Undertake catchment and receiving water quality modelling to quantify other (non-flood) benefits for waterways associated with potential landscape management actions.

13.4 Section 8 Structural Options

- **Wivenhoe Dam:** Support on-going investigations by DNRME and Seqwater on whether there is a suitable and appropriate upgrade option for Wivenhoe Dam (or other alternatives) that will reduce existing flood risks throughout the Brisbane River, and help to abate future exacerbation of flood risks due to projected climate change impacts.
- **Warrill Creek dry flood mitigation dam:** Determine State Government proponent agency. Progress to feasibility investigations including, consultation with DNRME and Seqwater, hydrologic modelling, consideration of interaction with dam operations, and failure assessment. Consult with ARTC regarding the potential for integration of the option into the Southern Freight Railway infrastructure proposed in the same vicinity as a means of overall cost and footprint reduction. Technical feasibility investigations including geotechnical drilling and test pits.
- **Brisbane CBD temporary barrier:** Progress to feasibility investigations in the Brisbane Phase 4 (LFMP), in concert with South Brisbane temporary barrier. Undertake local flood investigation at higher resolution to confirm all possible flowpaths for inundation (including via underground carparks) and refine scope of works and costs associated with temporary impoundment. Commence discussions with manufacturers of temporary barriers regarding feasibility, design and installation considerations.
- **South Brisbane temporary barrier:** Progress to feasibility investigations in the Brisbane Phase 4 (LFMP), in concert with Brisbane CBD temporary barrier. Undertake local flood investigation at higher resolution to confirm all possible flowpaths for inundation (including via basements) and

refine scope of works and costs associated with temporary impoundment. Commence discussions with manufacturers of temporary barriers regarding feasibility, design and installation considerations.

- **Ipswich CBD flood gate:** Progress to feasibility investigations for a flood gate at Marsden Parade in the Ipswich Phase 4 (LFMP). Consult with QR/DTMR regarding technical feasibility / integrity of railway embankment for flood impoundment.
- **Fernvale levee:** Assessment in the Somerset Phase 4 (LFMP), to investigate whether there are any other, more effective alternatives.
- **Goodna CBD levee / barrier:** Assessment in the Ipswich Phase 4 (LFMP), to investigate whether there are any other, more effective alternatives.
- **Amberley RAAF Air Base levee:** Progress in consultation with Department of Defence, and preferably in combination with Warrill Creek dry flood mitigation dam (to capitalise on improve immunity of access via Cunningham Highway, and offset downstream impacts).
- **Other dry flood mitigation basins:** Based on the same concept as the Warrill Creek dry flood mitigation dam, investigate other locations within the Brisbane / Bremer catchments where large scale flood mitigation dams can be established to reduce the magnitude of flood flows from the catchment, by configuring and designing new floodplain crossings of the Southern Freight Railway or other major linear infrastructure to appropriate dam standards for detention of floodwaters
- **Mt Crosby West Bank WTW levee:** Support Seqwater with the outcomes of this study to undertake more detailed investigations into the Mt Crosby West Bank WTW levee.

13.5 Section 9 Land Use Planning

- Phase 4 (LFMPs) and local flood risk assessments undertaken by each planning authority to inform the preparation of land use planning instruments incorporate the agreed SFMP defined potential hydraulic risk mapping and matrix as the technical basis to inform these studies, and is consistently applied by other floodplain managers and planning authorities, including the State, across the floodplain.
- Land use planning that requires filling, proposes changes to land form or the construction of buildings and other infrastructure results in 'no worsening' of flood hazard conditions or flood risk to other properties within the floodplain.
- A collaborative, regional cumulative impact assessment of fill, land form change and major development proposals is undertaken as a priority, to provide a holistic examination of the impact that currently planned and possible future development may have on flood behaviour across the floodplain. The regional cumulative impact assessment is prepared to inform Phase 4 (Local Floodplain Management Plans), local flood risk assessments and local planning instruments. Subject to the outcomes of the regional cumulative impact assessment, the target for total acceptable impact from cumulative filling and land form change across the floodplain does not exceed 10mm.The regional cumulative impact assessment should be updated periodically (e.g. every five years to coincide with the review of the SFMP) to include assessments undertaken as

part of development assessment to establish a new 'base case' for the future testing of cumulative impacts.

- In the absence of the regional assessment of cumulative impacts and in order to avoid any worsening of flood hazard conditions, filling and land form changes are avoided or mitigated in line with the impact on hydraulic conditions defined by the SFMP Potential Hydraulic Risk category.
- Climate change considerations are incorporated into all future flood hazard studies, local flood risk assessments, local floodplain management plans and land use planning responses, informed by a regionally coordinated climate change adaptation response. This response may be implemented via the Queensland Climate Resilient Councils Program (see Section 5.2.1).
- Tthe sensitivity analysis as detailed in Section 5.2 can be used to inform the strategic assessment of anticipated climate change impacts on future flood risk for land use planning (and other floodplain management activities).
- Local planning authorities consider "no regrets" actions that, in the absence of more detailed studies, will improve the resilience of local communities to future climate change related flood risks.
- Regional evacuation capability assessment and route network planning be prepared as a priority to inform Phase 4 (LFMPs), local flood risk assessments and subsequent land use planning responses.
- The consistent application of the identified Evacuation Risk Classification methodology is strongly encouraged as the basis for the assessment of evacuation risk to inform the preparation of Phase 4 (LFMPs), local flood risk assessments and subsequent land use planning responses.
- Vulnerable land uses involving vulnerable persons be regulated consistently across the floodplain in accordance with the following principle:
    - Vulnerable land uses involving vulnerable persons are avoided in Potential Hydraulic Risk categories, HR1 and HR2, where evacuation risk is moderate, serious or intolerable (as defined through an evacuation risk assessment).
- As part of the ongoing governance arrangements for the implementation of the SFMP, the Department of State Development, Manufacturing, Infrastructure and Planning (DSDMIP), in collaboration with the floodplain planning authorities, investigate whether there is a need for, planning implementation arrangement/s that may potentially be required in the interim to address priority land use and development regulation issues, whilst the Phase 4 (LFMPs) and planning instrument amendments proceed.
- Should it be required, DSDMIP in conjunction with the region's planning authorities and QRA, undertake an assessment of the implications of the ShapingSEQ regional planning assumptions with Brisbane River flood risk, to ensure integrated regional planning outcomes across the floodplain are identified and incorporated into future reviews of the SEQ Regional Plan.

13.6 Section 10 Disaster Management

- Use regional-scale information, data and analysis to update disaster management planning and flood intelligence for Brisbane River flooding, including LDMPs, emergency alert polygons, and other planning materials.
- Adapt and refine information, data and analysis provided in the Phase 3 (SFMP) to local contexts, including refinement of population, vulnerability and exposure data (where more detailed information available), and with consideration to other sources of flooding.
- Using the analysis provided in the Phase 3 (SFMP) and other tools, such as the DMT, determine if the available library of flood maps is sufficient to develop flood intelligence and inform flood planning and response for the full spectrum of possible flood events.
- Using relative time to inundation mapping, road inundation data (box and whisker plots) and local knowledge, identify regions which may require pre-emptive or early warning and / or evacuation.
- Review provided gauge reference areas to determine if these polygons require modification to better suit local conditions and evacuation policies, or to address multiple sources of flooding (e.g. the Jindalee Gauge reference area may require modification by Brisbane City Council to exclude those areas where early flooding is dominated by Oxley Creek).
- Undertake a high-level ‘screening’ assessment of regional evacuation capability assessment. This assessment will require identification of evacuation infrastructure (evacuation routes and centres) and evacuation policies, and should have a two-fold purpose of identifying constraints in the regional evacuation infrastructure, and determining if a detailed evacuation assessment is required at the regional scale (or would be better addressed at the local scale).
- Continue to monitor the reporting template process used to provide regular briefing reports to the State Disaster Coordination Centre and Queensland Reconstruction Authority to identify opportunities for continuous improvement, including opportunities to semi-automate the population of reports.
- Use findings from the (recently completed) study reviewing the flood warning network in Queensland via the flood warning consultative committee. Opportunities should be identified to streamline the flood warning process(e.g. limiting duplication), make better use of existing data, and identify gaps in the network where additional gauges may be valuable. This process should also identify opportunities to escalate ‘information’ gauges to ‘forecast’ gauges in the Bureau of Meteorology’s Service Level Specification for Flood Forecasting and Warning Services in Queensland.
- Using information provided in this study (including flood mapping and impact information), identify which stream gauge may require review of the gauge classifications. If gauge classification review is required, use Phase 3 (SFMP) guidance and information to support this review process.
- Scope and commence a study to develop a world-class system for undertaking real-time hydraulic modelling during flood events, producing flood inundation maps and estimations of potential flood impacts. This system should seek to integrate with existing systems operated by the Bureau of Meteorology and Seqwater, and deliver information which is accessible to all stakeholders.

Scoping of the study should aim to deliver interim products which provide value to the catchment prior to the complete delivery of the overall system. Recognising the limitations of current modelling in capturing flood operations in the complex upper catchments of the floodplain, investigate and implement improvements that will strengthen and increase the reliability of flood intelligence systems.

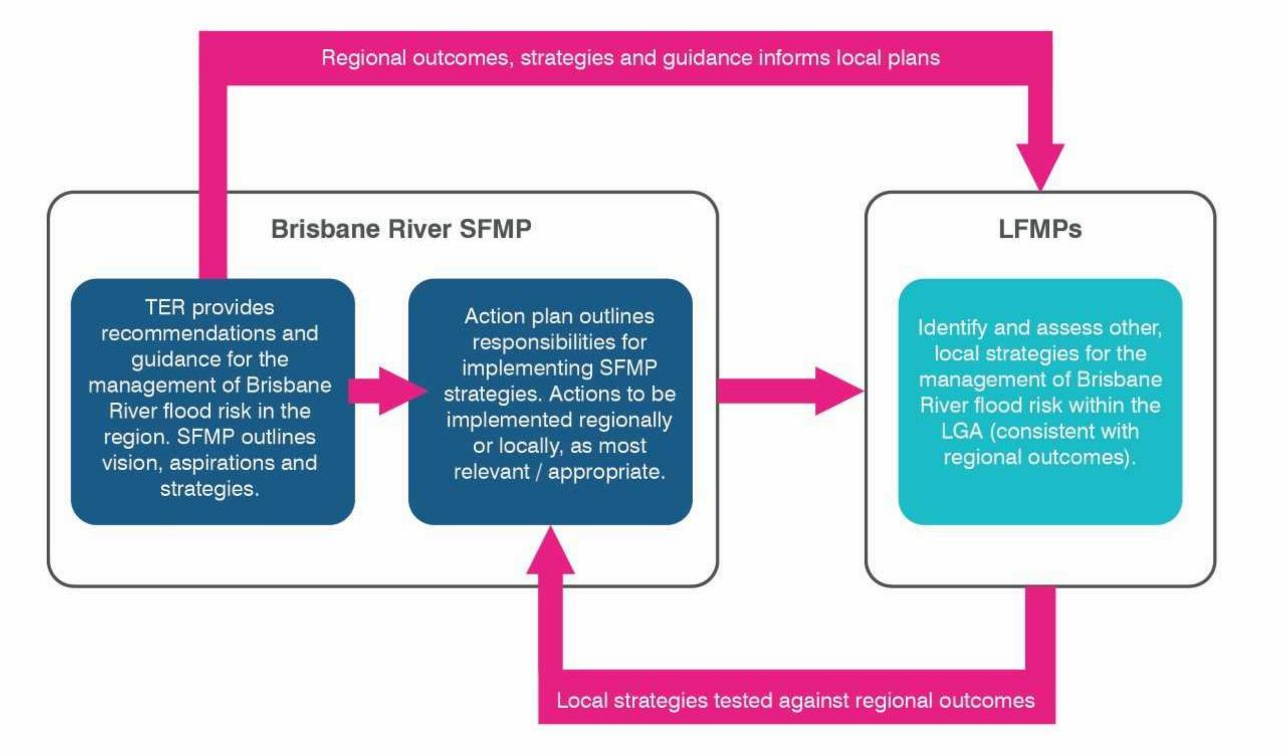
- Continue normal liaison with the Bureau of Meteorology to understand and implement new services and products which are scheduled for release in the near future.

13.7 Section 11 Community Awareness and Resilience

- Establish or utilise existing community awareness and resilience working group to facilitate coordinated awareness and resilience activities within the floodplain.
- Develop regional reference material including a compendium of current activities and learnings, toolkit of activities and guidelines for communication and engagement.
- Evaluate community awareness and resilience activities relating to flooding and share learnings from the evaluation in order to inform continual improvement in suitability and effectiveness of programs based on current research.
- Undertake regional activities including online flood mapping, provision of property-scale flood information, and place-based installations.
- Develop guidance for a community champion program to assist with disseminating information, resilience planning and activities, and communication of local conditions.
- Undertake local activities with regionally consistent elements, including updating existing processes, plans and activities with new information and learnings provided in the Phase 3 (SFMP). These activities should be designed to support the flood resilience aspirations and be informed by the principles for resilience activities provided in the Phase 3 (SFMP). Particular effort should be made to use existing community networks and support community-led initiatives.
- Undertake research on incorporating psychological preparedness into awareness and resilience campaigns, including materials or activities focusing on flood risk.

13.8 Phase 4 Local Floodplain Management Plans

Develop Phase 4 (LFMPs) based on the findings, aspirations and approaches identified in this Phase 3 (SFMP).



13.8.1 General Considerations

Phase 4 (LFMPs) should:

- Be developed cognisant of all appropriate frameworks, legislation, policies etc relevant at the time. These would include any relevant state instruments, as well as locally specific instruments that will guide Phase 4 (LFMPs).
- Support the vision of regional consistency, as established in the Phase 3 (SFMP). Regional consistency means all relevant authorities using the same approach and definitions of existing and future flood risks, so that common terminology can be used throughout the region without misrepresentation. This approach and definition of flood risks is described in Section 4 Current Flood Risk.
- Use a consistent methodology to developing Phase 4 (LFMPs) and local flood risk assessments across all LGA-wide local flood plans so that there is no disconnect at LGA boundaries in terms of flood risk definition or flood behaviour interpretation. The SFMP potential hydraulic risk matrix and mapping identifies the inherent and unmitigated flood risk and is used as the technical basis to inform the Phase 4 (LFMPs) and local flood risk assessments.
- Include a local flood risk assessment as part of the preparation of the LFMP, which addresses the requirements of the State Planning Policy – Natural hazards, risks and resilience – Flood.

- Address regional issues that have been identified as part of the Phase 3 (SFMP) and maintain consistency with Phase 3 (SFMP) outcomes. Some regional issues need local application within just one LGA, while some LGAs will be dependent on issues being addressed locally elsewhere (i.e. outside their LGA) to help manage their flood risks. Consideration of regional issues will likely require input and direction from State government and other stakeholders.
- Generally follow Phase 3 (SFMP) scope of works, including taking an integrated catchment planning approach that allows for an integrated risk assessment inclusive of both regional and local catchment matters. Integrated catchment planning enables floodplain management to be considered and addressed within the context of a holistic view of the catchment that also includes water supply, landscape management, land use planning and general environmental health. A finer level of granularity will be achieved through refined data (where available) and consideration of community-specific constraints/opportunities, such as demographics, evacuation access and local resilience.
- Apply the assessment primarily to riverine flooding, however councils could also look to include other inundation mechanisms (local catchments, overland flow, storm tide) where appropriate to do so to provide a more integrated floodplain management response, providing it does not compromise the ability for the plan to address flood risk management outcomes for riverine flooding circumstances.

13.8.2 Governance

Phase 4 (LFMPs) should incorporate appropriate governance and oversight to ensure they meet the general considerations listed above. Specifically:

- Phase 4 (LFMPs) should be guided by a local technical committee or similar – details of which would be determined by each council. A representative from the State Government who has good familiarity with the Phase 3 (SFMP) (and possibly Phase 2 (Flood Study)) could be included as an advisor or observer, to help maintain consistency across the Phase 4 (LFMPs). Members of the committee should be from relevant sections of council, such as engineering, land use planning, disaster management etc. Consideration could also be given to allow periodic input from other relevant stakeholders, such as the Bureau, Seqwater, DTMR, QR, etc.
- Community consultation and engagement is an important part of the governance structure; without community input, there is the potential that flood risk may not be adequately identified and described, that opportunities for managing risk may be missed, and that preferred options may not be supported by the community. Consultation channels with the community will be best established through councils' current engagement processes, and will be appropriate and tailored for the community, as this is the principal mechanism to determine community acceptability and tolerability.
- Where outputs from the Phase 4 (LFMP) intersect with other local areas or with the broader region, state government should have responsibility for facilitating integration across boundaries.

13.8.3 Scope

The scope of the Phase 4 (LFMPs) should largely follow the Phase 3 (SFMP) and should include the following elements.

13.8.3.1 Flood Damage Assessment

- An up-front assessment should be undertaken at project scoping stage to identify if data from the Phase 3 (SFMP) (and Phase 2 (Flood Study)) is suitable at the local scale. If additional data is required, the data should be developed and collated in a way which ensures it will be compatible with regional data (e.g. the same flood events are simulated and same process followed). It is not expected that local flood models will produce exactly the same flood levels as the regional model, but will require validation against the regional model.
- If no new flood data is available (and cannot be reasonably developed within available time and / or budget), then adopt the definition of flood risk from the Phase 3 (SFMP), including potential hydraulic risk, exposure, vulnerability, isolation and relative time to inundation, noting the more refined focus of attention at the local scale with thresholds set as appropriate. This approach should be applied with relevant caveats and recognition that improved data should be sought and utilised in the future.
- If new flood data is available and relevant, such as more refined flood modelling results (which demonstrably improves the accuracy of the Phase 2 (Flood Study)) or expansion of the model into local areas not covered by the Phase 2 (Flood Study), redefine local flood risk using the same process as adopted in the Phase 3 (SFMP), including potential hydraulic risk as defined by the Phase 3 (SFMP) risk matrix, exposure, vulnerability, isolation and relative time to inundation.
- Utilise existing property and damages database from the Phase 3 (SFMP). Where possible, update building database with more refined information on local sensitive institutions, local critical infrastructure etc. Where databases are refined, ensure that updates are provided to the 'custodian' of Phase 3 (SFMP) data to ensure that all users have access to the most up-to-date common datasets.
- Undertake engagement with the community and consult with relevant stakeholders to confirm local 'tolerability' to flood risk, based on the degree of acceptance/tolerance of flooding, isolation and warnings within individual communities across the LGA. Community consultation should also test acceptability of possible flood risk mitigation options, including the broad range of option types covering infrastructure, land use planning, disaster management, community awareness and property-specific measures.
- Reassess risk to communities posed by evacuation limitations and isolation. First, local evacuation routes and associated feeder roads need to be identified (beyond the state-controlled roads assessed in the Phase 3 (SFMP)), then assess populations using the routes, the capacity of the routes and the timeframe in which they would be utilised. Consider also alternative routes, and route destinations (e.g. flood free land, local evacuation centre) as well as flood warning, warning dissemination, active evacuation and shelter. Phase 4 (LFMPs) should investigate local

factors that can influence evacuation route usability, such as local flooding, culvert capacity etc, which was not captured by the regional assessment in the Phase 3 (SFMP).

13.8.3.2 Landscape Management

- Landscape management should be sponsored and pursued at a catchment scale. Phase 4 (LFMPs) should identify proposed landscape management works within the LGA, as part of overall catchment-wide initiatives, and ensure they are integrated into, and consistent with, other local environmental management strategies and land use plans.
- Councils can participate in field research and further investigations in assessing the hydrological impacts of landscape management such that of potential future benefits of these works can be quantified and included in decision-making.

13.8.3.3 New or Improved Infrastructure

- Identify structural options that can be implemented at the local scale to address local flooding issues. Draw on suggestions from local communities and relevant stakeholders (many of which were identified in the long list of options included in the Phase 3 (SFMP)), and assess structural options. A multi criteria assessment (MCA) process similar to that used in the Phase 3 (SFMP) is recommended, but can be modified, providing the assessment still meets stakeholder expectations.
- Benefit cost analysis of options should use the property damage database from the Phase 3 (SFMP) along with hydraulic impact modelling using the most up-to-date flood model for the local area to ensure consistency of results across the floodplain. It is noted that some options will be difficult or impossible to cost for the purposes of a benefit cost analysis, and therefore need particular attention in the MCA process.
- Preferred regional infrastructure solutions (identified in Phase 3 (SFMP)) to be applied locally within the LGA should be developed further, including optioneering with stakeholders, to optimise design for maximum benefit / least cost. This should be led by the state government or other stakeholders if it is beyond the capacity and scope of LGAs, including development of suitable funding arrangements for these options.
- Where relevant to do so, test suites of structural options, e.g. if a regional scale option is being considered within the local area, and additional local scale options are also being considered, undertake a hydraulic assessment to understand the combined impact of options.

13.8.3.4 Property Specific Actions

- Consider property-specific options for mitigating existing flood risk, residential property buyback / voluntary purchase, voluntary house raising, and flood-proofing (including possible adjustments to planning controls to support these measures) for a range of AEPs. Property-specific measures should be considered where flood risks are high and other alternative options are not feasible.

- Benefit cost analysis should be carried out to establish the financial merits of property specific actions. Assess property specific options using the same MCA process and criteria as per the structural options.

13.8.3.5 Land Use Planning

- Consider implications of the SFMP defined potential hydraulic risk categories, other SFMP flood risk factors and other relevant local considerations, on existing land use and zonings within the planning scheme, including areas of proposed future urban expansion. The higher the flood risk, the less likely it will be suitable for urban development without significant risk treatment. Where hydraulic risk is not compatible with existing or proposed land uses, consider changes to planning scheme responses including zonings as appropriate. The SFMP potential hydraulic risk matrix and mapping is used as the technical basis to identify the inherent and 'unmitigated' flood risk from flood behaviour and to inform the Phase 4 (LFMPs), including an assessment of the appropriateness of existing land use planning and development controls, as well as other non-planning scheme flood risk mitigation options. If it is determined that, on balance and notwithstanding the existing planning controls and other flood risk mitigation options, there still remains an intolerable level of risk, additional land use planning responses should be considered to reduce the risk to a tolerable or acceptable level, given there are no other feasible alternatives.
- Consider requirements of the SPP, and consult relevant guidance material provided in the SPP guidelines (flooding) and Brisbane River Phase 3 (SFMP) Land Use Planning Guidelines, for taking a risk-based approach to land use planning in addressing flood risk when amending planning schemes, including appropriateness of the strategic framework, zonings and overlays. In satisfying the SPP risk assessment process, the Phase 4 (LFMP) should identify any changes required to the planning schemes informed by the regional consideration of land use planning carried out in the Phase 3 (SFMP), and outlined in the Phase 3 (SFMP) Land Use Planning Guidance, in order to avoid inconsistencies at LGA boundaries (that is, potentially similar development within the same flood risk zone having different planning outcomes at the boundaries).
- Review local requirements for freeboard noting the recommendations of the Phase 3 (SFMP) and the sensitivity of hydraulic response of the floodplain.
- Review planning scheme provisions regulating filling and landform changes within the sensitive zones of the floodplain (particularly focussing on flow conveyance and storage areas) noting the recommendations of the Phase 3 (SFMP), especially in regard to potential impacts of landform changes and filling beyond LGA boundaries when considered on a cumulative basis. The outcomes of a cumulative impact assessment should inform development controls and restrictions for landform changes and filling and should take a whole-of-floodplain approach with collaboration and consistency across LGAs.
- Review local requirements for consideration of future climate change (as guided by ARR 2016) in land use allocation and development controls noting the recommendations of the Phase 3 (SFMP), and the sensitivity of the floodplain to increases in catchment flows and ocean tailwater levels. Climate change scenarios to be adopted consistently across the region are outlined in

Section 5 Future Flood Risk, with the SFMP definition of hydraulic risk applied to determine future implications of climate change at the local level.

13.8.3.6 Disaster Management

- Where additional (local) flood modelling is being undertaken to support the Phase 4 (LFMP), ensure the model outputs are sufficient to inform disaster management planning (e.g. information about inundation timing, hazards, isolation, road inundation etc.).
- Update the local disaster management plan (including evacuation planning) to incorporate the best available data from regional-scale and / or more refined local flood information generated as part of the Phase 4 (LFMP) process (depending on data availability and priority).
- Use outputs from evacuation capability assessment to inform isolation assessment and consider options to manage, including pre-emptive evacuation and opportunities for road upgrades/raising and route deviations.
- Where assessments indicate potential for fast-onset flooding, consider implementation of flash flood warning systems, informed by best-practice guidance via FLARE.
- Ensure that local / district / state disaster management systems and databases are maintained with refined or new data developed during the Phase 4 (LFMP).
- Use results of regional and local scale assessments to identify regions of similar risk and develop emergency alert polygons for these locations.
- Resource sharing across LGAs should be considered for disaster management actions, and also for community awareness and resilience actions.

13.8.3.7 Community Awareness and Resilience

- Refine demographic data identified through the regional-scale vulnerability assessment to develop sub-local area community profiles. These refinements may be informed by local knowledge of relevant stakeholders engaged with the community.
- Catalogue current awareness and resilience activities being undertaken within the local area, and state / regional scale activities which affect the local area.
- Informed by local-scale flood risk assessment, undertake a gap analysis to identify regions, communities, types of flood risks etc. where additional community awareness and resilience building is required.
- Use regional (and state) scale resources to develop materials and programs more efficiently, ensuring that any resources, such as online flood mapping, is not inconsistent or confusing with existing resources available through LGAs or other stakeholders.
- Maintain regional consistency in messaging facilitated by regional resilience and disaster management groups, and by state government participation on Phase 4 (LFMP) committee, as required.

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Appendix A Property Flood Damage Estimates by Postcode

Note that based on the property floor level database a small number of properties have floor levels that are lower than the adjacent ground levels.

Table A-1 Property flood damage estimates for 1 in 2 AEP design flood event

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4000	0	0	-	0	0	-	-
4005	0	0	-	0	0	-	-
4006	0	0	-	4	2	$0.244	$0.244
4007	0	0	-	4	1	$0.177	$0.177
4008	0	0	-	0	0	-	-
4009	0	0	-	0	0	-	-
4010	0	0	-	2	1	$0.024	$0.024
4011	0	0	-	0	0	-	-
4012	0	0	-	0	0	-	-
4013	0	0	-	0	0	-	-
4014	0	0	-	0	0	-	-
4017	0	0	-	0	0	-	-
4018	0	0	-	0	0	-	-
4030	0	0	-	0	0	-	-
4034	0	0	-	0	0	-	-
4051	0	0	-	0	0	-	-
4059	0	0	-	0	0	-	-
4060	0	0	-	0	0	-	-
4064	0	0	-	0	0	-	-
4065	0	0	-	0	0	-	-
4066	0	0	-	0	0	-	-
4067	0	0	-	0	0	-	-
4068	0	0	-	0	0	-	-
4069	0	0	-	0	0	-	-
4070	0	0	-	0	0	-	-
4073	0	0	-	0	0	-	-
4074	0	0	-	0	0	-	-
4075	0	0	-	0	0	-	-
4076	0	0	-	0	0	-	-
4077	0	0	-	0	0	-	-
4078	0	0	-	0	0	-	-
4101	0	0	-	4	1	$0.030	$0.030
4102	0	0	-	0	0	-	-
4103	0	0	-	0	0	-	-

Property flood damage estimates for 1 in 2 AEP design flood event continued

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4104	0	0	-	0	0	-	-
4105	0	0	-	0	0	-	-
4106	0	0	-	0	0	-	-
4107	0	0	-	0	0	-	-
4108	0	0	-	0	0	-	-
4109	0	0	-	0	0	-	-
4110	0	0	-	0	0	-	-
4115	0	0	-	0	0	-	-
4116	0	0	-	0	0	-	-
4120	0	0	-	0	0	-	-
4121	0	0	-	0	0	-	-
4151	0	0	-	0	0	-	-
4152	0	0	-	0	0	-	-
4153	0	0	-	0	0	-	-
4154	0	0	-	0	0	-	-
4169	0	0	-	3	0	$0.000	$0.000
4170	1	0	$0.002	0	0	-	$0.002
4171	0	0	-	2	1	$0.022	$0.022
4172	0	0	-	0	0	-	-
4173	0	0	-	0	0	-	-
4174	2	1	$0.035	0	0	-	$0.035
4178	0	0	-	0	0	-	-
4179	0	0	-	0	0	-	-
4300	0	0	-	0	0	-	-
4301	0	0	-	0	0	-	-
4303	0	0	-	0	0	-	-
4304	0	0	-	0	0	-	-
4305	0	0	-	0	0	-	-
4306	0	0	-	0	0	-	-
4307	0	0	-	0	0	-	-
4311	0	0	-	0	0	-	-
4341	0	0	-	0	0	-	-
4342	0	0	-	0	0	-	-
4343	0	0	-	0	0	-	-
Total	**3**	**1**	**$0.036**	**19**	**6**	**$0.497**	**$0.533**

Table A-2 Property flood damage estimates for 1 in 5 AEP design flood event

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4000	0	0	-	0	0	-	-
4005	0	0	-	0	0	-	-
4006	0	0	-	14	2	$0.828	$0.828
4007	0	0	-	4	1	$0.336	$0.336
4008	0	0	-	0	0	-	-
4009	0	0	-	0	0	-	-
4010	0	0	-	3	1	$0.053	$0.053
4011	0	0	-	0	0	-	-
4012	0	0	-	0	0	-	-
4013	0	0	-	0	0	-	-
4014	0	0	-	0	0	-	-
4017	1	0	$0.000	0	0	-	$0.000
4018	0	0	-	0	0	-	-
4030	0	0	-	0	0	-	-
4034	0	0	-	0	0	-	-
4051	0	0	-	0	0	-	-
4059	0	0	-	0	0	-	-
4060	0	0	-	0	0	-	-
4064	0	0	-	0	0	-	-
4065	0	0	-	0	0	-	-
4066	0	0	-	0	0	-	-
4067	0	0	-	0	0	-	-
4068	0	0	-	0	0	-	-
4069	0	0	-	0	0	-	-
4070	0	0	-	0	0	-	-
4073	0	0	-	0	0	-	-
4074	0	0	-	0	0	-	-
4075	1	0	$0.001	0	0	-	$0.001
4076	0	0	-	0	0	-	-
4077	0	0	-	0	0	-	-
4078	0	0	-	0	0	-	-
4101	0	0	-	4	1	$0.390	$0.390
4102	0	0	-	0	0	-	-
4103	0	0	-	0	0	-	-

Property flood damage estimates for 1 in 5 AEP design flood event continued

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4104	0	0	-	0	0	-	-
4105	0	0	-	0	0	-	-
4106	0	0	-	2	1	$0.058	$0.058
4107	0	0	-	0	0	-	-
4108	0	0	-	0	0	-	-
4109	0	0	-	0	0	-	-
4110	0	0	-	0	0	-	-
4115	0	0	-	0	0	-	-
4116	0	0	-	0	0	-	-
4120	0	0	-	0	0	-	-
4121	0	0	-	0	0	-	-
4151	0	0	-	0	0	-	-
4152	0	0	-	0	0	-	-
4153	0	0	-	0	0	-	-
4154	0	0	-	0	0	-	-
4169	0	0	-	3	0	$0.000	$0.000
4170	1	0	$0.003	0	0	-	$0.003
4171	0	0	-	2	1	$0.225	$0.225
4172	0	0	-	0	0	-	-
4173	0	0	-	0	0	-	-
4174	2	2	$0.060	0	0	-	$0.060
4178	0	0	-	0	0	-	-
4179	0	0	-	0	0	-	-
4300	0	0	-	0	0	-	-
4301	0	0	-	0	0	-	-
4303	0	0	-	0	0	-	-
4304	0	0	-	0	0	-	-
4305	1	0	$0.002	1	1	$1.026	$1.028
4306	8	3	$0.246	0	0	-	$0.246
4307	0	0	-	0	0	-	-
4311	13	2	$0.105	0	0	-	$0.105
4341	0	0	-	0	0	-	-
4342	2	0	$0.007	0	0	-	$0.007
4343	0	0	-	0	0	-	-
Total	**29**	**7**	**$0.424**	**33**	**8**	**$2.916**	**$3.340**

Table A-3 Property flood damage estimates for 1 in 10 AEP design flood event

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4000	9	0	$0.000	7	2	$0.033	$0.034
4005	0	0	-	0	0	-	-
4006	0	0	-	14	2	$0.749	$0.749
4007	0	0	-	4	1	$0.325	$0.325
4008	0	0	-	0	0	-	-
4009	0	0	-	0	0	-	-
4010	0	0	-	3	1	$0.093	$0.093
4011	0	0	-	0	0	-	-
4012	0	0	-	0	0	-	-
4013	0	0	-	0	0	-	-
4014	0	0	-	0	0	-	-
4017	1	0	$0.001	0	0	-	$0.001
4018	0	0	-	0	0	-	-
4030	0	0	-	0	0	-	-
4034	0	0	-	0	0	-	-
4051	0	0	-	0	0	-	-
4059	0	0	-	0	0	-	-
4060	0	0	-	0	0	-	-
4064	0	0	-	0	0	-	-
4065	0	0	-	0	0	-	-
4066	0	0	-	0	0	-	-
4067	0	0	-	0	0	-	-
4068	0	0	-	0	0	-	-
4069	0	0	-	0	0	-	-
4070	2	2	$0.090	0	0	-	$0.090
4073	0	0	-	0	0	-	-
4074	4	1	$0.088	0	0	-	$0.088
4075	13	1	$0.160	6	2	$0.224	$0.384
4076	0	0	-	0	0	-	-
4077	0	0	-	0	0	-	-
4078	0	0	-	0	0	-	-
4101	0	0	-	6	1	$0.336	$0.336
4102	0	0	-	0	0	-	-
4103	0	0	-	0	0	-	-

Property flood damage estimates for 1 in 10 AEP design flood event continued

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4104	0	0	-	0	0	-	-
4105	0	0	-	0	0	-	-
4106	10	0	$0.044	43	22	$2.286	$2.329
4107	0	0	-	0	0	-	-
4108	0	0	-	0	0	-	-
4109	0	0	-	0	0	-	-
4110	0	0	-	0	0	-	-
4115	0	0	-	0	0	-	-
4116	0	0	-	0	0	-	-
4120	0	0	-	0	0	-	-
4121	0	0	-	0	0	-	-
4151	0	0	-	0	0	-	-
4152	0	0	-	0	0	-	-
4153	0	0	-	0	0	-	-
4154	0	0	-	0	0	-	-
4169	0	0	-	3	0	$0.000	$0.000
4170	2	0	$0.004	0	0	-	$0.004
4171	0	0	-	2	1	$0.201	$0.201
4172	0	0	-	0	0	-	-
4173	0	0	-	0	0	-	-
4174	4	2	$0.081	0	0	-	$0.081
4178	0	0	-	0	0	-	-
4179	0	0	-	0	0	-	-
4300	0	0	-	0	0	-	-
4301	0	0	-	0	0	-	-
4303	0	0	-	0	0	-	-
4304	19	10	$0.969	0	0	-	$0.969
4305	79	21	$2.074	25	12	$5.561	$7.635
4306	25	17	$1.397	0	0	-	$1.397
4307	0	0	-	0	0	-	-
4311	41	10	$0.631	0	0	-	$0.631
4341	0	0	-	0	0	-	-
4342	12	3	$0.258	2	1	$0.193	$0.451
4343	2	0	$0.025	0	0	-	$0.025
Total	**223**	**67**	**$5.823**	**115**	**45**	**$10.00**	**$15.82**

Table A-4 Property flood damage estimates for 1 in 20 AEP design flood event

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4000	9	0	$0.000	7	2	$0.067	$0.067
4005	0	0	-	0	0	-	-
4006	0	0	-	26	3	$1.680	$1.680
4007	0	0	-	4	1	$0.368	$0.368
4008	0	0	-	0	0	-	-
4009	0	0	-	0	0	-	-
4010	6	2	$0.093	17	6	$0.416	$0.508
4011	0	0	-	0	0	-	-
4012	0	0	-	0	0	-	-
4013	0	0	-	0	0	-	-
4014	1	0	$0.003	0	0	-	$0.003
4017	2	0	$0.004	0	0	-	$0.004
4018	0	0	-	0	0	-	-
4030	0	0	-	0	0	-	-
4034	0	0	-	0	0	-	-
4051	0	0	-	0	0	-	-
4059	0	0	-	0	0	-	-
4060	0	0	-	0	0	-	-
4064	0	0	-	28	1	$0.010	$0.010
4065	0	0	-	0	0	-	-
4066	0	0	-	0	0	-	-
4067	0	0	-	0	0	-	-
4068	1	0	$0.001	0	0	-	$0.001
4069	1	0	$0.013	0	0	-	$0.013
4070	4	4	$0.498	0	0	-	$0.498
4073	0	0	-	0	0	-	-
4074	4	2	$0.179	0	0	-	$0.179
4075	98	31	$2.938	34	23	$7.990	$10.93
4076	0	0	-	0	0	-	-
4077	0	0	-	2	0	$0.000	$0.000
4078	0	0	-	0	0	-	-
4101	0	0	-	6	1	$0.395	$0.395
4102	0	0	-	0	0	-	-
4103	1	0	$0.018	0	0	-	$0.018

Property flood damage estimates for 1 in 20 AEP design flood event continued

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4104	0	0	-	0	0	-	-
4105	6	1	$0.158	7	2	$0.045	$0.203
4106	96	26	$2.493	138	80	$25.59	$28.08
4107	0	0	-	0	0	-	-
4108	0	0	-	0	0	-	-
4109	0	0	-	0	0	-	-
4110	2	1	$0.040	0	0	-	$0.040
4115	0	0	-	0	0	-	-
4116	0	0	-	0	0	-	-
4120	0	0	-	0	0	-	-
4121	0	0	-	0	0	-	-
4151	0	0	-	0	0	-	-
4152	0	0	-	0	0	-	-
4153	0	0	-	0	0	-	-
4154	0	0	-	0	0	-	-
4169	6	0	$0.011	3	0	$0.000	$0.011
4170	14	1	$0.045	1	0	$0.000	$0.045
4171	1	0	$0.001	3	1	$0.284	$0.285
4172	0	0	-	0	0	-	-
4173	0	0	-	0	0	-	-
4174	8	3	$0.137	1	0	$0.000	$0.137
4178	0	0	-	0	0	-	-
4179	0	0	-	0	0	-	-
4300	11	1	$0.262	2	0	$0.000	$0.262
4301	0	0	-	0	0	-	-
4303	0	0	-	0	0	-	-
4304	78	50	$5.869	0	0	-	$5.869
4305	209	100	$10.99	90	59	$19.21	$30.20
4306	58	35	$3.573	9	1	$0.099	$3.673
4307	0	0	-	0	0	-	-
4311	108	38	$2.844	0	0	-	$2.844
4341	2	1	$0.061	0	0	-	$0.061
4342	24	6	$0.735	4	1	$0.257	$0.992
4343	3	1	$0.065	0	0	-	$0.065
Total	**753**	**303**	**$31.03**	**382**	**181**	**$56.41**	**$87.44**

Table A-5 Property flood damage estimates for 1 in 50 AEP design flood event

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4000	12	1	$0.008	13	2	$0.116	$0.124
4005	63	6	$0.290	16	1	$0.126	$0.416
4006	0	0	-	64	15	$3.461	$3.461
4007	3	1	$0.068	4	0	$0.000	$0.068
4008	2	0	$0.003	0	0	-	$0.003
4009	0	0	-	0	0	-	-
4010	21	3	$0.548	91	45	$6.328	$6.876
4011	0	0	-	0	0	-	-
4012	0	0	-	0	0	-	-
4013	0	0	-	0	0	-	-
4014	6	5	$0.162	0	0	-	$0.162
4017	2	0	$0.005	0	0	-	$0.005
4018	0	0	-	0	0	-	-
4030	28	1	$0.228	18	2	$0.351	$0.579
4034	0	0	-	0	0	-	-
4051	0	0	-	0	0	-	-
4059	0	0	-	0	0	-	-
4060	0	0	-	0	0	-	-
4064	48	7	$1.533	227	67	$20.42	$21.96
4065	0	0	-	0	0	-	-
4066	90	14	$3.069	36	6	$2.222	$5.291
4067	123	7	$2.613	9	0	$0.000	$2.613
4068	109	31	$4.383	12	7	$1.412	$5.795
4069	17	6	$0.942	11	7	$5.074	$6.016
4070	16	14	$1.736	0	0	-	$1.736
4073	0	0	-	9	7	$1.447	$1.447
4074	17	7	$0.714	47	22	$5.935	$6.650
4075	473	245	$28.88	74	44	$32.28	$61.16
4076	1	0	$0.007	0	0	-	$0.007
4077	10	8	$0.736	2	0	$0.000	$0.736
4078	0	0	-	0	0	-	-
4101	32	6	$0.699	23	3	$1.019	$1.718
4102	1	0	$0.002	0	0	-	$0.002
4103	165	57	$7.641	5	2	$0.365	$8.006

Property flood damage estimates for 1 in 50 AEP design flood event continued

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4104	51	19	$2.297	2	1	$0.283	$2.579
4105	11	6	$0.745	46	19	$9.643	$10.39
4106	301	154	$18.95	559	382	$189.5	$208.4
4107	0	0	-	0	0	-	-
4108	21	5	$0.707	22	13	$1.763	$2.470
4109	0	0	-	0	0	-	-
4110	7	4	$0.374	0	0	-	$0.374
4115	0	0	-	0	0	-	-
4116	0	0	-	0	0	-	-
4120	0	0	-	2	1	$0.054	$0.054
4121	0	0	-	0	0	-	-
4151	5	0	$0.009	2	0	$0.000	$0.009
4152	0	0	-	0	0	-	-
4153	0	0	-	0	0	-	-
4154	0	0	-	0	0	-	-
4169	53	11	$1.086	5	0	$0.000	$1.086
4170	50	11	$0.921	5	2	$0.147	$1.068
4171	18	3	$0.188	10	4	$0.254	$0.442
4172	0	0	-	0	0	-	-
4173	0	0	-	0	0	-	-
4174	9	3	$0.163	1	0	$0.000	$0.163
4178	0	0	-	0	0	-	-
4179	0	0	-	0	0	-	-
4300	246	187	$25.41	35	24	$10.29	$35.70
4301	2	1	$0.053	8	3	$0.913	$0.966
4303	4	0	$0.076	0	0	-	$0.076
4304	341	253	$39.43	31	13	$4.509	$43.94
4305	1,083	685	$98.51	233	181	$134.4	$232.9
4306	280	202	$26.94	13	4	$1.615	$28.55
4307	0	0	-	0	0	-	-
4311	145	62	$5.868	0	0	-	$5.868
4341	4	1	$0.086	0	0	-	$0.086
4342	25	11	$1.035	5	2	$0.296	$1.331
4343	3	0	$0.043	0	0	-	$0.043
Total	**3,898**	**2,037**	**$277.2**	**1,640**	**879**	**$434.2**	**$711.4**

Table A-6 Property flood damage estimates for 1 in 100 AEP design flood event

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4000	131	5	$2.435	137	46	$12.39	$14.82
4005	275	56	$7.189	69	17	$2.251	$9.440
4006	15	4	$0.271	334	107	$21.08	$21.35
4007	5	2	$0.163	9	1	$1.464	$1.627
4008	23	2	$0.175	0	0	-	$0.175
4009	0	0	-	0	0	-	-
4010	36	6	$1.103	215	100	$20.05	$21.15
4011	0	0	-	0	0	-	-
4012	0	0	-	0	0	-	-
4013	0	0	-	0	0	-	-
4014	14	9	$0.344	0	0	-	$0.344
4017	9	2	$0.031	7	0	$0.000	$0.031
4018	0	0	-	0	0	-	-
4030	186	21	$3.838	36	7	$1.179	$5.016
4034	0	0	-	0	0	-	-
4051	0	0	-	0	0	-	-
4059	0	0	-	0	0	-	-
4060	0	0	-	0	0	-	-
4064	192	95	$12.68	401	181	$89.80	$102.5
4065	0	0	-	0	0	-	-
4066	320	109	$17.15	92	22	$11.28	$28.43
4067	514	220	$31.13	107	30	$12.56	$43.70
4068	959	641	$102.7	68	40	$16.03	$118.8
4069	351	275	$48.20	22	18	$13.36	$61.56
4070	163	138	$23.62	10	9	$16.35	$39.97
4073	64	38	$2.502	46	40	$27.85	$30.36
4074	872	646	$91.02	254	185	$169.7	$260.8
4075	1,541	1,203	$202.2	115	93	$131.8	$334.0
4076	73	57	$6.482	14	8	$2.068	$8.550
4077	33	14	$2.887	2	0	$0.000	$2.887
4078	0	0	-	0	0	-	-
4101	323	136	$17.84	707	205	$84.09	$101.9
4102	81	14	$2.126	63	16	$2.519	$4.645
4103	474	358	$60.66	13	10	$10.02	$70.68

Property flood damage estimates for 1 in 100 AEP design flood event continued

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4104	435	287	$42.08	16	8	$5.795	$47.88
4105	152	102	$14.26	162	78	$55.24	$69.50
4106	659	526	$82.30	971	781	$910.4	$992.7
4107	0	0	-	3	0	$0.000	$0.000
4108	87	56	$8.435	406	222	$109.8	$118.3
4109	0	0	-	0	0	-	-
4110	19	15	$2.115	31	21	$6.798	$8.912
4115	0	0	-	0	0	-	-
4116	0	0	-	0	0	-	-
4120	0	0	-	10	2	$0.227	$0.227
4121	0	0	-	0	0	-	-
4151	40	7	$0.774	39	7	$1.422	$2.196
4152	1	0	$0.001	0	0	-	$0.001
4153	0	0	-	0	0	-	-
4154	0	0	-	0	0	-	-
4169	116	32	$4.429	35	13	$1.815	$6.244
4170	145	39	$4.870	7	4	$1.066	$5.937
4171	232	46	$4.470	48	21	$3.542	$8.012
4172	0	0	-	0	0	-	-
4173	0	0	-	0	0	-	-
4174	18	3	$0.233	1	1	$0.045	$0.278
4178	0	0	-	2	0	$0.000	$0.000
4179	0	0	-	0	0	-	-
4300	559	490	$84.40	109	94	$71.48	$155.9
4301	42	37	$4.061	18	14	$7.630	$11.69
4303	40	26	$4.255	3	3	$1.934	$6.189
4304	850	659	$116.1	88	62	$107.1	$223.2
4305	1,958	1,429	$224.6	423	339	$227.0	$451.6
4306	611	505	$96.32	19	10	$4.213	$100.5
4307	0	0	-	0	0	-	-
4311	196	105	$10.81	10	2	$0.042	$10.85
4341	6	6	$0.369	0	0	-	$0.369
4342	29	12	$1.373	5	3	$0.758	$2.130
4343	3	1	$0.157	0	0	-	$0.157
Total	**12,852**	**8,434**	**$1,343**	**5,127**	**2,820**	**$2,162**	**$3,505**

Table A-7 Property flood damage estimates for 1 in 200 AEP design flood event

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4000	175	12	$5.458	304	105	$54.41	$59.87
4005	469	122	$16.89	204	50	$8.580	$25.47
4006	37	7	$0.722	502	182	$47.99	$48.71
4007	15	4	$0.388	13	1	$0.481	$0.870
4008	2	0	$0.034	8	1	$0.041	$0.075
4009	0	0	-	13	1	$0.017	$0.017
4010	44	12	$1.675	246	125	$37.13	$38.80
4011	0	0	-	0	0	-	-
4012	0	0	-	0	0	-	-
4013	0	0	-	0	0	-	-
4014	65	26	$1.284	0	0	-	$1.284
4017	60	6	$0.417	21	7	$0.103	$0.520
4018	0	0	-	0	0	-	-
4030	252	43	$7.711	53	16	$3.267	$10.98
4034	0	0	-	0	0	-	-
4051	10	1	$0.172	6	2	$0.188	$0.360
4059	0	0	-	0	0	-	-
4060	0	0	-	0	0	-	-
4064	368	223	$38.42	523	278	$177.5	$216.0
4065	0	0	-	0	0	-	-
4066	570	256	$46.93	140	47	$32.14	$79.07
4067	644	340	$56.82	130	52	$25.90	$82.72
4068	1,240	980	$201.3	82	52	$30.07	$231.4
4069	625	530	$111.3	27	23	$15.83	$127.2
4070	324	283	$59.58	16	15	$30.76	$90.35
4073	506	469	$64.40	79	66	$45.48	$109.9
4074	1,627	1,438	$271.7	321	263	$267.0	$538.7
4075	2,341	1,932	$379.7	154	119	$194.0	$573.7
4076	133	111	$19.09	87	53	$40.22	$59.32
4077	68	50	$6.028	31	17	$3.586	$9.614
4078	0	0	-	0	0	-	-
4101	504	283	$46.48	1,031	380	$286.6	$333.1
4102	125	33	$4.872	103	45	$9.725	$14.60
4103	599	507	$105.1	14	11	$19.44	$124.5

Property flood damage estimates for 1 in 200 AEP design flood event continued

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4104	706	542	$95.73	26	17	$16.00	$111.7
4105	239	190	$32.85	311	180	$131.5	$164.3
4106	728	686	$132.5	1,090	962	$1,371	$1,504
4107	31	25	$2.455	26	8	$3.675	$6.130
4108	180	150	$22.54	702	475	$318.4	$341.0
4109	0	0	-	0	0	-	-
4110	95	57	$7.051	65	37	$46.67	$53.72
4115	0	0	-	0	0	-	-
4116	0	0	-	0	0	-	-
4120	2	0	$0.009	19	6	$0.728	$0.737
4121	0	0	-	0	0	-	-
4151	113	27	$2.671	157	49	$9.696	$12.37
4152	17	2	$0.300	2	0	$0.000	$0.300
4153	0	0	-	0	0	-	-
4154	0	0	-	0	0	-	-
4169	170	59	$7.876	147	37	$8.765	$16.64
4170	236	105	$11.51	57	26	$2.852	$14.36
4171	562	194	$19.33	141	49	$11.72	$31.05
4172	0	0	-	0	0	-	-
4173	7	0	$0.014	0	0	-	$0.014
4174	44	8	$0.764	21	5	$0.473	$1.236
4178	0	0	-	9	1	$0.011	$0.011
4179	0	0	-	0	0	-	-
4300	755	686	$127.7	231	217	$120.3	$248.0
4301	113	81	$10.79	44	31	$31.11	$41.90
4303	88	60	$10.76	37	14	$8.026	$18.79
4304	1,286	1,124	$220.8	123	99	$192.0	$412.8
4305	3,495	2,779	$476.5	622	504	$331.4	$807.9
4306	1,103	981	$195.3	31	23	$7.387	$202.7
4307	0	0	-	0	0	-	-
4311	269	160	$19.53	43	14	$5.155	$24.69
4341	10	7	$0.574	0	0	-	$0.574
4342	34	19	$2.034	5	4	$1.023	$3.058
4343	3	2	$0.196	0	0	-	$0.196
Total	**21,089**	**15,612**	**$2,846**	**8,017**	**4,669**	**$3,949**	**$6,795**

Table A-8 Property flood damage estimates for 1 in 500 AEP design flood event

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4000	314	24	$9.035	593	192	$139.6	$148.7
4005	808	279	$41.74	297	100	$37.27	$79.00
4006	121	40	$5.149	819	332	$146.1	$151.2
4007	28	8	$1.012	49	7	$4.045	$5.057
4008	78	4	$0.435	48	7	$0.456	$0.890
4009	0	0	-	84	25	$2.455	$2.455
4010	147	42	$6.065	292	163	$66.90	$72.96
4011	0	0	-	0	0	-	-
4012	0	0	-	0	0	-	-
4013	0	0	-	0	0	-	-
4014	114	54	$3.501	3	1	$0.133	$3.634
4017	153	38	$2.905	25	12	$0.721	$3.625
4018	0	0	-	0	0	-	-
4030	342	82	$14.64	65	30	$9.485	$24.12
4034	0	0	-	0	0	-	-
4051	50	8	$1.563	19	12	$2.307	$3.870
4059	0	0	-	0	0	-	-
4060	0	0	-	0	0	-	-
4064	527	359	$70.95	611	396	$277.1	$348.1
4065	0	0	-	0	0	-	-
4066	766	447	$88.08	160	80	$60.87	$149.0
4067	773	499	$93.80	156	79	$43.11	$136.9
4068	1,499	1,268	$312.9	100	75	$49.43	$362.3
4069	886	789	$193.9	29	26	$17.73	$211.7
4070	513	468	$105.6	16	16	$35.26	$140.9
4073	698	655	$154.2	104	89	$65.83	$220.0
4074	2,350	2,181	$516.2	379	340	$364.2	$880.4
4075	3,305	2,833	$619.4	204	166	$271.1	$890.4
4076	174	162	$31.11	181	148	$168.4	$199.5
4077	139	114	$17.20	69	43	$17.02	$34.22
4078	0	0	-	0	0	-	-
4101	684	433	$90.18	1,230	651	$542.1	$632.2
4102	216	92	$12.36	169	103	$31.48	$43.84
4103	751	650	$151.9	17	14	$25.47	$177.3

Property flood damage estimates for 1 in 500 AEP design flood event continued

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4104	1,032	843	$174.3	32	24	$27.86	$202.1
4105	357	292	$59.58	441	325	$264.6	$324.2
4106	737	728	$162.1	1,153	1,093	$1,828	$1,990
4107	82	56	$7.989	45	31	$40.09	$48.08
4108	207	194	$39.47	915	770	$652.6	$692.1
4109	0	0	-	0	0	-	-
4110	137	106	$19.09	137	108	$117.2	$136.3
4115	0	0	-	0	0	-	-
4116	0	0	-	0	0	-	-
4120	124	15	$2.481	60	23	$6.002	$8.483
4121	0	0	-	0	0	-	-
4151	330	112	$13.01	241	131	$51.70	$64.71
4152	36	7	$1.257	4	2	$0.088	$1.345
4153	0	0	-	0	0	-	-
4154	0	0	-	0	0	-	-
4169	299	143	$19.64	282	88	$44.24	$63.88
4170	368	191	$26.37	132	73	$17.48	$43.85
4171	1,393	591	$66.34	244	114	$38.82	$105.2
4172	0	0	-	8	0	$0.000	$0.000
4173	15	4	$0.255	0	0	-	$0.255
4174	149	27	$2.504	75	19	$1.913	$4.416
4178	3	0	$0.028	14	5	$0.098	$0.126
4179	0	0	-	0	0	-	-
4300	972	867	$171.6	251	246	$148.1	$319.8
4301	281	219	$36.75	65	56	$160.6	$197.4
4303	177	129	$25.35	61	30	$32.83	$58.18
4304	1,497	1,394	$310.2	164	149	$262.5	$572.7
4305	4,715	3,923	$716.3	735	611	$430.6	$1,147
4306	1,938	1,759	$371.7	54	43	$19.83	$391.6
4307	0	0	-	0	0	-	-
4311	330	224	$29.74	62	42	$9.661	$39.40
4341	16	9	$0.913	0	0	-	$0.913
4342	40	21	$2.651	5	5	$1.656	$4.307
4343	3	2	$0.233	0	0	-	$0.233
Total	**30,674**	**23,385**	**$4,804**	**10,899**	**7,095**	**$6,535**	**$11,339**

Table A-9 Property flood damage estimates for 1 in 2,000 AEP design flood event

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4000	537	131	$31.26	929	382	$353.4	$384.7
4005	1,211	706	$127.2	402	177	$127.0	$254.2
4006	238	94	$16.29	1,158	555	$408.8	$425.1
4007	120	59	$7.107	174	52	$32.40	$39.51
4008	156	45	$4.230	279	88	$10.19	$14.42
4009	0	0	-	288	171	$52.73	$52.73
4010	209	121	$18.37	327	253	$122.7	$141.0
4011	0	0	-	0	0	-	-
4012	0	0	-	0	0	-	-
4013	0	0	-	0	0	-	-
4014	145	86	$8.720	3	3	$0.508	$9.228
4017	446	122	$12.56	28	21	$2.286	$14.84
4018	0	0	-	0	0	-	-
4030	458	299	$46.21	105	59	$31.05	$77.26
4034	0	0	-	0	0	-	-
4051	134	58	$8.221	47	36	$11.74	$19.96
4059	21	0	$0.446	16	4	$0.256	$0.702
4060	0	0	-	0	0	-	-
4064	806	625	$130.6	705	516	$504.3	$634.9
4065	2	0	$0.000	0	0	-	$0.000
4066	1,101	808	$165.1	307	155	$126.3	$291.4
4067	951	735	$147.5	230	130	$85.91	$233.4
4068	1,904	1,678	$435.5	138	103	$71.61	$507.1
4069	1,457	1,308	$332.2	36	35	$21.39	$353.6
4070	876	817	$192.7	21	18	$36.14	$228.9
4073	926	898	$251.9	133	121	$106.3	$358.1
4074	3,361	3,176	$854.6	427	410	$580.4	$1,435
4075	4,488	4,006	$963.4	287	250	$342.9	$1,306
4076	283	257	$46.84	347	296	$462.6	$509.4
4077	364	318	$61.73	134	109	$57.11	$118.8
4078	0	0	-	0	0	-	-
4101	955	700	$153.3	1,446	953	$973.1	$1,126
4102	337	243	$43.49	311	212	$94.62	$138.1
4103	949	851	$203.7	19	18	$32.45	$236.2

Property flood damage estimates for 1 in 2,000 AEP design flood event continued

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4104	1,457	1,258	$285.8	64	51	$55.77	$341.6
4105	643	531	$105.4	536	483	$450.3	$555.7
4106	737	737	$169.5	1,176	1,169	$2,169	$2,339
4107	277	203	$31.12	55	48	$101.3	$132.4
4108	296	258	$54.87	1,126	1,044	$1,120	$1,175
4109	0	0	-	0	0	-	-
4110	230	170	$33.44	236	219	$256.8	$290.2
4115	35	27	$3.639	0	0	-	$3.639
4116	0	0	-	0	0	-	-
4120	330	142	$19.18	185	103	$41.08	$60.26
4121	0	0	-	0	0	-	-
4151	659	383	$60.70	298	228	$152.4	$213.1
4152	72	46	$7.044	4	2	$1.596	$8.640
4153	0	0	-	0	0	-	-
4154	0	0	-	0	0	-	-
4169	556	345	$59.26	379	167	$125.5	$184.7
4170	777	473	$81.75	281	173	$77.83	$159.6
4171	2,207	1,461	$214.5	341	215	$130.0	$344.5
4172	1	0	$0.018	72	12	$0.641	$0.659
4173	58	14	$0.943	1	0	$0.000	$0.943
4174	187	53	$5.156	244	120	$14.59	$19.75
4178	9	3	$0.249	39	14	$1.383	$1.632
4179	0	0	-	0	0	-	-
4300	1,223	1,101	$225.8	257	255	$161.6	$387.4
4301	514	457	$91.96	173	127	$283.8	$375.8
4303	349	276	$53.02	97	60	$99.56	$152.6
4304	1,927	1,750	$389.6	220	206	$327.1	$716.7
4305	5,823	5,315	$1,086	868	753	$613.2	$1,699
4306	2,736	2,587	$606.3	100	86	$49.84	$656.1
4307	0	0	-	0	0	-	-
4311	430	315	$48.02	63	63	$21.12	$69.14
4341	29	23	$1.904	0	0	-	$1.904
4342	41	24	$3.357	5	5	$2.034	$5.391
4343	4	2	$0.255	0	0	-	$0.255
Total	**44,042**	**36,095**	**$7,902**	**15,117**	**10,730**	**$10,904**	**$18,807**

Table A-10 Property flood damage estimates for 1 in 10,000 AEP design flood event

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4000	676	400	$86.48	1,371	733	$970.8	$1,057
4005	1,634	1,288	$288.7	504	305	$322.5	$611.3
4006	393	260	$49.07	1,361	934	$906.2	$955.3
4007	544	365	$42.93	284	121	$144.3	$187.2
4008	168	128	$18.14	800	413	$212.9	$231.0
4009	3	2	$0.234	825	464	$477.7	$477.9
4010	309	268	$52.23	352	323	$196.0	$248.2
4011	0	0	-	0	0	-	-
4012	0	0	-	0	0	-	-
4013	0	0	-	0	0	-	-
4014	153	107	$13.21	3	3	$0.760	$13.97
4017	811	367	$37.81	30	21	$3.671	$41.48
4018	0	0	-	0	0	-	-
4030	608	554	$108.7	131	110	$98.38	$207.1
4034	0	0	-	0	0	-	-
4051	417	355	$54.83	77	57	$24.34	$79.17
4059	79	57	$7.976	55	32	$15.40	$23.38
4060	37	26	$2.735	0	0	-	$2.735
4064	1,309	1,205	$255.8	765	666	$772.7	$1,028
4065	33	28	$3.905	2	2	$0.099	$4.003
4066	1,815	1,576	$336.8	393	295	$282.9	$619.7
4067	1,277	1,132	$246.7	316	254	$193.3	$440.0
4068	2,818	2,610	$677.4	197	161	$115.5	$792.8
4069	2,316	2,178	$582.6	42	39	$24.78	$607.4
4070	1,314	1,278	$325.0	26	25	$41.23	$366.2
4073	1,214	1,186	$345.5	182	158	$143.2	$488.7
4074	4,587	4,485	$1,259	480	460	$680.8	$1,940
4075	6,061	5,921	$1,494	395	364	$466.7	$1,961
4076	518	486	$91.84	552	468	$845.4	$937.2
4077	1,049	987	$220.8	264	237	$169.9	$390.7
4078	0	0	-	9	4	$0.745	$0.745
4101	1,646	1,448	$318.6	1,649	1,312	$1,607	$1,926
4102	439	397	$84.47	403	319	$193.0	$277.4
4103	1,204	1,173	$286.5	20	20	$40.03	$326.6

Property flood damage estimates for 1 in 10,000 AEP design flood event continued

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4104	1,800	1,750	$430.9	70	68	$95.09	$525.9
4105	1,132	1,070	$231.0	606	565	$652.5	$883.4
4106	740	739	$170.0	1,186	1,184	$2,279	$2,449
4107	562	547	$114.7	133	98	$240.3	$355.0
4108	579	548	$113.7	1,339	1,284	$1,688	$1,802
4109	0	0	-	0	0	-	-
4110	866	780	$136.8	379	326	$462.4	$599.1
4115	279	254	$45.60	0	0	-	$45.60
4116	1	0	$0.000	0	0	-	$0.000
4120	727	622	$108.4	259	202	$120.2	$228.6
4121	0	0	-	0	0	-	-
4151	1,197	1,002	$189.4	325	302	$246.5	$435.9
4152	234	177	$29.73	22	10	$7.017	$36.75
4153	0	0	-	0	0	-	-
4154	0	0	-	0	0	-	-
4169	1,473	1,198	$205.3	528	313	$277.3	$482.6
4170	1,543	1,296	$242.6	401	322	$367.9	$610.5
4171	2,737	2,492	$544.3	406	336	$285.9	$830.2
4172	68	45	$3.521	196	93	$47.00	$50.52
4173	250	147	$14.26	30	8	$0.807	$15.07
4174	413	245	$28.23	364	270	$188.9	$217.2
4178	195	125	$10.84	250	113	$38.25	$49.10
4179	0	0	-	0	0	-	-
4300	1,668	1,612	$335.2	274	266	$170.7	$505.9
4301	877	851	$185.3	224	210	$466.1	$651.4
4303	565	517	$104.6	141	124	$198.1	$302.7
4304	2,598	2,491	$541.7	304	283	$413.4	$955.1
4305	7,551	7,189	$1,534	1,091	948	$850.3	$2,385
4306	3,754	3,624	$893.6	121	113	$93.70	$987.3
4307	0	0	-	0	0	-	-
4311	639	538	$90.63	100	92	$43.95	$134.6
4341	41	28	$2.824	0	0	-	$2.824
4342	44	29	$4.239	5	5	$2.252	$6.491
4343	7	3	$0.318	0	0	-	$0.318
Total	**65,972**	**60,186**	**$13,604**	**20,242**	**15,835**	**$18,187**	**$31,790**

Table A-11 Property flood damage estimates for 1 in 100,000 AEP design flood event

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4000	812	758	$179.3	1,655	1,368	$2,394	$2,574
4005	2,612	2,348	$592.2	632	520	$823.8	$1,416
4006	713	639	$151.2	1,820	1,506	$1,940	$2,091
4007	1,331	1,122	$245.3	400	275	$386.1	$631.4
4008	171	169	$35.41	919	693	$1,033	$1,068
4009	5	5	$0.988	951	779	$1,687	$1,688
4010	430	405	$100.5	430	398	$287.0	$387.5
4011	682	582	$70.43	168	49	$37.83	$108.3
4012	854	696	$83.86	84	35	$56.69	$140.6
4013	823	771	$124.9	460	241	$363.6	$488.5
4014	1,485	1,089	$129.5	557	248	$471.4	$600.9
4017	832	406	$38.80	30	21	$3.693	$42.49
4018	0	0	-	0	0	-	-
4030	968	930	$218.5	209	176	$215.1	$433.6
4034	0	0	-	0	0	-	-
4051	1,091	1,023	$255.5	142	125	$91.51	$347.0
4059	556	502	$107.5	101	93	$84.99	$192.5
4060	387	353	$79.83	20	13	$3.374	$83.20
4064	2,023	1,959	$491.1	808	785	$1,105	$1,596
4065	215	193	$49.37	16	15	$4.004	$53.37
4066	2,911	2,732	$684.7	486	448	$541.8	$1,227
4067	1,958	1,846	$458.8	334	326	$305.9	$764.7
4068	4,136	3,919	$1,078	361	304	$280.4	$1,358
4069	4,261	4,138	$1,173	88	82	$84.37	$1,258
4070	2,136	2,104	$564.7	37	36	$45.85	$610.5
4073	1,916	1,882	$555.5	270	240	$249.5	$805.0
4074	6,429	6,366	$1,892	583	556	$813.5	$2,706
4075	7,531	7,479	$2,097	459	451	$612.1	$2,709
4076	1,310	1,272	$280.7	981	835	$1,784	$2,065
4077	2,819	2,721	$689.6	734	661	$767.1	$1,457
4078	303	277	$58.32	11	11	$3.678	$62.00
4101	2,561	2,436	$621.2	1,766	1,639	$2,245	$2,866
4102	1,068	1,009	$250.2	661	581	$627.1	$877.4
4103	1,930	1,853	$469.5	52	41	$49.99	$519.5

Property flood damage estimates for 1 in 100,000 AEP design flood event continued

Postcode	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
4104	2,107	2,084	$558.8	82	80	$109.1	$667.9
4105	2,144	2,099	$526.2	649	635	$773.9	$1,300
4106	740	740	$170.2	1,186	1,186	$2,301	$2,472
4107	1,342	1,296	$320.3	291	249	$617.9	$938.1
4108	1,344	1,313	$317.7	1,422	1,392	$2,076	$2,394
4109	173	160	$34.36	5	4	$1.686	$36.05
4110	1,863	1,824	$415.9	716	589	$1,575	$1,991
4115	1,647	1,584	$437.4	14	10	$7.126	$444.5
4116	178	158	$30.00	1	1	$0.364	$30.36
4120	1,434	1,365	$354.2	294	286	$226.3	$580.5
4121	265	234	$44.76	14	5	$2.281	$47.04
4151	2,441	2,302	$576.4	402	389	$390.4	$966.8
4152	1,373	1,265	$242.5	65	53	$34.16	$276.6
4153	136	111	$19.30	0	0	-	$19.30
4154	19	14	$1.428	6	3	$2.954	$4.382
4169	2,661	2,466	$659.9	768	620	$721.2	$1,381
4170	3,207	3,006	$722.8	538	465	$719.0	$1,442
4171	3,575	3,467	$930.7	435	430	$465.7	$1,396
4172	196	189	$34.87	325	211	$311.7	$346.5
4173	1,415	1,351	$266.2	194	120	$86.21	$352.4
4174	747	739	$159.3	418	386	$750.3	$909.6
4178	1,278	1,216	$245.8	430	316	$597.2	$843.0
4179	0	0	-	9	3	$4.114	$4.114
4300	2,854	2,747	$627.9	452	385	$618.8	$1,247
4301	1,907	1,815	$449.3	297	294	$637.3	$1,087
4303	915	897	$193.2	179	172	$316.3	$509.5
4304	4,274	4,198	$993.3	386	378	$663.2	$1,656
4305	11,951	11,674	$2,758	1,545	1,440	$1,437	$4,194
4306	5,561	5,461	$1,400	212	190	$139.2	$1,540
4307	0	0	-	0	0	-	-
4311	1,381	1,306	$294.8	133	129	$76.88	$371.6
4341	65	54	$7.490	0	0	-	$7.490
4342	90	75	$10.47	5	5	$2.492	$12.97
4343	25	21	$2.216	0	0	-	$2.216
Total	**116,567**	**111,215**	**$27,633**	**27,698**	**23,977**	**$35,063**	**$62,697**

Appendix B Property Flood Damage Estimates by Seqwater Reporting Regions

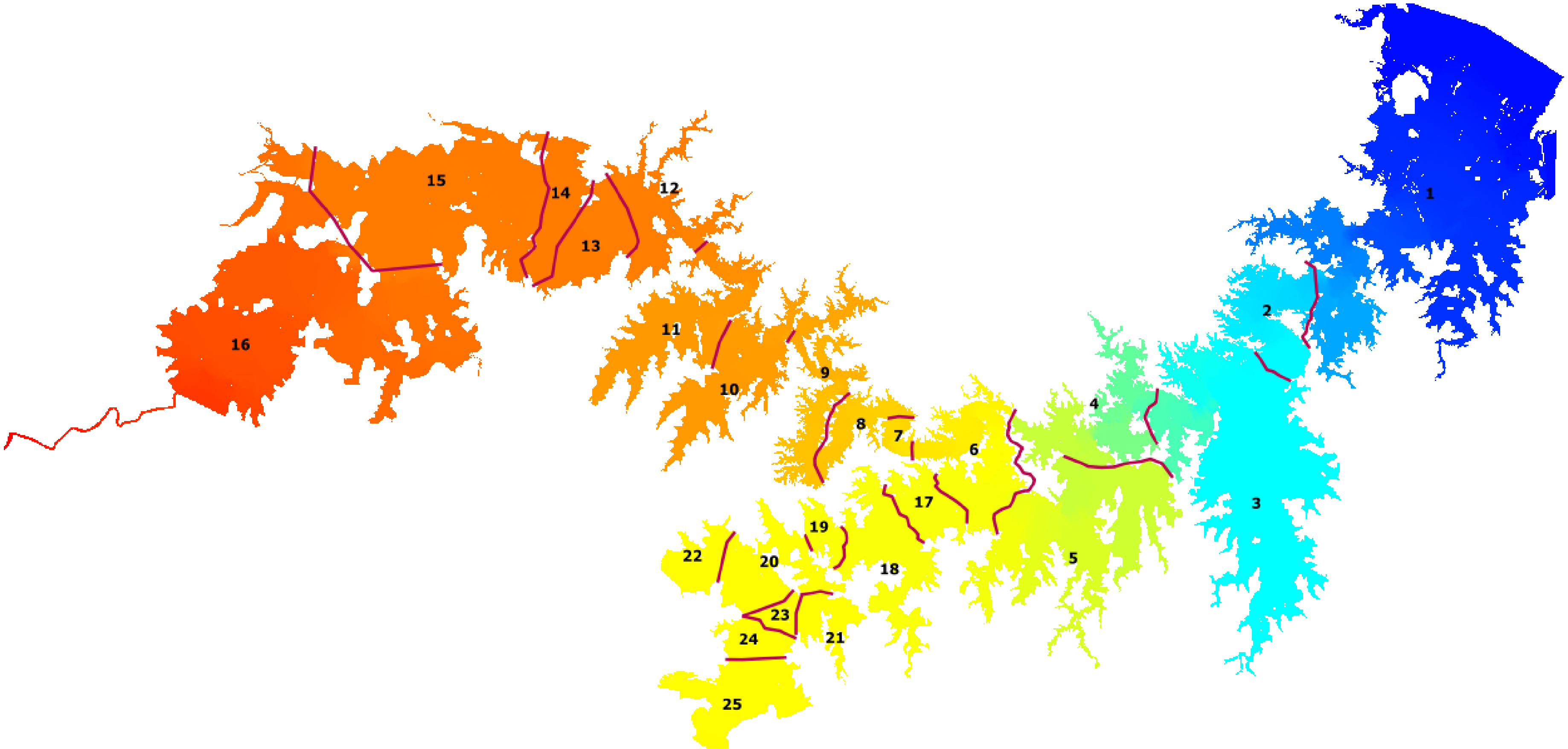


Figure B-1 Seqwater reporting regions

Table B-1 Peak discharge variation with AEP in the Brisbane River at Savages Crossing and Moggill

AEP (1 in x)	Peak flood discharge (m^3/s)	
	Brisbane River at Savages Crossing	Brisbane River at Moggill
2[a]	59	-422
5	1,075	1,846
10	1,881	2,964
20	2,844	4,340
50	5,449	6,862
100	9,284	9,949
200	12,117	11,887
500	14,651	14,738
2,000	19,541	19,494
10,000	27,706	28,436
100,000	51,839	57,166

[a] Negative flows shown for the 1 in 2 AEP event are peak tidal flows and not flood flows

Table B-2 Peak water level variations with AEP at upstream and downstream ends of Lockyer Creek and Bremer River reporting regions

Reporting zone		Peak flood levels at upstream and downstream ends of reporting zones (m AHD)										
		1 in 2 AEP	1 in 5 AEP	1 in 10 AEP	1 in 20 AEP	1 in 50 AEP	1 in 100 AEP	1 in 200 AEP	1 in 500 AEP	1 in 2,000 AEP	1 in 10,000 AEP	1 in 100,000 AEP
16	u/s end	86.46	97.03	100.82	102.97	102.64	103.71	104.12	104.58	105.22	105.34	107.1
	d/s end	n/a	57.25	60.39	61.41	61.66	61.7	61.77	61.86	61.99	62.22	63.26
15	u/s end	n/a	57.13	60.25	61.24	61.47	61.51	61.57	61.66	61.8	62.03	63.22
	d/s end	31.27	35.15	36.8	39.64	44.17	48.07	49.43	50.17	51.86	54.99	63.16
25	u/s end	27.2	31.73	32.14	32.24	32.82	32.95	33.1	33.35	33.71	33.86	36.8
	d/s end	20.79	26.16	27.29	27.47	28.18	28.32	28.61	28.78	29.83	31.68	36.67
24	u/s end	20.68	26.05	27.19	27.37	28.1	28.26	28.55	28.74	29.82	31.68	36.67
	d/s end	13.92	21.41	23.45	24.19	26.06	26.78	27.66	28.34	29.69	31.65	36.66
23	u/s end	13.92	21.36	23.41	24.17	26.04	26.76	27.64	28.33	29.68	31.65	36.65
	d/s end	11.07	19.72	21.97	23.19	25.26	26.18	27.41	28.2	29.6	31.61	36.65
21	u/s end	11.04	19.65	21.92	23.14	25.23	26.16	27.39	28.19	29.59	31.61	36.65
	d/s end	6.75	16.9	19.4	20.66	23.37	24.52	26.39	27.3	28.97	31.16	36.57
22	u/s end	26.44	30.48	31.08	31.51	32.01	32.42	32.7	33	33.01	34.19	36.75
	d/s end	20.62	25.56	26.62	27.45	27.97	28.42	28.67	29.25	29.9	31.93	36.67
20	u/s end	20.23	25.26	26.3	27.19	27.73	28.23	28.49	29.14	29.87	31.91	36.67
	d/s end	1.97	13.97	16.83	18.22	21.03	22.29	24.14	24.98	26.72	29.18	36.2
19	u/s end	1.97	13.92	16.8	18.18	20.99	22.25	24.1	24.95	26.69	29.16	36.19
	d/s end	1.89	11.79	14.78	16.1	18.69	20.15	21.86	23.44	25.74	28.97	36.12
18	u/s end	1.89	11.78	14.77	16.1	18.68	20.14	21.85	23.43	25.74	28.97	36.12
	d/s end	1.78	8.12	11.5	13.07	16.12	18.76	20.82	23.02	25.66	28.95	36.1
17	u/s end	1.78	8.1	11.46	13.04	16.11	18.76	20.82	23.02	25.66	28.95	36.1

Reporting zone		Peak flood levels at upstream and downstream ends of reporting zones (m AHD)										
		1 in 2 AEP	1 in 5 AEP	1 in 10 AEP	1 in 20 AEP	1 in 50 AEP	1 in 100 AEP	1 in 200 AEP	1 in 500 AEP	1 in 2,000 AEP	1 in 10,000 AEP	1 in 100,000 AEP
	d/s end	1.75	6.58	9.54	11.57	15.52	18.66	20.73	23	25.64	28.94	36.09

Table B-3 Property flood damage estimates for 1 in 2 AEP design flood event

Seqwater Region	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
1	3	1	$0.036	12	5	$0.467	$0.503
2	0	0	-	7	1	$0.030	$0.030
3	0	0	-	0	0	-	-
4	0	0	-	0	0	-	-
5	0	0	-	0	0	-	-
6	0	0	-	0	0	-	-
7	0	0	-	0	0	-	-
8	0	0	-	0	0	-	-
9	0	0	-	0	0	-	-
10	0	0	-	0	0	-	-
11	0	0	-	0	0	-	-
12	0	0	-	0	0	-	-
13	0	0	-	0	0	-	-
14	0	0	-	0	0	-	-
15	0	0	-	0	0	-	-
16	0	0	-	0	0	-	-
17	0	0	-	0	0	-	-
18	0	0	-	0	0	-	-
19	0	0	-	0	0	-	-
20	0	0	-	0	0	-	-
21	0	0	-	0	0	-	-
22	0	0	-	0	0	-	-
23	0	0	-	0	0	-	-
24	0	0	-	0	0	-	-
25	0	0	-	0	0	-	-
Total	**3**	**1**	**$0.036**	**19**	**6**	**$0.497**	**$0.533**

Table B-4 Property flood damage estimates for 1 in 5 AEP design flood event

Seqwater Region	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
1	4	2	$0.063	23	5	$1.442	$1.505
2	0	0	-	7	1	$0.390	$0.390
3	1	0	$0.001	2	1	$0.058	$0.059
4	0	0	-	0	0	-	-
5	0	0	-	0	0	-	-
6	3	1	$0.076	0	0	-	$0.076
7	0	0	-	0	0	-	-
8	0	0	-	0	0	-	-
9	0	0	-	0	0	-	-
10	0	0	-	0	0	-	-
11	0	0	-	0	0	-	-
12	0	0	-	0	0	-	-
13	0	0	-	0	0	-	-
14	0	0	-	0	0	-	-
15	5	1	$0.041	0	0	-	$0.041
16	10	1	$0.071	0	0	-	$0.071
17	0	0	-	0	0	-	-
18	0	0	-	1	1	$1.026	$1.026
19	0	0	-	0	0	-	-
20	1	0	$0.002	0	0	-	$0.002
21	0	0	-	0	0	-	-
22	5	2	$0.170	0	0	-	$0.170
23	0	0	-	0	0	-	-
24	0	0	-	0	0	-	-
25	0	0	-	0	0	-	-
Total	**29**	**7**	**$0.424**	**33**	**8**	**$2.916**	**$3.340**

Table B-5 Property flood damage estimates for 1 in 10 AEP design flood event

Seqwater Region	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
1	7	2	$0.087	23	5	$1.367	$1.454
2	9	0	$0.000	16	3	$0.370	$0.370
3	23	1	$0.204	49	24	$2.510	$2.714
4	6	3	$0.178	0	0	-	$0.178
5	0	0	-	0	0	-	-
6	4	3	$0.264	0	0	-	$0.264
7	0	0	-	0	0	-	-
8	0	0	-	0	0	-	-
9	0	0	-	0	0	-	-
10	0	0	-	0	0	-	-
11	0	0	-	0	0	-	-
12	0	0	-	0	0	-	-
13	0	0	-	0	0	-	-
14	0	0	-	0	0	-	-
15	18	3	$0.222	0	0	-	$0.222
16	37	10	$0.692	2	1	$0.193	$0.885
17	6	2	$0.263	0	0	-	$0.263
18	27	13	$1.331	6	4	$2.946	$4.277
19	18	6	$0.383	1	0	$0.000	$0.383
20	14	3	$0.567	10	5	$2.310	$2.877
21	33	7	$0.500	8	3	$0.304	$0.804
22	19	12	$1.016	0	0	-	$1.016
23	2	2	$0.117	0	0	-	$0.117
24	0	0	-	0	0	-	-
25	0	0	-	0	0	-	-
Total	**223**	**67**	**$5.823**	**115**	**45**	**$10.00**	**$15.82**

Table B-6 Property flood damage estimates for 1 in 20 AEP design flood event

Seqwater Region	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
1	38	6	$0.292	52	11	$2.747	$3.039
2	10	0	$0.019	44	4	$0.471	$0.490
3	203	59	$5.630	181	105	$33.62	$39.25
4	9	6	$0.690	0	0	-	$0.690
5	11	1	$0.262	2	0	$0.000	$0.262
6	13	9	$0.896	0	0	-	$0.896
7	0	0	-	0	0	-	-
8	0	0	-	0	0	-	-
9	0	0	-	0	0	-	-
10	2	0	$0.039	0	0	-	$0.039
11	0	0	-	0	0	-	-
12	0	0	-	0	0	-	-
13	0	0	-	0	0	-	-
14	0	0	-	0	0	-	-
15	60	16	$1.201	0	0	-	$1.201
16	77	30	$2.504	4	1	$0.257	$2.761
17	28	13	$1.612	0	0	-	$1.612
18	104	55	$6.817	31	19	$8.158	$14.97
19	42	23	$2.389	3	1	$0.072	$2.461
20	39	16	$2.476	12	12	$4.968	$7.443
21	74	44	$3.699	44	27	$6.016	$9.715
22	31	22	$2.133	9	1	$0.099	$2.232
23	8	3	$0.363	0	0	-	$0.363
24	0	0	-	0	0	-	-
25	4	0	$0.006	0	0	-	$0.006
Total	**753**	**303**	**$31.03**	**382**	**181**	**$56.41**	**$87.44**

Table B-7 Property flood damage estimates for 1 in 50 AEP design flood event

Seqwater Region	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
1	261	44	$3.673	215	70	$10.72	$14.39
2	509	103	$17.19	318	81	$24.43	$41.62
3	955	466	$56.19	734	479	$239.0	$295.2
4	36	20	$2.430	13	8	$5.439	$7.869
5	256	190	$25.76	78	41	$13.80	$39.56
6	116	87	$12.61	0	0	-	$12.61
7	0	0	-	0	0	-	-
8	0	0	-	0	0	-	-
9	0	0	-	0	0	-	-
10	2	2	$0.244	0	0	-	$0.244
11	0	0	-	0	0	-	-
12	0	0	-	0	0	-	-
13	0	0	-	0	0	-	-
14	0	0	-	0	0	-	-
15	81	33	$3.108	0	0	-	$3.108
16	96	41	$3.923	5	2	$0.296	$4.219
17	191	153	$21.47	8	3	$0.846	$22.31
18	570	348	$49.96	108	67	$39.18	$89.14
19	214	130	$17.04	12	8	$47.41	$64.45
20	228	156	$25.75	38	31	$12.79	$38.54
21	300	212	$31.28	98	85	$38.69	$69.97
22	39	29	$3.282	13	4	$1.615	$4.897
23	34	22	$2.946	0	0	-	$2.946
24	0	0	-	0	0	-	-
25	10	1	$0.305	0	0	-	$0.305
Total	**3,898**	**2,037**	**$277.2**	**1,640**	**879**	**$434.2**	**$711.4**

Table B-8 Property flood damage estimates for 1 in 100 AEP design flood event

Seqwater Region	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
1	1,190	242	$29.81	866	294	$56.46	$86.27
2	2,353	1,124	$171.5	1,518	519	$232.1	$403.6
3	3,972	2,979	$479.7	1,786	1,273	$1,266	$1,745
4	849	669	$98.55	20	18	$14.49	$113.0
5	834	702	$113.9	389	297	$252.6	$366.4
6	253	229	$49.12	4	4	$2.083	$51.20
7	0	0	-	0	0	-	-
8	0	0	-	0	0	-	-
9	2	2	$0.263	0	0	-	$0.263
10	2	2	$0.520	0	0	-	$0.520
11	8	8	$1.490	0	0	-	$1.490
12	87	59	$5.617	0	0	-	$5.617
13	36	23	$3.753	0	0	-	$3.753
14	17	14	$1.465	10	2	$0.042	$1.507
15	105	51	$5.261	0	0	-	$5.261
16	113	57	$5.385	5	3	$0.758	$6.143
17	249	239	$52.50	37	22	$63.93	$116.4
18	1,400	1,008	$165.0	288	224	$133.2	$298.2
19	392	270	$38.12	22	17	$65.75	$103.9
20	373	275	$49.12	48	40	$21.79	$70.91
21	492	395	$61.17	116	98	$49.33	$110.5
22	55	40	$4.805	14	6	$3.734	$8.538
23	54	42	$5.882	0	0	-	$5.882
24	3	1	$0.044	4	3	$0.330	$0.374
25	13	3	$0.434	0	0	-	$0.434
Total	**12,852**	**8,434**	**$1,343**	**5,127**	**2,820**	**$2,162**	**$3,505**

Table B-9 Property flood damage estimates for 1 in 200 AEP design flood event

Seqwater Region	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
1	2,215	645	$76.04	1,703	598	$140.7	$216.7
2	3,514	2,058	$370.9	2,233	915	$628.6	$999.4
3	6,168	5,227	$986.6	2,521	1,917	$2,150	$3,137
4	1,609	1,418	$276.2	27	23	$20.97	$297.2
5	1,369	1,187	$220.6	672	558	$463.6	$684.2
6	456	383	$77.11	36	13	$7.794	$84.91
7	0	0	-	2	2	$0.304	$0.304
8	0	0	-	0	0	-	-
9	14	9	$1.705	0	0	-	$1.705
10	20	18	$3.396	0	0	-	$3.396
11	12	12	$2.420	0	0	-	$2.420
12	202	193	$42.75	2	2	$0.030	$42.78
13	132	121	$20.98	3	2	$0.269	$21.25
14	45	34	$5.073	45	15	$5.191	$10.26
15	142	88	$9.541	0	0	-	$9.541
16	144	79	$8.242	5	4	$1.023	$9.265
17	279	268	$62.07	44	35	$102.7	$164.8
18	2,303	1,877	$347.4	441	357	$233.4	$580.8
19	934	737	$104.5	52	34	$80.63	$185.1
20	598	510	$97.51	69	59	$42.52	$140.0
21	789	634	$116.2	144	122	$64.97	$181.2
22	61	50	$6.201	14	9	$5.391	$11.59
23	66	54	$9.663	0	0	-	$9.663
24	4	3	$0.329	4	4	$0.741	$1.069
25	13	7	$0.786	0	0	-	$0.786
Total	**21,089**	**15,612**	**$2,846**	**8,017**	**4,669**	**$3,949**	**$6,795**

Table B-10 Property flood damage estimates for 1 in 500 AEP design flood event

Seqwater Region	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
1	4,759	1,732	$220.1	2,913	1,242	$458.4	$678.5
2	4,716	3,112	$639.8	2,873	1,481	$1,150	$1,790
3	8,209	7,202	$1,627	3,149	2,689	$3,311	$4,938
4	2,371	2,193	$517.6	31	29	$48.59	$566.2
5	2,016	1,770	$360.3	852	774	$809.5	$1,170
6	1,108	975	$197.5	61	32	$34.79	$232.3
7	1	1	$0.244	4	4	$0.781	$1.025
8	0	0	-	0	0	-	-
9	71	59	$10.28	0	0	-	$10.28
10	38	37	$7.994	3	2	$0.576	$8.571
11	23	22	$4.029	0	0	-	$4.029
12	260	243	$63.03	13	11	$2.293	$65.33
13	147	144	$31.70	3	3	$0.513	$32.22
14	59	48	$8.658	64	43	$10.18	$18.84
15	160	116	$14.57	0	0	-	$14.57
16	187	108	$12.36	5	5	$1.656	$14.02
17	337	329	$75.06	69	57	$122.7	$197.8
18	3,181	2,708	$549.7	522	441	$330.5	$880.2
19	1,212	1,037	$169.5	72	54	$106.6	$276.1
20	680	612	$122.4	81	73	$58.02	$180.4
21	974	806	$150.8	164	141	$78.27	$229.1
22	72	57	$7.762	16	10	$9.118	$16.88
23	71	59	$11.80	0	0	-	$11.80
24	4	4	$0.458	4	4	$1.077	$1.536
25	18	11	$1.138	0	0	-	$1.138
Total	**30,674**	**23,385**	**$4,804**	**10,899**	**7,095**	**$6,535**	**$11,339**

Table B-11 Property flood damage estimates for 1 in 2,000 AEP design flood event

Seqwater Region	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
1	8,316	4,745	$739.6	4,965	2,658	$1,432	$2,172
2	6,419	4,813	$1,050	3,779	2,254	$2,177	$3,226
3	11,576	10,331	$2,493	3,822	3,564	$4,733	$7,226
4	3,634	3,392	$886.9	50	44	$144.9	$1,032
5	2,942	2,673	$573.8	1,158	1,039	$1,305	$1,879
6	1,770	1,642	$378.9	90	62	$101.6	$480.4
7	3	2	$0.435	4	4	$0.829	$1.264
8	0	0	-	0	0	-	-
9	88	86	$20.01	0	0	-	$20.01
10	89	83	$17.97	5	5	$1.962	$19.94
11	36	36	$7.464	0	0	-	$7.464
12	312	302	$80.22	42	42	$20.39	$100.6
13	158	156	$38.08	3	3	$0.596	$38.67
14	108	85	$16.63	65	65	$23.11	$39.73
15	184	144	$22.51	0	0	-	$22.51
16	233	154	$18.11	5	5	$2.034	$20.15
17	454	429	$97.25	85	78	$153.6	$250.9
18	3,934	3,623	$777.0	634	558	$457.4	$1,234
19	1,466	1,311	$260.1	100	82	$146.0	$406.1
20	853	778	$172.7	104	89	$79.21	$251.9
21	1,279	1,150	$224.4	176	162	$110.7	$335.1
22	72	57	$7.798	25	11	$12.58	$20.37
23	82	77	$16.04	0	0	-	$16.04
24	4	4	$0.826	5	5	$2.317	$3.143
25	30	22	$3.002	0	0	-	$3.002
Total	**44,042**	**36,095**	**$7,902**	**15,117**	**10,730**	**$10,904**	**$18,807**

Table B-12 Property flood damage estimates for 1 in 10,000 AEP design flood event

Seqwater Region	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
1	14,413	11,507	$2,134	7,583	5,057	$4,161	$6,295
2	9,373	8,291	$1,847	4,678	3,425	$4,024	$5,870
3	17,627	16,890	$4,158	4,717	4,404	$6,282	$10,440
4	5,323	5,154	$1,407	70	62	$173.5	$1,581
5	4,272	4,138	$930.8	1,463	1,350	$1,961	$2,892
6	2,556	2,465	$608.6	115	101	$184.5	$793.2
7	7	5	$1.417	7	7	$1.122	$2.539
8	0	0	-	0	0	-	-
9	106	105	$24.76	1	1	$0.149	$24.91
10	134	127	$28.68	5	5	$2.072	$30.75
11	62	58	$12.25	0	0	-	$12.25
12	420	412	$105.3	43	43	$29.04	$134.3
13	175	173	$41.88	3	3	$0.597	$42.48
14	173	168	$35.19	102	94	$46.20	$81.39
15	304	258	$43.65	0	0	-	$43.65
16	280	197	$24.94	5	5	$2.252	$27.19
17	679	646	$148.5	106	98	$210.2	$358.8
18	5,059	4,884	$1,048	811	716	$600.9	$1,649
19	1,863	1,781	$380.5	156	126	$192.0	$572.5
20	1,172	1,100	$242.2	125	107	$116.5	$358.7
21	1,702	1,587	$335.0	208	195	$153.5	$488.5
22	138	119	$19.91	35	27	$41.61	$61.52
23	99	88	$19.94	0	0	-	$19.94
24	4	4	$0.932	9	9	$4.883	$5.814
25	31	29	$5.871	0	0	-	$5.871
Total	**65,972**	**60,186**	**$13,604**	**20,242**	**15,835**	**$18,187**	**$31,790**

Table B-13 Property flood damage estimates for 1 in 100,000 AEP design flood event

Seqwater Region	Residential Properties			Commercial/Industrial Properties			Total Flood Damage ($ millions)
	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	No. of Properties Flooded AGL	No. of Properties Flooded AFL	Flood Damage ($ millions)	
1	32,892	29,888	$6,769	11,339	8,942	$12,293	$19,062
2	14,024	13,358	$3,354	5,439	4,883	$6,953	$10,308
3	29,915	29,174	$7,783	6,135	5,774	$9,100	$16,882
4	8,286	8,163	$2,372	113	110	$223.3	$2,595
5	7,443	7,200	$1,747	2,244	1,987	$3,890	$5,637
6	3,548	3,507	$910.9	151	142	$286.2	$1,197
7	19	19	$4.380	8	8	$1.234	$5.613
8	0	0	-	0	0	-	-
9	139	135	$32.40	4	3	$4.354	$36.76
10	270	266	$61.76	7	7	$3.323	$65.08
11	193	187	$41.96	6	6	$2.031	$43.99
12	652	646	$176.1	47	47	$30.88	$206.9
13	233	230	$56.42	3	3	$0.597	$57.02
14	257	250	$63.30	130	129	$78.23	$141.5
15	855	822	$199.2	2	2	$0.890	$200.1
16	490	423	$62.06	8	5	$2.492	$64.55
17	1,344	1,300	$309.4	124	122	$363.8	$673.2
18	7,702	7,558	$1,781	1,139	1,078	$1,017	$2,799
19	2,688	2,650	$628.4	230	211	$275.5	$903.8
20	2,238	2,165	$520.8	207	186	$223.9	$744.6
21	2,902	2,820	$658.3	261	250	$238.4	$896.7
22	258	246	$55.18	35	35	$66.08	$121.3
23	163	153	$34.60	0	0	-	$34.60
24	9	8	$1.615	10	9	$5.398	$7.013
25	47	47	$10.34	56	38	$3.193	$13.53
Total	**116,567**	**111,215**	**$27,633**	**27,698**	**23,977**	**$35,063**	**$62,697**

Appendix C Derivation of Critical Infrastructure Database

The critical infrastructure database was developed independently to the building database. Although the building database includes some items identified as ‘utilities’, these were perceived to be an incomplete summary of critical infrastructure assets, and were therefore excluded from the building database for the purposes of the exposure assessment.

The following datasets were used to develop the critical infrastructure database:

- ENERGEX zone substation locations (provided for this study via QRA)
- QPS, QAS, QFES and SES locations (provided for this study via QRA). It was noted that there was not a 100% agreement between the council locations and the QFES locations so the QFES locations were used where there was a difference.
- Location of Telstra telephone exchanges (for BCC and ICC locations extracted from data developed by ERSA in 1999-2000 from data provided to the *Cities Project* by Telstra, and for LVRC and SRC based on field observation undertaken by ERSA in 2012 for a different project.

This database should be considered preliminary in nature, and verified with asset owners during local / detailed floodplain management studies, or when needed to inform detailed emergency response planning.

Appendix D Census Data used in Community Vulnerability Assessment

The attributes in Table D-1, below, were derived from the 2016 Australian Bureau of Statistics census and used to inform vulnerability indices:

Table D-1 Community Vulnerability Characteristics and their Sources

Characteristic	ABS Table
Children under 5 years	G01 Selected Person Characteristics by Sex
People over 64 years	G01 Selected Person Characteristics by Sex
People over 64 years living alone	G23B Relationship in Household by Age by Sex
Disabled	G18 Core Activity Need for Assistance by Age by Sex
Unemployed	G40 Selected Labour Force, Education and Migration Characteristics by Sex
Households renting	G33 Tenure and Landlord Type by Dwelling Structure
Families with low incomes	G29 Total Household Income (weekly) by Household Composition
Dwellings with no car	G30 Number of Motor Vehicles by Dwellings
Single parent families	G25 Family Composition
Large families	G31 Household Composition by Number of Persons Usually Resident
New residents	G41 Place of Usual Residence 1 Year Ago by Sex
No or little English	G11 Proficiency in Spoken English/Language by Year of Arrival in Australia by Age
Dwellings with no internet access	G37 Dwelling Internet Connection by Dwelling Structure

Appendix E Land Use Categorisation for Development Scenario

Table E-1 to Table E-4 detail allocation of land use zones to general land use categories suitable the purposes of hydraulic modelling under the development scenario. Tables have been prepared for each respective LGA.

Table E-1 Land Use Categorisation: Brisbane City Council

General Category	Zone Code (Prefix)	Zone Code Description
Residential (Low Density)	LDR	Low Density Residential
	RR	Rural Residential
	CR	Character Residential
	EC	Emerging Community
Residential (Low-Medium Density)	LMR	Low-Medium Density Residential
Residential (Medium Density)	MDR	Medium Density Residential
Residential (High Density)	HDR	High Density Residential
Community	CF	Community Facilities
	NC	Neighbourhood Centre
Commercial	DC	District Centre
	MC	Major Centre
	MU	Mixed Use
	PC	Principal Centre
	PDA	Priority Development Area
	SBCA	South Bank Corporation
	SC	Specialised Centre
Industry	IN	Industry
	EI	Extractive Industry
	II	Industry Investigation
	LII	Low Impact Industry
	SI	Special Industry
	SP	Special Purpose

Table E-2 Land Use Categorisation: Ipswich City Council

General Category	Zone Code (Prefix)	Zone Code Description
Residential (Low Density)	RL	Residential Low Density
	LLR	Large Lot Residential
	CHL	Character Housing Low Density
	LDC	Limited Development (constrained)
Residential (Medium Density)	RM	Residential Medium Density
	CHM	Character Housing Mixed Density
	FU	Future Urban
	SFCR	Community Residential
Residential (High Density)	RHD	CBD Residential High Density
Community	SU	Special Uses
	MED	CBD Medical Services
	SA	Special Opportunity
Commercial	BI	Business Incubator
	CN	CBD North Secondary Business
	PC	CBD Primary Commercial
	PR	CBD Primary Retail
	LC	Local Retail and Commercial
	MC	Major Centres
	SFTC	SF Town Centre
	TT	Top of Town
	CMU	Character Mixed Use
Industry	AA	Amberley Air Base & Aviation
	LB	Local Business and Industry
	LBIA	Local Business and Industry Investigation
	RB	Regional Business and Industry
	RBIA	Regional Business and Industry Investigation

Table E-3 Land Use Categorisation: Somerset Regional Council

General Category	Zone Code (Prefix)	Zone Code Description
Residential (Low Density)	n/a	General Residential
	n/a	Emerging Community
Residential (Medium Density)	n/a	Township
Community	n/a	Community Facilities
Commercial	n/a	Centre
Industrial	n/a	Industry

*Extracted from attribute columns ‘LVL1_Zone’ and ‘LVL2_Zone’.

Table E-4 Land Use Categorisation: Lockyer Valley Regional Council

General Category	Zone Code (Prefix)	Zone Code Description
Residential (Low Density)	n/a	Rural Residential
Community	n/a	Community Facility/Purpose
Commercial	n/a	Business
Industrial	n/a	Industrial

*Extracted from attribute column ‘Zoning’

Appendix F Future Development and Climate Change Flood Level Impacts

Table F-1 Development Scenario Peak Flood Level Difference

Addendum Table - Development Scenarios Peak Levels

		Peak Flood Level (mAHD)																				
		AEP (1 in....) and difference in peak level from Base Case (m)																				
		10			20			50			100			500			2000			100000		
ID	Reporting Location	Base	DS1	DS2	Base	DS1	DS2	Base	DS1	DS2	Base	DS1	DS2	Base	DS1	DS2	Base	DS1	DS2	Base	DS1	DS2
RL_01	Lockyer Creek at Tarampa	59.89	0.00	0.00	60.77	0.00	0.00	60.95	0.00	0.00	60.98	0.00	0.00	61.11	0.00	0.00	61.27	0.00	0.00	63.33	0.15	0.27
RL_02	Wivenhoe Dam Tailwater	36.06	0.00	-0.01	38.88	0.00	0.01	44.17	0.00	0.05	48.40	0.00	0.15	50.70	0.01	0.10	52.18	0.01	0.12	63.43	0.15	0.27
RL_03	Lockyer Creek at Lyons Bridge	62.97	0.00	0.00	63.89	0.00	0.00	64.24	0.00	0.00	64.31	0.00	0.00	64.53	0.00	0.00	64.75	0.00	0.00	66.39	0.00	0.00
RL_04	Brisbane River at Lowood Pump Station	33.66	0.00	0.00	36.27	0.00	0.00	40.94	0.00	-0.01	45.32	0.00	-0.11	48.55	0.00	0.05	51.00	0.02	0.16	63.17	0.16	0.29
RL_05	Brisbane River at Savages Crossing	29.41	0.00	0.00	32.07	0.00	0.00	37.03	0.00	0.02	41.67	0.00	-0.01	46.71	0.01	0.06	49.75	0.02	0.07	62.08	0.17	0.18
RL_06	Brisbane River Upstream Mt Crosby Weir	13.11	0.01	0.01	15.64	0.00	0.01	20.31	0.02	0.02	25.13	0.02	0.16	30.93	0.01	0.07	34.25	-0.08	-0.05	45.95	0.21	0.22
RL_07	Brisbane River downstream Mt Crosby Weir	11.82	0.01	0.01	14.90	0.00	0.02	19.80	0.02	0.03	24.79	0.02	0.17	30.55	0.02	0.07	33.90	0.05	0.09	45.44	0.19	0.27
RL_08	Brisbane River at Moggill	6.90	0.01	0.01	9.95	0.03	0.07	14.33	0.02	0.10	18.22	0.04	0.29	22.60	0.00	0.16	25.47	0.05	0.14	36.35	0.37	0.45
RL_09	Brisbane River at Jindalee	3.40	-0.01	0.00	5.68	0.00	-0.01	9.17	0.01	0.06	12.34	0.01	0.35	16.14	0.04	0.19	19.08	0.00	0.07	30.91	-0.15	-0.09
RL_10	Brisbane River at Tennyson	2.43	0.00	-0.01	3.84	0.00	0.01	6.40	0.01	0.11	9.36	0.00	0.14	13.07	0.00	0.10	15.82	0.01	0.07	28.67	-0.16	-0.13
RL_11	Brisbane River at Fairfield	2.26	0.00	-0.01	3.49	0.00	0.01	5.64	0.01	0.15	8.20	0.00	0.12	11.81	0.03	0.11	14.67	0.05	0.08	28.22	-0.12	-0.09
RL_12	Brisbane River at Toowong	2.08	0.00	-0.01	3.15	0.02	0.03	4.69	0.01	0.11	6.75	0.01	0.21	10.06	-0.03	0.07	12.85	-0.04	-0.01	26.30	0.17	0.20
RL_13	Port Office Gauge	1.85	0.00	0.00	2.29	0.00	0.00	3.27	0.01	0.07	4.59	0.00	0.14	7.35	-0.05	0.05	9.91	-0.06	-0.05	23.88	-0.12	-0.11
RL_14	Brisbane City Gauge	1.83	0.00	0.00	2.23	0.00	0.00	3.18	0.01	0.07	4.53	0.00	0.14	7.25	-0.05	0.05	9.84	-0.05	-0.04	23.61	-0.10	-0.09
RL_15	Brisbane River at Hawthorne	1.69	0.00	0.00	1.89	0.00	0.02	2.28	0.00	0.05	2.85	0.00	0.13	4.24	-0.06	0.05	6.00	-0.04	0.00	16.09	-0.10	-0.09
RL_16	Brisbane River at Gateway Bridge	1.68	0.00	0.00	1.75	0.00	0.00	1.83	0.00	0.00	1.89	0.00	0.05	2.67	0.00	0.02	2.98	-0.01	0.13	8.21	0.04	0.07
RL_17	Warrill Creek at Amberley	27.28	0.00	0.02	27.46	0.00	0.04	28.19	0.02	0.04	28.34	0.03	0.06	28.79	0.03	0.21	29.87	0.05	0.39	36.95	0.28	0.40
RL_18	Purga Creek at Loamside	27.61	0.00	0.00	27.77	0.00	0.00	27.91	0.00	0.00	28.65	0.00	0.00	28.90	0.00	0.06	29.90	0.04	0.39	36.96	0.28	0.40
RL_19	Bremer River at Walloon	26.35	0.01	0.03	27.23	0.01	0.05	27.78	0.02	0.07	28.29	0.04	0.13	29.23	0.07	0.23	29.92	0.04	0.38	36.94	0.28	0.39
RL_20	Bremer River at Three Mile Bridge	22.28	0.01	0.14	23.47	0.01	0.12	25.46	0.00	0.16	26.30	-0.03	0.30	28.25	-0.02	0.34	29.65	0.00	0.40	36.93	0.28	0.39
RL_21	Bremer River at One Mille Bridge	19.45	0.06	0.23	20.71	0.07	0.28	23.45	0.10	0.30	24.59	0.09	0.56	27.32	0.03	0.37	29.01	0.04	0.41	36.85	0.29	0.40
RL_22	Bremer River at David Trumpy Bridge	14.75	0.00	0.03	16.09	0.00	0.13	18.68	0.01	0.38	20.18	0.05	0.86	23.47	0.05	0.37	25.89	0.15	0.31	36.51	0.39	0.47
RL_23	Bremer River at Hancock Bridge	16.79	0.17	0.24	18.17	0.15	0.34	21.01	0.17	0.41	22.28	0.16	0.88	24.97	0.11	0.42	26.74	0.13	0.44	36.56	0.38	0.46
RL_24	Bremer River at Bundamba Confluence	11.67	0.00	0.11	13.19	0.00	0.19	16.17	0.01	0.49	18.80	0.03	0.41	23.08	0.06	0.26	25.81	0.15	0.29	36.49	0.39	0.47
RL_25	Bremer River at Warrego Highway	10.16	0.00	0.11	12.04	-0.02	0.18	15.75	0.00	0.13	18.75	0.03	0.31	23.07	0.06	0.25	25.81	0.15	0.29	36.49	0.39	0.47
RL_26	Bundamba Creek at Hanlon St Alert	11.67	0.00	0.10	13.18	0.00	0.20	16.15	0.02	0.51	18.79	0.03	0.42	23.08	0.06	0.27	25.81	0.15	0.30	36.49	0.39	0.47
RL_27	Woogaroo Creek at Brisbane Road Alert	5.47	0.01	0.01	8.44	0.03	0.04	12.60	0.02	0.09	16.56	0.06	0.37	21.02	0.03	0.19	23.90	0.08	0.18	35.61	0.37	0.44
RL_28	Oxley Creek at Rocklea	4.29	0.15	0.35	5.49	0.00	0.27	7.06	0.01	0.41	9.66	0.00	0.13	13.14	0.02	0.11	15.83	0.01	0.07	28.68	-0.16	-0.13

^ Development Scenario 1 (DS1) applies urban roughness values to a future development layout
^ Development Scenario 2 (DS2) applies urban roughness values to a future development layout and filling to the 1 in 100 AEP flood level for development within the 1 in 100 AEP extent

Table F-2 Climate Change Scenarios Peak Flood Level Differences

Addendum Table - Climate Change Sensitivity Scenarios Peak Levels

		Peak Flood Level (mAHD)																											
		AEP (1 in....) and difference in peak level from Base Case (m)																											
		10				20				50				100				500				2000				100000			
ID	Reporting Location	Base	CC2	CC4	CC5	Base	CC2	CC4	CC5	Base	CC2	CC4	CC5	Base	CC2	CC4	CC5	Base	CC2	CC4	CC5	Base	CC2	CC4	CC5	Base	CC2	CC4	CC5
RL_01	Lockyer Creek at Tarampa	60.45	0.56	0.83	0.56	60.85	0.08	0.14	0.08	60.98	0.02	0.05	0.02	61.01	0.02	0.05	0.02	61.17	0.06	0.13	0.06	61.37	0.09	0.20	0.09	65.12	1.94	3.63	1.94
RL_02	Wivenhoe Dam Tailwater	36.96	0.90	2.08	0.89	40.60	1.72	3.32	1.72	45.54	1.37	2.97	1.37	49.87	1.47	1.95	1.47	51.52	0.84	1.96	0.84	53.00	0.83	1.90	0.83	65.21	1.93	3.60	1.93
RL_03	Lockyer Creek at Lyons Bridge	63.56	0.59	0.85	0.59	64.01	0.12	0.24	0.12	64.30	0.06	0.10	0.06	64.36	0.05	0.10	0.05	64.62	0.08	0.18	0.08	64.88	0.13	0.29	0.13	66.58	0.19	0.46	0.19
RL_04	Brisbane River at Lowood Pump Station	34.48	0.82	1.89	0.82	37.65	1.38	2.81	1.40	42.19	1.25	3.01	1.26	47.27	1.95	2.87	1.95	49.85	1.29	2.78	1.29	52.11	1.12	2.33	1.12	65.00	1.99	3.71	1.99
RL_05	Brisbane River at Savages Crossing	30.00	0.59	1.65	0.59	33.59	1.52	3.07	1.51	38.53	1.51	3.25	1.51	44.44	2.77	4.47	2.77	48.42	1.72	3.39	1.72	50.91	1.18	2.44	1.18	63.86	1.95	3.65	1.95
RL_06	Brisbane River Upstream Mt Crosby Weir	13.83	0.72	1.52	0.73	17.10	1.46	2.87	1.46	22.05	1.76	3.61	1.76	27.98	2.86	5.12	2.87	32.61	1.69	3.60	1.70	35.49	1.16	2.40	1.12	47.38	1.64	3.04	1.61
RL_07	Brisbane River downstream Mt Crosby Weir	12.72	0.90	1.85	0.92	16.60	1.70	3.15	1.70	21.67	1.90	3.77	1.90	27.59	2.82	5.09	2.82	32.26	1.72	3.53	1.73	34.99	1.14	2.38	1.14	46.89	1.63	3.02	1.63
RL_08	Brisbane River at Moggill	7.72	0.82	1.75	0.96	11.39	1.46	2.85	1.49	15.79	1.49	3.02	1.50	20.37	2.20	3.94	2.22	24.25	1.65	3.12	1.65	26.83	1.41	2.53	1.41	37.12	1.13	2.08	1.13
RL_09	Brisbane River at Jindalee	4.05	0.64	1.51	0.80	6.80	1.12	2.28	1.19	10.34	1.18	2.64	1.28	14.18	1.84	3.32	1.87	17.72	1.62	3.31	1.63	20.59	1.51	2.80	1.52	32.49	1.43	2.69	1.43
RL_10	Brisbane River at Tennyson	2.93	0.50	1.10	0.75	4.67	0.84	1.71	0.98	7.46	1.06	2.48	1.17	11.00	1.64	3.24	1.69	14.51	1.45	3.00	1.47	17.27	1.47	3.01	1.48	30.22	1.39	2.55	1.39
RL_11	Brisbane River at Fairfield	2.71	0.46	1.07	0.75	4.19	0.70	1.53	0.88	6.54	0.91	2.17	1.02	9.80	1.61	3.14	1.67	13.28	1.49	3.08	1.52	16.20	1.58	3.23	1.60	29.77	1.43	2.61	1.43
RL_12	Brisbane River at Toowong	2.50	0.41	1.00	0.72	3.56	0.44	1.20	0.68	5.44	0.76	1.83	0.91	8.28	1.54	2.99	1.62	11.61	1.52	3.04	1.56	14.36	1.48	3.11	1.50	27.48	1.35	2.46	1.35
RL_13	Port Office Gauge	2.19	0.34	0.90	0.67	2.75	0.46	1.05	0.71	3.88	0.62	1.31	0.83	5.86	1.27	2.58	1.38	8.90	1.49	2.86	1.55	11.29	1.32	2.93	1.35	25.25	1.25	2.25	1.25
RL_14	Brisbane City Gauge	2.16	0.33	0.89	0.67	2.69	0.46	1.05	0.71	3.82	0.65	1.34	0.86	5.77	1.25	2.54	1.35	8.81	1.50	2.89	1.57	11.19	1.30	2.87	1.32	24.95	1.25	2.25	1.25
RL_15	Brisbane River at Hawthorne	2.00	0.31	0.83	0.63	2.24	0.35	0.85	0.64	2.69	0.40	0.94	0.65	3.47	0.62	1.46	0.81	5.25	0.95	2.05	1.12	6.95	0.91	1.88	0.95	17.47	1.28	2.35	1.28
RL_16	Brisbane River at Gateway Bridge	1.98	0.30	0.79	0.63	2.05	0.30	0.80	0.63	2.12	0.30	0.79	0.62	2.28	0.39	0.91	0.65	3.06	0.39	0.85	0.63	3.74	0.75	1.30	0.86	8.77	0.60	1.15	0.60
RL_17	Warrill Creek at Amberley	27.51	0.23	0.44	0.23	27.69	0.23	0.41	0.23	28.30	0.13	0.26	0.13	28.47	0.16	0.30	0.16	29.11	0.35	0.77	0.35	30.39	0.56	1.13	0.56	37.69	1.02	1.93	1.02
RL_18	Purga Creek at Loamside	27.77	0.16	0.32	0.16	27.91	0.14	0.28	0.14	28.05	0.14	0.28	0.14	28.79	0.14	0.27	0.14	29.15	0.26	0.71	0.26	30.44	0.58	1.15	0.58	37.70	1.02	1.92	1.02
RL_19	Bremer River at Walloon	26.72	0.38	0.71	0.38	27.48	0.25	0.47	0.25	27.94	0.18	0.36	0.18	28.48	0.23	0.47	0.23	29.49	0.34	0.70	0.34	30.44	0.57	1.12	0.57	37.69	1.02	1.92	1.02
RL_20	Bremer River at Three Mile Bridge	22.94	0.67	1.27	0.67	24.11	0.64	1.23	0.64	26.03	0.57	1.04	0.57	26.87	0.53	1.01	0.53	28.83	0.56	1.08	0.56	30.27	0.62	1.21	0.62	37.68	1.03	1.93	1.03
RL_21	Bremer River at One Mille Bridge	20.12	0.74	1.46	0.74	21.51	0.86	1.61	0.87	24.16	0.82	1.58	0.82	25.37	0.86	1.58	0.86	27.96	0.67	1.29	0.67	29.66	0.70	1.35	0.70	37.61	1.05	1.96	1.05
RL_22	Bremer River at David Trumpy Bridge	15.57	0.81	1.48	0.82	16.85	0.76	1.49	0.77	19.44	0.77	1.50	0.78	21.04	0.90	2.42	0.91	24.67	1.25	2.54	1.26	27.15	1.42	2.51	1.42	37.25	1.13	2.09	1.13
RL_23	Bremer River at Hancock Bridge	17.49	0.88	1.62	0.88	18.87	0.85	1.69	0.86	21.67	0.83	1.57	0.83	22.99	0.88	1.64	0.89	25.86	1.00	2.01	1.00	27.37	0.76	1.81	0.77	37.31	1.13	2.08	1.13
RL_24	Bremer River at Bundamba Confluence	12.51	0.84	1.63	0.86	13.88	0.69	1.49	0.71	17.20	1.04	2.06	1.06	20.77	2.00	3.70	2.02	24.56	1.53	2.90	1.54	27.09	1.43	2.53	1.44	37.23	1.13	2.09	1.13
RL_25	Bremer River at Warrego Highway	10.89	0.73	1.64	0.76	12.92	0.87	1.83	0.89	16.96	1.21	2.34	1.23	20.76	2.04	3.74	2.06	24.55	1.54	2.91	1.54	27.09	1.43	2.53	1.44	37.23	1.13	2.09	1.13
RL_26	Bundamba Creek at Hanlon St Alert	12.51	0.84	1.63	0.86	13.86	0.68	1.47	0.69	17.18	1.04	2.06	1.06	20.77	2.01	3.71	2.02	24.56	1.53	2.90	1.54	27.09	1.43	2.53	1.44	37.24	1.13	2.09	1.13
RL_27	Woogaroo Creek at Brisbane Road Alert	6.25	0.78	1.75	0.92	9.68	1.28	2.67	1.32	13.98	1.40	3.08	1.44	18.76	2.26	3.97	2.28	22.69	1.70	3.17	1.71	25.37	1.55	2.86	1.56	36.39	1.15	2.10	1.15
RL_28	Oxley Creek at Rocklea	4.74	0.59	0.84	0.63	5.87	0.38	0.92	0.39	7.78	0.73	2.13	0.83	11.24	1.59	3.04	1.63	14.53	1.40	2.94	1.42	17.27	1.46	3.00	1.47	30.23	1.39	2.56	1.39

^ Climate Change Scenario 2 (CC2) incorporates a 0.3m sea level rise and a 10% increase in rainfall
^ Climate Change Scenario 4 (CC4) incorporates a 0.8m sea level rise and a 20% increase in rainfall
^ Climate Change Scenario 5 (CC5) incorporates a 0.63m sea level rise and a 10% increase in rainfall

Appendix G Limitations of NGC Surveyed Floor Levels

Strategic Floodplain Management Plan

Appendix G – Flood Level Accuracy Assessment

Introduction

The purpose of this Flood Level Accuracy Assessment is to confirm the level of accuracy obtained for the floor level survey undertaken as part of the *Brisbane River Strategic Floodplain Management Plan* (Strategic Plan).

Surveying work was carried out on approximately 63,000 properties across the Brisbane River floodplain, making it the largest property level survey known to have occurred to date within Australia. Following this work, an independent surveyor was contracted to verify the accuracy of the floor level dataset. This assessment details the results of the independent survey, which is to be considered when utilising the floor level survey data from the Strategic Plan.

The Strategic Plan is a regional scale, catchment wide study. The floor level survey has been used for the following purposes:

- understanding the consequences of flooding by quantifying properties flooded above floor level for a range of flood AEPs (Annual Exceedance Probabilities) as modelled in the Flood Study
- a flood damages assessment of the floodplain for the full range of flood AEPs identified in the Flood Study
- benefit cost ratios of structural options assessed in the Strategic Plan.

The accuracy of the floor level dataset, as determined in this assessment, is considered fit for purpose for informing the development of the Strategic Plan. It shows that floor level heights are marginally over-estimated, with average biases ranging between 0.12m – 0.3m by local government area (Refer **Table 3**).

The dataset is a valuable resource and has many potential applications beyond the Strategic Plan. Having a detailed understanding of the accuracy of the data as confirmed through the data verification process, enables users to apply the information with confidence and understanding of its limitations and uncertainties.

Strategic Plan floor level data

In 2017, a surveying consultancy undertook a floor level survey of approximately 63,000 properties across 10 zones within the Brisbane River floodplain. The floor level survey data formed a critical component of the flood damages assessment developed for the Strategic Plan.

Floor levels were captured using either Airborne Laser Scanning (ALS) or Mobile Laser Scanning (MLS). Both methodologies required elements of remote, manual processing, involving a number of assumptions such as applying a standard adjustment to the measured eave level to determine the floor level of a property. Upon delivery, the accuracy of the actual floor levels data obtained was not confirmed.

Verification data by an independent surveyor

An independent surveyor was engaged to undertake a manual capture of 1000 properties to confirm the accuracy of data provided by the original surveyors. The statistically significant sample size of 1000 was used to verify the accuracy of the data with 95 per cent confidence and a five per cent margin of error.

The independent survey involved a field capture of building floor levels using a combination of Global Navigation Satellite System (GNSS) and total station methodologies, to provide horizontal and vertical coordinates. Local survey marks were measured to confirm consistent datums. Capture locations were selected throughout each project zone ensuring a variety of different land uses, building and terrain types were represented in the dataset.

The data capture methodology for the independent survey was as follows:

- Total station shots were taken to measure the elevation of the lowest habitable[1] floor level at the base of the front/main door of the buildings.
- Additional measurements were taken on the first, and if necessary second floor, of multi-storey buildings with defined floors. However, only the lowest habitable floor level was used in the dataset comparison.
- A second measurement of the floor level was taken as a quality check for approximately 10 per cent of the properties surveyed.

Dataset Comparison

The data obtained by the independent surveyor was reconciled against the Strategic Plan dataset to ensure the correct properties were being compared. Where an exact match could not be confirmed, the property was excluded from the database comparison.

To ensure a statistically significant number of floor levels was acquired for comparison within each local government area, the verification dataset provided by the independent surveyor was checked against the minimum requirements for a statistically representative dataset, as shown in **Table 2.**

Table 2: The final numbers from the verification dataset following cleaning.

Confidence interval	Margin of error	Local governme nt	Minimum required ALS Sample	Minimum required MLS Sample	Actual ALS sample	Actual MLS sample
95%	5%	Ipswich	137	135	147	144
		Brisbane	138	138	155	158
		Lockyer Valley	117	73	119	76
		Somerset	129	100	133	109

[1] The lowest habitable floor level was determined visually by the surveyors and may not align with planning records.

Results

The Strategic Plan and verification datasets were compared by calculating the difference in habitable floor level measurements for each property. The accuracy of the data was determined using the two following methods:

1. average floor level difference between the two datasets
2. percentage of floor levels within the accuracy targets referenced in **Table 1**.

The average floor level difference was -0.19m across the entire dataset, and -0.28m and -0.09m for the ALS and MLS capture methods respectively.

Table 3 outlines the average difference for each capture method for the four local government areas.

Table 3: The average difference (verification dataset minus Strategic Plan dataset) for each capture method and across each local government.

LGA	Capture method	Average difference (m)	Local government average difference (m)
Brisbane	ALS	-0.34	-0.23
	MLS	-0.13	
Ipswich	ALS	-0.19	-0.12
	MLS	-0.04	
Lockyer Valley	ALS	-0.42	-0.30
	MLS	-0.10	
Somerset	ALS	-0.19	-0.15
	MLS	-0.11	

A bias analysis was undertaken to identify the average difference in data for different floor types such as slab on ground or house on stilts. This analysis identified a larger difference between low-set and high-set buildings, or those with an unknown floor type. Refer **Table 4.**

Table 4: The average difference (verification dataset minus Strategic Plan dataset) for each capture method and floor type across each local government

Local government area	Data source	Floor type	Average difference (m)	Totals (m)	
Brisbane	ALS	Higher than 2m	-0.835	-0.336	-0.231
		Lower than 2 m	-0.577		
		Slab on ground	-0.092		
		Unknown	0.004		
	MLS	Higher than 2m	-0.117	-0.127	
		Lower than 2 m	-0.041		
		Slab on ground	-0.163		
		Unknown	-0.114		
Ipswich	ALS	Higher than 2m	-0.311	-0.193	-0.120
		Lower than 2 m	-0.277		
		Slab on ground	-0.118		
		Unknown	-0.153		
	MLS	Higher than 2m	-0.045	-0.045	
		Lower than 2 m	-0.038		
		Slab on ground	-0.055		
		Unknown	0.118		
Lockyer Valley	ALS	Higher than 2m	-0.709	-0.424	-0.295
		Lower than 2 m	-0.353		
		Slab on ground	-0.092		
		Unknown	-0.730		
	MLS	Higher than 2m	-0.081	-0.097	
		Lower than 2 m	-0.212		
		Slab on ground	-0.015		
Somerset	ALS	Higher than 2m	-0.286	-0.191	-0.152
		Lower than 2 m	-0.199		
		Slab on ground	-0.131		
		Unknown	-0.305		
	MLS	Higher than 2m	-0.010	-0.106	
		Lower than 2 m	-0.052		
		Slab on ground	-0.184		
		Unknown	-0.108		

Tables 5 to 7 outline the accuracy of the Strategic Plan dataset for different accuracy bands. The Strategic Plan dataset has an overall accuracy of 62 per cent for properties within ± 0.3m for ALS and ± 0.15m for MLS.

Table 5 - percentage of measured floor levels that meet each vertical accuracy band across the entire study area

Capture method	± 0.15m	± 0.3m	± 0.5m	± 1m	± 2m
ALS	37%	62%	79%	89%	96%
MLS	62%	84%	93%	97%	98%

Table 6 - percentage of ALS measured floor levels that meet each vertical accuracy band by local government

Local government	Capture method	± 0.3m	± 0.5m	± 1m	± 2m
Brisbane	ALS	64%	75%	85%	95%
Ipswich	ALS	66%	91%	98%	99%
Lockyer	ALS	57%	73%	80%	90%
Somerset	ALS	62%	74%	92%	98%

Table 7 - percentage of MLS measured floor levels that meet each vertical accuracy band by local government

Local government	Capture method	± 0.15m	± 0.3m	± 0.5m	± 1m
Brisbane	MLS	54%	78%	89%	93%
Ipswich	MLS	72%	90%	99%	100%
Lockyer	MLS	62%	83%	92%	96%
Somerset	MLS	59%	85%	92%	98%

Implications for use in the Strategic Plan

The Strategic Plan has been informed by the floor level survey through the following processes:

- understanding the consequences of flooding by quantifying properties flooded above floor level for a range of flood AEPs (Annual Exceedance Probabilities) as modelled in the Flood Study
- a flood damages assessment of the floodplain for the full range of flood AEPs identified in the Flood Study
- benefit cost ratios of structural options assessed in the Strategic Plan.

Overall the assessment has shown that floor level heights are marginally over-estimated, with average biases ranging between 0.12m – 0.3m by local government area (Refer **Table 3**).

The following information should be considered when referring to the Strategic Plan.

Whilst the dataset is considered fit for purpose there is likely to be an under-estimation of properties inundated above floor level, which means the estimated figures of properties impacted, flood damages and economic benefits of the structural options may be lower than actual.

The implications of this under-estimation are considered negligible on the actions and decisions made as part of the Strategic Plan for the following reasons.

- Property counts of above floor inundation are primarily used in the assessment of current and future flood risk to give an indication of the consequences of flooding. This information is used in conjunction with a number of other factors, such as community vulnerability, isolation and road access to identify regional scale hotspots. As such, the areas identified are not directly tied to those properties inundated above the main habitable floor level and are considered unlikely to change with further refinement of the survey data.
- The property count is influenced by the flood level information resulting from the Brisbane River Catchment Flood Study (Flood Study). The Flood Study stipulated its own requirements for accuracy, varying from ± 0.15m to ± 0.5m, based on 30 metre grid cell resolution. As such, even with improved floor level accuracy, property counts will still include a level of uncertainty.
- Peak levels for different AEPs are based on an envelope of a number of different flood events. The process for selecting these events was based on maximising peak levels and the anticipated bias from this process is up to approximately 0.1 metre.
- Flood damage assessments are an estimation of the expected economic damages resulting from flooding, based on a number of assumptions including flood levels, floor levels and stage damages. Each of these components carry a level of uncertainty. Therefore, flood damage assessments are used as an indication of damage and are not suitable for estimates at the property scale. Whilst further refinement of floor levels may adjust the overall flood damage assessment, and may lead to a marginal increase, it is unlikely to have a significant impact on the overall trends outlined in the Strategic Plan.
- As part of the Technical Evidence Report, a sensitivity test on the damages assessment was undertaken which considered the impact that a ± 0.15m change in the floor levels would have on flood damages. These changes only resulted in a 4 per cent change to Average Annual Damages (AAD) and concluded that flood damages were not sensitive to changes in the floor level dataset.
- One of the primary uses of the flood damage estimates is within the benefit cost ratios (BCR) used as part of the multi-criteria assessment of structural options assessed in the Strategic Plan. A lower flood damage assessment would lead to BCRs trending lower (i.e. being shown to be less economically viable). However, within the Strategic Plan, the economic assessment only accounts for 20 per cent of the overall Multi-Criteria Assessment score, and no option was discounted based solely on BCR.

The dataset is a valuable resource and has many potential applications beyond the Strategic Plan. Having a detailed understanding of the accuracy of the data as confirmed through the data verification process, enables users to apply the information with confidence and understanding of its limitations and uncertainties.

Appendix H Long List of Options – First Pass Assessment Results

Measure Type	Location	Measure name (location)	# of Green Dots	# of Orange Dots	# of Red Dots	Comments
Flood gates	1.1	Oxley Creek		3	4	As part of a number of 'Oxley Creek' measures? Including levee (O) Loss flood storage for Brisbane River (R) Ditto (R)
	1.2	Pamphlet Bridge		1		Possible but need to check impact on river level (O)
	1.3	Norman Creek		2	1	Loss of flood storage (ie, to work properly need to cut-off entire creek. Floodplain - ditto for Oxley Creek (R)
	1.4	Breakfast Creek		1		Local flooding is a possibility (O)
Dams	2.1	Additional dam on the Brisbane River where the bridge crosses the river on Esk-Kilcoy Rd. O'Shea Crossing			2	Being considered under PIFMS12 -> see 2.6 (R)
	2.2	Bremer River		2	3	May help reduce flood flows in Brisbane Rivers that affects CBD (O) Worth demonstrating if of any benefit or not (O) Didn't "fly" under PIFMSI (R) Would need severd in Bremer River catchment - fail b/c test (R) Would have very limited benefit - primary flow through Warrill catchment (R)
	2.3	New dam on Oxley Creek in Greenbank Military Training area		4		May help reduce flooding caused by Oxley Creek (won't help reduce flood impact from Brisbane River) (O)
	2.4	Increase flood storage of Wivenhoe Dam/Upgrades/Operation	3		2	Increasing storage allows more effective control of flows entering the Brisbane River (1/2 the Brisbane River catchment is upstream of Wivenhoe Dam) (G) Currently being investigated but also needs to include option around Somerset an mel and also 2.6 (G) Being considered elewhere (R) Ditto (R)
	2.5	Expansion of Lake Atkinson			2	
	2.6	New dam near Linville	3	1	2	Definite FM benefits (G) Potential next consideration after Wivenhoe investigations (G) Impacts on grazing land (GQAH) (O) Out of scope - being considered elsewhere (R) Ditto (R)
	2.7	New dam on lower Warrill Creek near Willowbank	1	2		Looked at in PIFMSI but worth re consideration in light of better damage/impacts data (G) Only if costs can be shared with rail construction (G) Helps reduce flows into Bremer River and therefore Brisbane River (O)
	2.8	Laidley		4		Only benefits Laidley would need to be part of a "sleite" but still probably questionable (O) Local benefit (O) Would help reduce flow ionto Lockyer Creek that flows into Brisbane River (O)

Measure Type	Location	Measure name (location)	# of Green Dots	# of Orange Dots	# of Red Dots	Comments
Channel Bypass	3.1	Canal from the Brisbane River to the Logan River			7	Would fail feasibility and economics **(R)** Transfers problem **(R)** Cost and effectiveness **(R)** Major social and environmental impacts **(R)** Transfer of sediments into a stressed system **(R)**
	3.2	Overflow for Somerset Dam		2	2	To where? (O) Ditto (O) Transfer scheme just not feasible because of volume and timing and land requirement **(R)** Already considered in dams scenario **(R)**
	3.3	Develop a combined canal/river route using the Warrego as a conveyance to the Murray Darling Basin			7	? Over the range? **(R)** Silly **(R)** Cost and effectiveness **(R)** Transfer scheme just note feasible because of volume and timing and land requirement **(R)** High construction cost and ongoing cost to pump water up over great dividing range **(R)**
	3.4	Escape channel/spillway from Wivenhoe to another reservoir or to Morton Bay		4	3	? England Creek (O) Consider dual purposed - Transport/flood conveyor (O) Maybe part of the Dam assessment, would need to be to another storage (England Ck, la'a manchester (O) Maybe to England Creek **(R)**
Pumping and Pipes	4.1	Divert flood water from the Bremer, Lockyer & Brisbane River catchments using a pump and pipeline complex from the intersection of the Lockyer and Brisbane River			10	Not feasible as nowhere to pump it **(R)** Ditto **(R)** x2 Silly **(R)** Ineffective **(R)**
	4.2	Pipe water to NSW for trading			9	Not based around floodwater, market wouldn't allow it **(R)** They would afford the cost! **(R)** Just ridiculous! **(R)** Ditto **(R)**
	4.3	Transfer of water from Wivenhoe using tunnel/channel options	1	3	3	With England Creek storage (G) Agree -> more info (O) to where? **(R)** Not feasible **(R)** Cost **(R)**
	4.4	England Creek overflow storage (from Wivenhoe)	1	7		Definitely should be assessed (G) Possibly already assessed (O) Previously considered but would stand a re-look (O) More info (O)

Measure Type	Location	Measure name (location)	# of Green Dots	# of Orange Dots	# of Red Dots	Comments
Levee Banks	5.1	River Park, Fig Tree Pocket area, Madalay Street	1	2		Need more info - is it more local? (O) Ditto (O)
	5.2	Brisbane/Oxley Creek banks in Indooroopilly-Canoe reaches	1	3		Local flooding needs assessing and should consider in conjunction with flood rate (O) Ditto (O)
	5.3	Ipswich CBD & Marsden Parade	1	3	1	Understand the economic benefits to local businesses & flow on impacts to neighbouring communities (O) Possible practically Cn all Ipswich Levees however tested to be not feasible. Confirm with ICC (O) Goodnda CBD levee - Ipswich Motorway enbankment. Confirm with ICC (O)
	5.4	Mary Street & Martin Street Ipswich	1		1	Tested, not feasible (R)
	5.5	Old railway workshops, North Ipswich			1	
	5.6	Chubb Street, One Mile			2	
	5.7					
	5.8	Fernvale levee	4			Good local benefits, would slightly benefit downstream by storage hour u/s (G)
	5.9	Brisbane CBD (both sides separtely)	3	1	2	Regional significant/economically affordable (G) Need to be looked at on a "hot-spot" basis (G) Significant impact to not feasible but could be worth running into for information and community engagement (to show not feasible) (O) Significant visual impact and practical impact, eg services relocation, roads & building would need to be moved to make way for the levees (R) Cost benefit? must of CBD is actually flood free (R)
	5.1	Temorary barriers in Southbank	5			Regional significant/economically affordable (G) Need to be looked at on a "hot-spot" basis (G)
	5.11	Temorary barriers @ hotspot locations	6	1		This option should really be run from the model to identify a number of hotspot scenarios to test (G) Where proven cost effective and doesn't raise flood levels elsewhere (G) Need to be looked at on a "hot-spot" basis (G) Investigate locations/land availability effect (O)
	5.12	Levee removal (consideration)	7	4		At regional scale, upper rural areas Bremer, Warrill, Lockyer etc (G) Multiple benefits-floodplain reengagement, wetlands, water quality (G) Flood storage (G) Potential increase in flooding directly surrounding removal (O) Potential increase to isolated communities (O) Possibly limited flood benefit overall but needs to be tested with other compents not on its own (O) Rural levees only (O)

Measure Type	Location	Measure name (location)	# of Green Dots	# of Orange Dots	# of Red Dots	Comments
Channel Modification	6.1	Straighten waterways (Brisbane River)			6	Environmental impacts - increase flood issues downstream - bank erosion - increased velocity **(R)** Ditto **(R)** Not innovative or sustainable **(R)**
	6.2	Concrete line creeks and drainage paths			9	Not at Regional scale - env impacts **(R)** Old thinking **(R)** Maintenance $$ **(R)** Community backlash **(R)** Not innovative and sustainable **(R)** The rest of the world are removing concrete lined channels for a reason **(R)**
	6.3	Redirect mouth of Oxley Creek		4	2	Not great options but due to community feedback good to rule out (O) May need a study to demonstrate to community (O) Would be good to rule out (O) Trivial benefits (eg 2011) **(R)** Unlikely to make any difference to water levels in Oxley Ck **(R)**
	6.4	Instream channel management		6	1	Needs investigation to confirm best approach (O) Need to consider broader floodplain a waterway management implicates -> systems approach needed (O) Ditto (O) Flood impacts to be considered, but prob needs to occur anyway for WQ (O) Ditto (O) Ongoing lot/trivial benefits in large floods **(R)**
Dredging	7.1	Dredge Brisbane River		3	3	Quantify current dredging activities (Port of Brisbane eg:) and see if increasing has impact (O) Sediment might be hard to dispose off-contaminants (O) Requires ongoing commitment to dredging, better to focus on source control **(R)** Reactive and unlikely to be of benefit **(R)** Not sustainable **(R)**
	7.2	Dredge mouth of Oxley Creek		4		✓ Water would not come out of Oxley Creek faster (from creek flooding) × Water would flow back up creek faster (from higher flood level from Brisbane River) (O) Community intercit to worth exploring even to rule over (O) Worth it? (O) Local creek flooding (O)
	7.3			1		Consider increasing compacity in heavily silted waterways where environmental issues are considered (O)

Measure Type	Location	Measure name (location)	# of Green Dots	# of Orange Dots	# of Red Dots	Comments
Detention Basins (this scale does nothing.) (Local measure)	8.1	Deebing Creek - cascading basins/small flood storage dams			1	Not of significant scale (R)
	8.2	Build flood water storage tanks on the Bremer and Brisbane Rivers		3	4	Could also be water supply storages (O) $ and size (R) x3
	8.3	Lockyer CAP basins	3	1		Include in 1x Regional Cummulative Scenario (G) Could contribute to positive reduction in flood flows into Brisbanr River (Lockyer Ck = 25% of Brisbane R catchment) and an opportunity to replenish the Lockyer Ck floodplain with silt and stop silt flowing downstream to Moreton Bay (G) Worth including qiven existing strategy but unsure if impact significant enough by maybe as part of suits (O)
Cumulative and broad scale landscape modification	9.1	Holistic approach	9	2		Essential to meet ICM objectives (G) Include 5:12 in this scenario (G) Limited flood rise imp - requires analysis (O) Unlikely to offer enough mitigation (must be kept in perspective) (O)

Appendix I Summary of Options not Included in Short-List

Summary of Options not Included in Short-List

Potential structural measure ID	Description (location, immunity etc)	Origin of option	Regionality Assessment	Recommended for further assessment	Reason	Modelling comments	No. Properties mitigated	Run Number
BNR-CM-04	Straighten waterways (Brisbane River)	Workshop	No. Local benefits only	No	Likely to fail environmental and hydraulic assessments			
BNR-CM-05	Concrete line creeks and drainage paths	Workshop	No. Local benefits only	No	Likely to fail environmental and hydraulic assessments			
BDC-LF-01	1 in 50 AEP protection levee around Lamont Street North Booval (Bundamba Creek)	BMT WBM	No. Bundamba Ck fringe areas only	Possible	Flood impact to commercial, residential and industrial properties from Bremer River backflow into Bundamba Creek		For 1 in 50 AEP Residential = 178 Commercial = 29 Other = 1 (showground)	
BDC-LF-02	1 in 100 AEP protection levee around Kirk Street North Booval (Bundamba Creek)	BMT WBM	No. Bundamba Ck fringe areas only	Possible	Significant flood impact to commercial, residential and industrial properties from Bremer River backflow into Bundamba Creek		For 1 in 100 AEP Residential = 532 Commercial = 60 Other = 35 (school, church etc)	
BRK-LF-01	1 in 50 AEP protection levee and floodgate on Breakfast Creek	Workshop	No. Breakfast Ck fringe areas only	Possible	Flood impact to commercial, residential and industrial properties from Brisbane River backflow into Breakfast Creek. Constrained creek mouth provides good opportunity for flood control		For 1 in 50 AEP Residential = 310 Commercial = 171 Other = 23 (showground, church)	
BRK-LF-02	1 in 100 AEP protection levee and floodgate on Breakfast Creek	Workshop	No. Breakfast Ck fringe areas only	Possible	Flood impact to commercial, residential and industrial properties from Brisbane River backflow into Breakfast Creek. Constrained creek mouth provides good opportunity for flood control			
NOR-LF-01	1 in 50 AEP protection levee and floodgate on Norman Creek	Workshop	No. Norman Ck fringe areas only	Possible	Flood impact to commercial, residential and industrial properties from Brisbane River backflow into Norman Creek. Constrained creek mouth provides good opportunity for flood control		For 1 in 50 AEP Residential = 121 Commercial = 16 Other = 25 (school, church)	
NOR-LF-02	1 in 100 AEP protection levee and floodgate on Norman Creek	Workshop	No. Norman Ck fringe areas only	Possible	Flood impact to commercial, residential and industrial properties from Brisbane River backflow into Norman Creek. Constrained creek mouth provides good opportunity for flood control			
OXL-CM-01	Channel modification of Oxley Creek to realign the creek entrance (to 'point' downstream in Brisbane River)	Workshop	No. Oxley Ck fringe areas only	Possible	Strong community support for testing of option			
OXL-LF-01	1 in 50 AEP protection levee and floodgate near Pamphlet Bridge (Graceville) on Oxley Creek	Workshop	No. Oxley Ck fringe areas only	Possible	Significant impact to commercial, residential and industrial properties from Brisbane River backflow into Oxley Creek		For 1 in 50 AEP Residential = 723 Commercial = 362 Other = 89 (school, utilities)	
OXL-LF-02	1 in 100 AEP protection levee and floodgate near Pamphlet Bridge (Graceville) on Oxley Creek	Workshop	No. Oxley Ck fringe areas only	Possible	Significant impact to commercial, residential and industrial properties from Brisbane River backflow into Oxley Creek		For 1 in 100 AEP Residential = 1933 Commercial = 815 Other = 131 (school, utilities)	
WGC-FG-01	1 in 50 AEP protection flood gate on Woogaroo Creek at the Walston Park Golf Club	BMT WBM	No. Goodna area only	Possible	Flood impact to commercial and residential properties from Brisbane River backflow into Woogaroo Creek at Goodna. Creek mouth (at golf course) is a location of constraint, suitable for a flood gate		For 1 in 50 AEP Residential = 268 Commercial = 24 Other = 5 (childcare, caravan pk)	
WGC-FG-02	1 in 50 AEP protection flood gate on Woogaroo Creek at the Ipswich Motorway overpass near Martin Coogan Park	BMT WBM	No. Local benefits only	No	Ipswich Motorway overpass is a location of constraint for Brisbane River flooding backing into Woogaroo Creek, however, flood may need to be up to 10m to protect against 1 in 50 AEP event, with challenging geometry between bridge piers			
WLC-LF-01	1 in 100 AEP protection levee on Walston Creek at Sumner	BMT WBM	No. Sumner industrial park only	Possible	Flood impact to commercial and industrial properties (few residential properties) due to Brisbane River backflow into Wolston Creek at Sumner. Creek mouth may be sufficiently constrained to install flood gate		For 1 in 100 AEP Residential = 288 Commercial = 79	
BLC-LF-01	1 in 100 AEP protection levee and floodgate on Bulimba Creek	BMT WBM	No. Bulimba Ck fringe areas only	No	Minimal risk to residential properties in frequent events including 1 in 100 AEP			
DBC-CM-01	Deebing Creek - cascading basins/small flood storage dams	Workshop	No. Local benefits only	No	Not regional scale			
DBC-LF-01	1 in 50 AEP protection flood gate on Deebing Creek at Warrick Road crossing (incl raising Warrick Road)	BMT WBM	No. Local benefits only	No	Gate would need to be 5-10m tall to provide 50y protection to small number of properties. Option not feasible			
OXL-DM-01	New dam on Oxley Creek in Greenbank Military Training area	Workshop	No. Local benefits only as small sub-catchment	No	Does not address Brisbane River flooding			
OXL-DR-01	Dredge mouth of Oxley Creek	Workshop	No. Local benefits only	No	Likely captured under OXC-CM-01			
OXL-LV-01	Brisbane/Oxley Creek banks in Indooroopilly-Canoe reaches	Workshop	No. Local benefits only	No	May be covered in OXC-LF-01/02, else is local scale and not within study scope			

Watercourse code	Watercourse name
BDC	Bundamba Creek
BLC	Bulimba Creek
BMR	Bremer River
BNR	Brisbane River
DBC	Deebing Creek
LOC	Lockyer River
NOR	Norman Creek
OXL	Oxley Creek
WGC	Woogaroo Creek
WRC	Warrill Creek
LDC	Laidley Creek
STR	Stanley River
BRC	Buaraba Creek
BRK	Breakfast Creek

Structure code	Structure type
LF	Permanent levee with floodgate
DM	Dam
IC	Integrated catchment management measures (e.g. revegetation, detention basins etc)
PL	Permanent levee
TL	Temporary levee
DR	Dredging
CM	Channel modification (e.g. re-alignment, straightening etc)
FG	Floodgate
PP	Pipe and / or pump measure

Source name	Description
Workshop	Ideas assessed at Study Workshop 1, held 09/03/2017. Includes ideas provided to BMT WBM by QRA before workshop and new ideas generated during workshop
PIFMP report	Prefeasibility Investigation into Flood Mitigation Storage Infrastructure Report for the Brisbane River Catchment (Dept of Energy and Water Supply 2014)
BMT WBM	Supplementary ideas provided by BMT WBM's team of experts

	Definition of Regionality:
	As agreed by the Steering Committee and included in the EOI & RFQ. Regional options are defined as those which have:
1	regional scale impacts and/or
2	cross-council boundary implementation or impacts and/or
3	significant local benefits and/or
4	large implementation footprint and/or
5	significant cost

Appendix J Summary of Aggregated Zone Groups

Land use categories	Relevant planning scheme zones	
Future Urban	Brisbane	• Emerging community • Industry investigation
	Ipswich	• Future urban • Local business and industry investigation • Regional business and industry investigation • Special opportunity
	Somerset	• Emerging community
Industry	Brisbane	• Low impact industry • Industry • Special industry • Extractive industry
	Ipswich	• Local business and industry • Local business and industry buffer • Regional business and industry (medium impact sub-area) • Regional business and industry – low impact • Regional business and industry – medium impact • Regional business and industry buffer
	Somerset	• Industry
	Lockyer	• Industry
Centre	Brisbane	• Principal centre • Major centre • District centre • Neighbourhood centre • Mixed use • Specialised centre
	Ipswich	• Business incubator • CBD medical services • CBD north secondary business • CBD primary commercial • CBD primary retail • Community residential (Springfield) • Local retail and commercial • Major centres • SF town centre • Top of town • Character mixed use
	Somerset	• Centre • Township
Rural/Rural Residential	Brisbane	• Rural • Rural residential
	Ipswich	• Large lot residential • Rural A • Rural B • Rural C • Rural D • Rural E • Limited development (constrained)

Land use categories	Relevant planning scheme zones	
		• Rural constrained – Ripley Valley
	Somerset	• Rural
	Lockyer	• Rural
Special Use	Brisbane	• Community facilities • Special purpose
	Ipswich	• Amberley Air Base and aviation • Bundamba Racecourse stables areas • Special uses
	Somerset	• Community facilities
	Lockyer	• Community facility • Special purpose
Open Space/Environment	Brisbane	• Sport and recreation • Open space • Environmental management • Conservation
	Ipswich	• Conservation • Open space (Springfield) • Recreation
	Somerset	• Recreation and open space
	Lockyer	• Recreation and open space
Low Density Residential	Brisbane	• Low density residential • Character residential
	Ipswich	• Character housing low density • Character housing mixed density • Residential low density
	Somerset	• General residential
	Lockyer	• General residential
Medium Density Residential	Brisbane	• Low-medium density residential • Medium density residential
	Ipswich	• Residential medium density
High Density Residential	Brisbane	• High density residential
	Ipswich	• CBD high density residential
Priority Development Area	Brisbane	• South Bank Corporation Area • Northshore Hamilton • Fitzgibbon • Woolloongabba • Bowen Hills
	Ipswich	• Ripley Valley

Appendix K Risk-Based Planning Stakeholder Briefing Note

This briefing note provides introductory material to assist workshop attendees prepare for the risk-based planning workshop on the 10 April 2017, undertaken as part of the Brisbane River Strategic Floodplain Management Plan (SFMP).

K.1 Purpose of Workshop

The purpose of the workshop is to begin to establish a shared understanding of current and best practice approaches to land use planning for flood hazards, within the context of the Brisbane River floodplain.

The workshop will focus on approaches consistent with the State Planning Policy (SPP) and recommendations of the Queensland Floods Commission of Inquiry (QFCoI) final report, to provide an appreciation of how can be applied within the context of the SFMP.

K.2 Key Concepts

The workshop will:

- Provide an overview of the SFMP project.
- Discuss the tools and outputs from the SFMP that will assist local governments with risk-based land use planning.
- Outline drivers for adopting a coordinated, integrated and consistent approach to managing flood risk in the Brisbane River floodplain, including ‘whole of floodplain’ flood risk mapping.
- Describe the difference between a flood hazard map and a flood risk map, and the limitations of current practices to mapping flood hazard, including the need to move beyond the 1 in 100 AEP flood event.
- Demonstrate a need to move beyond current practice to a stronger risk-based planning approach to mapping flood risk, and ensuring land use planning and development responses are risk appropriate.
- Present the State’s position on risk-based planning for natural hazards as included in the SPP.

K.3 Introduction

The SFMP is the third stage in the wider Brisbane River Catchment Flood Studies project. The Queensland Reconstruction Authority (QRA) is delivering the project in collaboration with the Brisbane City Council, Ipswich City Council, Lockyer Valley Regional Council, Somerset Regional Council, and other State agencies, with assistance from BMT and project partners.

The SFMP will align with the SPP state interests for natural hazards, the draft SEQ Regional Plan and, the QFCoI recommendations which the Queensland Government and Councils have committed to implementing. In doing so, the SFMP will be the first step to implementing an evidence-based risk management approach to land use planning and flood risk mapping.

Representatives from each of the stakeholder councils and State agencies are primarily involved in the project through participation on the Steering Committee and/or working groups. The project has now reached a stage where it is important to engage more broadly with stakeholders, particularly with planners and engineers across the four Council organisations in the Brisbane River floodplain.

While not the only 'floodplain risk managers' in the Brisbane River floodplain, local governments, particularly council planners and engineers have a key role in influencing and implementing policy, and delivering action to respond to flood risk. It is important a shared understanding is established of what the SFMP is, how the tools or outputs of the SFMP can assist councils, and to incorporate stakeholders' expertise and knowledge into the development of the SFMP.

The workshop is an important step toward establishing a shared understanding of risk-based land use planning amongst the broader stakeholders, particularly local government planners and engineers.

K.4 What is the Brisbane River Strategic Floodplain Management Plan Project?

The Brisbane River floodplain, downstream of Wivenhoe Dam, is home to more than one million Queenslanders, spanning four local government areas. The region has a long history of flooding and in January 2011, experienced a major flood that caused widespread inundation and extensive damage to public and private property, the evacuation of towns, and loss of more than 30 lives. Queensland learned from the 2010-11 floods the flood waters don't stop at local government boundaries, and a more coordinated, integrated and consistent approach to how we identify, prioritise and respond to flood risk is required.

In the final report of the QFCoI (March 2012), the Commission found that *"government agencies need to engage in a process of floodplain management involving a combination of land planning and building controls, emergency management procedures, and structural mitigation measures".*

The preparation of the BR SFMP is intended to provide strategic direction across the catchment, including preparation of whole of catchment flood risk mapping and prioritisation of flood risk so that responses to priorities can be agreed and delivered across the whole floodplain in a way that is cost effective, and benefits as many people as possible.

Because there is a large number of stakeholder organisations influencing floodplain management across the Brisbane River floodplain, it is essential we have a shared understanding and can work together towards agreed floodplain management outcomes.

The SFMP will identify the vision and priorities for flood risk management and how best to respond to these flood risks using a comprehensive and integrated suite of implementation and delivery tools. There are many different ways to reduce and manage flood risks and build community resilience, including community awareness and education, insurance, flood warning systems, emergency response and disaster management, structural mitigation options, land use planning and building controls and natural environment responses such as protecting wetlands. The key is choosing the most appropriate tools and finding the right balance or mix of flood management solutions for each location.

K.5 What is Risk-Based Planning and Why Do It?

Risk-based planning is based on the principle of distributing land uses within the floodplain to be risk-appropriate, and graduating or tailoring development and building controls to minimise and manage the consequences of flooding. It moves beyond solely relying on risk assessments to be undertaken on a site by site basis at the development application stage.

The risk-based approach to flood hazard mapping and land use planning responses focusses on strategic planning. It involves setting a clear policy direction in the strategic framework, within relevant overall outcomes and performance outcomes of codes to confidentially encourage or discourage land use and development relative to flood risk.

From a planning perspective, different land uses, densities and forms of development have different vulnerabilities to flood hazard. Understanding how flood risk varies for development and different vulnerabilities of people and users of buildings assists in identifying risk-appropriate development. We need to ensure land use and development is planned in ways that achieve risk levels which meet expectations of both existing and future communities and accords with the SPP. Specifically, we need to understand:

- areas in the floodplain where development is to be avoided because of unacceptable risk;
- areas where risk needs to be reduced to an acceptable or tolerable level and how this is to occur;
- areas where no special conditions or modification of land is required.

A true risk-based approach to planning for flood hazards as mandated by the SPP is quite different to current approaches. Across Australia, current approaches to flood hazard management predominantly focus on a single flood event for planning purposes, such as the 1% (1 in 100) AEP. However, limiting land use decisions and building controls to the consequences of only the 1% AEP, means the flood risk is not fully understood.

The QFCoI recommendations are very clear in that the focus on one defined flood event should not continue and that the full range of possible floods up to and including the Probable Maximum Flood (PMF) is required. The QFCoI also recommends that a planning approach which includes a map showing at least three bands of flood risk, integrating flood likelihood and flood behaviour, should be taken. This approach allows the risk of flooding to be understood across the full spectrum of floods, and enables land use and development controls to be tailored and risk-appropriate.

The SPP mandates that planning schemes are informed by natural hazard risk assessments. The evidence-based risk assessment and flood risk mapping are critical to identifying locations and types of uses that should be avoided because of unacceptable flood risk. The risk assessments inform the identification of locations and land uses that can be mitigated to an acceptable or tolerable level of risk subject to certain conditions or development requirements.

K.6 Summary

In summary,

- Effective floodplain management requires an integrated suite of risk management actions/measures and delivery tools to respond to current and future flood risks (one of which is planning).

- Best practice planning needs to consider more than just the 1 in 100 AEP flood event.
- A risk-based approach to flood management by understanding the behaviour and consequences of flooding across the full range of likelihoods aligns with best practice, the SPP and QFCoI recommendations.
- Best practice flood risk management considers:
    - the full range of floods that are possible
    - the full floodplain extent
    - behaviour and consequences of flooding
    - categories or 'bands' of flood risk
    - the important role of land use planning and development control on the exposure and vulnerability of communities to future flood hazard risk.
- Best practice planning reflects a risk-based approach to flood hazard mapping and land use planning responses. This means preparing flood risk mapping and using this mapping to inform strategic planning and policy development to ensure uses are appropriate for certain areas of the floodplain and to the level of flood risk, and tailoring scheme provisions to reduce and/or manage the risk.
- Best practice planning for flood risk means integrating risk-based considerations into all levels of the planning scheme – strategic framework, overlays, relevant zones and detailed provisions.

K.7 References and Further Reading

The following identifies recommended reading and further references.

K.7.1 Recommended Reading

(1) National Land Use Planning Guidelines for Disaster Resilient Communities, Planning Institute of Australia, 2015 https://www.planning.org.au/documents/item/7804

(2) Flood Commission of Inquiry Final Report, 2012

http://www.floodcommission.qld.gov.au/__data/assets/pdf_file/0007/11698/QFCI-Final-Report-March-2012.pdf

Recommendations 2.13, 7.2, 7.16, 7.24, 8.7.

(3) Managing Flood Risk Through Planning Opportunities – Guidance on Land Use Planning in Flood Prone Areas, 2011, Hawkesbury-Nepean Floodplain Management Steering Committee:

http://www.floodcommission.qld.gov.au/__data/assets/pdf_file/0010/10900/QFCI_Exhibit_967_Managing_Fl ood_Risk_Through_Planning_Opportunities.pdf

- Chapter 4 – Risk and Hazard
- Chapter 5 – Planning for Evacuation
- Chapter 6 – Impacts of flooding on households, pages 49-50
- Chapter 11 – Reducing the risk through Land Use Planning, Graduated panning controls

K.7.2 Other Relevant Documents

- Draft SPP, November 2016 http://betterplanning.qld.gov.au/resources/planning/irp/draft-state-planning-policy.pdf
- SPP – State Interest Guideline - Natural hazards, risk and resilience http://dilgp.qld.gov.au/resources/guideline/spp/spp-guideline-natural-hazards-risk-resilience.pdf
- SPP – State Interest Guideline - Natural hazards, risk and resilience: Technical Manual: A 'fit for purpose' approach in undertaking natural hazard studies and risk assessments http://dilgp.qld.gov.au/resources/guideline/spp/spp-technical-manual-natural-hazards-fit-for-purpose-approach.pdf
- SPP – State Interest Guideline - Natural hazards, risk and resilience: Technical Manual: Evaluation
- Report: Flood Hazards http://dilgp.qld.gov.au/resources/guideline/spp/spp-technical-manual-evaluation-report-flood-hazards.pdf
- Planning for stronger, more resilient floodplains – Part 2, Measures to support floodplain management in future planning schemes, QRA, 2012 http://qldreconstruction.org.au/u/lib/cms/Planning-for-stronger-more-resilient-flo.pdf

Appendix L Freeboard Options Paper

L.1 Summary

Freeboard is an allowance that is applied over and above a best-estimate of relevant design conditions (e.g. defined flood event levels) to provide a factor of safety that compensates for uncertainties in flood level estimation. These uncertainties include inaccuracies with computation modelling of the design conditions; unpredictable and indeterminate local flood hydraulic conditions (e.g. afflux, waves etc); and possible impacts that evolve in the future (e.g. new development, climate change, new design rainfall patterns). Even though the Brisbane River Catchment Flood Study is one of the most detailed and robust studies of its kind, it is still subject to uncertainties, which should be accommodated through inclusion of freeboard provisions.

Uncertainty in the hydraulic modelling create notable uncertainties in flood level estimates in the more incised reaches of the river system, downstream of Lowood. Generous provisions for freeboard should be considered in these areas. In comparison, the areas across the Lockyer Creek floodplain (between Morton Vale and the Brisbane River), and also in the area influenced primarily by storm-tide inundation, is less sensitive to uncertainties in the modelling and as such, lesser allowances for freeboard could be accommodated.

The Brisbane River Catchment is very sensitive to increased catchment inflows (which are possible under future climate conditions) and increased water levels in Moreton Bay (due to projected sea level rise). There would be few river systems in Australia that are more sensitive to these potential future conditions. While design conditions, such as the DFE, generally include a specific provision for future climate conditions, which has been quantified separately, freeboard should be used to accommodate some of the uncertainty around best estimates for future projections (including variability of rainfall and sea level rise projections). Sensitivity to future conditions is particularly significant in the incised reaches of the Brisbane River, between Lowood and Brisbane CBD.

L.1.1 Freeboard Options Framework

One of the aims of the Brisbane River SFMP is to provide a mechanism for establishing consistency across the region when managing floods. This does not imply that freeboard levels need to be the same from one local government area to the next or within the same local government area, but rather, that a consistent approach has been followed and consistent factors have been considered. Indeed, taking a pragmatic and risk-based approach to freeboard considerations, there is merit in having variable freeboard conditions within a local government area.

The factors that would influence selection of a freeboard value can be simplified to:

(1) The sensitivity to flooding of the development to which freeboard is being applied; and

(2) The sensitivity or uncertainty of the flood behaviour at the location of the development.

Consideration of these two 'rolled-up' factors can be expressed in a 2x2 matrix as shown in Table L-1.

Table L-1 Freeboard options assessment (and existing planning scheme values)

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Flood behaviour sensitivity / uncertainty</td></tr>
<tr><td>Low</td><td>High</td></tr>
<tr><td rowspan="2">Development sensitivity</td><td>Low</td><td>Minimal
(minimum 300mm)</td><td>Moderate
(300 – 500mm)</td></tr>
<tr><td>High</td><td>Moderate
(300 – 500mm)</td><td>Maximal
(at least 500mm)</td></tr>
</table>

As shown in this matrix, developments with a ‘low’ sensitivity to flooding that are to be located in areas of ‘low’ flood behaviour sensitivity/uncertainty can be accommodated with a minimal freeboard. Based on existing provisions within Brisbane River Catchment planning schemes, this would reflect values up to about 300mm. On the other hand, if the development is particularly sensitive to flooding, and it is located in an area that has sensitive hydraulic behaviour, then freeboard provisions should be maximal. Based on existing planning scheme provisions, this would reflect freeboard values of 500mm or more.

Values to be adopted for freeboard by each local government authority in the future should account for the risk appetite of the authority. They should also consider potential for flooding from local catchments and overland flowpaths (which is not covered specifically as part of the Brisbane River Strategic Floodplain Management Plan).

Freeboard values should also generally consider legacy aspects of past decisions for consistency, as far as practical.

In **Table L-1**, the following definitions apply:

Low development sensitivity – development that is less sensitive to flooding. This may include particular land uses, such as commercial, industrial or rural, or may relate to the specific context of the development, such as a temporary structure, non-habitable use etc.

High development sensitivity – development that is more sensitive to the impacts of flooding. This would include residential developments, critical infrastructure, and development that would have a high cost (tangible or intangible) if damaged by flooding.

Low flood behaviour sensitivity / uncertainty – these areas of the floodplain are less sensitive to changes in local effects, catchment inflows and levels in Moreton Bay. Generally, there is not a large variation in flood levels between similar AEP events (e.g. less than 1m difference between 1 in 50 and 1 in 100 AEP; and between 1 in 100 and 1 in 200 AEP). Within the Brisbane River floodplain, these areas are essentially restricted to the broad floodplains of lower Lockyer Creek, the upper reaches of the Bremer River (in the vicinity of the Warrill Ck and Purga Ck junctions) and the lower reaches of the Brisbane River downstream of Brisbane CBD (including the lower tributaries of Norman, Breakfast and Bulimba Creeks).

High flood behaviour sensitivity / uncertainty – these areas of the floodplain are more sensitive to changes in local effects, and are highly responsive to changes to catchment inputs and levels in Moreton Bay. There is typically a significant difference in flood levels between similar AEP events (e.g. more than 1m difference between 1 in 50 and 1 in 100 AEP; and between 1 in 100 and 1 in 200 AEP).

Within the Brisbane River floodplain, this category covers the area between Lowood and Brisbane CBD, including the tributaries of lower Bremer River and Oxley Creek. Areas of higher hydraulic risk (HR1 and HR2 categories) may additionally be considered as high flood behaviour sensitivity if the hydraulic risk category is driven by high velocities.

Figure D-1 identifies the flood height differential between the 1 in 100 AEP and the 1 in 50 AEP and is helpful in understanding where the Brisbane River is more sensitive or less sensitive to flood level differences. Areas of greater differential indicate a higher degree of flood sensitivity and therefore more generous freeboard allowances should be considered.

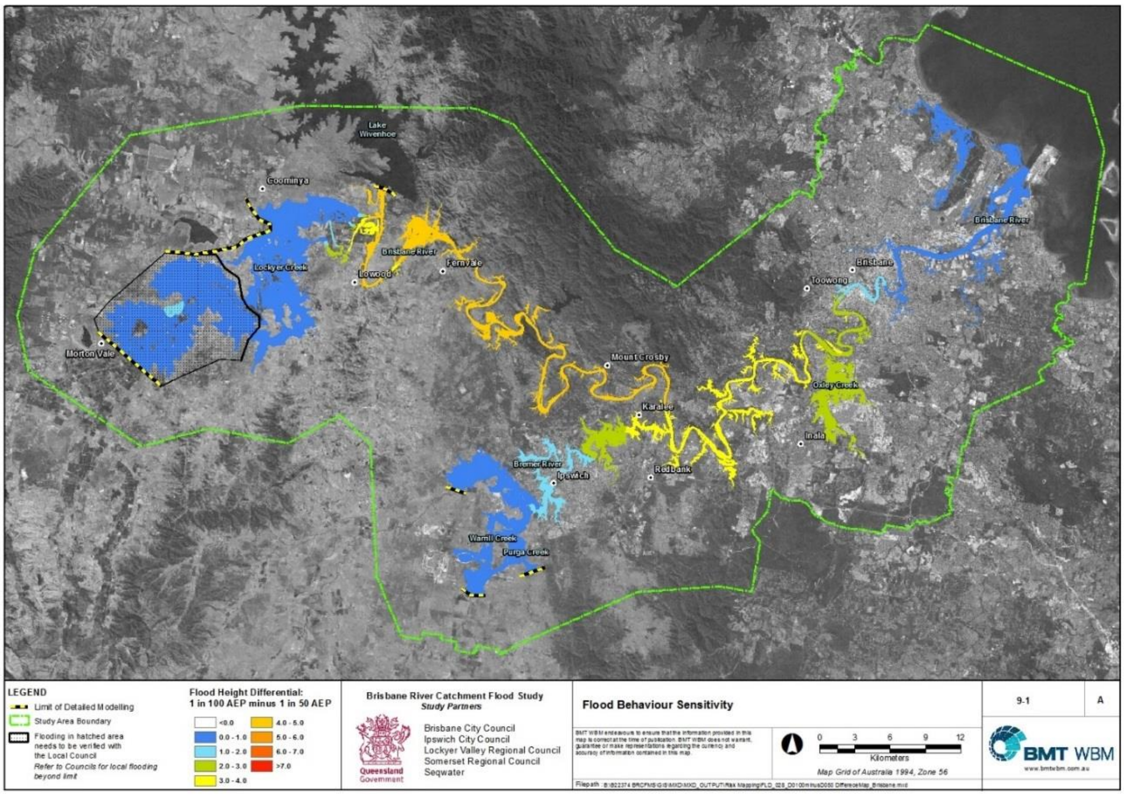


Figure L-1 Flood Behaviour Sensitivity Map

This briefing note documents a review of current and best practice approaches, including relevant legislative requirements, for the use of freeboard provisions and informs the FMS7 Land Use Planning work package for the Brisbane River Catchment Strategic Floodplain Management Plan (BR SFMP).

This review identifies key considerations in setting freeboard provisions and provides a framework for assessment of freeboard values to be adopted for each of the four local government areas in the study area.

The document specifically discusses:

- definition and purpose of the freeboard concept;

- approach currently applied in each of the four local government areas within the study area;
- examples of approaches used in other SEQ local government areas outside the study area;
- current best practice;
- relevant legislation and regulations;
- emerging directions from the Brisbane River SFMP study to date and implications for freeboard use in the study area;
- key considerations in setting freeboard levels; and
- preliminary options assessment.

The purpose of the review is to understand current approaches to freeboard use across the study area and whether these approaches align with and support the development of the BR SFMP

L.2 Definition and Purpose of Freeboard

There are many definitions of 'freeboard' that are used by various agencies and documented within relevant literature. In the context of floodplain management, freeboard is essentially a provision that is over and above a best-estimate of relevant design conditions (e.g. defined flood event levels) to provide a factor of safety when nominating a particular standard. Freeboard is applied to design requirements to help mitigate the impacts of flooding, such as the requirements for floor levels, lot fill levels and flood defence (e.g. levee) levels.

The reason for applying a freeboard is to provide an allowance for circumstances whereby the designated design conditions would be exceeded. As outlined in various literature (see Emergency Management Australia, 1999; ARMCANZ, 2000; NSW Government, 2005; HNFMSC, 2006; DEWS, 2013; Australian Government, 2013), this could occur as a result of various factors, including the following:

- inaccuracies and uncertainties associated with determination of the design conditions;
- unpredictable and indeterminate local flood hydraulic conditions (e.g. afflux, waves etc); and
- uncertainty in modelling possible future conditions and impacts, such as future climate change (i.e. changes to rainfall patterns and sea level rise). Note that flood modelling cannot calculate, with any level of certainty, climate change related flood behaviour; freeboard gives a "factor of safety" to development which is likely to be impacted by future climate change.

For the BR SFMP study area, the accuracy of design flood levels calculated by the detailed hydrologic and hydraulic models is based on the tolerance of the calibration achieved for the models. The acceptable calibration tolerances were:

- Brisbane River downstream of Oxley Creek ± 0.15 m;
- Brisbane River between Goodna and Oxley Creek ± 0.30 m;
- Ipswich urban area ± 0.30 m;

- Brisbane River and tributaries upstream of Goodna (for non-urban areas), including Bremer River and Lockyer Creek ± 0.50 m.

Freeboard is a floodplain management planning tool. It does not influence the determination of design floods or defined flood events (DFEs). 'DFE + Freeboard' is generally considered as the 'Flood Planning Level'.

The Recommendations of the Queensland Floods Commission of Inquiry (2012) noted that Councils typically use a freeboard to provide a buffer that allows for uncertainty in estimating flood water heights, as well as the effects of wave action and unforeseen variation in local flood behaviour.

The Commission of Inquiry found that it was not mandatory for Councils to set a freeboard level, although most were typically in the range of 300 to 500mm. Higher freeboard was considered necessary where there was a higher level of uncertainty surrounding the estimate of flood level.

Freeboard is used in floodplain management worldwide. Within Australia, there are a number of national and state-based guidelines and manuals that provide direction regarding freeboard, although all mandatory provisions are generally specified at the local government level through planning schemes and similar instruments.

L.3 Current Freeboard Approaches by Councils in the Brisbane River SFMP Study Area

The current planning scheme (and relevant temporary local planning instruments) for each local government in the study area has been reviewed to identify current approaches to designating freeboard levels. The planning schemes reviewed include:

- Brisbane City Plan 2014;
- Ipswich Planning Scheme 2006;
- Somerset Region Planning Scheme 2016;
- Lockyer Valley Region:
  1) Gatton Shire Planning Scheme 2007;
  2) Laidley Shire Planning Scheme 2003; and
  3) Lockyer Valley Regional Council TLPI 01/2017 – Flood Regulation

A summary of these approaches is identified below.

L.3.1 Brisbane City Plan 2014

Freeboard is dealt with in the relevant flood overlay code[42] and supported by the flood planning scheme policy. Freeboard levels vary according to variables such as flooding source, habitable/non-habitable floor levels and type of land use (i.e. sensitive or less sensitive development). The information has been outlined, verbatim from the plan in Annex 1.

[42] Brisbane City Plan 2014 also includes freeboard provisions for coastal hazards being storm tide inundation. The use of freeboard provisions for coastal hazards have not been considered in this review.

The primary determinant of freeboard levels relies on the source of inundation (Brisbane River, Creek/waterway or overland flow flooding) and category of development. Higher freeboard levels are applied to sensitive uses (i.e. dwellings and community/essential infrastructure) and where the floor level is habitable (generally requiring 500mm freeboard). Non-habitable floor space requires a lesser freeboard level of generally 300mm. Freeboard level is also tied to the flood immunity level (AEP).

For ease of reference, key definitions of DFE, DFL and RFL from the relevant City Plan table excerpt are provided below:

Term	Definition
Defined flood event (DFE)	The flood event adopted by Brisbane City Council for the management of development in a particular locality. The DFE varies for different classes of development and flood source. *Note—Most commonly, the Defined flood event is the 1% Annual Exceedance Probability (AEP) flood for creek/waterway, 2% AEP for overland flow flooding sources, or the Residential Flood Level (RFL) for Brisbane River flooding. The DFE for a particular locality is determined in accordance with the Flood overlay code.*
Defined flood level (DFL)	The DFL for Brisbane River flooding is a level of 3.7m AHD at the Brisbane City Gauge based on a flow of 6,800 m^3/s.
Residential flood level (RFL)	Residential flood level (RFL) for Brisbane River flooding equates to the flood level applicable to the extent of January 2011 floods as depicted by mapping on the Queensland Reconstruction Authority website or the Council's defined flood level (DFL) for the Brisbane River, whichever is higher.

L.3.2 Ipswich Planning Scheme

The *Ipswich Planning Scheme 2006* embeds flood planning provisions in the Development constraints overlay code and applies these to development below and/or between the 1 in 20 AEP development line or the adopted flood regulation line. The majority of freeboard provisions are called up in Specific Outcomes (and not the Overall Outcomes) of the overlay code in the following sections (and presented in Annex 2): 1 (a) (ii), (c) (ii), (iv), e (ii), (iii) and 2 (b) (i).

Freeboard provisions are called up in ‘Specific Outcomes’ in the Development constraints overlay code and are provided in Annex 2.

Freeboard provisions are only assigned for residential development. Where freeboard is referred to, the Specific Outcomes require development to be 500mm ‘above’ the adopted flood regulation line or above the adopted flood level. Specific Outcomes also refer to a freeboard above the adopted flood regulation line where located either below or between the 1 in 20 AEP Development Line and the adopted flood regulation line. This same 500mm freeboard is applied to development in stormwater/urban catchment flow paths; however, is measured from the adopted flood level (and not the regulation line). Therefore, there appears to be a potential difference in applying flood levels and freeboards between the development line and in flow paths and which should be relied on during assessment.

While there are no specific freeboard provisions for non-residential, commercial and industrial uses, the code includes “Notes” that suggest the siting and location of more sensitive community uses (e.g.

cemeteries, crematoriums, funeral premises, veterinary clinics, self-storage units, warehousing) be "carefully considered".

L.3.3 Somerset Region Planning Scheme

Freeboard is dealt with in the flood hazard overlay code, as presented in Annex 3. The code specifically requires development within the different flood hazard areas to be elevated above the 'defined flood level and freeboard' and these terms are separately defined.

Key observations with the operation of the code and definitions include:

- freeboard and defined flood level (DFL) are used as independent terms and do not appear to be consistently applied in both the overall outcomes and assessment criteria;
- the overall outcomes appear to be potentially inconsistent with the acceptable outcomes as they ask for development to be above the DFL and provide freeboard. The acceptable outcomes only ask for development to be located above the DFL. In effect, it appears the overall outcomes are asking for development to be 800mm above AEP and are much more stringent than the acceptable outcomes. This can be clarified during discussions with Council officers as to the intent and implementation of these provisions in development assessment;
- the concept of freeboard, in its own right, is not provided in the acceptable outcomes and as such if freeboard is not provided but the development is located above the defined flood level (as defined above), compliance would be achieved;
- the definition of defined flood level (DFL) includes an allowance of 500mm above AEP events, however an additional freeboard allowance is also separately defined and is defined as 300mm above defined flood level. It may potentially be the case that the allowance of 500mm above AEP events as part of the definition for DFL, may not be freeboard as such, but be a specific allowance for uncertainty in modelling;
- the acceptable solutions, in some instances, provide an option to either be located above the DFL or where this cannot be achieved, simply be located above the 1% AEP level. This approach effectively allows a lower floor level to be provided where the development cannot be located above the DFL. This approach could potentially erode the intent of Council's policy by providing an 'easier way out'.

L.3.4 Lockyer Valley Regional Council

While the Temporary Local Planning Instrument (TLPI) – Flood Regulation overrides and varies the effect of the two planning schemes in the Lockyer Valley Regional Council area, the Gatton Planning Scheme and Laidley Planning Scheme, these two schemes have been reviewed in Sections D.4.4.1 and D.4.4.2 below for completeness. An assessment of the TLPI approach to freeboard is then provided in the subsequent section D.4.4.3.

L.3.4.1 Gatton Planning Scheme

Requirements for freeboard are identified in the land use and development codes of the planning scheme. In particular, the following codes identify probable solutions (or acceptable outcomes) for flood immunity:

- **Residential codes** including: Accommodation unit and dual occupancy code (A3.1-3.3), Annexed unit code(A1.1-1.6), Caretaker's residence code (A2.1-2.6), Dwelling house code (A2.1-2.6), Motel code (A2.1-2.6) and Small lot house code(A1.1-1.6);
- **Commercial codes** including: Commercial premises and shops code (A2.1-2.6) and Service station and car wash code (A2.1-2.6);
- **Industrial codes** including: Industrial development code (A2.1-2.6); and
- **Reconfiguring a lot code** (A1.1-1.6, P37).
- **Infrastructure code** (A2.2(iii)).

The probable solution in each use code and the reconfiguring a lot code requires development to be located above a prescribed DFL (identified as an AHD level) specific to a locality 'plus 300mm'. In some instances, specific DFL's are also provided for individual lots.

The infrastructure code also identifies that any on-site sewerage system is situated above the Q10 level and is above 5m AHD.

The reconfiguring a lot code also identifies the following in respect of stormwater flows *"habitable rooms have floor levels 250mm above the estimated flood level resultant for a 1 in 100 year flood are protected".*

Item 2.5 of PSP No. 9 – Flooding and Stormwater flow paths also requires that '*the location and height of buildings, particularly habitable floor areas*' is to be provided in a flooding analysis that accompanies development affected by flood extents.

L.3.4.2 Laidley Planning Scheme

Provisions relevant to freeboard levels are provided in the scheme's *Areas of natural and environmental significance overlay code*. A single provision requires:

Column 1 Specific Outcomes	Column 2 Acceptable Solutions
9. People, property and the environment are not subjected to unacceptable risks to health or safety.	**9.1** All dwellings and other habitable buildings shall be constructed with a building platform level at least 300mm above the Q100 floodline.

The Residential uses code also requires:

4. Habitable rooms have acceptable levels of flood immunity; and	**4.1** Where a lot is on floodable land, the minimum flood level for habitable rooms is 300mm above the Q100 flood line on the allotment; and

The two requirements differ slightly as the overlay requires a building platform level at least 300mm above the Q100 floodline, whereas the use code requires habitable rooms to be 300mm above the Q100 floodline. In effect, this means that the overlay requirements are more stringent as all floor levels, regardless of whether habitable or not, need to be elevated. These provisions create potential inconsistencies in delivery of scheme outcomes and confusion in interpreting policy.

L.3.4.3 Lockyer Valley Regional Council TLPI 01/2017 – Flood Regulation

Lockyer Valley Regional Council's Temporary Local Planning Instrument (TLPI) for flood regulation has been in place since January 2013, with the most recent TLPI introduced on 2 January 2017 and provides 'improved flood regulation based on the identification of flood inundation areas' in both the Gatton and Laidley planning scheme areas. The TLPI introduces a number of changes to each planning scheme, including a flood overlay map (with investigation areas, overland flow areas and high, medium and low hazard flood areas) and overlay code.

The TLPI has effect for a period of 1 year (i.e. to 2 January 2018), and focusses on residential uses but does not apply to the Commercial and Industrial zones for non-vulnerable development or for certain building work aspects of development (alterations to an existing building, raising or repairing an existing building, adding an extra storey above or some class 10a and 10b buildings).

Freeboard provisions that either vary existing requirements in the planning scheme or are new include:

L.3.4.4 Gatton Planning Scheme

- Services and infrastructure code and Reconfiguring a lot code requires "The finished surface level of any sewerage treatment system or openings into the sanitary drainage system shall be a minimum of 150mm above the Defined Flood Level". Note that this requirement refers to on-site effluent systems.
- Services and infrastructure code and Reconfiguring a lot code requires "All electrical equipment of any sewerage treatment system that may be subject to water damage shall be a minimum of 150mm above the Defined Flood Level". Note that this requirement refers to on-site effluent systems.
- Use codes have been amended to require a "habitable floor level a minimum of 300mm above the Defined Flood Level". This includes new builds and extensions to existing buildings. In some instances, depending on the type and location of development, provisions can require development to be "located on land that is a minimum of 300mm above the defined flood level" or be "above the Defined Flood Level".
- The reconfiguring a lot code amends the 250mm freeboard requirement for stormwater inundation, identifying that "habitable rooms have floor levels 300 mm above the Defined Flood Level flood are protected".

L.3.4.5 Laidley Planning Scheme

- No specific changes to freeboard requirements.

A new Flood hazard overlay code and mapping has been prepared for both planning schemes. The content of the overlay code appears to be the same for each planning scheme in terms of freeboard requirements which provides consistency in approach.

AO2.1 of the code specifically requires that *"The floor levels of any habitable room of a proposed building or extension to an existing building are a minimum of 300mm above the Defined flood level"*.

AO2.5 of the same code further identifies that *"The finished surface level of any sewerage treatment system or openings into the sanitary drainage system is a minimum of 150mm above the Defined flood level"*.

These outcomes are consistent with other amendments made to each original planning scheme.

Both schemes also have an updated definition of "Defined Flood Level", which now states "*means the flood level which Council may from time to time determine".*

The overlay provisions also vary assessment levels.

In general, the amendments through the TLPI appear to be relatively consistent with the existing requirements, but more responsive to categories of risk. The freeboard level provides a consistent approach and by identifying a minimum level expectation, provides opportunities for, and actively encourages, development to exceed 300mm above the DFL. The change in definition for Defined Flood Level is, however, less certain and would appear to rely upon either the applicant requesting this information from Council or a site-based flood assessment.

L.4 Freeboard Approaches by SEQ Local Governments Outside the Brisbane River SFMP Study Area

A review of three other SEQ planning schemes outside the study area were also undertaken, to understand approaches to freeboard used elsewhere in Queensland. The planning schemes reviewed included Sunshine Coast, Gold Coast and Logan planning schemes.

L.4.1 Sunshine Coast Planning Scheme

Freeboard considerations in the Sunshine Coast Planning Scheme are as follows:

Flood Hazard Overlay Code
Table 8.2.7.3.1 – Dual occupancy & Dwelling house AO1 *The finished floor level of all habitable rooms is at least 500mm above the DFE and DSTE*
OR

Where the DFE and DSTE has not been modelled for the area, the finished floor level of all habitable rooms is at least 600mm above the highest recorded flood or storm tide inundation level

Table 8.2.7.3.2 – All other development AO3.1 *Finished surface and floor levels of urban lots, and buildings and infrastructure comply with the flood immunity requirements specified in Table 8.2.7.3.3 (Flood levels and flood immunity requirements for development and infrastructure)*[43]*.*

L.4.2 Logan Planning Scheme

Freeboard considerations in the Logan Planning Scheme are limited to habitable (i.e. residential) floor levels only, being 500mm above the DFE, as presented in Annex 4.

[43] Table 8.2.7.3.3 provides minimum design levels for lot surface and building floors for all land use types. The DFE and DSTE are the respective 1% AEP at the year 2100. Generally, the freeboard allowance for floor levels of buildings of most development types is 0.5m, or 0.6m where there is no DFE/DSTE available (i.e. where a historical level is utilised). 1m freeboard is required for community infrastructure, utilities and hazardous and other materials in areas with only historical levels.

L.4.3 City of Gold Coast Planning Scheme

For the Gold Coast City Plan 2016, a declaration was made under section 13 of the *Building Regulations 2006,* to allow freeboard above 300mm. If unspecified by the planning scheme, the freeboard used in the Regulation (i.e. 300mm) will apply.

The Gold Coast City Plan also includes a separate definition of freeboard and embeds references to freeboard within the definition of 'design floor level'.

Relevant code provisions are presented in Annex 5.

L.5 Relevant Legislation and Regulations

L.5.1 State Planning Policy

The State interest policy for natural hazards, risk and resilience in Part E of the SPP, requires risks associated with natural hazards, including projected impacts of climate change, are avoided or mitigated to achieve an acceptable or tolerable level of risk for personal safety and property.

While the draft State Planning Policy (SPP, November 2016) does not prescribe specific freeboard requirements, the supporting State interest guideline for natural hazards, risk and resilience notes the state interest can be met where development does not involve land uses that create an intolerable risk to people and property.

The SPP mandates that planning schemes are informed by a fit for purpose risk assessment and the SPP Guidelines identify that the risk assessment should be consistent with the principles and framework of AS/NZSISO 31000:2009. The SPP Natural Hazards, Risk and Resilience Technical Manual suggests a 'fit for purpose' flood risk assessment using one of two approaches. The comprehensive, more localised flood hazard investigation approach is encouraged by the Manual as a way of informing freeboards through sensitivity analysis. This type of analysis can better account for uncertainty in mapping hydraulic/hydrologic risk, while also reducing design, depth and velocity error by changing certain. input variables.

In addition, the State interest guideline for natural hazards, risk and resilience identifies that each local government's flood hazard area, determined to be the 'Natural Hazard Management Area' under the SPP, is subject to the building assessment provisions in Section 13 of the *Building Regulation 2006*. Section 13(1) (b) enables the local government to make certain declarations around both freeboard (i.e. >300mm) and the minimum finished floor levels for Class 1 (residential) buildings. This is demonstrated in the model Flood hazard overlay code provision AO2.1 where making a material change of use: *"the development incorporates an area on-site that is at least 300mm above the highest known flood level with sufficient space to accommodate the likely population of the development in safety for a relatively short time until flash flooding subsides or people can be evacuated."*

Similar model provisions are suggested when designing and locating hazardous materials and structures, as well as essential infrastructure components; these should be located above the defined flood event level or highest known flood level on-site (AO5.1 and AO7.2) and resist flood inundation and the force of water. Such provisions are, however, provided as a guide, and local governments are not bounded by these model codes. They are an example of how the State Government sees and encourages freeboard provisions in planning scheme drafting.

L.5.2 Sustainable Planning Act 2009 and Regulation

The *Sustainable Planning Act 2009* establishes a framework for development assessment but does not set standards against which applications should be assessed. There are also no specific requirements for freeboard provided under the State Development Assessment Provisions (SDAP).

The *Sustainable Planning Regulation 2009* provides referral jurisdiction to local governments for buildings proposed in flood hazard areas where the application states the flood level is below the defined flood level declared by the local government under the *Building Regulation 2006*. This jurisdiction involves assessment as to the appropriateness of the proposed flood level by reference to flood modelling, recorded flood levels in the area, and any other matter the local government considers relevant.

L.5.3 Planning Act 2016 and Draft Regulation

The *Planning Act 2016* will replace the *Sustainable Planning Act 2009* on 3 July 2017 as the pre-eminent planning legislation for Queensland. While the new act identifies a process for development assessment, specific details have been delegated to the DA Rules document. As with the current *Sustainable Planning Act 2009*, this document does not identify standards against which development applications should be assessed and as such does not include any relevant provisions for freeboard.

The draft *Planning Regulation 2017* appears to carry across the referral jurisdiction to local governments for buildings proposed in flood hazard areas. The two triggers are identified below.

Table 15—Flood hazard area

Column 1	Column 2
1 Development application requiring referral	Development application for building work that is assessable development under section 1, if all or part of the premises are in a flood hazard area and 1 or both of the following apply— (a) the application states a defined flood level that is lower than a defined flood level declared by the local government under the Building Regulation, section 13 for the part of the flood hazard area where the premises are;
	(b) the application states a maximum flow velocity of water that is lower than a maximum flow velocity of water declared by the local government under the Building Regulation, section 13 for the part of the flood hazard area where the premises are

There have also been no amendments to the State Development Assessment Provisions that specify requirements for freeboard.

L.5.4 Queensland Building Regulations

In response to the 2011 Queensland floods, and as highlighted through the subsequent Commission of Inquiry, the Queensland Government introduced new mandatory requirements for freeboard through the Queensland Development Code (QDC) Mandatory Part 3.5 - Construction of buildings in flood hazard areas, which commenced on 26 October 2012. Changes were also made to the *Building Regulation 2006* under the *Building Act 1975* on 20 December 2013. The *Building Regulation 2006* now sets a minimum freeboard of 300mm.

L.5.5 Building Code of Australia 2013

The Standard for the "Construction of Buildings in Flood Hazard Areas (Version 2012.2)" has been adopted to achieve the objectives of the Building Code of Australia and provides acceptable provisions around designing buildings to minimise risk to life and property up to and including the defined flood event (DFE). The following design parameters are applied to minimum floor heights, as determined using the Flood Hazard Level (FHL) (this includes the DFL, plus freeboard):

"Unless otherwise specified by the appropriate authority–

a) the finished floor level of habitable rooms must be above the FHL; and
b) the finished floor level of enclosed non-habitable rooms must be no more than 1.0m below the DFL.

Note: The structural provisions of this Standard are based on the DFL being a maximum of 1.0m above the finished floor level of enclosed rooms. Therefore, if the appropriate authority permits more than 1.0m, additional structural analysis should be undertaken."

Consistent with the Building Regulation, the Standard also requires habitable floor levels to be above the FHL. This provision also applies to the siting and design of electrical systems, mechanical and HVAC systems and utilities. Furthermore, non-habitable floor levels should not be more than 1m below the DFL. It is important to note, however, that the appropriate authority is given discretion in (a) determining the DFL, subject to performing a structural assessment, and therefore, (b) the height at which the FHL (including freeboard) is set.

Further to the Standard is a non-mandatory Handbook (of the same title). This is drafted to provide guidance and advice in applying and interpreting the Standard and identifies different flood requirements in each State and Territory. In the Queensland context, the Handbook defers to the SPP, as well as the options available to local governments under Section 13 of the Regulation to designate their natural hazard area and minimum habitable floor levels.

L.6 Current National Best Practice

L.6.1 NSW Floodplain Development Manual (NSW Government, 2005)

In accordance with the NSW Flood Prone Land Policy, Councils have a statutory responsibility for managing floodplains. The NSW Government has prepared and gazetted the Floodplain

Development Manual (FDM) (2005) to assist Councils in this regard. The FDM is amended by a further Direction issued in January 2007. Importantly, under the provisions of s733 of the NSW *Local Government Act 1993*, Councils have been considered to have acted in 'good faith' and are indemnified from liability with respect to matters involving flooding if they have acted substantially in accordance with the principles in the Manual.

The FDM (Appendix K) states that the purpose of freeboard is to provide reasonable certainty that the reduced risk exposure provided by selection of a particular flood as the basis of a flood planning level (FPL) is actually provided, given uncertainties relating to a number of factors. These factors include the following:

- uncertainties in the estimates of flood levels;
- 'local factors' influencing water surfaces;
- wave action, from wind as well as from boats and vehicles moving through flooded areas;
- changes in rainfall patterns and ocean water levels as a result of climate change; and
- cumulative effect of future infill development (especially on existing zoned land).

Whilst not a mandatory requirement, the FDM (as amended) requires the adoption of an FPL of 1% AEP plus a freeboard (typically 500mm) for standard residential development (i.e. excluding residential uses such as seniors living housing).

The 1% AEP for residential development cannot be varied without Ministerial approval and only in exceptional circumstances; however, the 500mm freeboard can be varied but typically is not. The FDM acknowledges that freeboard provisions may differ based on the following:

- land use type;
- location within the floodplain; and
- presence of mitigation works (may need additional freeboard to accommodate future changes, such as post-construction settlement of a levee).

Typically in NSW, a freeboard of 500mm has been traditionally accepted when defining a FPL for riverine flooding. As NSW councils progress the preparation of flood studies for overland flow flooding, it is understood that the prevailing approach is to adopt a lower freeboard of 300mm in this situation where the flood depth range is not significant.

L.6.2 Guidelines for Development in Flood-prone Areas (Melbourne Water, 2007)

Under the *Victorian Building Regulations 2005*, floor level heights for buildings should be set a minimum 300mm above the applicable flood level, or as otherwise determined by the relevant floodplain management authority.

Melbourne Water, as the lead floodplain management authority within the Greater Melbourne area distinguishes between flooding from riverine/creek system and flooding from overland flowpaths. For riverine floodplains, Melbourne Water specifies that building floor levels should be at least 600mm above the 1% AEP flood level, while associated outbuildings are to be 300mm above the 1% AEP. These freeboard requirements are defended on the following basis:

- flood levels can surge or fluctuate due to wave action or other wind effects or tidal influences; or
- floods bigger than the 1% AEP flood would cause significant increases in flood level; or
- the estimated 1% AEP flood level is based on approximations or interpolations that reduce confidence in the absolute accuracy; or
- essential services or other particularly sensitive activities or assets are to be incorporated on a site.

By way of comparison, freeboard provisions specified by Melbourne Water for overland flows are 300mm for buildings and 150mm for outbuildings, above the 1% AEP flood level.

L.6.3 Managing the Floodplain: a Guide to Best Practice in Flood Risk Management in Australia Handbook 7 (AIDR, 2013)

The Australian Emergency Handbook 7 (Handbook) acknowledges the purpose of freeboard is to provide certainty of achieving a desired level of service for a designated flood standard (i.e. DFE). The freeboard is to account for potential increases in flood level during the designated event as a result of various factors including uncertainties in the estimates of flood levels, local differences in water level, wave action, future development and future climate change. Importantly, the Handbook states that freeboard should not be considered to provide additional protection beyond the DFE.

The Handbook indicates that there are many circumstances where a freeboard of 300mm to 600mm may be considered acceptable. Lower freeboards would generally be acceptable for shallow water conditions, where the potential for higher levels would be limited. Higher freeboards would be more applicable for deeper flooding and where estimated design flood levels are less certain, or are particularly sensitive to modelling assumptions.

To assist in selecting appropriate freeboard, the Handbook recognises the need for computational flood studies to identify numerical uncertainties and to quantify the implications of these uncertainties through sensitivity analyses.

L.6.4 Managing Flood Risk through Planning Opportunities: Guidance on Land use planning in flood prone areas (HNFMSC, 2006)

Within the series of documents prepared by the Hawkesbury-Nepean Floodplain Management Steering Committee (HNFMSC, 2006), freeboard is recognised as an important floodplain management tool that compensates for uncertainties associated with flood model estimation/confidence, including wave action, afflux and climate change.

This is required because of the impossibility of quantifying either the increase in flood levels associated with these factors, or the likely consequence of two or more factors occurring simultaneously. Provision of a freeboard therefore negates the need to undertake rigorous review of these factors.

While most freeboard provisions across NSW are defined as 500mm, the guidelines state that freeboard higher than 500mm can be justified through a cost-benefit analysis, which would be carried out as part of a floodplain risk management study.

Given that flood planning levels (or DFEs) rely on the application of computational flood models, which are based on limited data (in terms of catchment flows, floodplain topography, flood frequency analysis, historical flood event information, etc), it becomes necessary to understand the broader uncertainties of the model results, as well as more site-specific uncertainties across the floodplain.

L.6.5 Queensland Urban Drainage Manual (DEWS, 2013)

The Queensland Urban Drainage Manual (QUDM) notes that water surfaces during flood events and overland flows are rarely smooth and level. Therefore, the primary purpose of freeboard is to provide protection of buildings from flood inundation resulting from a DFE above the 'theoretical' flood level. Factors potentially influencing water levels that may be higher than the theoretical flood level include uncertainties in flood level prediction, variations in structure blockage, variations in water level across the floodplain (e.g. superelevation), conversion of water's kinetic energy (velocity head) into potential energy (i.e. afflux), the effects of wave action, and the risk of future building works within the floodplain.

In coastal regions, QUDM notes that higher freeboards are often recommended. Also, local governments may choose a major design storm standard less than the 1% AEP but may combine this with higher freeboard requirements.

QUDM recommends a minimum of 300m for freeboard to account for variables that potentially influence the DFE.

L.7 Emerging Directions from Brisbane River Catchment Flood Study

The Brisbane River Catchment Flood Study (BMT WBM, 2017) is the most comprehensive flood study ever carried out for a large riverine system in Australia. The study uses a 'Monte Carlo' analysis to consider the probability of occurrence of coincidence of multiple factors affecting flooding, such as variable rainfall across sub-catchments, dam water levels, initial soil saturation conditions, and water levels in Moreton Bay.

To some degree the direct consideration of these factors takes account for some of the variables that may influence freeboard. Analysis during the flood study showed that there is indeed a high degree of variability in conditions that produce AEP events. For example, a 1 in 20 AEP rainfall across the catchment may actually produce a 1 in 100 AEP flood if the catchment conditions are suitable (e.g. saturated soils, minimal detention available within dams etc).

Further, sensitivity tests have been carried out on the modelling that provide an indication of the potential response of the river to variability in some key parameters. The results indicate that a large part of the river system is very sensitive to changes in catchment inflow and also sensitive to removal of floodplain storage in some locations.

The hydraulic behaviour of flooding in the Brisbane River can also be considered when determining appropriate freeboard provisions. In the Lockyer Creek floodplain, floodwaters are able to spread out over a large area. Changes to flow therefore do not result in marked changes in flood level. This contrasts with the lower Brisbane River reaches, from Lowood to Brisbane CBD, which are relatively narrow and confined, with little adjacent floodplain areas. For these lower reaches of the river, an increase in flood flow results in relatively responsive increases in flood level (as the floodwaters cannot inundate more floodplain, the additional flow is accommodated through deeper waters in the channel). This is also reflected in large changes in water level between similar AEPs (e.g. large difference between 1 in 50 AEP and 1 in 100 AEP levels).

From a freeboard perspective, uncertainty in the modelling (and the specific factors that create the flood event) would potentially lead to a greater variability in flood levels in the more incised reaches of the river, downstream of Lowood. Thus, generous provisions for freeboard should be considered in these areas. In comparison, uncertainty in the modelling would result in much less variability in flood levels across the Lockyer Creek floodplain, between Morton Vale and the Brisbane River, and also in the area influenced primarily by storm-tide inundation. As such, lesser allowances for freeboard could be accommodated in these sections of the river system.

L.8 Key Considerations in Setting Freeboard Levels in the Brisbane River Catchment

There are a number of factors that are generally considered by authorities when calculating appropriate freeboard requirements.

L.8.1 Uncertainties in Modelling

Computational modelling is used to provide best-estimates of flood inundation and flood behaviour. The accuracy of the modelling relates to the accuracy of the data used to construct the model and the information used to calibrate and validate the results.

Parameters within the model are typically chosen on the basis of matching model results to actual observations for specific flood event (i.e. model calibration). However, if there are not many reliable observations, and if observed events do not cover a reasonable spectrum of events, then the suitability of parameters can be limited. Potential uncertainties arising from the computational predictions of flood levels can be established through sensitivity testing of the flood model, targeting variations in critical parameters such as discharge, floodplain roughness (vegetation), topography, grid size, boundary conditions, structure details and so on.

There are a number of modelling assumptions related to design flood event predictions, including temporal rainfall pattern, the spatial distribution of rainfall across catchment, antecedent conditions and initial levels of storages, rainwater tanks and detention basins.

The accuracy of the modelling also relates to the robustness of the methods undertaken. This is related to the financial investment made in development of the model, as well as the experience and expertise of the practitioners responsible for the build, and the type of model used. It is common practice in Australia and overseas to adopt a higher freeboard for circumstances where the reliability of flood model predictions is considered to be low.

For the Brisbane River Catchment Flood Study, the hydraulic model was successfully calibrated to thousands of flood marks and hundreds of gauged hydrographs from five historical floods. The targeted level of accuracy of calibration was highest in the lower reaches of the river, with ± 0.15 m downstream of Oxley Creek, ± 0.30 m between Goodna and Oxley Creek and in the Ipswich urban area, and ± 0.50 m upstream of Goodna and in tributaries, including Bremer River and Lockyer Creek.

L.8.2 Unpredictable Flood Behaviour

During floods, water levels are rarely smooth and even across a floodplain. Therefore, there is often a notable difference between the ‘theoretical’ flood level and the actual water surface during a flood event. Localised blockages can occur within flowpaths. This creates affluxes, where the water surface is increased locally on the upstream side of the blockage. Examples of blockage of a flowpath can include buildings, fences, dense vegetation, embankments, debris build-up and siltation. Areas of concentrated flow are particularly susceptible to blockage, such as culverts and bridge openings. Once blocked, alternative flowpaths are required, which may result in overtopping of road deck levels, engagement of secondary floodways etc.

For areas where floodwaters flow rapidly, large scale standing waves can be generated (as occurred through Toowoomba in January 2011). Flood levels around floodplain edges can also be ‘set-up’ due to wind effects, while wind waves may also create surface turbulence and affect localised flood levels. Given that rainfall is generated from an intense storm event, the occurrence of high winds would be highly likely.

Localised waves can also be generated by boats travelling on the floodwaters, as well as vehicles driving through floodwaters. Larger vehicles (such as 4WDs) travelling at moderate speed (~20km/hr) can generate reasonable size bow waves (in the order of 200mm or more).

Due to the size of the Brisbane River, the effects of local factors, such as blockage or debris build-up, would tend to be limited to the immediate area only. Broadscale blockage of the waterway would be unlikely except in smaller events.

The incised nature of the floodplain means that depths over the floodplain can be large – with access during events essentially restricted to boats. High velocities within the channel can cause elevated water levels around sharp bends.

L.8.3 Allowance for Future Conditions

Across the four local government areas, future conditions will involve more development within the study area. While the direction provided by the SFMP is intended to reduce the extent of flood impacts external to a development, the potential for development in existing zonings, including ‘emerging community or future urban/investigation’ zones in the study area, might have an impact. An increase in the amount of development within the floodplain, and more broadly across the catchment, can introduce the following:

- changes to catchment parameters associated with urbanisation;
- changes to roughness associated with vegetation change;
- infilling of floodplain storage due to development (linear infrastructure as well as land development especially within existing zonings); and
- future flood mitigation works (i.e. improvements in some areas, but possibly worsen in other areas, such as impacts of larger culverts or bridge openings).

The Brisbane River Catchment is sensitive to filling and changes in the floodplain.

As well as future development, the Brisbane River Catchment is very sensitive to increased catchment inflows (which are possible under future climate conditions) and increased water levels in Moreton Bay (due to projected sea level rise). While design conditions, such as the DFE, generally include a specific provision for future climate conditions, which has been quantified separately, freeboard can be used to accommodate some of the uncertainty around best estimates for future projections (including rainfall and sea level rise projections). The SFMP aims to address the impact of future development and the intensification of existing development within urban zones by ensuring that

L.8.4 Variable Freeboard

While there is some merit in maintaining a consistent freeboard for all future development within each of the respective local government areas, a risk-based management approach should be used to provide more customised solutions. The DFE and/or the freeboard requirements may differ across the Brisbane River catchment and for each local government planning area depending on the following:

- the proposed land use (e.g. residential, commercial, industrial, recreational);
- the location within the study area and the hydraulic behaviour of the river (e.g. broad floodplains versus incised river valley);
- the potential hydraulic risk (e.g. HR1, HR2, HR3, HR4 or HR5 and how these translate into flood risk areas;); and
- the specifics of the development (e.g. function, serviceability, life expectancy, future expansion).

In many locations, freeboard differs based on the land use or development type. This inherently relates to the level of risk considered acceptable for the particular use of the land. For example, it is common for non-habitable rooms to have a lower (or even nil) freeboard provisions compared to habitable rooms.

Similarly, some planning schemes allow different freeboard requirements for different land use, such as industrial and recreational lands (and sometimes also a different DFE compared to residential and commercial development). In addition to freeboard, other provisions may need to be applied though to help minimise flood-related damages, including the use of flood resistant materials.

L.9 Annex 1: Brisbane City Council Planning Scheme Details

Flood Overlay Code

Minimum flood planning levels for development are called up as acceptable outcomes in the flood overlay code and include the following:

Table 8.2.11.3.B – Flood planning levels for a dwelling house (BCA building classification 1a)

Flooding source	*Minimum habitable floor level*	*Minimum non-habitable floor level (ie: utility areas, garage, laundry, storage room and basement entries)*
Brisbane River	*Residential Flood Level (RFL) + 500mm*	*2% AEP flood level + 300mm*
Creek/waterway	*1% AEP flood level + 500mm*	*1% AEP flood level + 300mm*
Overland flow	*2% AEP flood level + 500mm*	*2% AEP flood level + 300mm*

	Note – where no detailed flood level information is available from Council such as an overland flow path, a RPEQ with expertise in flood studies is to derive the relevant flood level and certify that the development level for the dwelling house, including any secondary dwelling, meets the required immunity standards.

Table 8.2.6.3.D – Flood planning level categories for development types[44]

BCA Building Classification	*Development types and design levels, assigned design floor or pavement levels*	*Category refer to Table 8.2.6.3.C*
Class 1-4	*Habitable room*	*Category A*
	Non-habitable room including patio and courtyard	*Category B*
	Non-habitable part of a Class 2 or Class 3 building excluding the essential services control room	*Category B*
	Parking located in the building undercroft of a multiple dwelling	*Category C*
	Carport; unroofed car park; vehicular manoeuvring area	*Category D*
	Essential electrical services of a Class 2 or Class 3 building only	*Category A*
	Basement parking entry	*Category C + 300mm*
Class 5, Class 6, or Class 8	*Building floor level*	*Category C – Risk management approach to Brisbane River flooding is permitted (refer to Flood planning scheme policy)*
	Garage or car park located in the building undercroft	*Category C*
	Carport or unroofed car park	*Category D*
	Vehicular access and manoeuvring area	*Category D*
	Basement parking entry	*Category C*
	Essential electrical services	*Class 8 – Category C* *Class 5 and 6 – Category A*
Class 7a	*Refer to the relevant building class specified in this table*	
Class 7b	*Building floor level*	*Category C*
	Vehicular access and manoeuvring area	*Category D*
	Essential electrical services	*Category C*
Class 9	*Building floor level*	*Category C*
	Vehicular access and manoeuvring area	*Category D*
	Essential electrical services	*Category C*
	Building floor level	*Category C*
	Vehicular access and manoeuvring area	*Category D*

44 This table is a reproduction of that provided in the Brisbane City Plan. The original table includes a range of notations that for brevity have been removed from this reproduction. Please refer to the Brisbane City Plan 2104 for the original table.

BCA Building Classification	Development types and design levels, assigned design floor or pavement levels	Category refer to Table 8.2.6.3.C
	Essential electrical services	*Category C*
Class 10a	*Car parking facility*	*Refer to the relevant building class specified in this table*
	Shed or the like	*Category D*
Class 10b	*Swimming pool*	*Category E*
	Associated mechanical and electrical pool equipment	*Category C*
	Other structures	*Flood planning levels do not apply*

Table 8.2.11.3.L – Categories of flood planning levels (for vulnerable or difficult to evacuate uses)

Flooding source	*Minimum design floor or pavement levels (mAHD) (refer to Table 8.2.11.3.D for assignment of these categories)*				
	Category A	***Category B***	***Category C***	***Category D***	***Category E***
Brisbane River	*RFL + 500mm*	*RFL + 300mm*	*DFL*	*5% AEP flood level*	*5% AEP flood level*
Creek/waterway	*1% AEP flood level + 500mm*	*1% AEP flood level + 300mm*	*1% AEP flood level*	*1% AEP flood level*	*5% AEP flood level*
Overland flow	*2% AEP flood level + 500mm*	*2% AEP flood level + 300mm*	*2% AEP flood level*	*2% AEP flood level*	*5% AEP flood level*

L.10 Annex 2: Ipswich City Council Planning Scheme Details

Section (1)

(a) Land Situated Below the 1 in 20 Development Line – Residential Uses

(ii) Unless otherwise determined by Council, the floor levels of any habitable rooms of a proposed building are a minimum of 500mm above the adopted flood regulation line, whilst having regard to the visual amenity and streetscape impacts on nearby dwellings, associated with the raising of floor levels and the resulting height of buildings.

(b) Land Situated Between the 1 in 20 Development Line and the Adopted Flood Regulation Line – Residential Uses

(i) Engineering solutions that provide flood immunity to a minimum of 500mm above the adopted flood regulation line for habitable rooms and do not negatively impact on the overall hydrology, hydraulics and flood capacity of the waterway may be considered to facilitate residential intensification where the land –

(A) is contained within areas zoned for medium and high density housing or for mixed use/centre development where involving residential uses, including Character Housing Mixed Density, Residential Medium Density, Residential High Density, Ipswich City Centre and Major Centre Zones; and

(B) is located near the edge of the adopted flood regulation line; and

(C) has a flood depth of generally no more than 800mm over the site based on the adopted flood regulation line level; and

(iv) Unless otherwise determined by Council, the floor levels of any habitable rooms of a proposed building area a minimum of 500mm above the adopted flood regulation line, whilst having regard to the visual amenity and streetscape impacts on nearby dwellings, associated with the raising of floor levels and the resulting height of buildings.

(e) Land Situated Within Urban Catchment Flow Paths – Residential Uses

(ii) Engineering solutions that provide flood immunity to a minimum of 500mm above the adopted flood level for habitable rooms and do not negatively impact on the overall hydrology, hydraulics and flood capacity of the waterway may be considered to facilitate residential intensification where the land–

(A) is contained within areas zoned from medium and high density housing or for mixed use/centre development where involving residential uses, including the Character Housing Mixed Density, Residential Medium Density, Residential High Density, Ipswich City Centre and Major Centre Zones; and

(B) is located near the edge of the adopted flood level; and

(C) has a flood depth of generally no more than 800mm over the site based on the adopted flood level; and

(D) has direct vehicular access to a flood free evacuation route.

(iii) Unless otherwise determined by Council, the floor levels of any habitable rooms of a proposed building are a minimum of 500mm above the adopted flood level, whilst having regard to the visual amenity and streetscape impacts on nearby dwellings, associated with the raising of floor levels and the resulting height of buildings.

Section (2)

(b) Evacuation Routes

(i) At least one road access will remain passable for the performance of emergency evacuations at a level of no more than 300mm below the adopted flood level.

The Division 2 – Administrative Terms – defines the adopted flood level and adopted flood regulation line as follows:

"Adopted Flood Level" means the flood level which has been selected as the basis for planning purposes within the City, which unless otherwise specifically stated is based on the flood event depicted by the Adopted Flood Regulation Line and the flood level depicted by an Urban Catchment Flow Path.

"Adopted Flood Regulation Line" means the flood line as depicted on the Flood and Urban Catchment Flow Paths Overlay Map (OV5).

L.11 Annex 3: Somerset Regional Council Planning Scheme Details

(2)(a) Development in the ***Extreme flood hazard area****:*

(iii) is limited to:

E. replacement of existing lawful development, including accommodation activities where habitable rooms are elevated above the defined flood level and freeboard;

(b) Development in the ***High flood hazard area****:*

(iii) is limited to:

E. industrial activities and business activities where it is accepted that flood damage is incurred as an operational cost and where flood sensitive elements of the development or use are elevated above the defined flood level and freeboard;

(v) elevates habitable rooms for all accommodation activities (including where for minor building work) above the defined flood level and freeboard.

(c) Development in the ***Significant flood hazard area****:*

(iii) is limited to:

B. industrial activities and business activities where it is accepted that flood damage is incurred as an operational cost and where flood sensitive elements of the development or use are elevated above the defined flood level and freeboard;

(iv) locates habitable rooms for all accommodation activities above the defined flood level and freeboard; and

(v) locates the minimum floor level for all buildings other than accommodation activities, industrial activities and business activities above the defined flood level.

(d) Development in the ***Low flood hazard area****:*

(ii) locates habitable rooms for all accommodation activities above the defined flood level and freeboard; and

(iii) locates the minimum floor level for all buildings other than accommodation activities above the defined flood level and freeboard.

(e) Development in the ***Potential flood hazard area****:*

(iii) locates habitable rooms for all accommodation activities above the defined flood level and freeboard; and

(iv) locates the minimum floor level for all building work other than accommodation activities above the defined flood level and freeboard.

[Emphasis added]

Table 8.2.7.3.A of the flood hazard overlay code identifies, in AO1(b), AO2.1, AO4.1(b), AO4.4(a), AO8.1(b), AO8.2, AO8.9(a), AO13.1 and AO13.2, that development must be either '*located'* or '*elevated' 'above the defined flood level'*.

Where development cannot be located above this level, the assessment provisions identify that development is either to avoid the area or be located above the 1% AEP level.

The definition for 'defined flood level' (DFL) includes an allowance of 500mm above the defined flood event:

Defined flood level (DFL)	Means: (a) Where for habitable rooms of buildings: (i) level of the 1% AEP flood event plus 500mm where a 1% AEP flood event inundation line has been approved; or (ii) the highest recorded flood level where no 1% AEP flood event inundation line has been approved. (b) Where for essential services, nursing homes and the like: (i) level of the 0.2% AEP flood event plus 500mm (c) Where for non-habitable buildings (except for buildings classified under the Building Code of Australia as Class 7a and Class 10): (i) level of the 1% AEP flood event where a 1% AEP flood event inundation line has been approved; or (ii) the highest recorded flood level where no 1% AEP flood event inundation line has been approved.

SC1.2 – Administrative Definitions of the planning scheme also provides a definition of freeboard:

Freeboard	300mm above the *defined flood level*, which accounts for matters such as wave action and localised hydraulic behaviour which may cause a flood level to rise above the *defined flood level*.

L.12 Annex 4: Logan City Council Planning Scheme Details

Flood Hazard Overlay Code

Table 8.2.5.3.1 – Risk to people and premises PO1
A building floor level of a habitable room has adequate allowance for the hydraulic gradient above the main floodway.

AO1 A building has a finished habitable floor level a minimum of 500mm above the defined flood event.

Table 8.2.5.3.1 – Risk to people and premises PO3
Development provides a development envelope area that is above the flood level during the defined flood event.

AO3 Development provides a development envelope area above the flood level during the defined flood event with a minimum size and dimension specified in Table 8.2.5.3.2–Development envelope area.

Table 8.2.5.3.1 – Risk to people and premises PO4
Public safety and the environment are not adversely affected by floodwater by:

(a) locating a Medium impact industry or High impact industry to be able to function safely during and immediately after flood events;
(b) safely storing hazardous materials.

AO4 Development:

(a) for a Medium impact industry or High impact industry is above the flood level specified in column 2 of Table 8.2.5.3.3—Minimum flood levels;
(b) involving the storage, sale or use of hazardous materials is located above the flood level during the defined flood event.

Table 8.2.5.3.1 – Risk to people and premises PO6
Development for any of the uses identified in column 1 of Table 8.2.5.3.3—Minimum flood levels, are able to function effectively during and immediately after flood events.

AO6 Development for any of the uses identified in column 1 of Table 8.2.5.3.3—Minimum flood levels is located above the flood level specified in column 2 of Table 8.2.5.3.3—Minimum flood levels.

Table 8.2.5.3.2–Development envelope area

Zone or precinct	Development envelope area specification	
	Minimum area	Minimum dimension
Rural zone	4000m^2	50m
Rural residential zone	4000m^2	50m
Environmental management and conservation zone—Environmental management precinct	2000m^2	30m
Environmental management and conservation zone—Rural environmental management precinct	4000m^2	50m
All other zones	The entire lot	–

Table 8.2.5.3.3—Minimum flood levels

Column 1 Development for a material change of use	Column 2 Land is to be above the following minimum flood level
Emergency services not specified elsewhere in this table	The 0.2% AEP flood level
Hospital	The 0.2% AEP flood level
Major electricity infrastructure	The 0.2% AEP flood level
Detention facility	The 0.2% AEP flood level
Utility installation, being a power station	The 0.2% AEP flood level
Residential care facility or Retirement facility	The 0. 2% AEP flood level
Emergency services, being police facilities and emergency shelters	The 0.5% AEP flood level
Substation	The 0.5% AEP flood level
Utility installation, being a sewage treatment plant or water treatment plant	The 0.5% AEP flood level
Stores of valuable records or items of historic or cultural significance (eg galleries and libraries)	The 0.5% AEP flood level
An industry activity, involving the manufacture or storage of noxious or hazardous materials (e.g. a regional fuel storage facility)	The 0.5% AEP flood level
Warehouse, being a food storage warehouse	The 0.5% AEP flood level
Development involving the use of Class 5, 6, 7(b), 8 or 9(b) buildings other than specified above	The 1% AEP flood level

Schedule 1 Definitions, section SC1.2 – Administrative Definitions also provides definitions for the following relevant terms:

Term	Definition
Defined flood event	The one percent annual exceedance probability (AEP) flood event.
Annual exceedance probability (AEP)	The likelihood of occurrence of a flood of a given size or larger in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 cubic metres per second has an AEP of five percent, it means that there is a five percent risk that is the probability of 0.05 or a likelihood of one in twenty, of a peak flood discharge of 500 cubic metres /second or larger occurring in any one year.

Term	Definition
	The AEP of a flood event gives no indication of when a flood of that size will occur next. Note—definition from the State Planning Policy.
Flood level	The maximum level of the water surface during a flood event. Note—Flood events can be caused by heavy rainfall in the catchment, dam releases, storm surge or a combination of these.

L.13 Annex 5: Gold Coast City Planning Scheme Details

Flood Overlay Code

Freeboard levels for self-assessable and assessable development are to be provided in accordance with the AO2.1 designated flood level table.

Table 8.2.8-6 – Building Floor Levels
This flood table is to be read in conjunction with AO2.1 to determine the minimum habitable floor level, which is taken to mean the combined designated flood level and freeboard. The designated flood level is identified on a use-by-use basis, and freeboard provisions generally vary between 400mm and 500mm.

SO2 Building floor levels of habitable rooms must be at or above the height of the combined designated flood level and minimum freeboard derived from **Table 8.2.8-6 – table to acceptable outcome AO2.1.**

SO5 Driveway crest to underground car parking must be 50mm above the designated flood level or where not possible, flood gates must be installed.

Associated PO2 is drafted to encompass aspects of the freeboard definition and provides relevant policy direction:

PO2 Development that is located on flood prone land shall not be inundated by floodwaters during a designated flood and allowance must be made for elements that could result in an elevated flood, including:

(a) the hydraulic gradient above the main floodway
(b) the impact of events such as wind and wave action on the flood surface; and
(c) uncertainty associated with the designated flood level.

AO2.1 Building floor levels of habitable rooms must be at or above the height of the combined designated flood level and minimum freeboard derived from **Table 8.2.8-6 – table to acceptable outcome AO2.1.**

AO2.2 Where a proposed land use does not reasonably apply to any land use listed in the **Table 8.2.8-6: Table to acceptable outcome AO2.1**, the applicant is to submit:

(a) the proposed minimum flood AEP for building floor levels;
(b) the proposed design freeboard above the specified flood level; and
(c) a flood hazard and flood risk assessment for the proposed development, assessing the effects on costs, safety, access and potential losses.

Table 8.2.8-6: Table to acceptable outcome AO2.1

Land use	Designated flood level[1] plus minimum freeboard
Disaster management facilities	0.2% AEP + 500mm freeboard
Hospitals	0.2% AEP + 500mm freeboard
Major electrical switchyards, Power stations, Water treatment plants[2]	0.2% AEP + 500mm freeboard
Fire and Police stations[3]	0.5% AEP + 400mm freeboard
Places of refuge	0.5% AEP + 400mm freeboard
Electricity Substations[2]	0.5% AEP + 400mm freeboard
Sewage Treatment Plants4	0.5% AEP + 400mm freeboard
Homes for the aged, Hospices5	0.5% AEP + 400mm freeboard
Regional fuel storage	0.5% AEP + 400mm freeboard
Food storage warehouses	0.5% AEP + 400mm freeboard
Hotel residential	1.0% AEP + freeboard[8]
Educational facilities6	1.0% AEP + freeboard[8]
Residential buildings	1.0% AEP + freeboard[8]
Camping grounds, Caravan parks and Relocatable homes reclamation levels	1.0% AEP + freeboard[8]
Commercial7	1.0% AEP
Light industrial/ Warehousing7	1.0% AEP
Theme parks	Not specified, but ancillary structures are subject to medium hazard considerations at the designated flood.
Clubs/ Non-habitable buildings associated with enjoyment of public open space	Not specified, but ancillary structures are subject to medium hazard considerations at the designated flood.
Car parking below buildings/at basement or detached	Not specified, but ancillary structures are subject to medium hazard considerations at the designated flood.
Open space	Not specified, but ancillary structures are subject to appropriate hazard considerations at the designated flood.
Rural	Not specified

Table 8.2.8-5 – Building floor levels

While non-habitable spaces (e.g. car parks and garages) do not have a minimum design floor level, there is direction to ensure that these areas are not inundated by more than a medium flood hazard, the characteristics of which are described in Table 8.2.8-5.

AO3.1 Building floor levels of garages and non-habitable rooms, constructed at approximately the same level as, and attached to, the main dwelling, are constructed at a height above the Designated Flood Level, except where the dwelling has a suspended floor, constructed one metre or more above ground, or where the building is to be constructed within a Rural zone.

AO3.2 Garages and carparks are not inundated to cause more than a medium hazard, as identified within **Table 8.2.8-5 Table to acceptable outcome AO11**, for the designated flood.

Table 8.2.8-5: Table to acceptable outcome AO11

Criteria	Degree of flood hazard			
	Low	**Medium**	**High**	**Extreme**
Wading ability	If necessary children and the elderly could wade. (Generally, safe wading velocity depth product is less than 0.25.)	Fit adults can wade. (Generally, safe wading velocity depth product is less than 0.4.)	Fit adults would have difficulty wading. (Generally, where wading velocity depth product is less than 0.6.)	Wading is not an option.
Evacuation distances	<200metres	200-400metres	400-600metres	>600metres
Maximum flood depths	<0.3metres	<0.6metres	<1.2metres	>1.2metres
Maximum flood velocity	<0.4 metres per second	<0.8metres per second	<1.5metres per second	>1.5metres per second
Typical means of egress	Sedan	Sedan early, but 4WD or trucks later	4WD or trucks only in early stages, boats or helicopters	Large trucks. Boats or helicopters
Timing **Note:** **This category cannot be implemented until evacuation times have been established in the Counter Disaster Plan (flooding).**	Ample for flood forecasting. Warning and evacuation routes remain passable for twice as long as evacuation time.	Evacuation routes remain trafficable for 1.5 times as long as the evacuation time.	Evacuation routes remain trafficable for only up to minimum evacuation time.	There is insufficient evacuation time.

Note: The evacuation times for various facilities or areas would (but not necessarily) be included in the Counter Disaster Plan (flooding).

Generally, safe wading conditions assume even walking surfaces with no obstructions, steps, soft underfoot, etc.

Table 8.2.8-3 – Development for certain purposes

This table provides specific direction for particular types of development where the Designated Flood is the 1% AEP (or otherwise, the historic flood level if not defined). This is read with AO7 of the overlay:

AO7 Development is constructed at or above the Designated Flood Level, shown in Table 8.2.8-3, to acceptable outcome AO7, where the Designated Flood is the 1% AEP flood event, or historic level where a modelled AEP does not exist, except as follows:

a) **Broadwater:** the 1% AEP storm surge level, plus allowance of 0.27 metres, to account for sea level rise resulting from climate change;
b) **Logan and Albert Rivers:** the designated flood is based, in part, on rainfall that occurred during the January 1974 flood and assumptions made regarding the ultimate level of development, in accordance with the relevant local planning instruments; and
c) **Nerang River**: the designated flood level is based on Hinze Dam Stage 2 condition.

Table 8.2.8-3: Table to acceptable outcome AO7

Land use	Designated flood
Disaster management facilities	0.2% AEP
Hospitals	0.2% AEP
Major electrical switchyards, power stations, water treatment plants	0.2% AEP
Fire/police stations	0.5% AEP
Places of refuge	0.5% AEP
Electricity substations	0.5% AEP
Sewage treatment plants	0.5% AEP
Home for the aged, hospice	0.5% AEP
Regional fuel storage	0.5% AEP
Food storage warehouses	0.5% AEP
Hotel residential	1.0% AEP
Education facilities	1.0% AEP
Residential buildings	1.0% AEP
Camping grounds, caravan parks and relocatable homes reclamation levels	1.0% AEP
Commercial	1.0% AEP
Light industrial/warehousing	1.0% AEP
Theme parks	Not specified, but users should not be subjected to any more than high hazard conditions in the designated flood, as specified in **AO11**
Clubs/non-habitable buildings associated with enjoyment of public open space	Not specified, but users should not be subjected to any more than high hazard conditions in the designated flood, as specified in **AO11**
Car parking below buildings	Not specified, but users should not be subjected to any more than medium hazard conditions in the designated flood, as specified in **AO11**
Open space	Not specified, but ancillary structures are subject to appropriate hazard conditions in the designated flood, as specified in **AO11**
Rural	Not specified

Notes for Table to acceptable outcome AO7:

(1) The designated flood level is the level that is associated with the minimum flood annual exceedence probability (AEP) for different land use types. For the Nerang River catchment the flood AEP must be calculated based on the Hinze Dam stage 2 condition. Where a modelled flood AEP is not available, historic information must be used. The designated flood level for each site must be obtained from the Council's flood search database.

The following administrative definitions are also provided in SC1.2 of City Plan and identify:

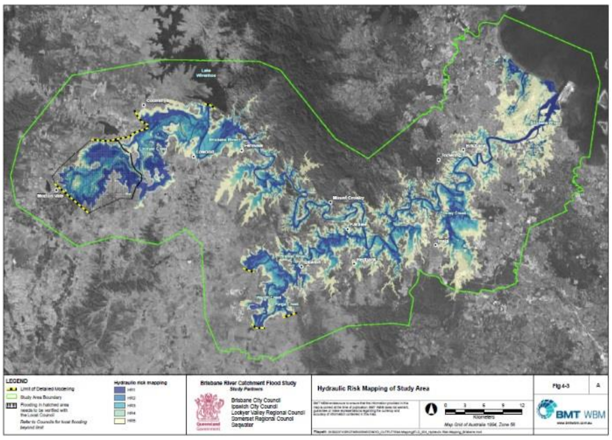
Term	Definition
Annual exceedance probability (AEP)	The likelihood of occurrence of a flood of a given size or larger in any one year, usually expressed as a percentage.
Average recurrence interval (ARI)	The average or expected value of the periods between exceedances of given rainfall total accumulated over a given duration. It is implicit in this definition that the periods between exceedances are generally random.
Design floor level	A minimum floor level specified as part of a building control program, usually equivalent to the level of the designated flood plus design freeboard. (The design flood level is specified for the design of works to ensure immunity from the designated flood.)

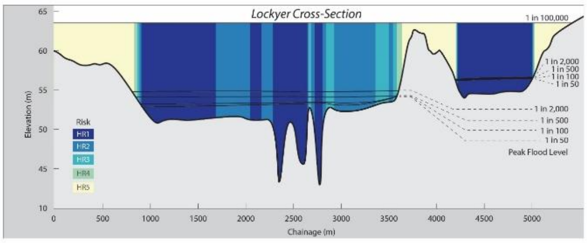
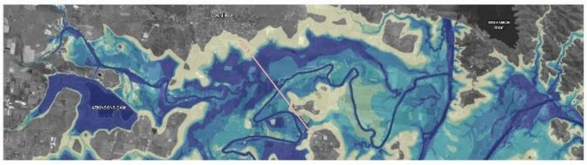
Term	Definition
Designated flood	The flood selected for planning and administration of a particular flood plain.
Designated flood level	The flood level associated with a designated flood.
Flood prone land	Land that would be inundated as a result of the occurrence of the probable maximum flood (PMF).
Flood risk	The quantification of the likelihood of occurrence or probability of flooding (e.g. a flood as big as, or bigger than, the 1:100 risk annual flood has a risk of 1 in 100 of occurring in any one year). This is equivalent to a 1% AEP flood and the 100 year ARI flood).
Flood storage	Those parts of the floodplain that provide temporary storage for a significant volume of flood water during the passage of a flood.
Freeboard	The height above a designated flood level, typically used to provide a factor of safety in setting of floor levels, levee crest levels and similar. (Freeboard provides a 'factor of safety' to compensate for effects such as wave action, localized hydraulic behaviour and other factors. It also provides protection from floods that are marginally above the Design Floor Level, but should not be relied upon to provide protection for events larger than the Designated Flood Event).
Probable maximum flood (PMF)	The theoretical greatest run off event from a particular catchment

Appendix M Flood Risk Factor Tools

M.1 Flood Risk Factor Tools

Table M-1 Summary of available flood risk factor tools

Flood risk tools	Application to LUP
	Potential Hydraulic Risk category mapping This is a regional spatial representation of the five categories of Potential Hydraulic Risk derived from the Potential Hydraulic Risk matrix as defined in the SFMP and Evidence Report (2017). The five Potential Hydraulic Risk categories (HR1 areas of highest risk and priority, to HR5 areas of lowest risk and priority) are identified across the Brisbane River floodplain within the SFMP Study Area. The SFMP Potential Hydraulic Risk matrix (and resultant mapping) were derived using best practice flood risk assessment standards. A range of defined hydraulic hazard characteristics, as per the six identified in the AIDR guideline, were considered for seven AEP likelihoods. A two-dimensional, 42 cell matrix was then produced. A gradation of risk is captured vertically (i.e. between areas more vs. less frequently inundated), and horizontally (i.e. between areas where the hazard creates a high vs. low risk to life and property). The mapping of this matrix “on the ground” adopts the maximum Potential Hydraulic Risk in any given location (i.e. the highest risk rating possible). As is discussed in Section 6.1 of the Milestone Report, the mapping is sufficiently granular to pick up different bands and areas of flood risk across the floodplain. For land use planning purposes, an agreed Potential Hydraulic Risk matrix and its mapping is critical to representing the “base constraint” and setting the foundation for

Flood risk tools	Application to LUP
	regional consistency of flood behaviour in the floodplain.
 	<u>Potential Hydraulic Risk cross-sections</u> The gradation of the five 'zones' of hydraulic risk in the Potential Hydraulic Risk matrix can be effectively shown at key floodplain cross-sections across the SFMP Study Area. Selected cross-sections were produced for the SFMP Study Area as part of understanding which 'dominant cells' were driving the maximum Potential Hydraulic Risk results identified in the mapping of the matrix. Cross-section locations were selected in each local government area, showing the spread of Potential Hydraulic Risk at different elevations and across different flood event sizes along the cross-section chainage. This tool can be used in land use planning to convey the different levels of hydraulic risk when considered cumulatively for similar sites across the floodplain section. The tool is useful in communicating the nuances and complexity of floodplain behaviour across the floodplain. Understanding these nuances means that land use planning can respond appropriately. For example, it clearly shows that the traditional approach of relying on the 1 in 100 AEP as the means to regulate residential development, is too simplistic and does not recognise flood hazard. The cross-sections interpret the potential Hydraulic Risk mapping in another way, and again represent the 'baseline' hydraulic hazard (considering depth and velocity and how these conditions are influenced by the physical characteristics of the floodplain).

Flood risk tools	Application to LUP

Land use activity group	Potential Hydraulic Risk Category				
	HR1	HR2	HR3	HR4	HR5
Critical uses & essential community infrastructure	Intolerable	Intolerable	Intolerable	Tolerable*	Acceptable
Vulnerable uses	Intolerable	Intolerable	Intolerable	Tolerable*	Acceptable
Filling	Intolerable	Intolerable	Tolerable*	Tolerable*	Acceptable
Residential & accommodation	Intolerable	Intolerable	Tolerable*	Tolerable*	Acceptable
Commercial & industrial	Intolerable	Intolerable	Tolerable*	Acceptable	Acceptable
Non-urban & recreation uses	Tolerable*	Tolerable*	Tolerable*	Acceptable	Acceptable

Potential land use compatibility table

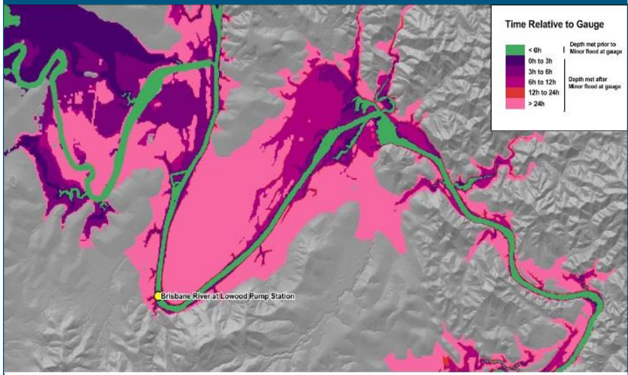
This table is a 'ready reckoner' for strategic planning and planning scheme preparation and determines, for each major land use activity group, its vulnerability or susceptibility to flooding. It assists in helping to inform a preliminary decision as to whether the proposed land use is acceptable, tolerable or intolerable to the level or category of Potential Hydraulic Risk.

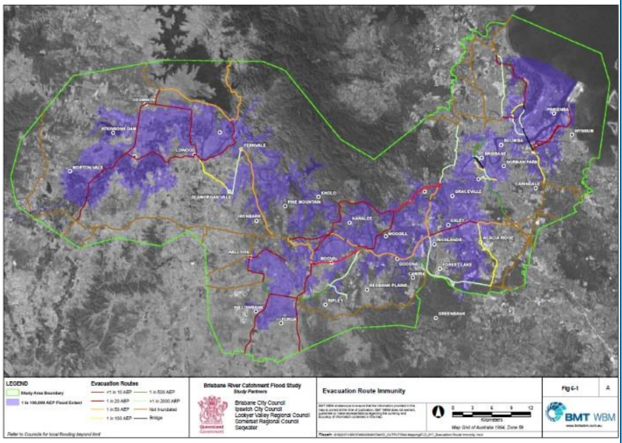
The table identifies the uses' tolerability to the category of Potential Hydraulic Risk and, in doing so, differentiates between flood behaviour characteristics across the floodplain, and the risk appropriateness of the land use class proposed.

Considering the vulnerability of particular land uses to changes in flood behaviour will ensure that the distribution of land uses across the floodplain (and in the settlement pattern for the region) is risk-appropriate, while the location of infill development in existing areas can be tailored to the level of risk and managed through development controls.

For each land use group, this tool summarises the land use compatibility subject to the baseline risk and suggests three development responses: avoid areas of **intolerable** risk, mitigate (subject to requirements) in areas of **tolerable** risk and allow development in areas of **acceptable** risk. Where tolerable subject to requirements, footnotes can be added to the potential land use compatibility matrix, as relevant, to clarify the development requirements.

This high-level tolerability assessment directly aligns with state interest policies for Natural hazards, Risk and Resilience in the SPP and therefore, will help to reflect the State interest in planning schemes.

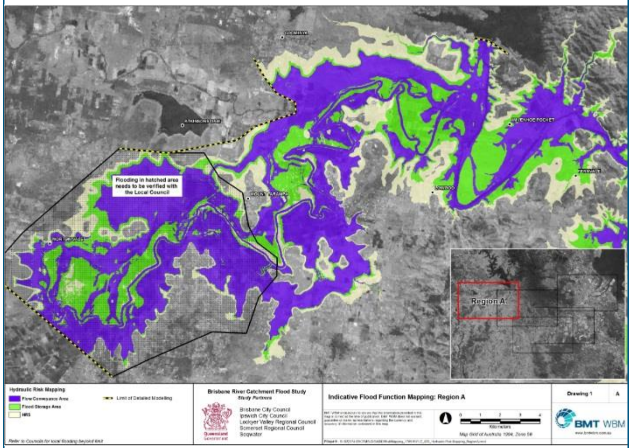
Flood risk tools	Application to LUP
	Relative time to inundation This mapping illustrates the ‘theoretical’ time available to respond to the onset of flooding. Mapping has been provided for the 1 in 500 AEP, which allows for consideration of impacts beyond the standard 1 in 100 AEP. The ‘theoretical’ time is defined as the time taken from when flooding first reaches a minor flood level at the closest upstream flood gauge to when flooding reaches a depth of 300mm. The 300mm threshold was chosen as this depth of flooding highly constrains self-evacuation using regular vehicles. In considering evacuation, the relative time to inundation should be assessed along the entire evacuation route, with the minimum time used as a basis for response and action. Five major gauges have been used for mapping, viz: Lowood pump station, David Trumpy Bridge, Moggill, Jindalee and Brisbane City. Actual response time for each flood experienced in the Brisbane River SFMP Study Area will vary from this theoretical relative time to inundation, depending on the characteristics of the flood hydrology. In land use planning, the tool is very useful for strategic planning purposes as it identifies those locations in the floodplain that have more (or less) time available for response and action before inundation. This mapping tool can assist in planning evacuation routes and prioritising where new, or upgrades to existing, evacuation routes need to occur and can help assess the shortest relative time for evacuation. If relative time to inundation is a critical point for informing land use planning and more detailed information is required, the Evidence Report (2017) provides this (in the form of Box and Whisker Plots).

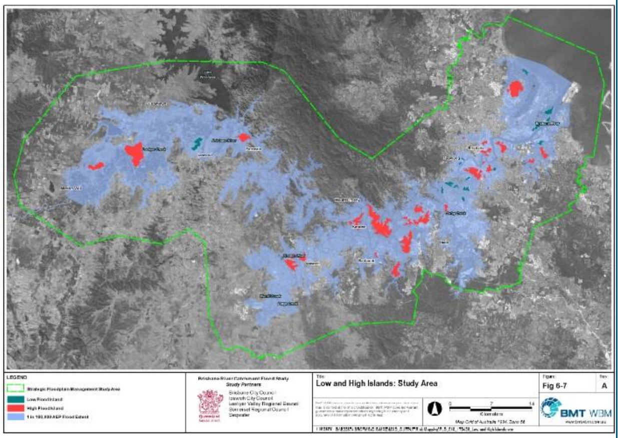
<table>
<tr><th>Flood risk tools</th><th>Application to LUP</th></tr>
<tr><td></td><td><u>Potential evacuation route immunity mapping</u>
This tool maps the major State Controlled Roads (SCRs) across the SFMP Study Area that may be relied on by emergency services and disaster management during a flood event. Importantly, the mapping records the potential flood immunity of these road segments.

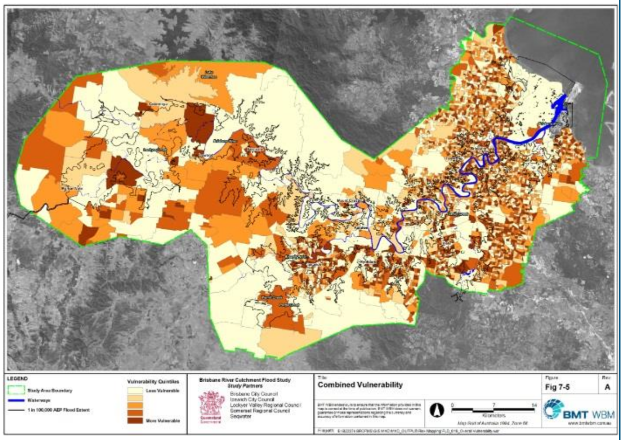
The mapping identifies the most frequent flood event that would cut-off access to each segment of road. Six AEPs are included:
• ≤ 1 in 10 AEP
• 1 in 20 AEP
• 1 in 50 AEP
• 1 in 100 AEP
• 1 in 500 AEP
• 1 in 2,000 AEP

This mapping tool is useful in network analysis and infrastructure planning. It is noted that the SFMP can provide more detailed information on the timing and duration of the earliest road closure, beyond the information shown on this mapping. This relies on the BRCFS Phase 2 (Flood Study) fast model, which simulated 11,300 unique events for design purposes. The estimated time and duration of road closure data may be used by local governments in strategic land use and contingency planning to better understand isolation risk.

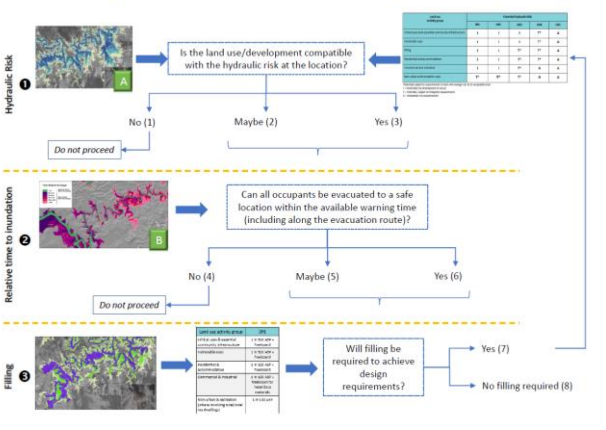
This tool does not consider the immunity of local feeder roads and may overestimate network immunity. As such, this map should be considered indicative only and planning authorities will need to undertake local studies to assess the immunity of local evacuation routes.</td></tr>
</table>

Flood risk tools	Application to LUP
	<u>Indicative flood function mapping</u> Flood function mapping characterises the floodplain into areas of flood flow conveyance and flood storage. Flood flow conveyance areas comprise the Potential Hydraulic Risk categories of HR1 and HR2, and typically include areas within or immediately adjacent to the river bank and channel and areas that can have deep and fast flowing water, which results in high risk to life and the potential structural failure of buildings. Flood storage areas consist of Potential Hydraulic Risk categories HR3 and HR4, and depict those overbank floodplain areas used for flood storage capture. Flood storage areas can also be deep but the velocities are lower. Loss of flood storage (through development, for example) can change flood detention behaviour and result in worsening of flood flows elsewhere. The balance of the floodplain is the 'flood fringe' area as defined by Potential Hydraulic Risk category HR5. In land use planning, this mapping tool will be very useful in helping to identify locations that are more or less tolerable to filling and changes to landform. This is important because testing shows that flood behaviour in the Brisbane River floodplain is particularly sensitive to further development if filling is proposed to raise land as a risk treatment measure to enable development. The sensitivity of the floodplain is due to the incised valley and other physical characteristics of the floodplain. Planning schemes can incorporate this mapping to manage the impact of changes to flood behaviour and flow regimes resulting from future development.

<table>
<tr><th>Flood risk tools</th><th>Application to LUP</th></tr>
<tr><td>
</td><td><u>Low and high flood islands mapping</u>
Mapping identifies isolation risk in the form of high and low flood islands. High islands are not inundated in the 1 in 100,000 AEP. Low islands are areas that become isolated in smaller events but eventually become completely flooded as flows rise up to a rare event.

The mapping only considers those islands that are substantially developed, as the isolation of these areas will have more significant implications region-wide. From a land use planning perspective, this information would best be used in conjunction with potential evacuation and warning time mapping to determine the number of properties and residents potentially isolated.</td></tr>
<tr><td>
</td><td><u>Vulnerability mapping</u>
The vulnerability of a particular land use or community can exacerbate the level of exposure and its flood risk. The SFMP has produced vulnerability mapping, built into which are the following key social vulnerability metrics:
physical (age and disability)
social and economic (financial and employment)
mobility (evacuation means and living situation)
awareness (barriers to language and access to information)
Four vulnerability indices were derived based on the characteristics described above using census data. Normalising each index gave a value from 0 (less vulnerable) to 1 (more vulnerable). The sum of each vulnerability index can be mapped individually. Alternatively, all four indices can be summed to show combined vulnerability (or an ‘overall ranking’) across the floodplain.</td></tr>
</table>

<table>
<tr><th>Flood risk tools</th><th>Application to LUP</th></tr>
<tr><td></td><td>Although not considered suitable for direct inclusion in a planning scheme to regulate development, vulnerability mapping should be a key input into local risk assessments, which will inform strategic planning and planning scheme responses to treat flood risk. Vulnerability mapping will also influence community resilience, recovery and response. Certain aspects of the vulnerability tool (e.g. physical and mobility mapping) may inform the location of, and land use planning responses adopted for, vulnerable uses for example.</td></tr>
<tr><td>
Concept Plan for Brisbane River SFMP Planning Framework (Flooding)



<table>
<tr><td>1</td><td>Flood (hydraulic) behaviour is too hazardous for the proposed development. Do not proceed.</td></tr>
<tr><td>2</td><td>Proposed development may be compatible with potential hydraulic risk, depending on design conditions and an acceptable evacuation solution. Proceed to step 2.</td></tr>
<tr><td>3</td><td>Proposed development is compatible with potential hydraulic risk. Proceed to step 2.</td></tr>
<tr><td>4</td><td>Occupants cannot be safely evacuated. Significant risk to life. Do not proceed.</td></tr>
<tr><td>5</td><td>Occupants may be safely evacuated if specific actions are put in place. This could include physical works (raising, drainage) to evacuation route or enhancement of warning time. Warnings during night may reduce response time. Proceed to step 3.</td></tr>
<tr><td>6</td><td>Safe evacuation of all occupants from the proposed development is achievable. Proceed to step 3.</td></tr>
<tr><td>7</td><td>Check filling compatibility at step 1. Filling is a designated land use/development type.</td></tr>
<tr><td>8</td><td>No filling required as part of proposed development. Proceed subject to other site-based conditions as requirements.</td></tr>
</table>
</td><td>
<u>Flood risk factors decision support tool (‘support tool’)</u>

The decision support tool provides a ‘problem solving tree’ or framework that has regard to the majority of (but not all) SFMP flood risk factor tools presented earlier in this table. It focusses on the key flood risk factors that are of the highest priority when considering risk to life. This includes Potential Hydraulic Risk, relative time to inundation and indicative flood function mapping, as well as the potential land use tolerability table. The tool is intended to show how these key flood risk factor tools come together and can be logically applied.

Appended to the support tool is a series of outcome statements to assist in decision-making. These statements correspond to key risk-based questions posed in the support tool, the answers to which determine the most risk-appropriate development pathway:

1) Is the land use/development compatible with the hydraulic risk at the location?
2) Can all occupants be evacuated to a safe location within the available warning time (including along the evacuation route)?
</td></tr>
</table>

Flood risk tools	Application to LUP
	3) *Will filling be required to achieve design requirements?* The tool sets up a framework for deciding land use and development within the SFMP Study Area. From a flooding perspective, it also identifies the most relevant items of information upon which to base the decision. Used in land use planning, the tool would help inform risk-appropriate land use planning, including a risk responsive settlement pattern, as well as provide a consistent method for assessing development applications in the floodplain. Local governments can choose to add to the framework.

M.2 Application of Tools

The following two examples demonstrate how the above identified flood risk factor tools can be applied to inform appropriate land use planning in both an expansion (greenfield) and consolidation (infill) scenario.

M.2.1 Expansion (Greenfield) Scenario

A local government has an area of vacant land located in the Rural Zone of approximately 148 ha in area and comprising 18 parcels. Increased population and development pressures have led to the Council commissioning a local planning investigation of the area ('the subject area') to identify its suitability for future urban purposes. A key consideration as part of this process is to ensure that the land use is risk-appropriate to the level of flood risk.

The following assumptions are made of this land; these are mapped in Figure M-1 and Figure M-2 using the range of available flood risk factor tools (as relevant):

- the subject area has a Potential Hydraulic Risk of both HR3, characterised by a 1 in 50 AEP and a H2 hazard, and HR2, characterised by a 1 in 20 AEP and H2 hazard on the risk matrix;
- the potential land use compatibility table indicates that urban uses have different tolerability depending on the Potential Hydraulic Risk category within which the uses are located. These range from intolerable to tolerable subject to requirements;
- the potential available response time map shows that part of the subject area has a longer warning time greater than 24 hours, while other parts have less than 12 hours' warning time;
- the subject area is not well located to an existing evacuation route but, as advised, the majority of the subject area has a long warning time; and

- the subject area comprises both flow conveyance and flood storage areas on the indicative flood function map. The potential land use compatibility table suggests that in Potential Hydraulic Risk category, HR2, filling is intolerable but may be tolerable (subject to requirements) in Potential Hydraulic Risk category, HR3. Further analysis would need to be undertaken to determine if filling is an appropriate risk treatment option.

To arrive at a risk-appropriate land use and development decision, the range of relevant flood risk factor tools are applied in Figure M-2. Based on the above assumptions and associated flood risk factor tools, the decision support framework concludes that:

1) *the proposed development may be compatible with Potential Hydraulic Risk, depending on design conditions and an acceptable evacuation solution;*

2) *occupants may be safely evacuated if specific actions are put in place. This could include physical works (raising, drainage) to evacuation route or enhancement of warning time. Warnings during night may reduce response time.*

3) Filling is tolerable (subject to requirements) in parts of the subject area, as shown in the potential land use compatibility table. ***Proceed subject to other site-based conditions as requirements.***

Based on the application of the relevant flood risk factor tools and decision support framework, the type of greenfield development envisaged in the subject area is risk-appropriate, subject to the recommendations of a more detailed local flood study and risk.

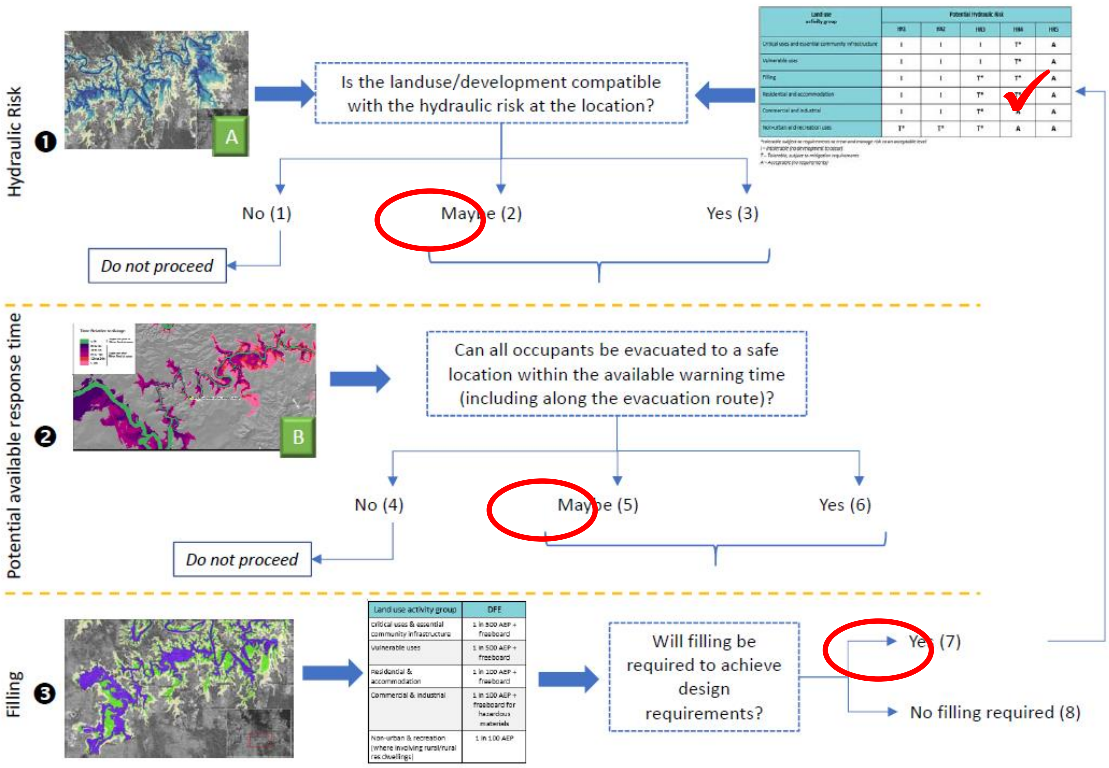


Figure M-1 Scenario 1: Expansion (greenfield) – decision support tool

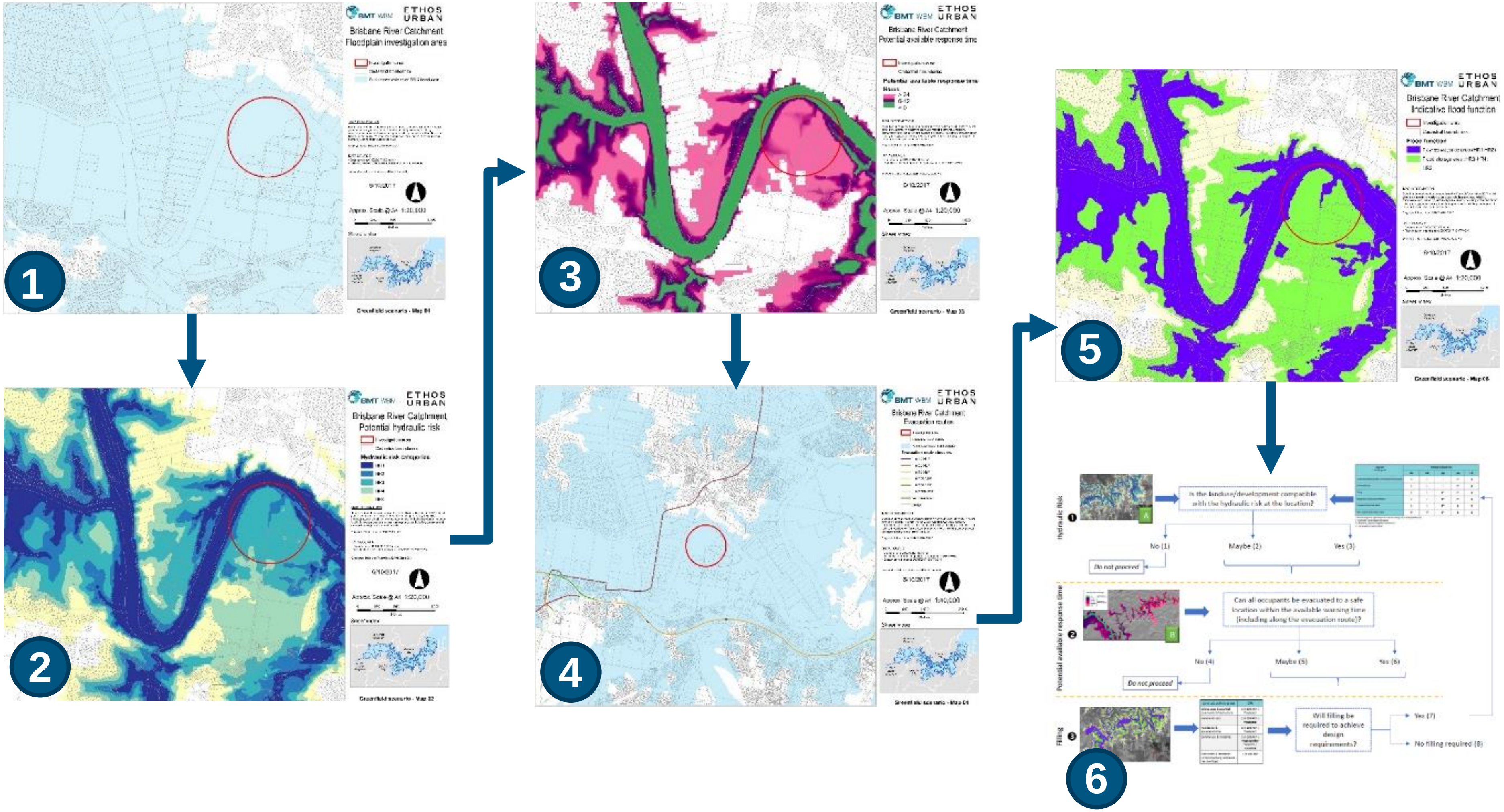


Figure M-2 Scenario 1: Expansion (greenfield) example – application of flood risk factor tools

M.2.2 Consolidation (infill) scenario

A large developer is proposing to develop an existing infill site within the Brisbane River floodplain for a mixed-use purpose, comprising 50 residential units and ground floor retail. To facilitate this development, the developer wants to make a submission to the local government during its notification of a major planning scheme amendment, to change the zoning of the land ('the subject area') to Mixed Use. The subject area comprises 28 ha of 19 parcels in a currently lower intensity zone.

The developer has identified that there are flood impacts over the subject area and needs to determine whether the level of risk is appropriate to the type of land use and development proposed.

The following assumptions are made of this land; these are mapped in Figure M-3 and Figure M-4 using the range of available flood risk factor tools (as relevant):

- the subject area has a Potential Hydraulic Risk of HR1, characterised by a 1 in 20 AEP and H4 hazard; HR2, characterised by a 1 in 100 AEP and H4 hazard; and HR3, characterised by a 1 in 500 AEP and H4 hazard;
- the potential land use compatibility table indicates "residential and accommodation" and "commercial and industrial" type uses as potentially intolerable within Potential Hydraulic Risk categories, HR1 and HR2, but potentially tolerable (subject to requirements) in Potential Hydraulic Risk category, HR3;
- the potential available response time map shows that the majority of the subject area has a shorter warning time of either 6–12 hours or 12–24 hours. Peripheral parts of the subject area have a longer warning time (>24 hours);
- the subject area is not well located to an existing evacuation route, the closest of which is approximately 500m to the west; and
- the subject area comprises flow conveyance, with peripheral parts identified as flood storage areas on the indicative flood function map. The potential land use compatibility table suggests that filling is potentially intolerable in Potential Hydraulic Risk categories, HR1 and HR2, but tolerable (subject to requirements) in Potential Hydraulic Risk category, HR3.

The development is proposing to fill some of the subject area to achieve a building pad level above the 1 in 100 AEP.

To arrive at a risk-appropriate land use and development decision, the range of relevant flood risk factor tools are applied in Figure M-3 below. Based on the above assumptions and the associated risk factor tools, the decision support framework concludes that:

1) *the proposed development may be compatible with Potential Hydraulic Risk, depending on design conditions and an acceptable evacuation solution;*
2) *occupants cannot be safely evacuated. Significant risk to life.* ***Do not proceed.***
3) (Filling is not compatible with the potential land use compatibility table).

Based on the application of the relevant flood risk factor tools and decision support framework, the type of infill development envisaged in the subject area is **not** risk-appropriate, and the developer should not proceed with making a submission in this instance.

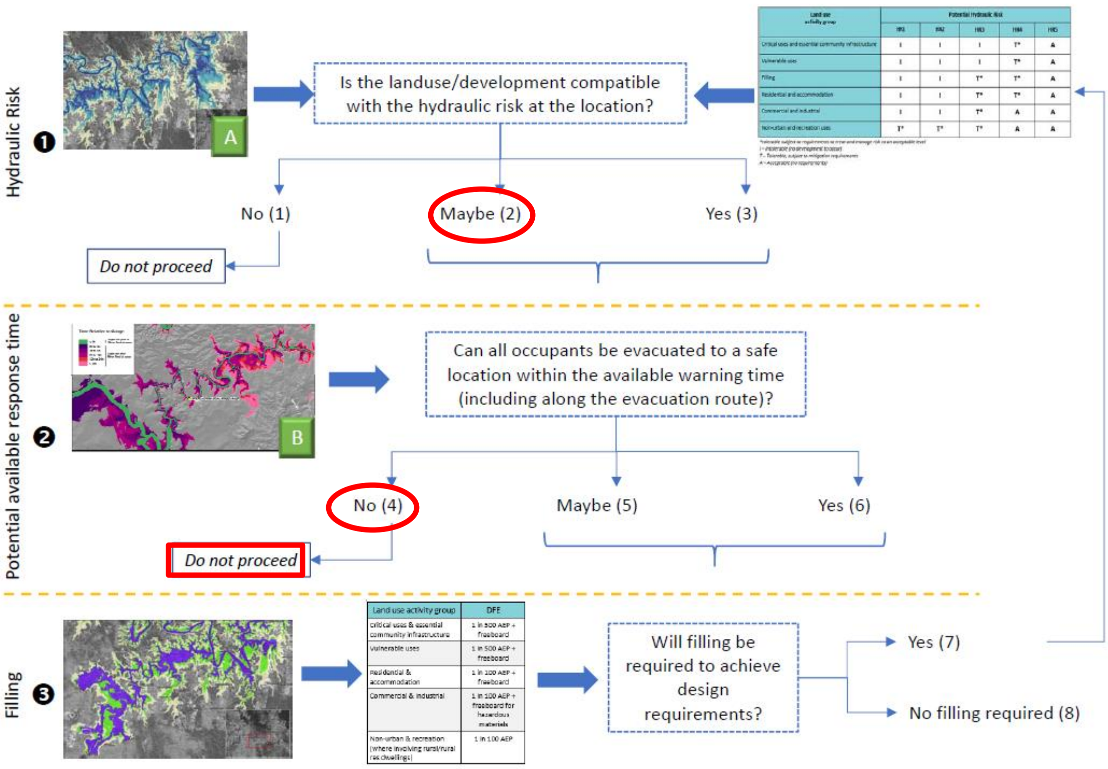


Figure M-3 Scenario 2: Consolidation (infill) – decision support tool

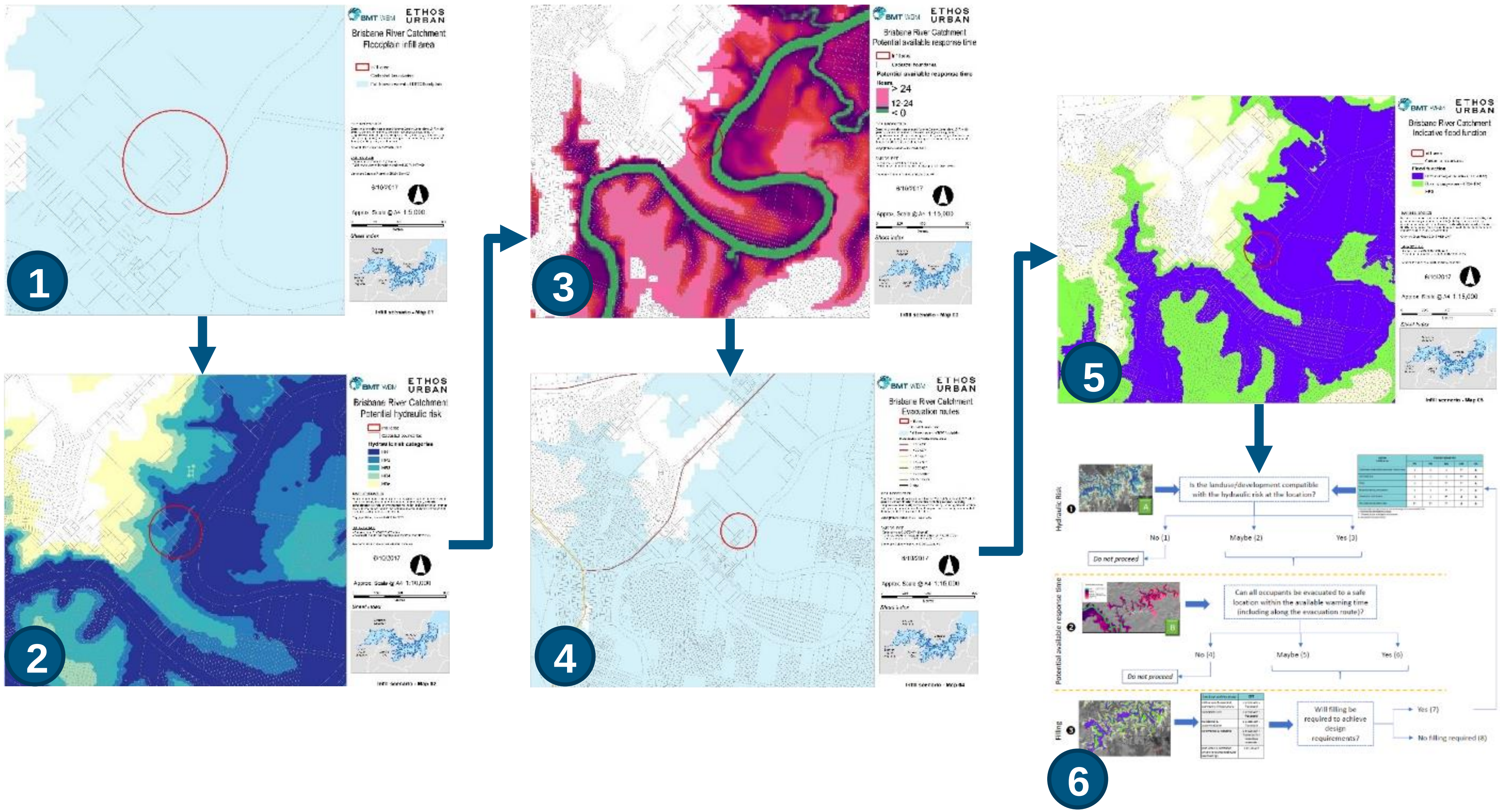


Figure M-4 Scenario 2: Consolidation (infill) example – application of flood risk factor tools

Appendix N Workshop 1

N.1 Activities

The workshop primarily comprised two group activity / discussion sessions asking stakeholders two key questions relating to disaster management:

- What's not working? (and)
- What can we do about it?

[It should be noted that the workshop responses are the opinions of individuals, and do not necessarily represent the viewpoints of stakeholder organisations.]

N.2 What's Not Working

N.2.1 Communication and Evacuation Infrastructure

- Internet and phone connectivity to disseminate warnings
- Alternate power sources are needed
- Connectivity via roads can be an issue
- Poor awareness of flood vulnerability of critical infrastructure

N.2.2 Community Understanding

- Community does not have access to information needed to identify and appropriately respond to the risk
- Community may not understand how flood warnings and / or gauge levels relate to their personal circumstances
- Minor / moderate / major flood categorisations may not be helpful
- Community engagement and awareness measures may not be working effectively

N.2.3 Governance and Collaboration

- Unclear division of responsibilities between agencies
- Uncertain whether district disaster management groups (DDMGs) add value
- The decision-making process is not complicated enough [unsure what the issue is here]
- Poor sharing of information between agencies
- Important information is not centralised for ease of access and consistency between response agencies

N.2.4 Resources, Information, Understanding

- Unclear trigger points for activation and / or escalation (based on real-time or modelled data)

- Poor understanding of flood risk assessment and lack of standard operating procedures
- Councils do not have sufficient specialist resources to enable effective decision making
- Current gauge network may not provide sufficient information

N.2.5 Intersection with Other Work Packages

- Land use planning provisions do not consider disaster management issues (e.g. evacuation)

N.2.6 Other

- Too focused on response actions rather than preparedness
- Unregulated levees modify flood behaviour in unforeseen ways
- Challenging to manage volunteers during events

N.3 What Can We Do?

N.3.1 Communication and Evacuation Infrastructure

- Establish agreement from state on standards for critical infrastructure on roads, power stations etc.
- Improve understanding of how the NBN will affect communication to community during events and if some communities will be vulnerable

N.3.2 Community Understanding

- Provide ongoing community education and awareness, which is targeted and relevant
- Provide community awareness programs which provide information about evacuation centres, preparedness measures etc.
- Translate standard warnings (such as ‘moderate flood’) into ‘real’ terms. Real current examples include coloured markers on power poles in Innisfail, and stickers in power boxes in Cairns.
- Translate risk to communities, ensuring that downstream communities understand their risk
- Provide permanent sign posting for flood evacuation routes
- Provide personalised information for the public which allows users to look up their property and understand the potential impact during an event
- Improve the community’s understanding of the probability of flood events
- Provide better community awareness of risk indicators and agency disaster management responses

N.3.3 Governance and Collaboration

- Apply a regional approach to disaster management and sharing of data
- Improve collaboration between preparedness, response, relief and recovery agencies

- Undertake collaborative and coordinated relationship building between local and state government
- Establish clear accountabilities and shared responsibility
- Provide consistent mapping, communications and messaging across the region, including flood classifications
- Improve data sharing throughout agencies within the region
- Review the appropriateness of Queensland disaster management arrangements and those of other states
- Review disaster local districts to provide holistic catchment response management. This applies to all hazards, not just flood
- Delegate community awareness programs to community organisations who have more knowledge and are able to have a higher impact in the community
- Modify the local government area boundary to have Somerset Regional Council above Wivenhoe

N.3.4 Resources, Information, Understanding

- Create a central hub for flood data, information and intelligence which is accessible by various agencies (with different security clearances) and translates warnings and levels into information for the public
- Use SDCC QFES indicator tool to get ahead of triggers
- Link live flood maps to flood predictions
- Provide better resourcing for councils
- Develop triggers from the Brisbane River Catchment Phase 2 (Flood Study)
- Investigate GPU / fast models for real-time flood forecasting
- Provide integrated mapping layers to agencies
- Develop better understanding of flood warnings [not clear if this relates to agencies / emergency responders etc. or the community]
- Understand big data

N.3.5 Intersection with Other Work Packages

- Target communities in flood risk areas, rather than the entire community

N.3.6 Other

- Use paleoclimate data to understand South-East Queensland flooding (per 'The Big Flood' study)
- Undertake regular disaster management exercises
- Improve training of liaison officers

- Match governance to community expectation, e.g. Twitter alerts

N.4 Summary of Workshop 1

Theme	Main Issues	Stakeholder Ideas to Address
Communication and evacuation infrastructure	Stakeholders are keen to better understand the flood immunity of critical infrastructure and how this might impact residents and dissemination of information	Establish standards for critical infrastructure
Community understanding	Particularly relating to translating flood warnings and gauge levels to 'on the ground' impacts	Provide personalised and translated information to the community, plus broader community awareness measures
Governance and collaboration	Issues relate particularly to information sharing and ensuring consistency of information, although there is some recognition of unclear division of responsibilities	Apply a regional approach to DM. Improve collaboration between state and local agencies. Clarify accountabilities and responsibilities. Make mapping, messaging etc. consistent. Improve sharing of information
Resources, information, understanding	This relates to a broad range of issues including availability of gauged data, understanding of SOPs, and trigger points	Have a central hub for flood data, information and intelligence accessible for all agencies. Link live maps to flood predictions. Develop triggers from Phase 2 (Flood Study) and investigate GPU models

Appendix O Stakeholder Consultation

Note that this stakeholder consultation is based on the views of individuals and may not necessarily represent the views of the stakeholder agencies.

O.1 Activities

This consultation sought to clarify disaster management opportunities and better understand needs of individual stakeholders. These sessions particularly focused on the following:

- Summary of work done to date (particularly the 'existing risk' profiling presented in Section 4 Current Flood Risk);
- Challenges faced by stakeholders in terms of tools, data and information; and
- Ideas for how the Phase 3 (SFMP) might help stakeholders improve disaster management outcomes.

O.2 Current Tools

O.2.1 Disaster management tool (DMT)

- Brisbane City Council has created the DMT and use it in their disaster management operations. [The DMT is described in more detail in Section 10.6.3.4]
- Mapping from the DMT has been extended to Bremer River and Lockyer Creek dominated events. This mapping has been provided to the relevant councils
- Other councils use the DMT, but not to the extent that BCC does. It is seen to be a bit 'Brisbane-centric'.
- The DMT is seen to have value when trying to plan for floods which are larger than those on record, and particularly for dam releases.
- There is interest in having more support in linking the DMT outputs to the Bureau predictions.

O.2.2 Disaster Dashboard

- Three of the four councils use the Disaster Dashboard
- The dashboard capabilities are used or understood in different ways between the councils. For instance, ICC uploads the expected inundation line to their dashboard, whereas SRC believes that no councils are currently updating the dashboard with 'live' mapping.
- The dashboards are very community focused and generally seen as a good tool to share information with the community.

O.2.3 WaterRide

- WaterRide is used by all Councils, particularly for the 'bender' function, which interpolates between flood maps (e.g. to estimate what a flood map might look like for an intermediate event size between two design events)
- WaterRide can be used to undertake complex operations, e.g. LVRC have linked hydrology models and are (possibly?) running hydrologic models in real-time for flash flooding catchments

O.2.4 Tasking Software

- All councils and some support agencies use 'tasking' software, which manages job allocation during emergencies.
- A range of software is used, primarily Guardian and Noggin.
- At present these systems do not directly interface
- Councils and agencies have generally invested heavily in the software, related training, and integrating the software in their standard procedures. There is no indication that councils or agencies wish to change from their current systems.
- It is understood that a study was undertaken previously which assessed the potential for system interoperability, but the recommendations of this study have not been implemented. [QRA: can you provide more information on this study?]

O.2.5 FloodHub

- *QRA to provide additional information*

O.3 Desired Outcomes from FMS6

O.3.1 Consistency

- There is some difference of opinion on the degree of consistency that should be in place across the region.
- All stakeholders support the use of standardised language, icons on maps, road signage etc.
- There is particular support for consistency in language in emergency messaging, and crisis communication more broadly.
- There is mixed support for consistency of disaster management systems. While it is recognised that a consistent forecasting or flood mapping tool would be beneficial to the region (to ensure that all parties are referring to the same data set / single point of truth), each party has slightly different needs and established systems. A balance would need to be established between need for regional consistency and meeting local needs.
- Residents in border areas, particularly between ICC and BCC may receive messages from both Councils; there is a concern that the information might conflict and confuse residents.

- There is a desire for consistency of procedures for dealing with isolated communities (e.g. whether to evacuate, re-supply etc.), particularly in the border areas.

O.3.2 Interface with Other Flooding Sources

- Any tools or guidance delivered through this study need recognise that Brisbane River is not the only source of flooding in the catchment. Creek flooding is also a consideration, particularly for ICC and BCC. Creek flooding usually occurs well before riverine flooding and is a more significant risk for some locations.
- Councils don't necessarily need a system that includes creek flooding, but the study should capture those issues and provide some guidance for how to use any proposed systems in conjunction with existing systems (e.g. ICC's creek flash flood forecasting system).

O.3.3 Interagency Information Sharing

- All stakeholders identified a need for an information sharing system across the region.
- This system should, as a minimum, be available to relevant stakeholders (councils, state agencies, etc.), but may also extend to include an interface for sharing information with the community.
- Different logins should be provided for different users / agencies to protect any private data (e.g. rates notices).
- The system should be web-based (which could be accessed from home, in case access to disaster management centres not possible).
- In general, would prefer a system which has a greater degree of automation in producing / populating data, to ensure system is useful to all levels of users.
- The system should be GIS focused. Pre-loaded layers should definitely be included, with options to add additional GIS information during an event (and possibly options for e.g. drawing a polygon on a map which provides a profile of how many cars, people etc. within the polygon).
- The system might also include the ability to add geospatial 'pins' with attributes
- Types of information that could be included in the system are population data (via census), live updates of telemetry, linking of stream gauge levels with required actions (e.g. if gauge at X level, which roads are likely to be closed, which residents should be evacuated, which critical or sensitive infrastructure will be inundated etc.).
- A 'what-if' capability would be helpful to enable stakeholders to explore future scenarios (e.g. more or less rainfall).
- System should have options for downloading relevant data into Excel to create pivot tables. Tables or lists are needed in addition to maps.
- Request for pre-populated situation reports listing current conditions, impacts etc.
- System would ideally interface with Guardian / Noggin etc. (tasking software). Stakeholders are not looking for something to replace existing tasking software, but would like to be able to share

actions or updates on each other's actions, e.g. the system might automatically estimate that a substation will be inundated until X time, then Energex might leave a comment on that alert to note that substation won't be restored until Y time. Similarly, Energex might issue a polygon to show an area where power is likely to be out for two weeks.

- Prefer that a separate agency, such as QRA, manage the system.

O.3.4 Flood Intelligence

- Flood intelligence is needed to support stakeholder decisions, share with other stakeholders, and provide to the community. Not all information needs to be shared with all parties, and not always in the same format / language etc.
- Stakeholders identified a need to identify what information should / must be shared at each local / district / state level, and why.
- Stakeholders have a strong desire for automated or semi-automated, real-time flood intelligence which can be shared with other stakeholders via a common platform.
- Generation of flood intelligence should be automated or semi-automated, but still requires human intervention to undertake sensibility checks before sharing or acting upon the intelligence.
- The types of flood intelligence needed include: how will a flood unfold (both timing and behaviour), where are evacuations required, which roads will become inundated, where will flood extents reach and how does this relate to real-world reference points (e.g. "flooding will reach second step of post office").
- Timing related-information was a major challenge identified by stakeholders. It was recognised that Bureau forecasts for gauges may provide timing of expected peak levels, but not the lead-up timing. Similarly, stakeholders noted that the DMT does not provide information on flood timing and evolution. Timing is critical for understanding when assets become inundated or isolated, sequencing evacuations, generating emergency messaging etc.
- There is interest in understanding the translation of rainfall intensity to river levels to provide 'heads-up' type alerts. However, there is also consideration that this is a forecast action, which is typically the responsibility of the Bureau.
- Flood intelligence is needed to inform decisions about when to warn the public, how early to warn, which areas should be warned etc.
- Sharing of flood intelligence will require establishment of standard formats, e.g. address data can be provided in various slightly different ways which prevents usage in local systems
- There is a need to understand exposure of community assets, roads, evac routes etc. at particular levels and locations.
- The floor level survey being undertaken as part of this study is agreed to be very valuable.

O.3.5 Real-Time Modelling

- Stakeholders recognise there are many ‘permutations’ of possible flood events, many of which were modelled in the fast model during the flood study. Stakeholders are not sure how to leverage this information in an operational context.
- There was strong support for real-time information in a simple to understand format. Stakeholders generally have a preference for pre-cooked, specific information rather than generic principles.
- It’s recognised that the Bureau is the lead forecasting agency for non-flash flood locations, and there is no desire to overlap with the Bureau’s responsibility in this area.
- Support is needed to translate forecast gauge levels into flood extents / flood maps
- Real-time modelling would help inform development of real-time flood intelligence
- Stakeholders identify that real-time modelling would allow constant modelling during an event to better predict outcomes. However, these systems are seen as complex and there is a concern that additional resources (hydrologists) would be required to interpret modelling results.
- Some stakeholders may have sufficient skills and resources to undertake real-time modelling, however an MOU may be required to share information during an event. [See current challenges >> resourcing for further discussion].
- It is recognised that models may not provide ‘exact predictions’ of flood extents, but there is a willingness from councils to ‘ground truth’ modelled information via CCTV, site inspection etc.
- Any real-time modelling system would need to be developed with consideration of existing forecast models for creeks, the DMT, WaterRide ‘bender’ etc.
- The DMT is particularly useful for Wivenhoe Dam outflows and for extreme events. In these cases, information on flows / levels should be available for multiple gauge locations in an area, in case the usual reporting gauge fails during the event.
- Some stakeholders queried whether the DMT should be updated using the Flood Study model.
- Some stakeholders would like information on lower flows in the DMT.
- Any system should ensure it has a whole of catchment / region focus.
- LVRC is interested in expanding the fast model further up Lockyer Creek for disaster management purposes, and may also seek to improve the hydrology in this area.

O.3.6 Automated Alerts

- Some stakeholders indicated that automated alerts for council officers would be helpful.
- In the past, councils have established triggers based on the DMT, Bureau levels etc. These triggers could be updated based on results from Flood Study and linked to automated alerts to officers. When these triggers are breached, officers may need to e.g. set off sirens, issue SMS alerts etc.

O.3.7 Interface with Other Studies

- Any disaster management options recommended in the study should help stakeholders meet the standards outlined in the Emergency Management Assurance Framework.
- Stakeholders need assurance that the Phase 3 (SFMP) will align and coordinate with the QFES risk management framework.

O.4 Current Challenges

O.4.1 Interoperability of Systems

- All stakeholders noted that it can be challenging to share information when different stakeholders use different, incompatible systems. There is no known interoperability between systems at present.
- Interoperability is a particularly great challenge in border areas, such as the boundary between ICC and BCC. It is understood that both councils use the WaterRide 'bender' feature independently and may therefore develop different water levels / extents for the same region.
- Stakeholders are worried that interoperable systems may result in 'double dipping', i.e. separate stakeholders flagging the same issue and both assigning resources. When resources are scarce, this is particularly undesirable.

O.4.2 Inconsistent Warnings

- Councils generally advise the community to refer to the Bureau website, however during floods, Councils can disagree with information from the Bureau (e.g. due to local flash flood forecasting / modelling, or on-ground evidence).
- Concern that language or message in alerts may be inconsistent. [Councils provide their own early warning alerts, but emergency alerts are issued through a federal system, coordinated by the State, that councils provide input into]
- Social media can also provide inconsistent information to Councils, particularly some of the louder voices, e.g. Higgins Storm Chasing. There is a need for a 'single point of truth'.
- Recognised that inconsistencies in social media notices could be partially alleviated by providing a source of publicly available information that social media could repeat / amplify, without changing the nature of the message.

O.4.3 Data

- There is interest in installing additional acoustic Doppler current profilers (ADCPs) in the Brisbane river to collect more detailed information about the velocity profiles. It is understood that Seqwater has recently installed ADCPs at Moggill.
- Stakeholders expressed concern about redundancy in the current flood forecasting system, and in any future or recommended systems. They are keen to understand whether additional gauges can be readily used for reporting or adapted to flood analysis if the primary forecasting gauges fail during an event.

- Some stakeholders identified that the cost to accessing commercial data for emergency management purposes (e.g. from the Bureau) was a barrier. Types of data include radar rainfall and gridded rainfall (such as ADFD and NowCast). There is a preference that data for emergency management purposes be supplied free of charge.
- LVRC identified that the Laidley showground gauge, which is managed by Seqwater, has not been checked since the 1980s and may be out by as much as 3m. The Bureau issues forecasts for this gauge, but they don't correlate with LVRC's WaterRide derived information. [Note: the Laidley showground gauge is beyond the extent of the hydraulic model].
- Glenore Grove was identified as a critical location for LVRC emergency response. At present, the site is not a Bureau forecast site, however council has requested that it become one. [Note: Glenore Grove is beyond the hydraulic model extent].

O.4.4 Resourcing

- Resources (staff) available to stakeholders varies significantly. Larger councils generally have sufficient resources, whereas smaller councils are quite stretched. For these smaller councils, adequate resourcing is seen to be a greater issue than availability of data or information.
- Limits on resources mean that disaster management efforts need to be very targeted and focused; further increasing reliance on good quality and detailed flood intelligence.
- Real-time information, easily shared between stakeholders means that councils can focus their attention on community safety, rather than responding to information requests.
- Accessing disaster management centres can be challenging during a flood event (due to road closures), hence ability to access information from home is desirable.
- Although there is a general desire to coordinate more broadly across the catchment, there is a reluctance to rely on other stakeholders for active provision of information or support during an event. If a flood is occurring, the established provider of information or support may not be able to allocate resources to support other stakeholders.
- If real-time models were considered for the region, will also need to consider who manages the model, who runs it, interprets the results etc. May require a trained hydrologist or similar specialist.

O.5 Additional Comments

O.5.1 General Approach

- It was identified by stakeholders that current systems (including forecasting systems) are already in place in some council areas, and that these systems may be more detailed than information which may be delivered through a regional-scale study.
- Stakeholders are generally looking for support to supplement existing systems, rather than replace them.
- Stakeholders support the pure floodplain management approach of considering all flood event sizes up to the PMF. It was recognised that flood forecasters and emergency management

professionals need to look beyond historical events and plan for the worst (e.g. PMF, dam break etc.

- The flood gauge classification review process is recognised as being quite complex. Councils are seeking to engage further with the Bureau on the topic and are keen to receive available guidance on the topic.

O.5.2 Personal Liability Protection

- Comment was received from one stakeholder regarding the need to ensure personal liability protection in the emergency management space. The comment noted that “it doesn’t matter what legislation or corporate support is in place, we are personally liable for our actions under the Professional Engineers Act (QLD). When a disaster is not declared, we are even more exposed without having the Disaster Management Act clauses to give some sort of support. If we make a mistake, and somebody dies, we are potentially personally liable, not the organisation. Training and the like does not remove this issue. Removing or lessening this personal risk may assist in parties become more active in providing crucial data in flood events (or at least trying to).” [Note: this issue wasn’t directly addressed with other stakeholders; the view may be widespread].

O.5.3 Infrastructure Design

- There is a broad interest in establishing a standard of service for road infrastructure which form evacuation routes.
- Although structures may be designed for inundation immunity, there is support for development of a prioritisation process which considers which roads are part of evacuation routes and potentially provides higher immunity.

O.5.4 Post-Flood Data Collection

- There is a general desire for coordinated post-flood data collection, then a shared resource of data post-event.
- There is also interest in coordinating submissions for NDRRA claims, with the view that a riverine flood affects multiple councils, but it’s all the same flood.
- There is particular interest in collection of aerial photographs of flood extents during events, with a need to plan for these collections in advance of floods.
- Many flood marks were lost from the 2011 floods due to over-vigorous ‘mud army’ volunteers cleaning marks before they were recorded. Future messaging should address this issue.

O.6 Intersection with Other Work Packages

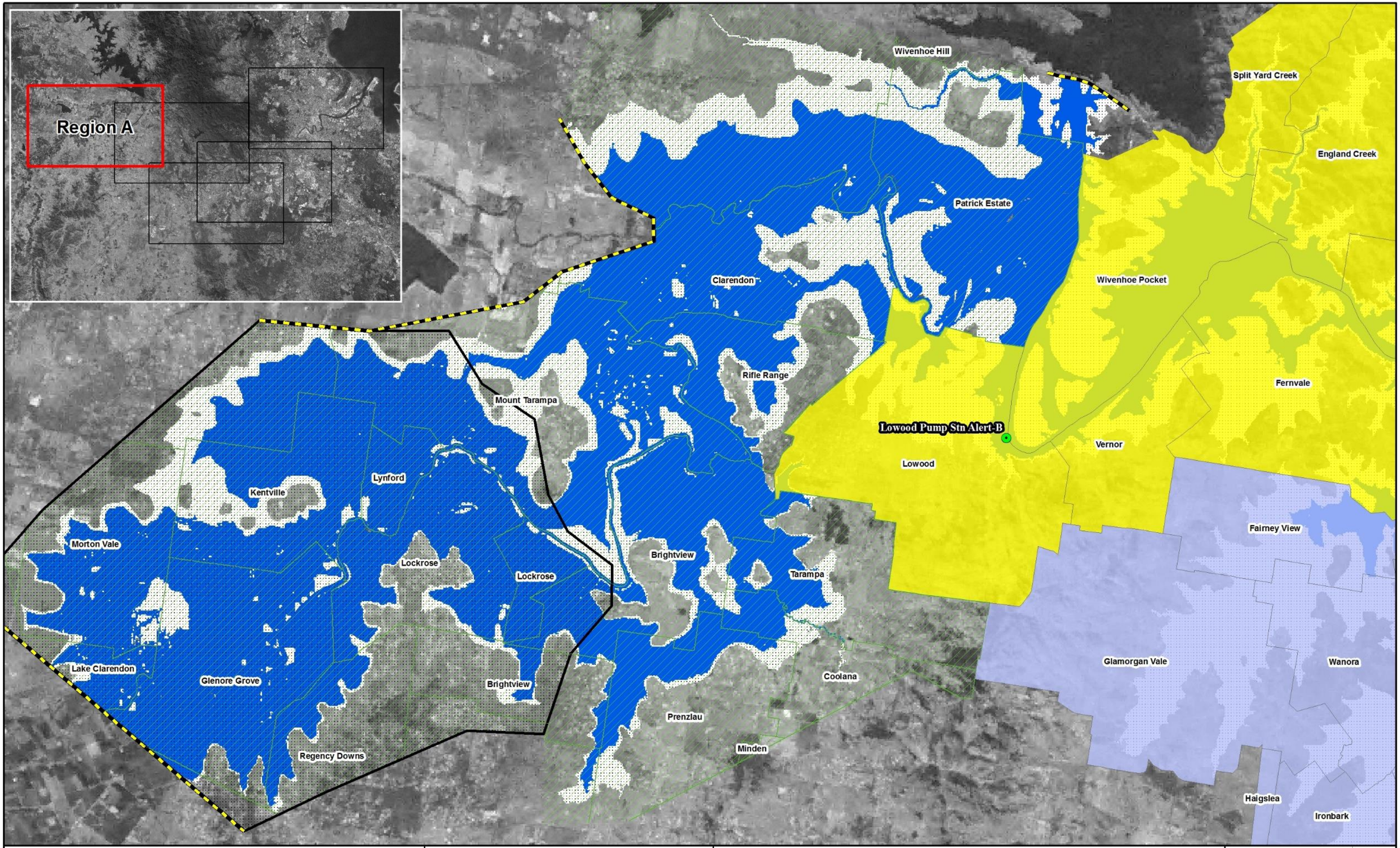
O.6.1 Community Resilience and Awareness

- In addition to the flood intelligence requirements identified for stakeholders, it was recognised that much of the same information needs to be conveyed to the community. A region-wide web-site is one option that was identified to meet this need.

- Some stakeholders are currently or will soon go through the stream gauge classification review process. There is concern about the communication of new classifications to the community and the potential for confusion. [Note: it is understood that the QRA will soon commence a study on this topic].
- There is a need for community education around what particular gauge heights mean.
- It was suggested that power poles can be used as default gauge height references.
- Language used in alerts or other community communication needs to assist with managing public understanding, e.g. height of stairs, knee deep in backyard etc.
- One stakeholder noted that an increase of flooding by 2m has sometimes been misunderstood by public to be 2 metres in the horizontal (not vertical). Recommendations regarding language and messaging should consider these kinds of common misinterpretations.

ICC shared details of their pre-event planning process, including the development of isolated communities reports, community profiling etc. In the lead-up to events, ICC identifies the numbers of properties likely to be impacted, sets up evacuation timelines, and the SES undertakes targeted door knocking. This door knocking provides a letter to residents warning them of potential flooding and advises residents to sign-up to council's alert tool. The process is focused particularly on low socio-economic areas, where there tends to be high resident turnover. [Note: pre-event planning was not discussed with other councils during stakeholder consultation, however it is understood that all councils undertake pre-event planning].

Appendix P Stream Gauge Reference Areas



LEGEND

- Forecast Stream Gauges
- 1 in 100 AEP Extent
- 1 in 100,000 AEP Flood Extent
- Limit of Detailed Modelling
- Flooding in hatched area needs to be verified with the Local Council

Influence Zones of Flood Forecast Gauges

- Brisbane City
- Centenary Bridge
- Ipswich Alert
- Ipswich Upstream
- Lowood Pump Stn Alert-B
- Moggill Alert
- Mt Crosby AL
- Forecast Gauge Outside Model Boundary

*Refer to Councils for local flooding beyond limit

Brisbane River Catchment Flood Study

Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Zones of Influence to Forecast Gauge Location - Region A

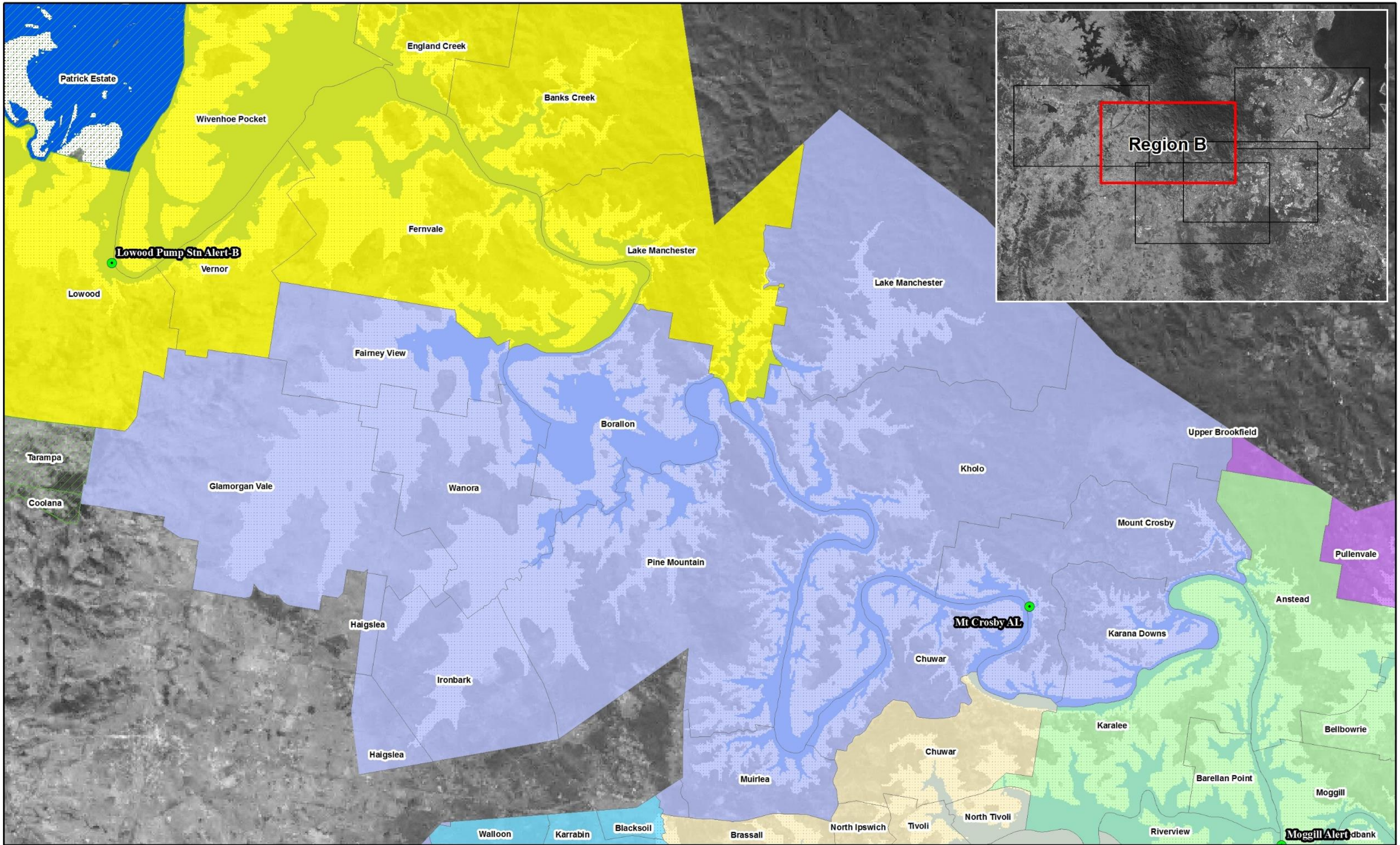
0 1 2 3 4
Kilometers

Map Grid of Australia 1994, Zone 56

Filepath : B:\B22374 BRCFMS\GIS\MXD\Forecast Gauges\FLD_001_Zones of Influence to Forecast Gauge Locations_RegionA.mxd

Fig P-1 | **A**

BMT
www.bmt.org



LEGEND

- Forecast Stream Gauges
- 1 in 100 AEP Extent
- 1 in 100,000 AEP Flood Extent
- Limit of Detailed Modelling

Influence Zones of Flood Forecast Gauges

- Brisbane City
- Centenary Bridge
- Ipswich Alert
- Ipswich Upstream
- Forecast Gauge Outside Model Boundary
- Lowood Pump Stn Alert-B
- Moggill Alert
- Mt Crosby AL

Brisbane River Catchment Flood Study
Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Zones of Influence to Forecast Gauge Location - Region B

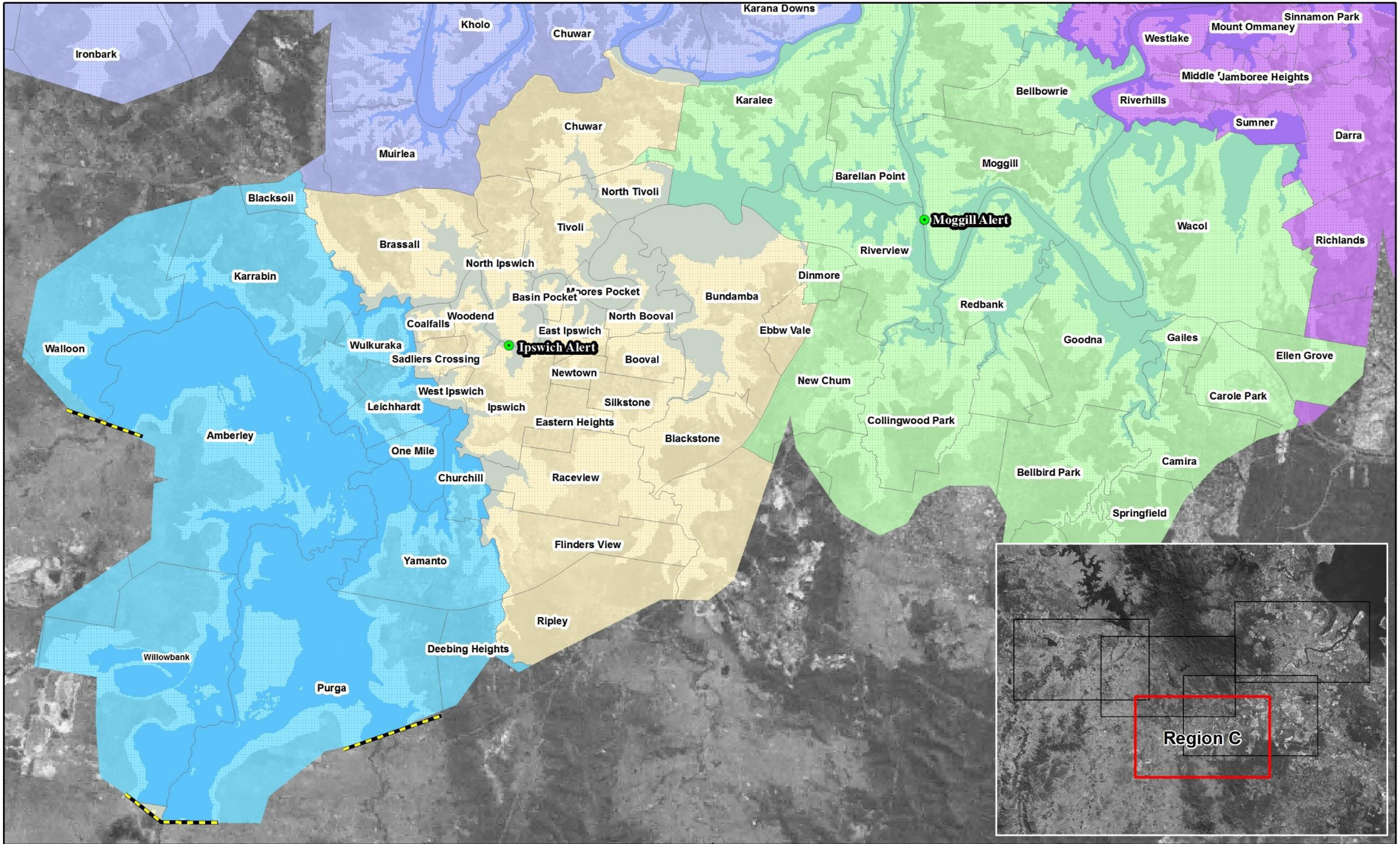
0 1 2 3 4
Kilometers

Map Grid of Australia 1994, Zone 56

Fig P-2 | A

BMT
www.bmt.org

Filepath : B:\B22374 BRCFMS\GIS\MXD\Forecast Gauges\FLD_002_Zones of Influence to Forecast Gauge Locations_RegionB .mxd



LEGEND

- Forecast Stream Gauges
- 1 in 100 AEP Extent
- 1 in 100,000 AEP Flood Extent
- Limit of Detailed Modelling

Influence Zones of Flood Forecast Gauges

- Brisbane City
- Centenary Bridge
- Ipswich Alert
- Ipswich Upstream
- Forecast Gauge Outside Model Boundary
- Lowood Pump Stn Alert-B
- Moggill Alert
- Mt Crosby AL

Brisbane River Catchment Flood Study
Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Zones of Influence to Forecast Gauge Location - Region C

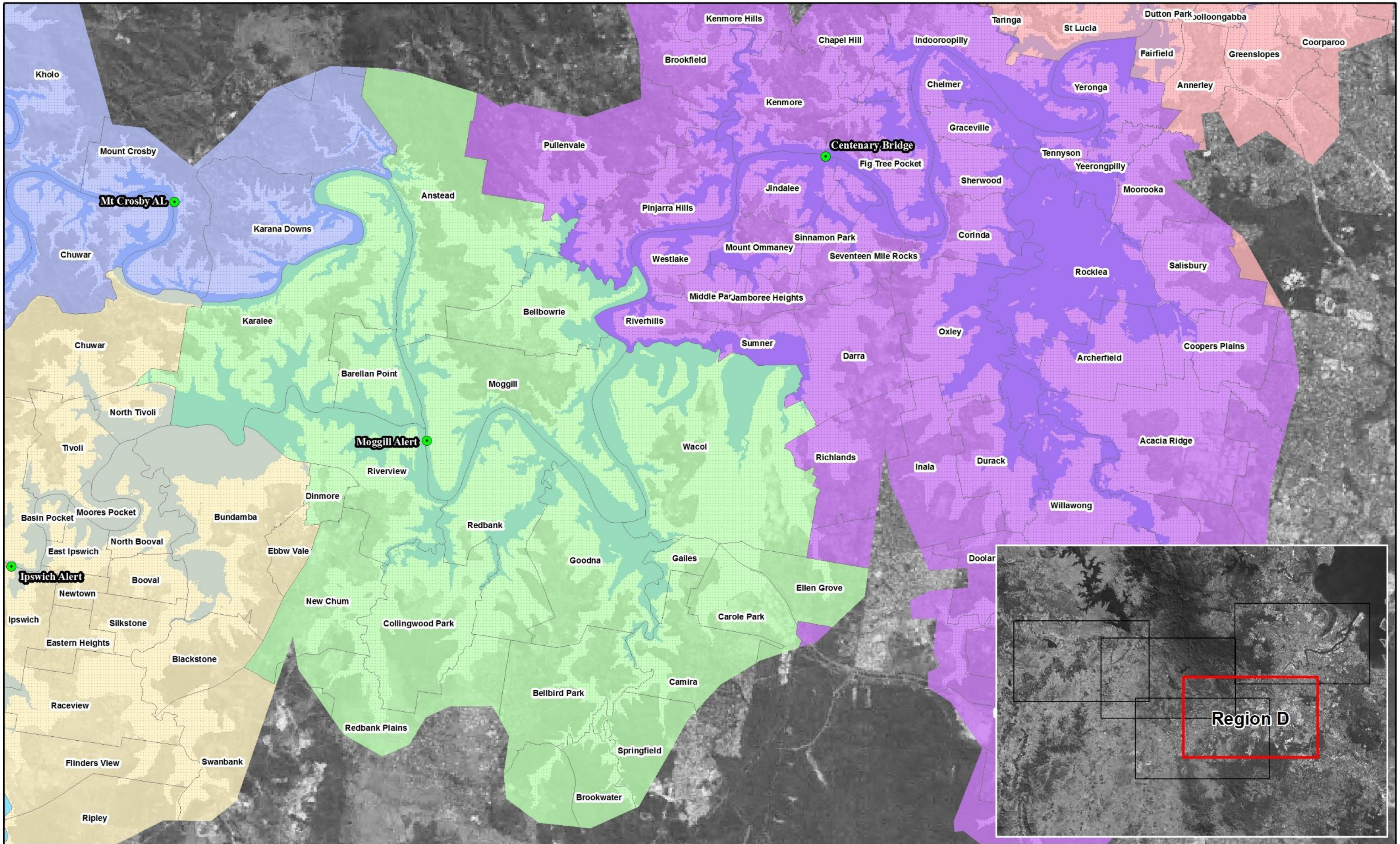
0 1 2 3 4
Kilometers

Map Grid of Australia 1994, Zone 56

Fig P-3 | A

www.bmt.org

Filepath : B:\B22374 BRCFMS\GIS\MXD\Forecast Gauges\FLD_003_Zones of Influence to Forecast Gauge Locations_RegionC .mxd



LEGEND

- Forecast Stream Gauges
- 1 in 100 AEP Extent
- 1 in 100,000 AEP Flood Extent
- Limit of Detailed Modelling

Influence Zones of Flood Forecast Gauges

- Brisbane City
- Centenary Bridge
- Ipswich Alert
- Ipswich Upstream
- Lowood Pump Stn Alert-B
- Moggill Alert
- Mt Crosby AL
- Forecast Gauge Outside Model Boundary

Brisbane River Catchment Flood Study
Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Zones of Influence to Forecast Gauge Location - Region D

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

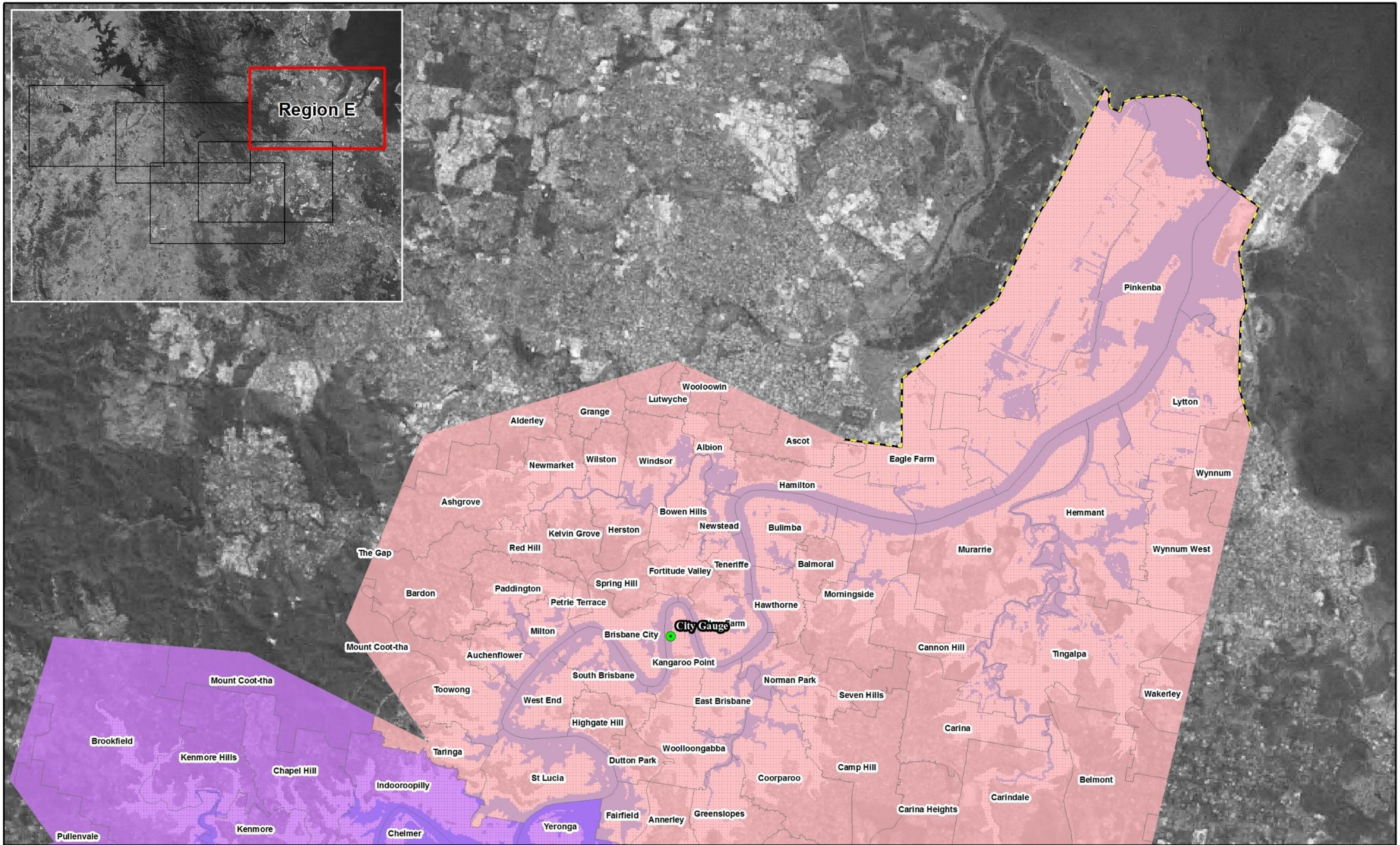
0 1 2 3 4
Kilometers

Map Grid of Australia 1994, Zone 56

Filepath : B:\B22374 BRCFMS\GIS\MXD\Forecast Gauges\FLD_004_Zones of Influence to Forecast Gauge Locations_RegionD .mxd

Fig P-4 | A

BMT
www.bmt.org



LEGEND

- Forecast Stream Gauges
- 1 in 100 AEP Extent
- 1 in 100,000 AEP Flood Extent
- Limit of Detailed Modelling

Influence Zones of Flood Forecast Gauges

- Brisbane City
- Centenary Bridge
- Ipswich Alert
- Ipswich Upstream
- Forecast Gauge Outside Model Boundary
- Lowood Pump Stn Alert-B
- Moggill Alert
- Mt Crosby AL

Brisbane River Catchment Flood Study
Study Partners

Queensland Government

Brisbane City Council
Ipswich City Council
Lockyer Valley Regional Council
Somerset Regional Council
Seqwater

Zones of Influence to Forecast Gauge Location - Region E

0 1 2 3 4
Kilometers

Map Grid of Australia 1994, Zone 56

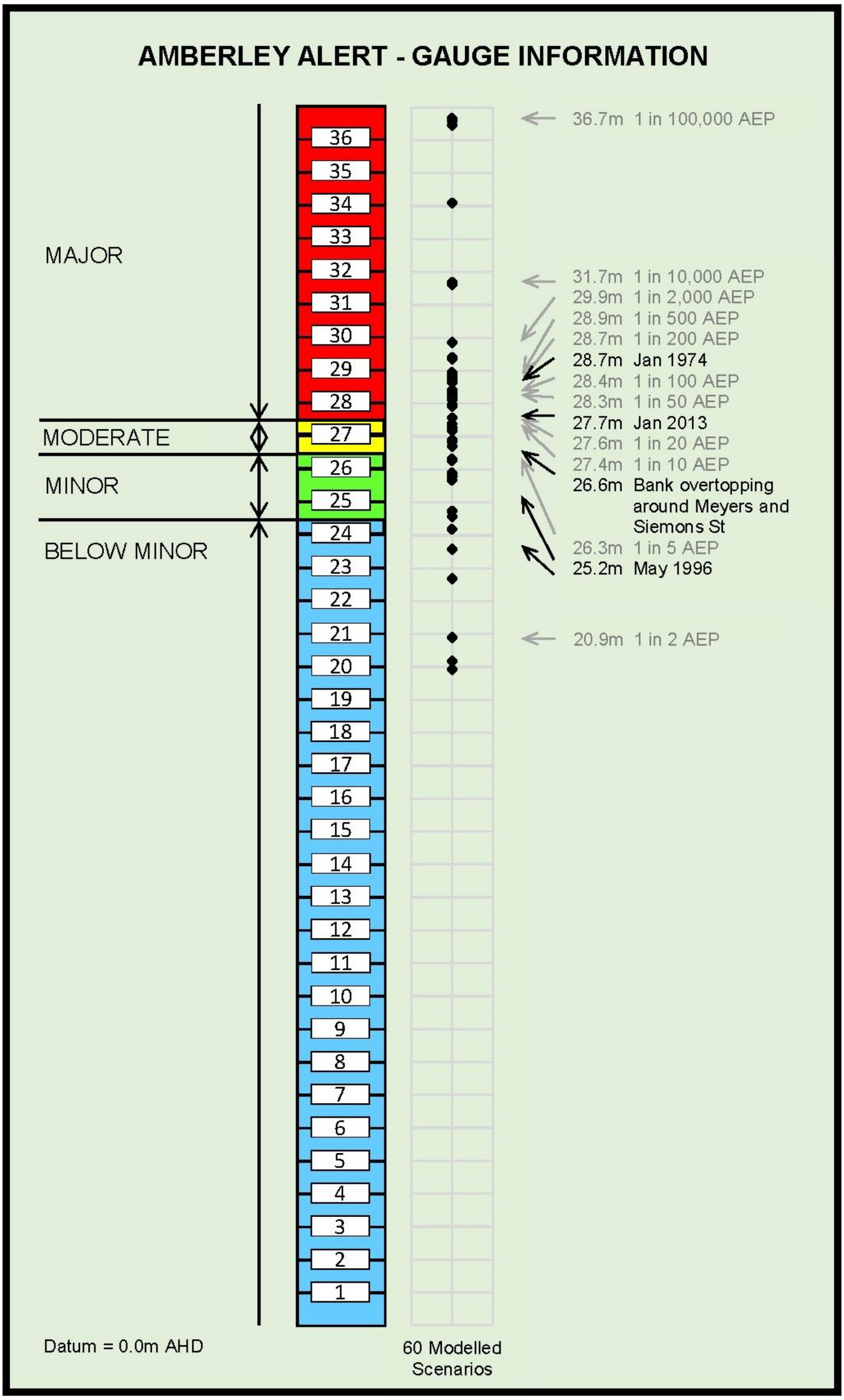
Fig P-5 | A

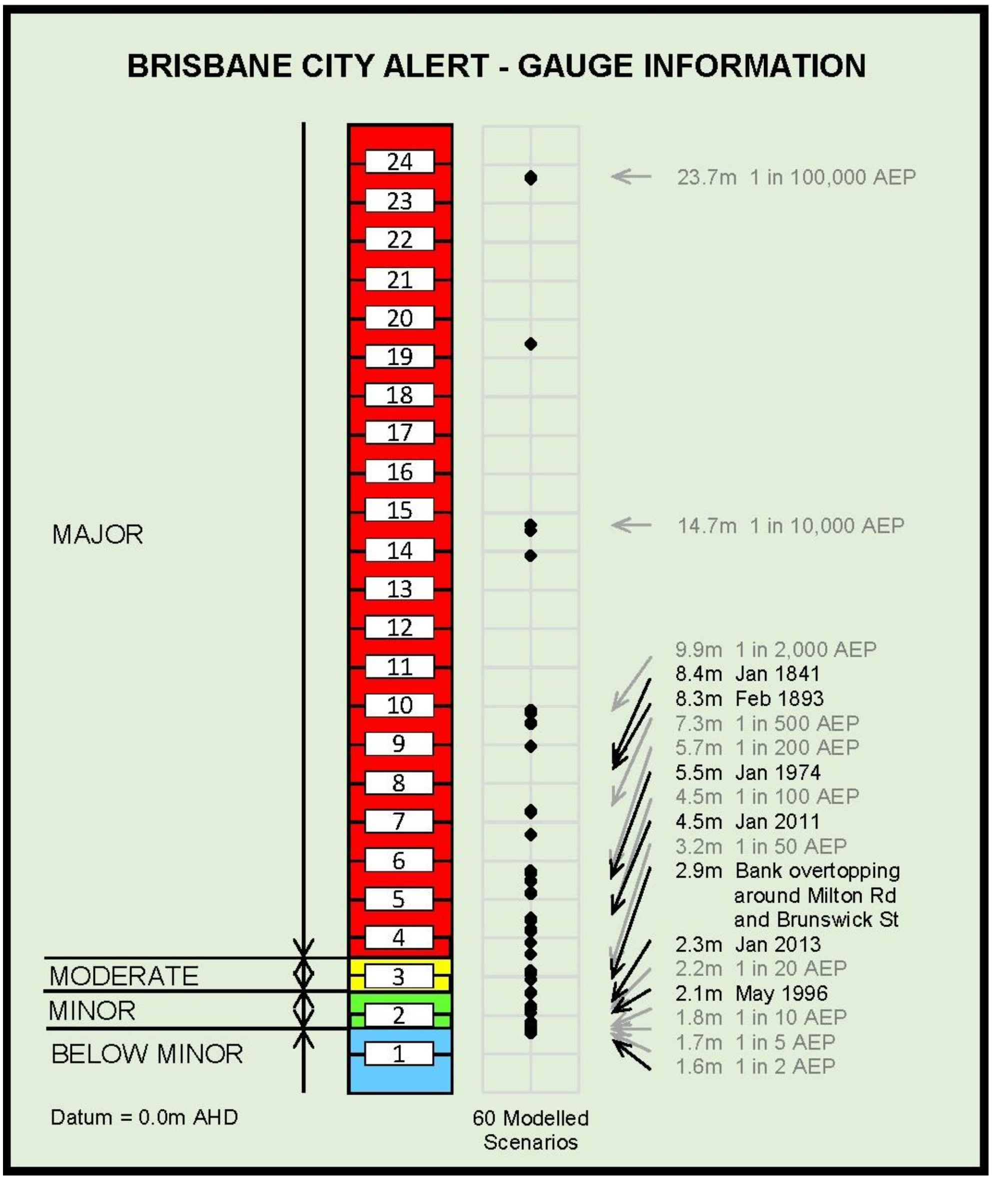
BMT
www.bmt.org

Filepath : B:\B22374 BRCFMS\GIS\MXD\Forecast Gauges\FLD_005_Zones of Influence to Forecast Gauge Locations_RegionE.mxd

Appendix Q Forecast Location Diagrams

Q.1 Australian Height Datum




BRISBANE CITY ALERT - GAUGE INFORMATION
24
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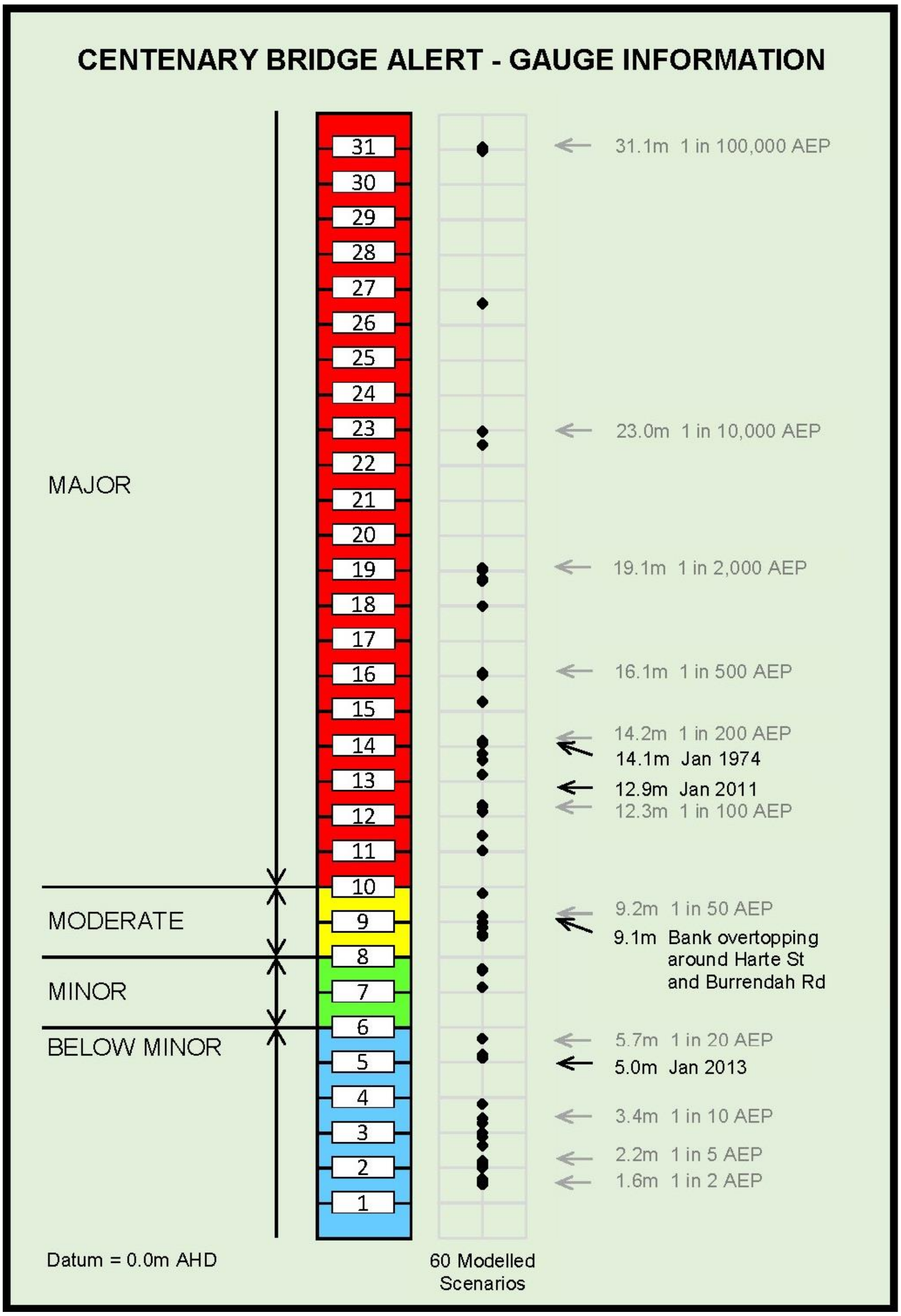
9
8
7
6
5
4
3
2
1
MAJOR
MODERATE
MINOR
BELOW MINOR
Datum = 0.0m AHD
60 Modelled Scenarios
23.7m 1 in 100,000 AEP
14.7m 1 in 10,000 AEP
9.9m 1 in 2,000 AEP
8.4m Jan 1841
8.3m Feb 1893
7.3m 1 in 500 AEP
5.7m 1 in 200 AEP
5.5m Jan 1974
4.5m 1 in 100 AEP
4.5m Jan 2011
3.2m 1 in 50 AEP
2.9m Bank overtopping around Milton Rd and Brunswick St
2.3m Jan 2013
2.2m 1 in 20 AEP
2.1m May 1996
1.8m 1 in 10 AEP
1.7m 1 in 5 AEP
1.6m 1 in 2 AEP


CENTENARY BRIDGE ALERT - GAUGE INFORMATION
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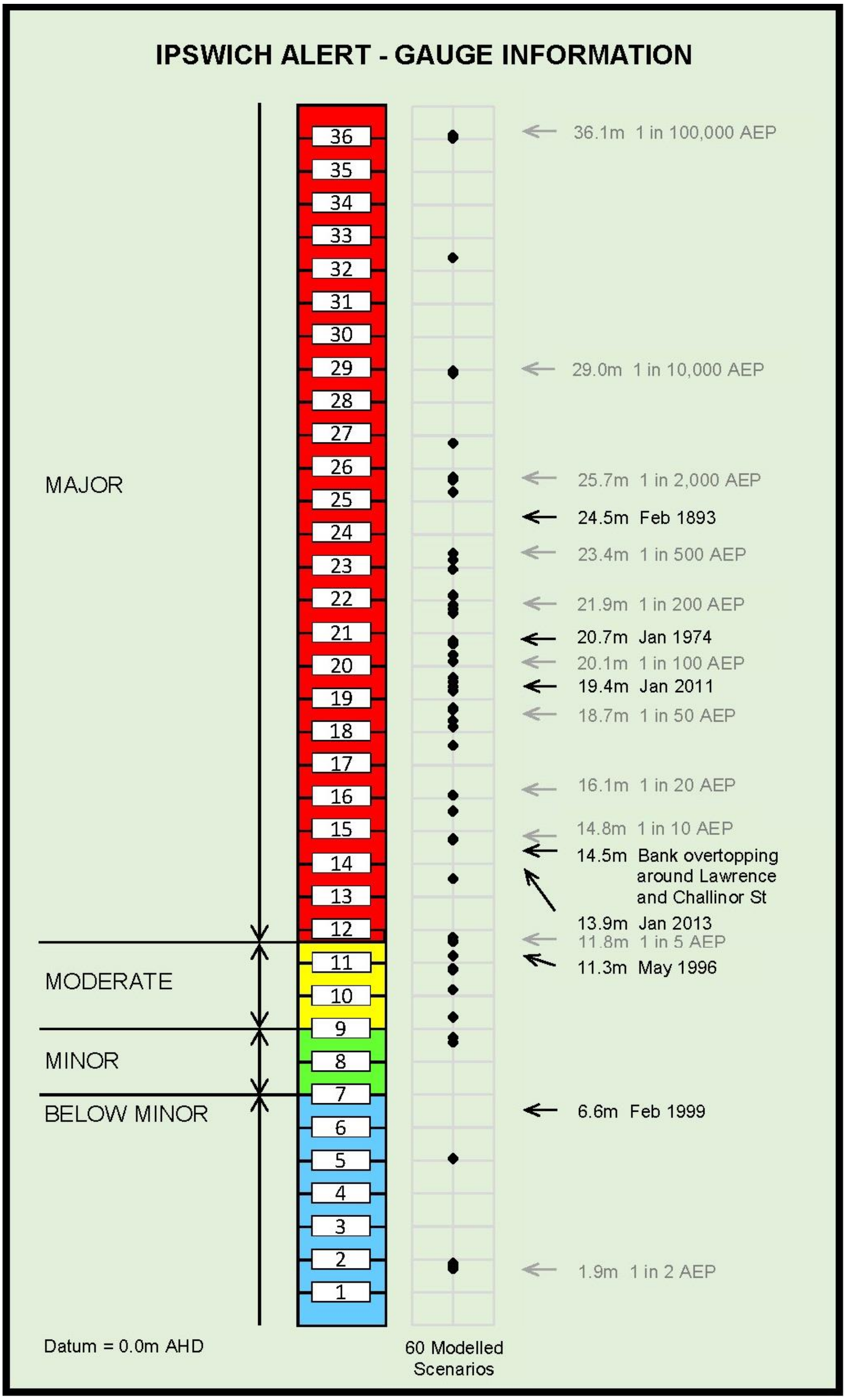
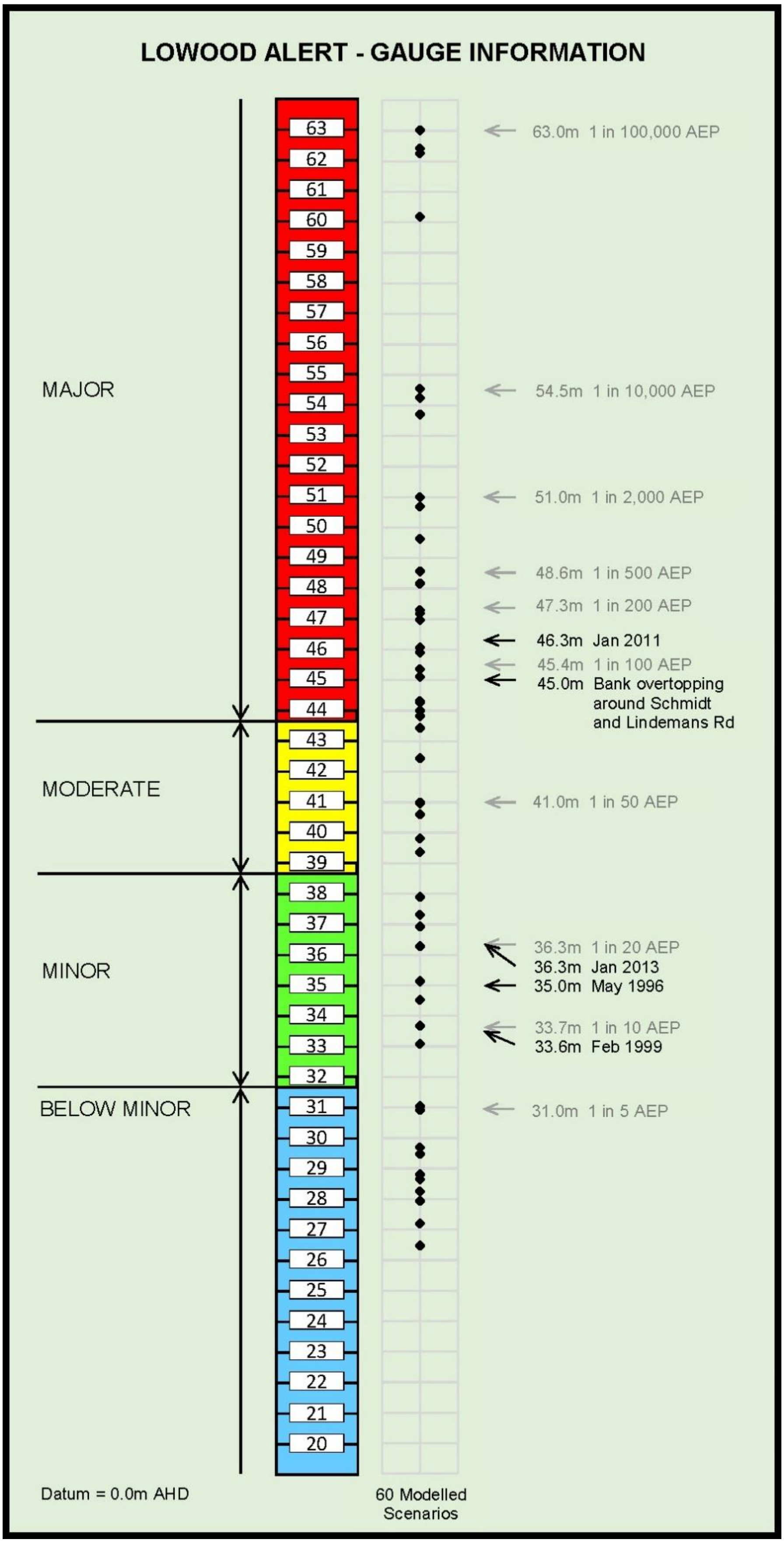
2
1
MAJOR
MODERATE
MINOR
BELOW MINOR
Datum = 0.0m AHD
60 Modelled Scenarios
31.1m 1 in 100,000 AEP
23.0m 1 in 10,000 AEP
19.1m 1 in 2,000 AEP
16.1m 1 in 500 AEP
14.2m 1 in 200 AEP
14.1m Jan 1974
12.9m Jan 2011
12.3m 1 in 100 AEP
9.2m 1 in 50 AEP
9.1m Bank overtopping around Harte St and Burrendah Rd
5.7m 1 in 20 AEP
5.0m Jan 2013
3.4m 1 in 10 AEP
2.2m 1 in 5 AEP
1.6m 1 in 2 AEP


IPSWICH ALERT - GAUGE INFORMATION
MAJOR
MODERATE
MINOR
BELOW MINOR
36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
36.1m 1 in 100,000 AEP
29.0m 1 in 10,000 AEP
25.7m 1 in 2,000 AEP
24.5m Feb 1893
23.4m 1 in 500 AEP
21.9m 1 in 200 AEP
20.7m Jan 1974
20.1m 1 in 100 AEP
19.4m Jan 2011
18.7m 1 in 50 AEP
16.1m 1 in 20 AEP
14.8m 1 in 10 AEP
14.5m Bank overtopping around Lawrence and Challinor St
13.9m Jan 2013
11.8m 1 in 5 AEP
11.3m May 1996
6.6m Feb 1999
1.9m 1 in 2 AEP
Datum = 0.0m AHD
60 Modelled Scenarios


LOWOOD ALERT - GAUGE INFORMATION
MAJOR
MODERATE
MINOR
BELOW MINOR
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22
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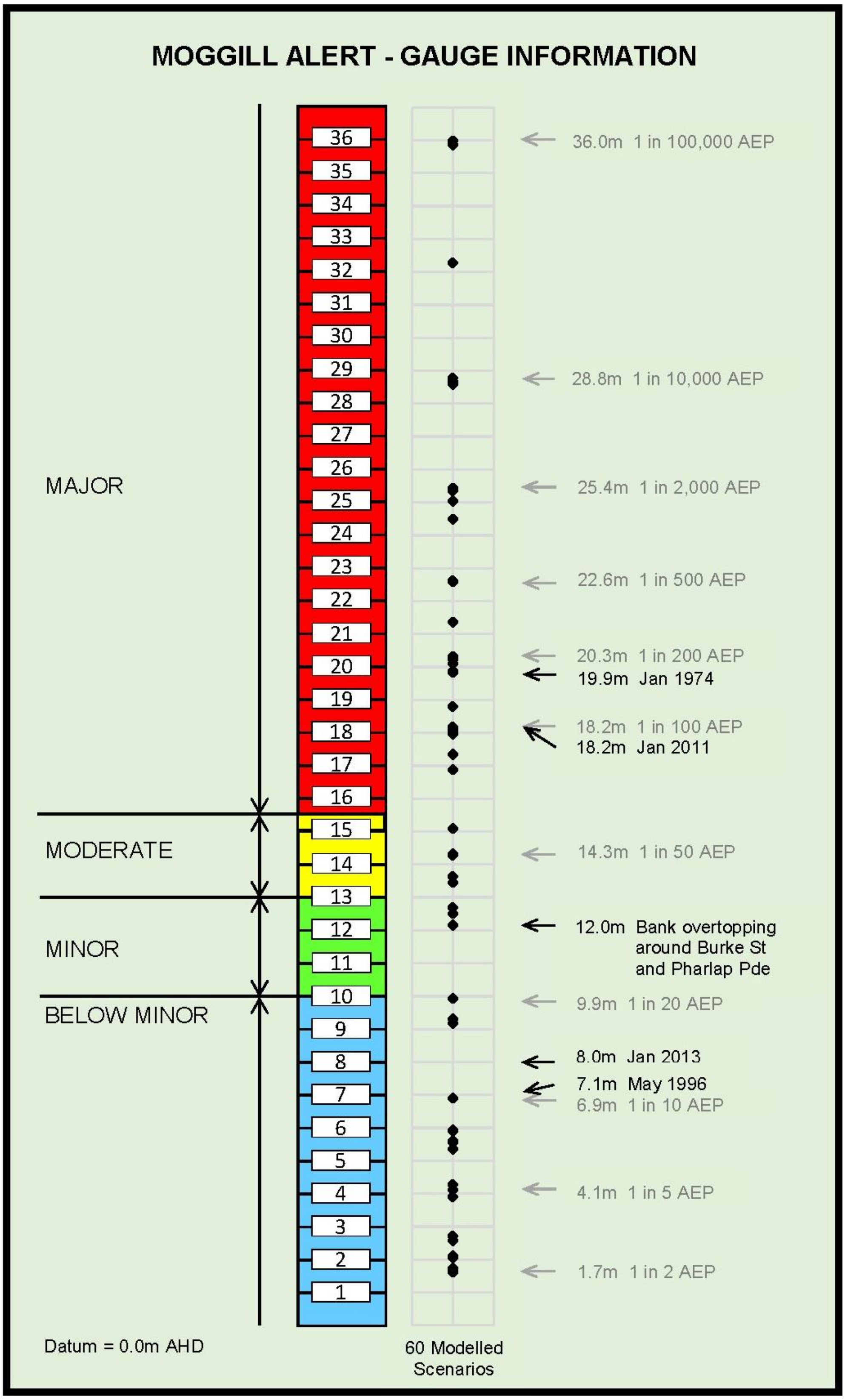
63.0m 1 in 100,000 AEP
54.5m 1 in 10,000 AEP
51.0m 1 in 2,000 AEP
48.6m 1 in 500 AEP
47.3m 1 in 200 AEP
46.3m Jan 2011
45.4m 1 in 100 AEP
45.0m Bank overtopping around Schmidt and Lindemans Rd
41.0m 1 in 50 AEP
36.3m 1 in 20 AEP
36.3m Jan 2013
35.0m May 1996
33.7m 1 in 10 AEP
33.6m Feb 1999
31.0m 1 in 5 AEP
Datum = 0.0m AHD
60 Modelled Scenarios


MOGGILL ALERT - GAUGE INFORMATION
MAJOR
MODERATE
MINOR
BELOW MINOR
36
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27
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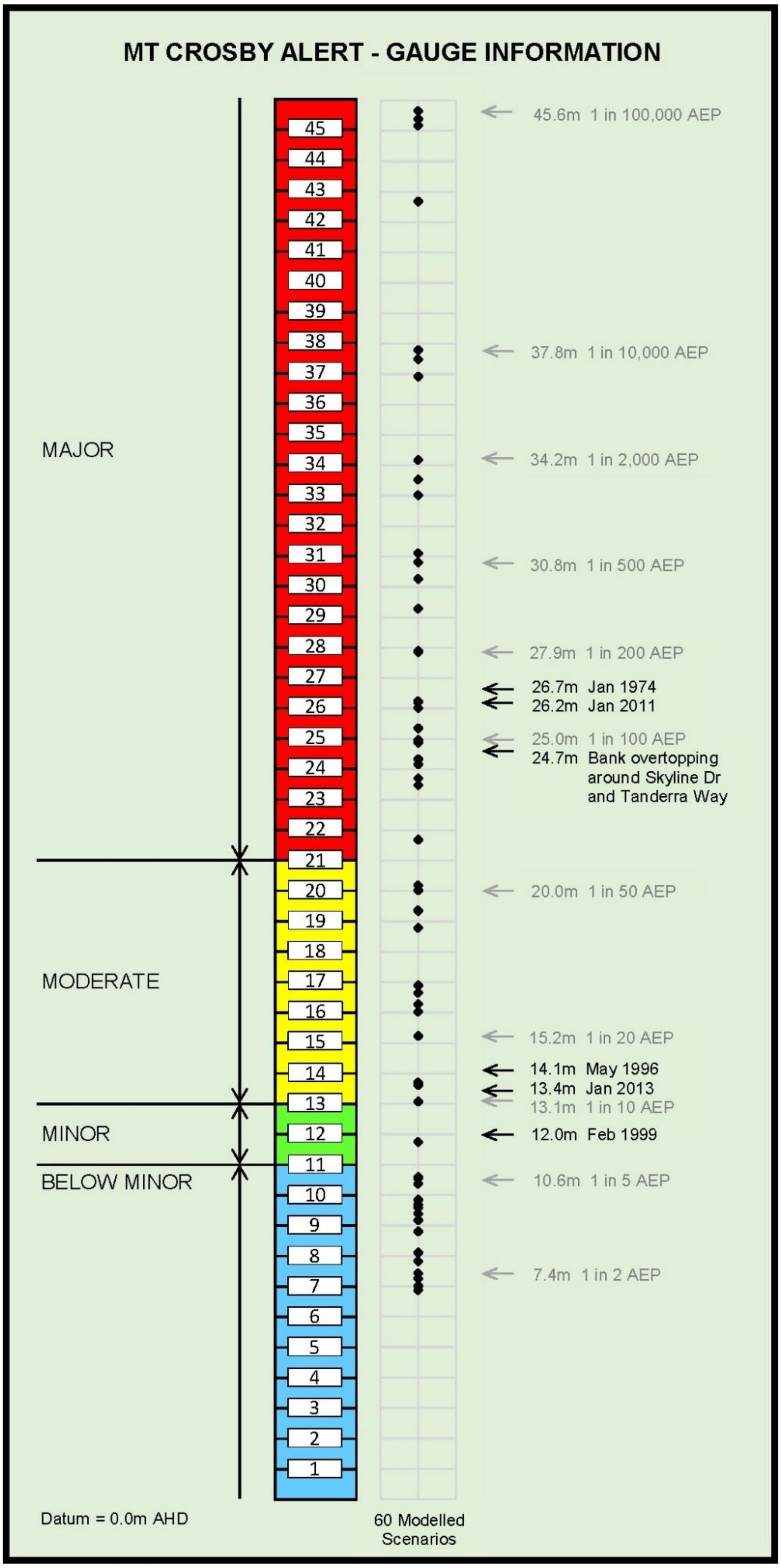
36.0m 1 in 100,000 AEP
28.8m 1 in 10,000 AEP
25.4m 1 in 2,000 AEP
22.6m 1 in 500 AEP
20.3m 1 in 200 AEP
19.9m Jan 1974
18.2m 1 in 100 AEP
18.2m Jan 2011
14.3m 1 in 50 AEP
12.0m Bank overtopping around Burke St and Pharlap Pde
9.9m 1 in 20 AEP
8.0m Jan 2013
7.1m May 1996
6.9m 1 in 10 AEP
4.1m 1 in 5 AEP
1.7m 1 in 2 AEP
Datum = 0.0m AHD
60 Modelled Scenarios


MT CROSBY ALERT - GAUGE INFORMATION
MAJOR
MODERATE
MINOR
BELOW MINOR
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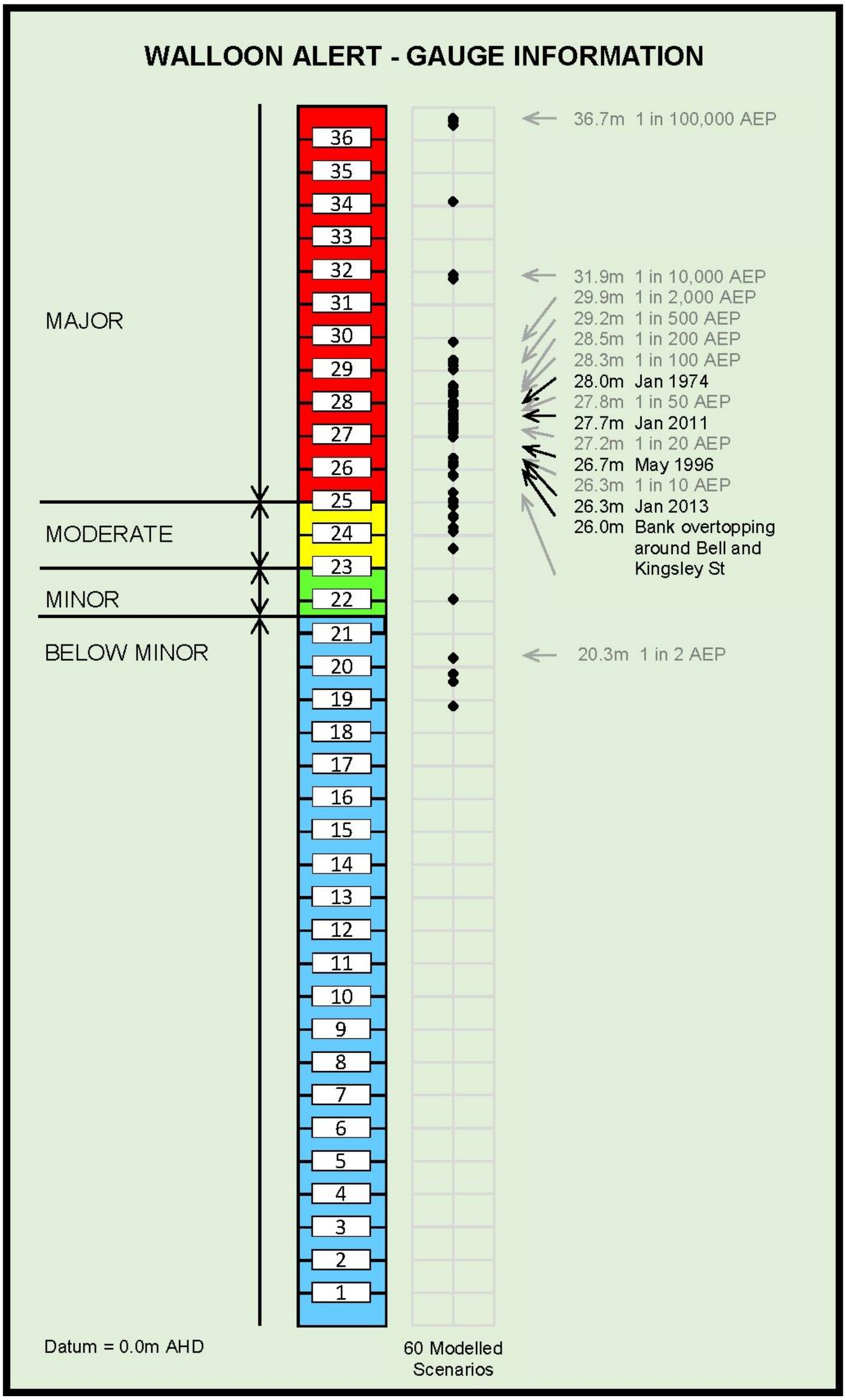
45.6m 1 in 100,000 AEP
37.8m 1 in 10,000 AEP
34.2m 1 in 2,000 AEP
30.8m 1 in 500 AEP
27.9m 1 in 200 AEP
26.7m Jan 1974
26.2m Jan 2011
25.0m 1 in 100 AEP
24.7m Bank overtopping around Skyline Dr and Tanderra Way
20.0m 1 in 50 AEP
15.2m 1 in 20 AEP
14.1m May 1996
13.4m Jan 2013
13.1m 1 in 10 AEP
12.0m Feb 1999
10.6m 1 in 5 AEP
7.4m 1 in 2 AEP
Datum = 0.0m AHD
60 Modelled Scenarios


WALLOON ALERT - GAUGE INFORMATION
MAJOR
MODERATE
MINOR
BELOW MINOR
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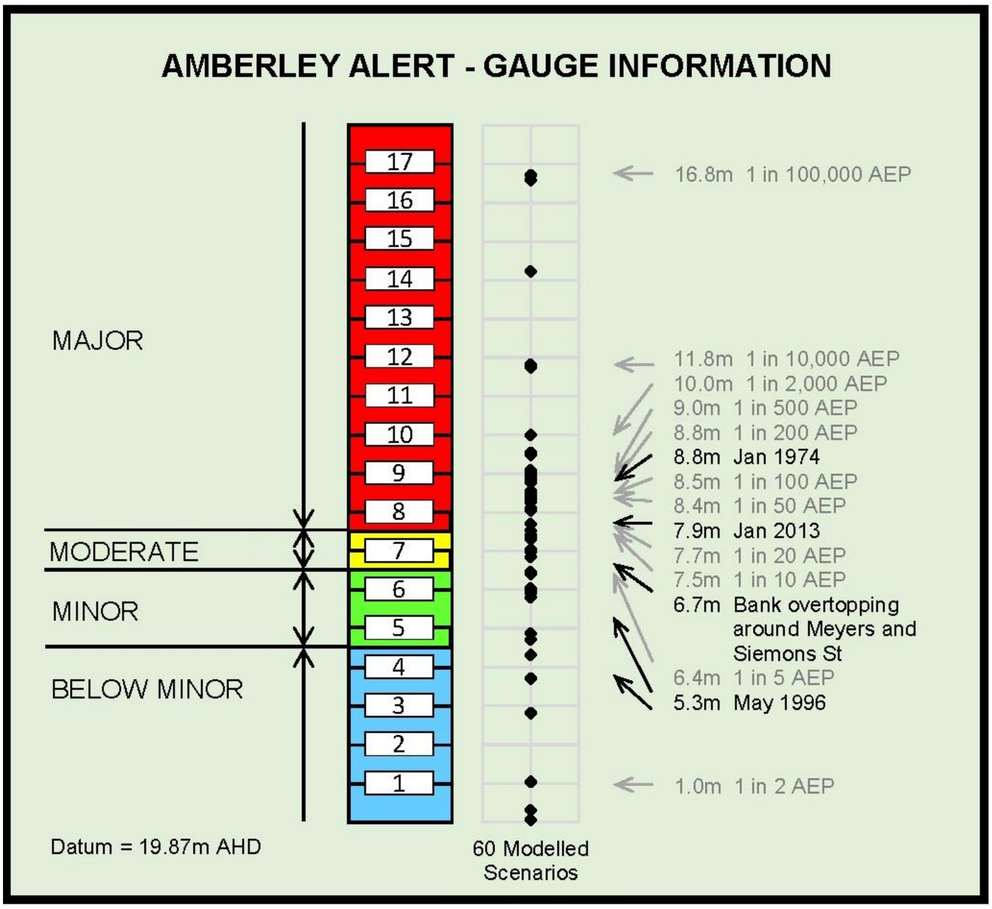
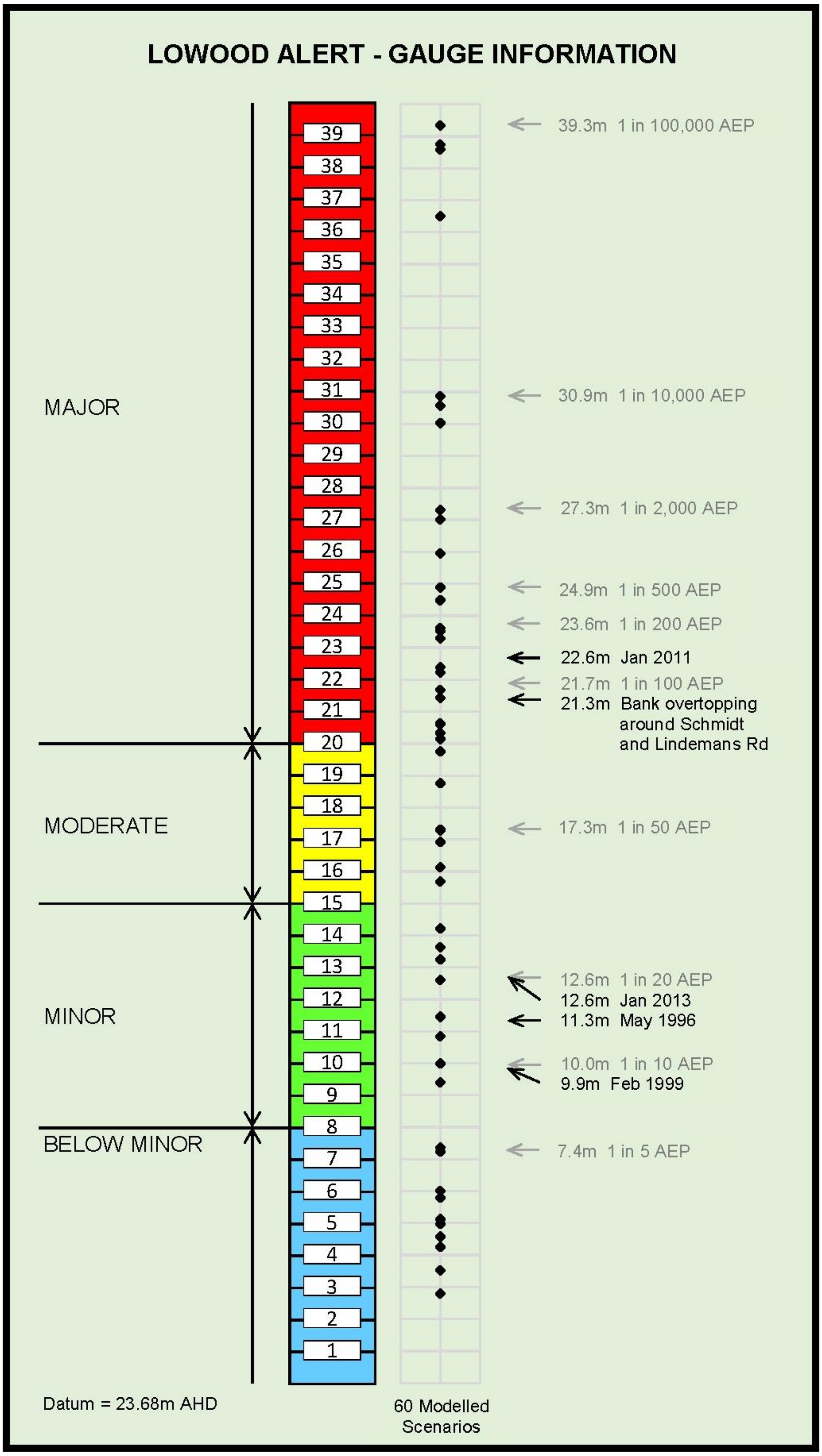
36.7m 1 in 100,000 AEP
31.9m 1 in 10,000 AEP
29.9m 1 in 2,000 AEP
29.2m 1 in 500 AEP
28.5m 1 in 200 AEP
28.3m 1 in 100 AEP
28.0m Jan 1974
27.8m 1 in 50 AEP
27.7m Jan 2011
27.2m 1 in 20 AEP
26.7m May 1996
26.3m 1 in 10 AEP
26.3m Jan 2013
26.0m Bank overtopping around Bell and Kingsley St
20.3m 1 in 2 AEP
Datum = 0.0m AHD
60 Modelled Scenarios

Q.2 Local Gauge Datum




LOWOOD ALERT - GAUGE INFORMATION
39
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37
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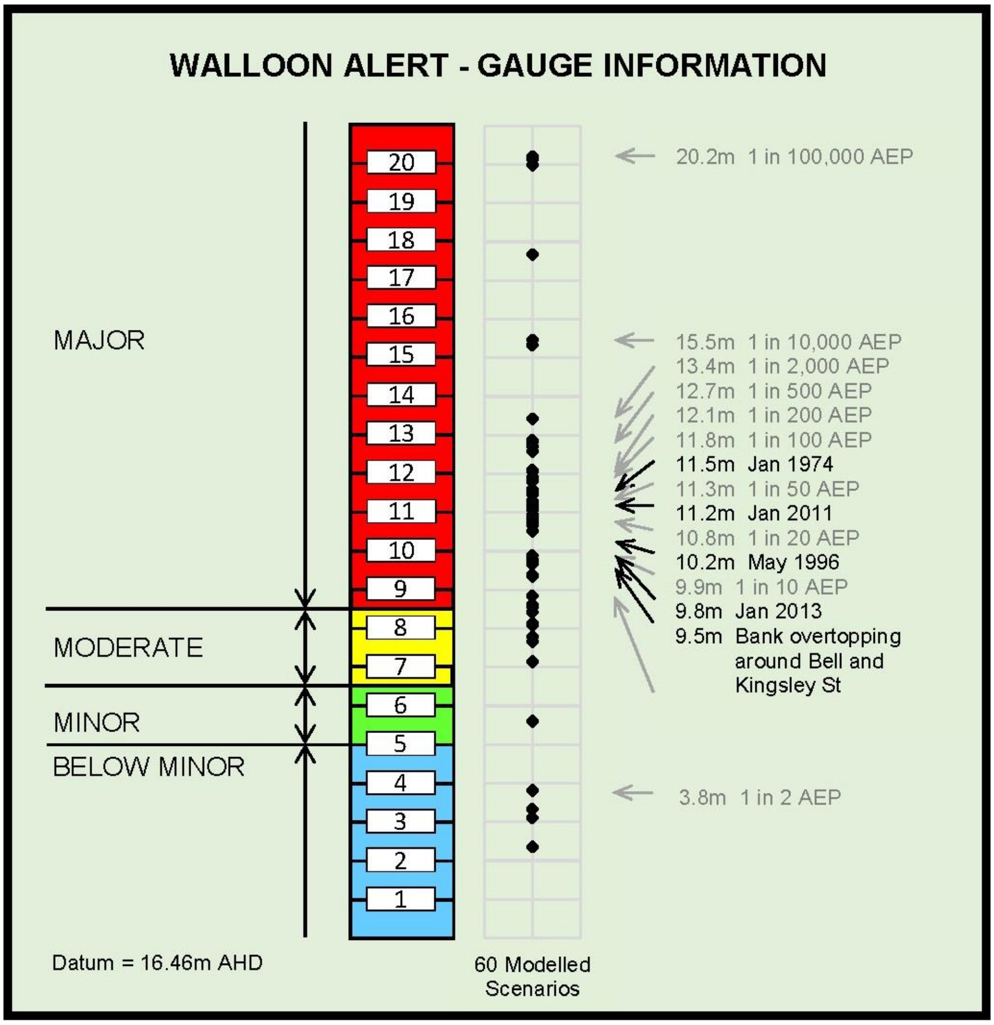
1
MAJOR
MODERATE
MINOR
BELOW MINOR
39.3m 1 in 100,000 AEP
30.9m 1 in 10,000 AEP
27.3m 1 in 2,000 AEP
24.9m 1 in 500 AEP
23.6m 1 in 200 AEP
22.6m Jan 2011
21.7m 1 in 100 AEP
21.3m Bank overtopping around Schmidt and Lindemans Rd
17.3m 1 in 50 AEP
12.6m 1 in 20 AEP
12.6m Jan 2013
11.3m May 1996
10.0m 1 in 10 AEP
9.9m Feb 1999
7.4m 1 in 5 AEP
Datum = 23.68m AHD
60 Modelled Scenarios


WALLOON ALERT - GAUGE INFORMATION
20
19
18
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16
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4
3
2
1
MAJOR
MODERATE
MINOR
BELOW MINOR
20.2m 1 in 100,000 AEP
15.5m 1 in 10,000 AEP
13.4m 1 in 2,000 AEP
12.7m 1 in 500 AEP
12.1m 1 in 200 AEP
11.8m 1 in 100 AEP
11.5m Jan 1974
11.3m 1 in 50 AEP
11.2m Jan 2011
10.8m 1 in 20 AEP
10.2m May 1996
9.9m 1 in 10 AEP
9.8m Jan 2013
9.5m Bank overtopping around Bell and Kingsley St
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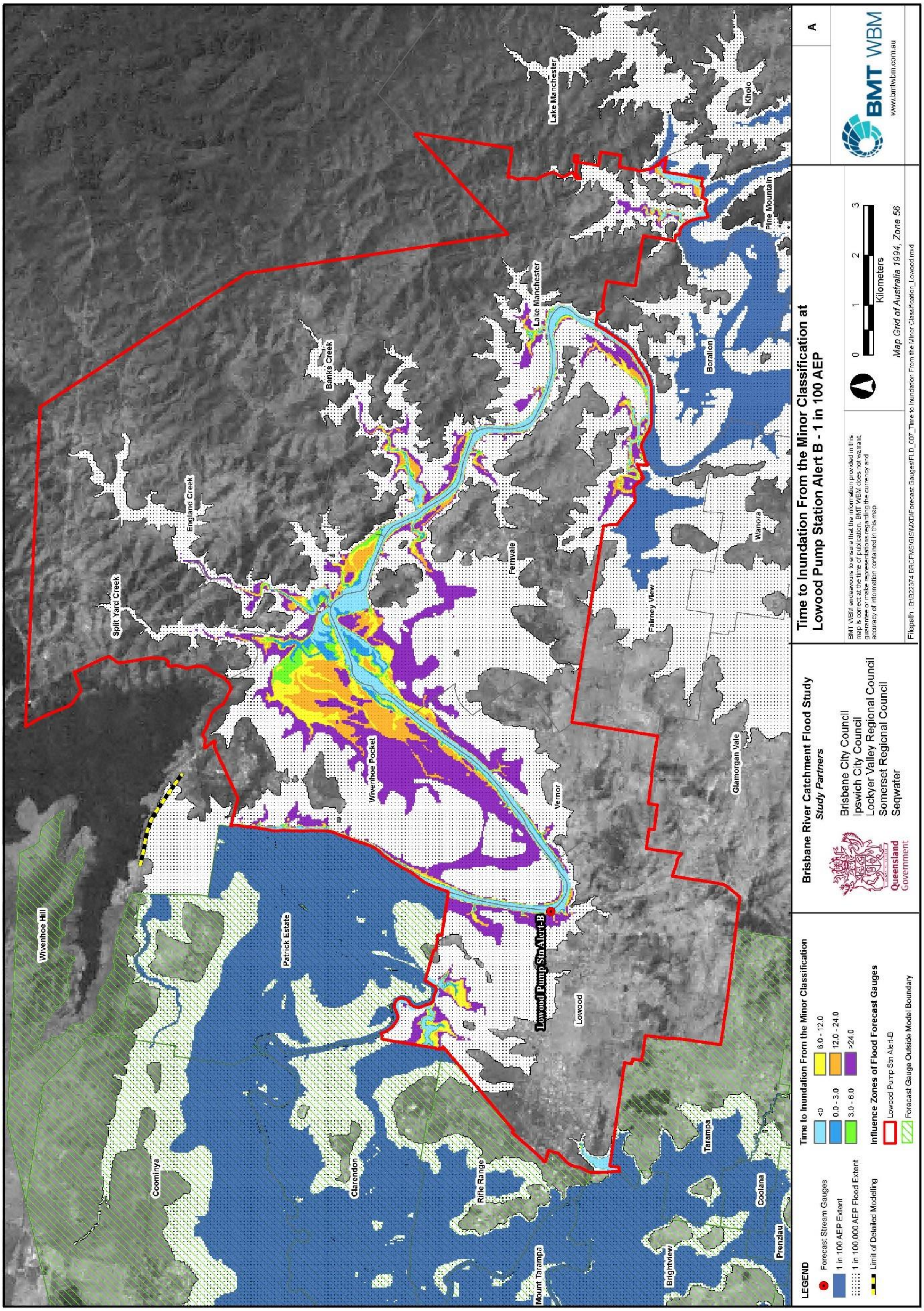
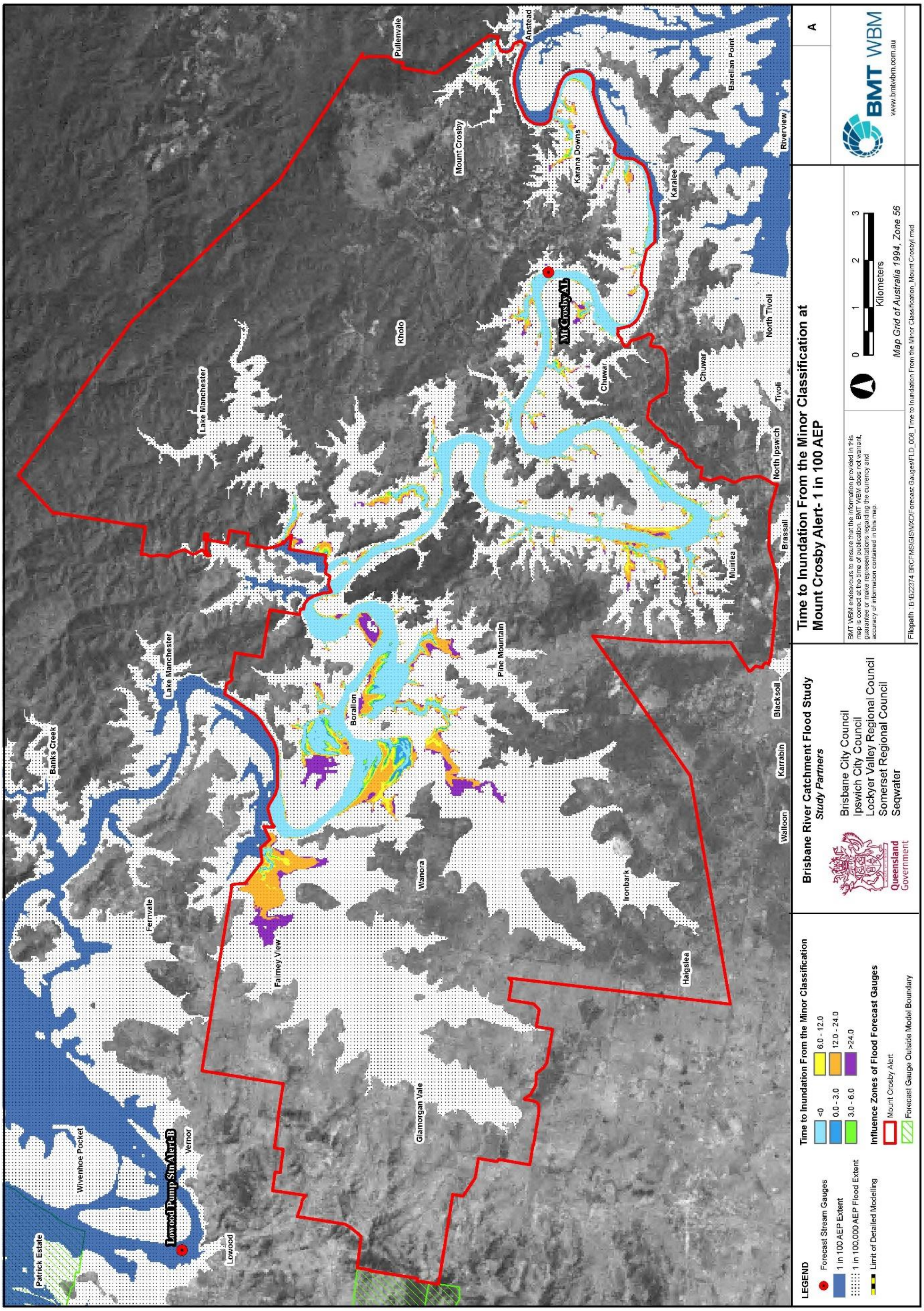
60 Modelled Scenarios

Appendix R Time to Inundation Maps, 1 in 100 AEP

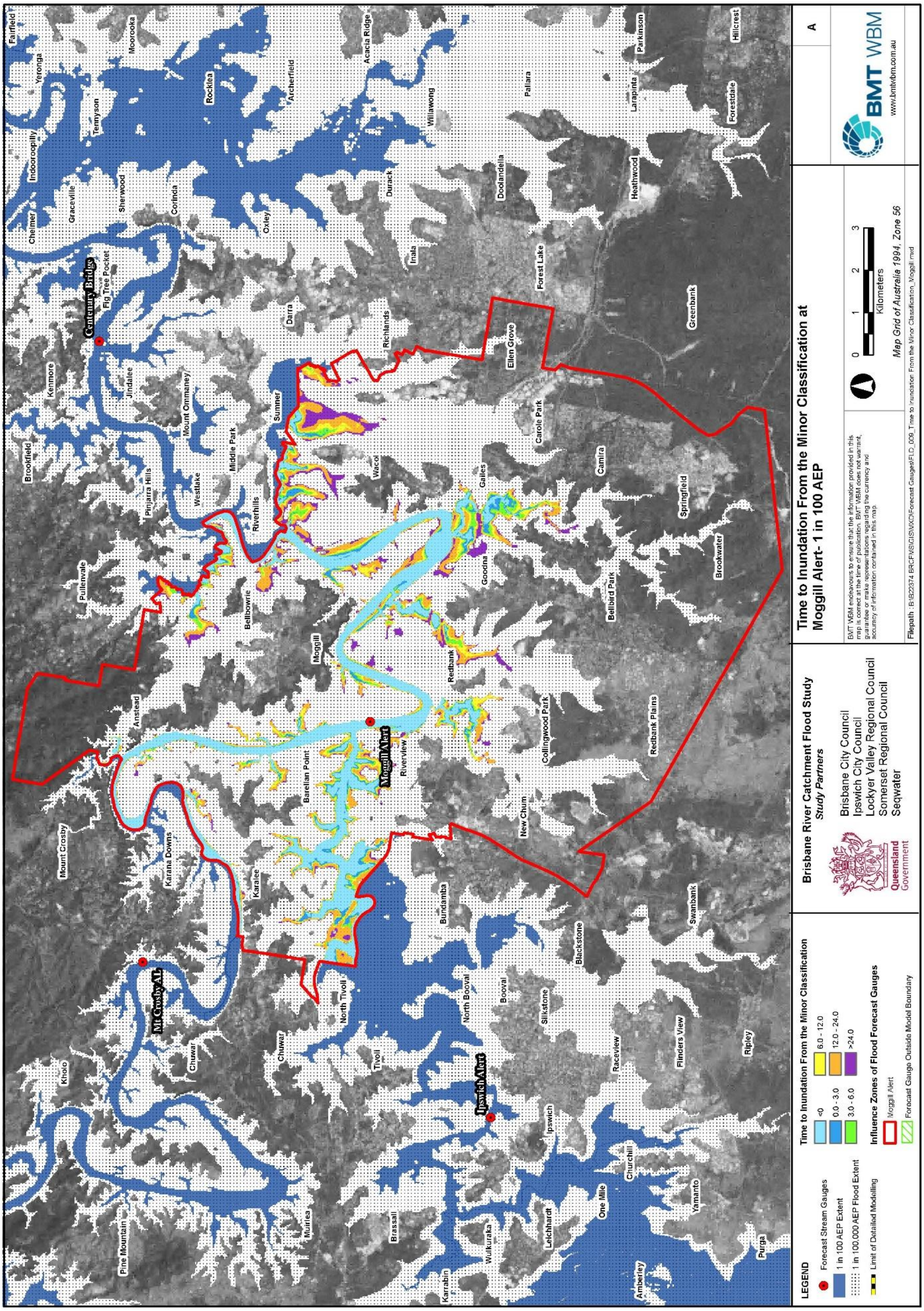
Time to Inundation Maps, 1 in 100 AEP



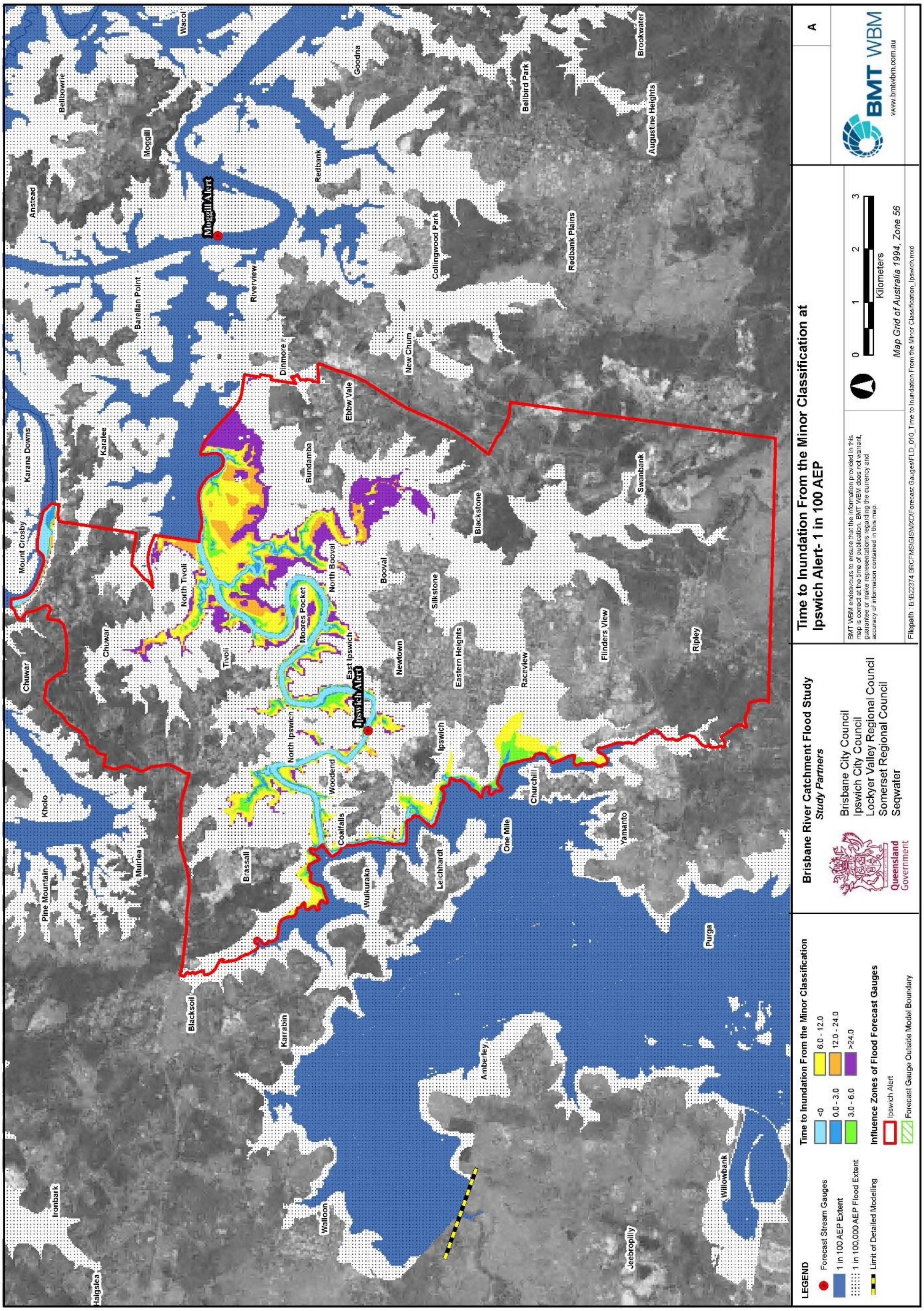
Time to Inundation Maps, 1 in 100 AEP



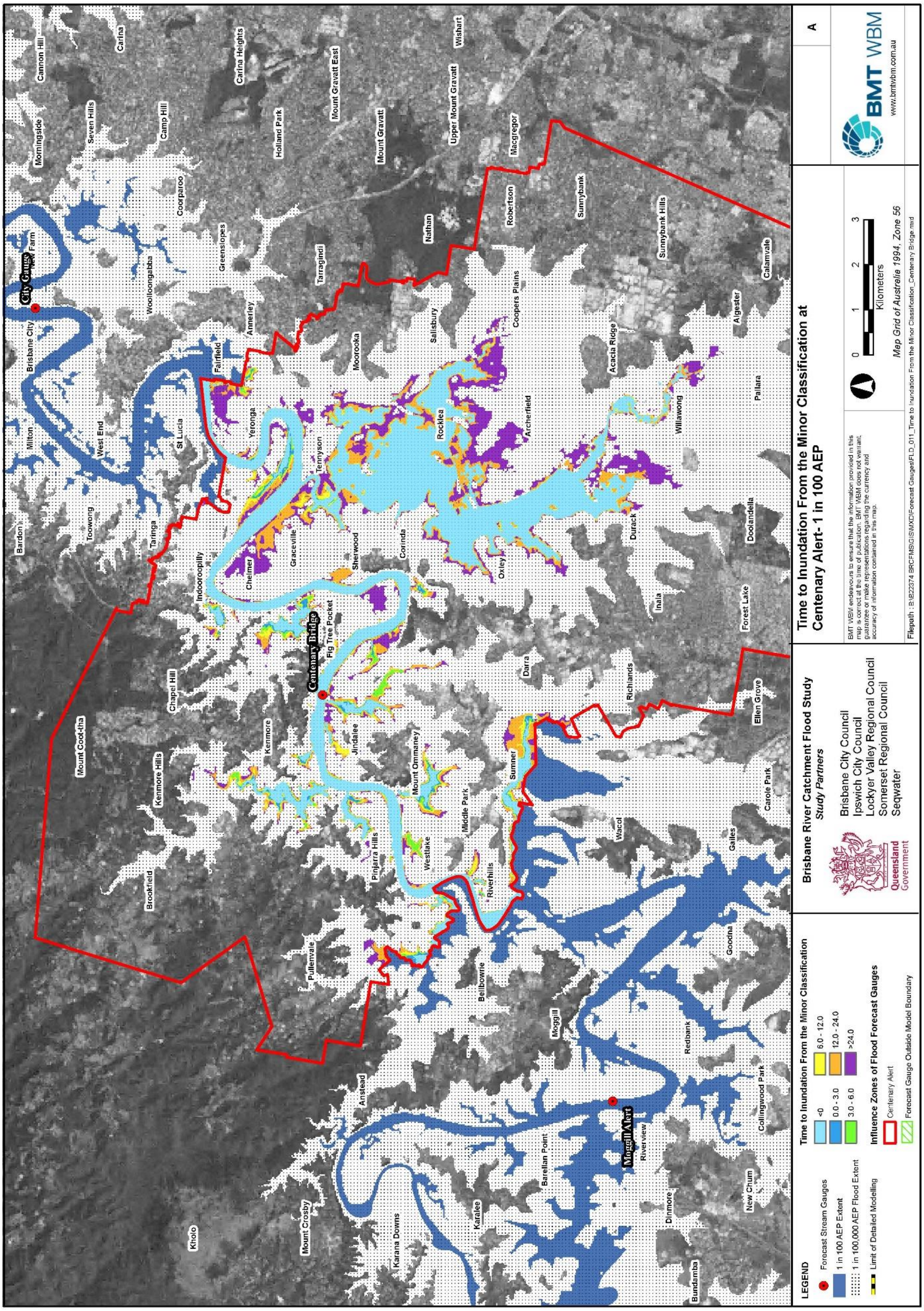
Time to Inundation Maps, 1 in 100 AEP



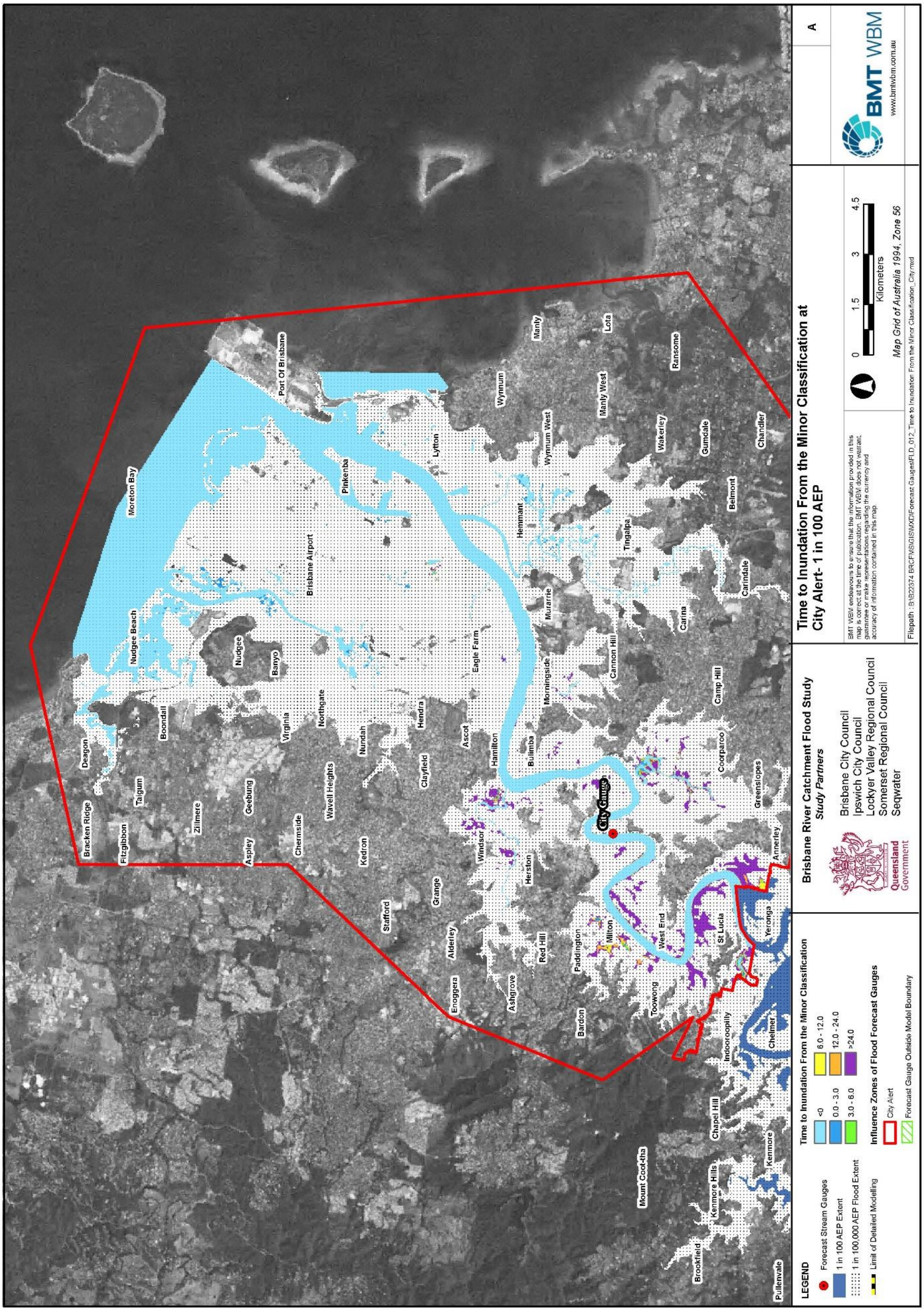
Time to Inundation Maps, 1 in 100 AEP



Time to Inundation Maps, 1 in 100 AEP



Time to Inundation Maps, 1 in 100 AEP



Appendix S Components of Flood Resilience (Workshop 1)

All responses provided by stakeholders during Workshop 1 are provided below.

- Aware of local hazards
- Understand own personal risk
- School education
- Strong community networks
- Recover well from flood events
- Understanding notifications
- Personal resilience v's property resilience
- Empowered and supported
- Good planning control
- Low reliance on Government
- Educate community on risk appetite
- Community acceptance of disasters
- Community preparedness
- Targeted engagement activities
- The capacity to adapt
- I know how to respond
- Resilient critical infrastructure to mitigate disruption to essential services
- Individual responsiveness - know where and how to act
- Easy to access to relevant and understandable information about flood risk
- Limit vulnerability, low vulnerability, design in construction/systems
- Brisbane River catchment - expectation or assumption - I will be looked after
- Community empowered to drive community resilience locally - grants and programs
- Acknowledge individual responsibility
- Has an emergency management structure
- Minimise disruption
- Is aware of local risks
- Knows historical impacts
- Good insurance policy
- Support networks
- Aware of risks - informed
- Critical infrastructure is not impacted.
- Prepared - understands risk and act on it
- Community groups planning for events
- Takes responsibility for their own actions
- Makes decisions based on evidence
- $ up social capital
- Has social capital
- Community complacency and expectation
- Ability to physically to restore the community - services, restore property, etc.
- Shocks -> incidents, stresses -> ongoing issues - another way to communicate
- Actually wanting 'Get Ready' or equivalent messaging and take action
- Health levels of community connectedness, trust and cooperation
- Aware of your risks and results - have plan in place
- Adapt to consequences of disaster not just 'impacts'

- Personal responsibility not waiting for assistance and looking after themselves and neighbours
- Communities learning from historic events and identifying ways to minimise impacts in future events
- Has either full time or volunteer emergency management organisations and/or community groups
- Formal and informal networks annoy the community
- Education and engaged - why do they care (?), is it situational - understanding risk + personal impact + responsibility to take action
- AWARs of situational risks; well connected, sense of community, agency partnership, effective community networks, personal resilience, community infrastructure, effective risk based communication for everyone incl. at risk
- What to do when essential service lost. Can my family cost with extended power, water, sewage and tele communication loss
- Ability for normal activities of society to continue: individuals travel, housing, services, economy
- Good collaboration amongst the community. A community that works together is a good community
- Resilience of the critical infrastructure helps the resilience of the community
- Resilience is "the ability to bounce back". Don't use this to expand the terms to include personal preferences

Appendix T Market Research Summary Report

KANTAR PUBLIC=

Brisbane River Catchment Attitudes Survey

Research Report - DRAFT

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Kantar Public contact: Richard Bishop

June 2017

263104619

Certified System
Market & Social Research ISO 20252
SAI GLOBAL
A/S 20252:2012
Certificate No.: MSR20016

Queensland Government

Contents

1.
Executive Summary

Executive Summary

- More than one in two surveyed Brisbane Floodplain residents have experienced a flood event, with the most common being the 2011 flood.
  - Prior experience of a flood does cause some nervousness when a flood is expected; three in ten state they would be nervous in such a situation.
  - Interestingly, despite the 2011 flood being widely described as a ‘once in a 100 year event’, almost one in two residents believe a similar size flood will happen within the *next ten years*, and three in ten the *next five years* suggesting that there is not a widespread belief that Brisbane is safe from a large flood event for the next several generations. Results were consistent across the regions.
- Whilst almost all expect to be able to use Council reports and flood maps to understand the flood risk for their property, two in five residents expect professional bodies such as real estate agencies, lawyers, insurance agents and banks to be able to provide this advice.
- Mass ‘immediate’ media such as television and radio remains the key sources of information residents would go to for information about flood warnings followed by Emergency SMS.
  - Whilst social media ranks down the list of ‘go-to’ channels at an overall level, it is more important for younger residents (and conversely much less important among older residents) suggesting that a multi-channel approach to providing flood warnings and information is critical.
- In terms of when preventative action is likely to be taken, it is when locations nearby are named (whether suburb or street) that is the tipping point for the majority of residents. Official confirmation of the warning is also important, with one in two needing to hear from sources such as Councils, emergency services or other government sources before they would take action.
- Older residents are significantly more prepared across the range of “basic” actions (such as having candles, torches, radios, evacuation kits) and are more likely to be insured than younger residents. This may suggest the need for a communication campaign targeted at younger residents about practical ways in which they can prepare for a flood event.
- Of some concern is the financial impact of a flood on many Floodplain residents.
  - One in five residents would be in financial distress if unable to work for two weeks due to a flood, whilst one in three would not have anyone to stay with for ‘a few weeks’ and two in three for a ‘few months’ if they had to evacuate.
- Also of concern is the lack of knowledge regarding level of insurance relating to flood damage
  - Around one in four don’t know if their home building or car insurance is covered, whilst one in five aren’t sure about their home contents insurance.

2.
Background and Objectives

Background and Objectives

Established following the 2011 floods, the Queensland Floods Commission of Enquiry recommended that a flood study be undertaken to ascertain the likely impact of future flood events across the Brisbane River Floodplain.

The data from this study will be used to inform the Brisbane River Strategic Floodplain Management Plan with a particular focus on how local and state Governments can support community response and resilience mechanisms during times of flood.

In 2017, Kantar Public was commissioned to undertake research to provide an initial benchmark of community attitudes, awareness and levels of resilience in relation to flood risk within the Brisbane River Floodplain.

The primary objective of the research is to provide an evidence base of current community awareness, attitudes and levels of resilience to flood risk in the Brisbane River Floodplain.

Methodology

Quantitative research was conducted between 8-22 May 2017; with an additional wave of data collection to collect in smaller regions between 5-10 July 2017. A total of n=855 residents from nominated postcodes (provided by Queensland Reconstruction Authority) in the Brisbane Rover Floodplain participated in the research via an online survey, representing a margin of error of +/- 3.0%.

All data was post weighted to align with ABS data (based on age, gender and location).

The average length of interview was 15 minutes.

The questionnaire was designed in consultation with the Queensland Reconstruction Authority, and covered the following key areas:

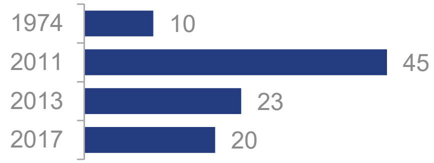
1. Your household	2. Risk Perceptions and Preparedness	3. Information	4. Social Capital	5. Economic Resources	6. Demographics

This project was carried out in accordance with ISO 20252

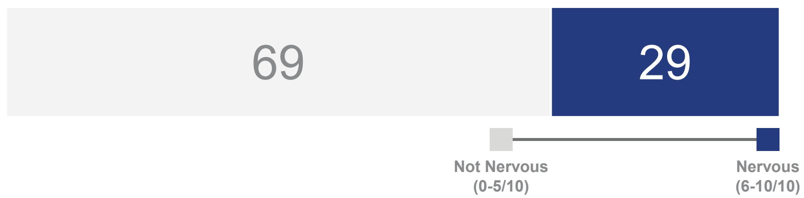
3.
Risk Perceptions

Impact of Flooding

57% have been impacted by a Brisbane flood event in the past.



Level of nervousness if flooding expected (%)



67% Took time off work

4% Received medial treatment

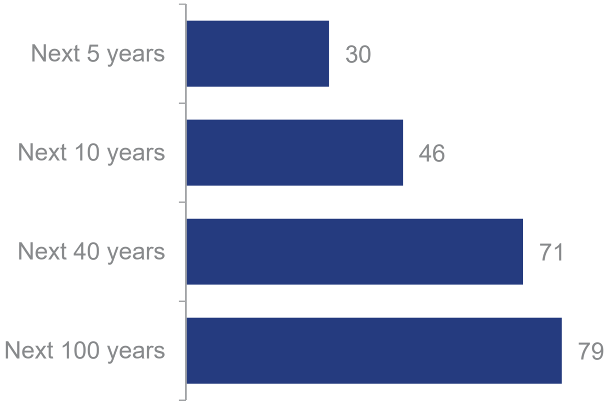
1% Received counselling

- Among those surveyed, more than one in two (57%) have been personally impacted by a flood event in the past, with the majority impacted by the 2011 floods.
- For those who have previously been impacted by a flood event, three in ten (29%) state that they feel nervous when flooding is expected in their area.
  - Culturally and Linguistically diverse respondents (CALD) (44%) are more likely to state they feel nervous should flooding be expected.
- More than two in three (67%) of those impacted by a flood event have had to take time off work.
  - Those aged 41-50 were more likely to have had to take time off work.

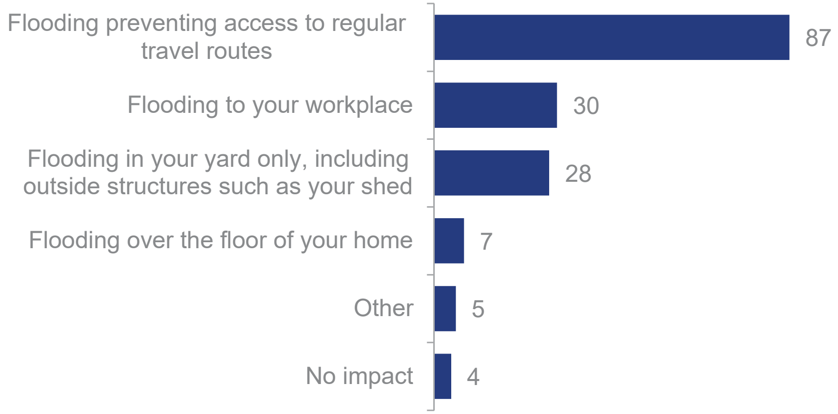
B1. Which of the following Brisbane flood events have you personally been impacted by? Base: All respondents (n=855)
B2. On a scale of 0-10 (where 0 is not at all nervous and 10 is very nervous), how nervous do you become if flooding is expected in your area?
B3. Have you ever received any medical treatment following a flood event?
B4. Have you ever received any counselling following a flood event?
B5. Have you ever had to take any time off work as a result of a flood event?
Base: Those impacted by a flood (n=484)

Flood recurrence

Whether 2011 size flood likely in ... (%)



Impact if 2011 size flood were to occur (%)



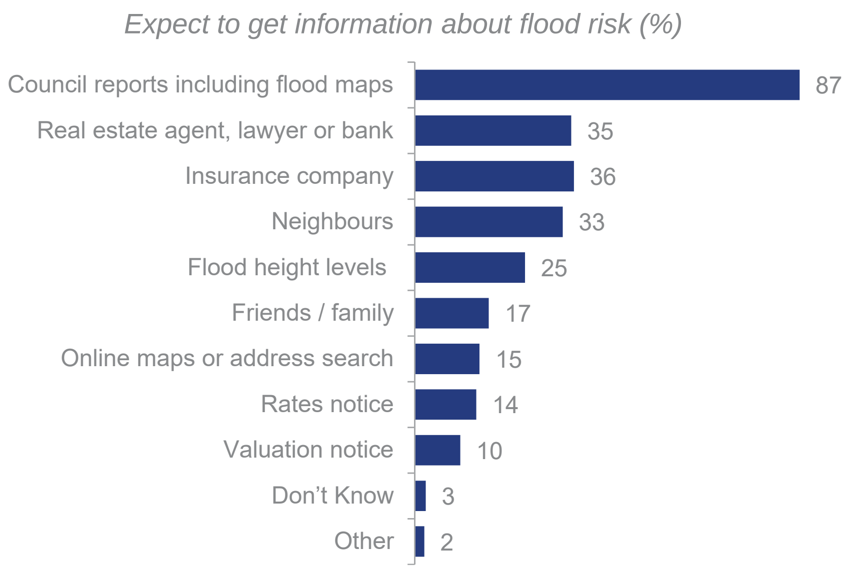
- Whilst the majority (79%) consider that a flood similar to 2011 will occur again in the next 100 years, interesting almost three in ten (30%) Floodplain residents expect a comparable flood event within just the next five years and almost one in two (46%) in the next ten years.

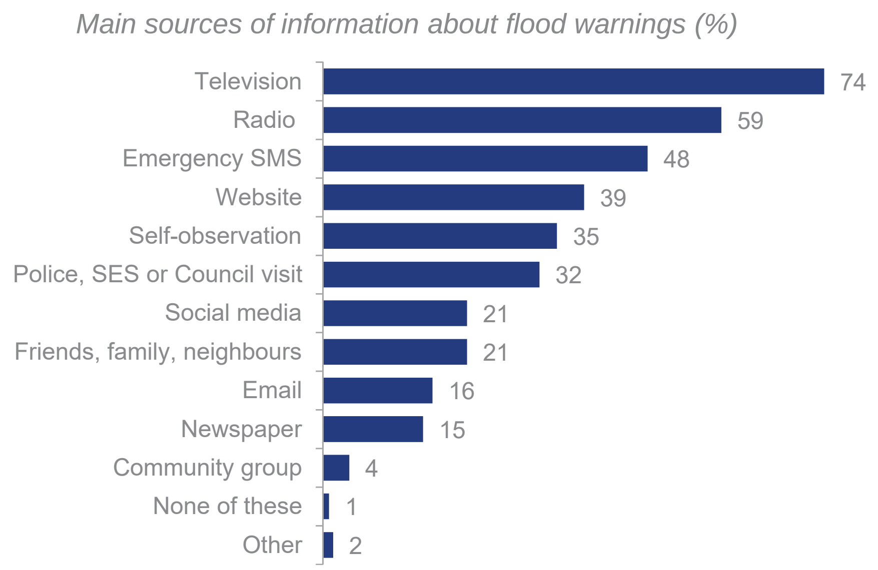
- Of those residents impacted by the 2011 flood event, almost all (87%) cite that they would be prevented from accessing their usual travel routes should a similar (or larger) flood event occur. A further three in ten would expect flooding to their workplace (30%) and to their yard or outdoor structures (28%). Less than one in ten think they would experience flooding over the floor of their home.

B6. If there was another flood the size of 2011 or larger, how would you expect to be impacted?
Base: If impacted by 2011 flood (n=377)
B7. How likely do you think it is that we will experience a flood the same size as 2011 sometime in the next…
Base: All respondents (n=794)

4.
Information Sources

Sources of Information



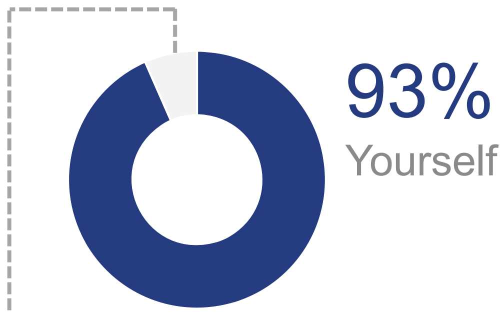


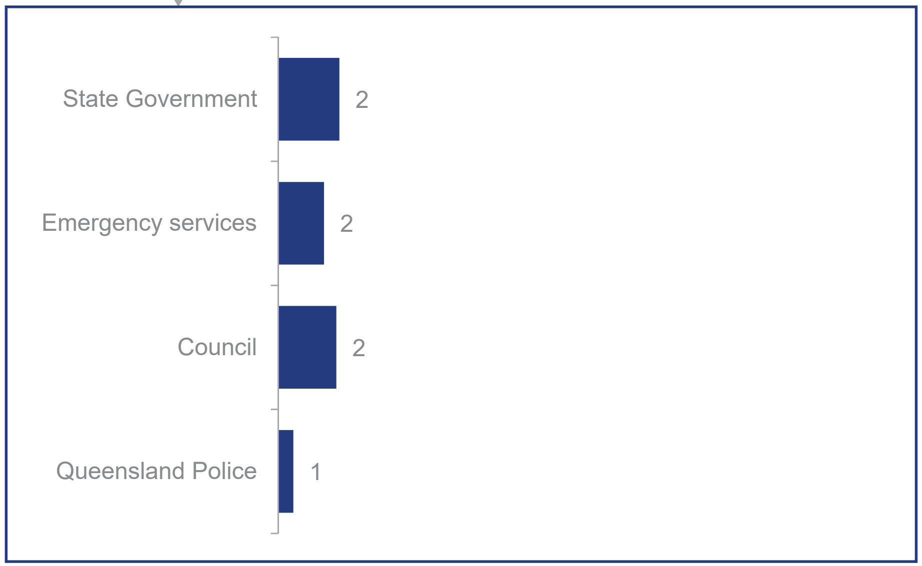
- Nearly all residents (87%) expect to receive information about the level of flood risk for their own property from the Council’s reports, including flood maps. One in three (35%) expect to receive flood risk information from professionals such as real estate agents, lawyers or banks, whilst a similar proportion expect to be able to get information from an insurance company.
- The two most likely go-to channels for flood information are those of mass-media (television (74%) and radio (59%)). Almost one in two would use emergency SMS. Only around one in five would go to social media for information about flood warnings (although this channel shows a significant age skew with 36% of those aged 18-30 stating they would use social media as an information source compared to 12% of those aged over 50)

C1. Where would you expect to get information about the level of flood risk for your property?
C2. What are the main sources you go to for important information such as flood warnings?
Base: All respondents (n=855)

5.
Action Taken

Responsibility for safety during a flood event



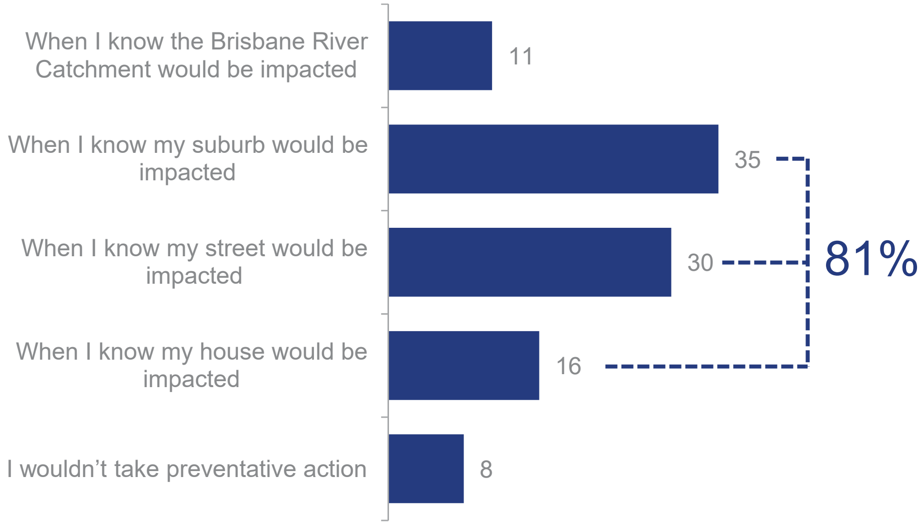


- There is almost universal agreement (93%) that residents are responsible for their own safety during a flood event.
  - This result is consistent across different ages and regions.

E3. Who do you think is primarily responsible for your safety during a flood event?
Base: All respondents (n=855)

Preventative Action

When preventative action would be taken (%)



52%
Would need to hear from or check with official sources before taking preventative action

- Following a flood warning, whilst one in ten (11%) residents would take preventative action upon learning that the Brisbane River Catchment would be impacted, the majority (81%) would only take action once learning that their immediate location (suburb, street or home) would be impacted.
  - Those aged 18-30 years were more likely to take preventative action once knowing their suburb would be impacted (45%), those aged above 61 years were less likely to do so (28%).
- More than one in two residents (52%) would need to hear from or check with official government sources before taking preventative actions.

C3a. At which point do you think you would take preventative action following a flood warning (such as raising valuables in your home or sandbag doorways)?
C3b. In the event of a flood, do you need to hear from, or check with official sources such as local Council, emergency services, other government sources, before you take preventative actions on a flood warning (such as raising valuables in your home or sandbag doorways)?
Base: All respondents (n=855)

Likely evacuation behaviour

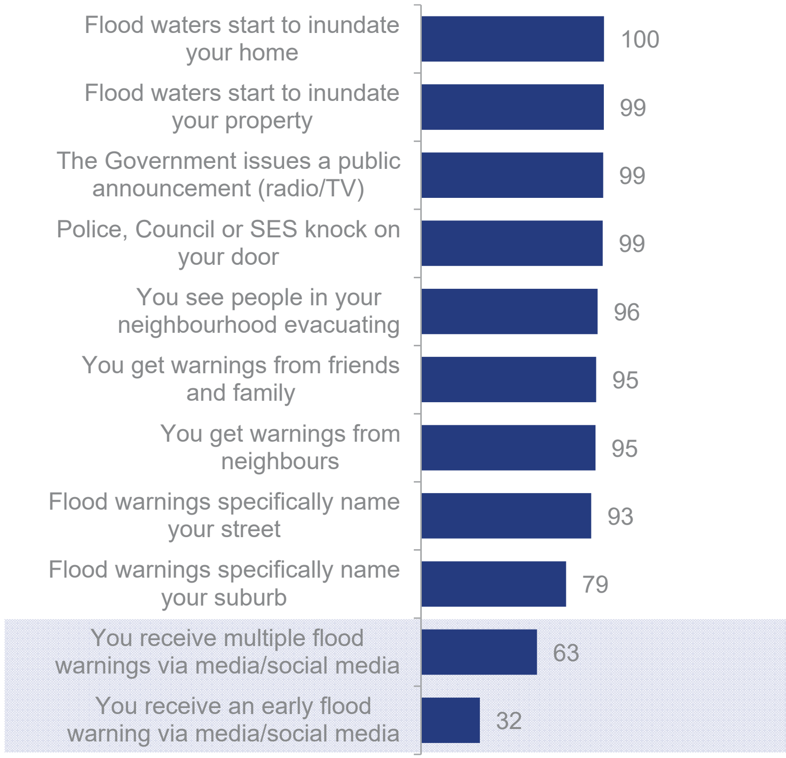
- Likelihood to evacuate is consistent between those who have and have not been impacted by a flood event in the past. Three in five (63%) of those likely to evacuate will have done so simply as a result of receiving flood warnings via the media / social media. This rises to almost eight in ten (79%) once their suburb is named, and almost all (93%) by the time flood warnings are specific enough to mention their street.

15% I would **always** evacuate

75% I would **decide** whether to evacuate depending on the flood

90%

Would evacuate when…



8% I would **never** evacuate

"We live on a high hill and can't be flooded. If we flood, Brisbane will be devastated beyond repair."

"If my house floods - then the whole of Brisbane would be under water."

"The house is built above flood levels so no need."

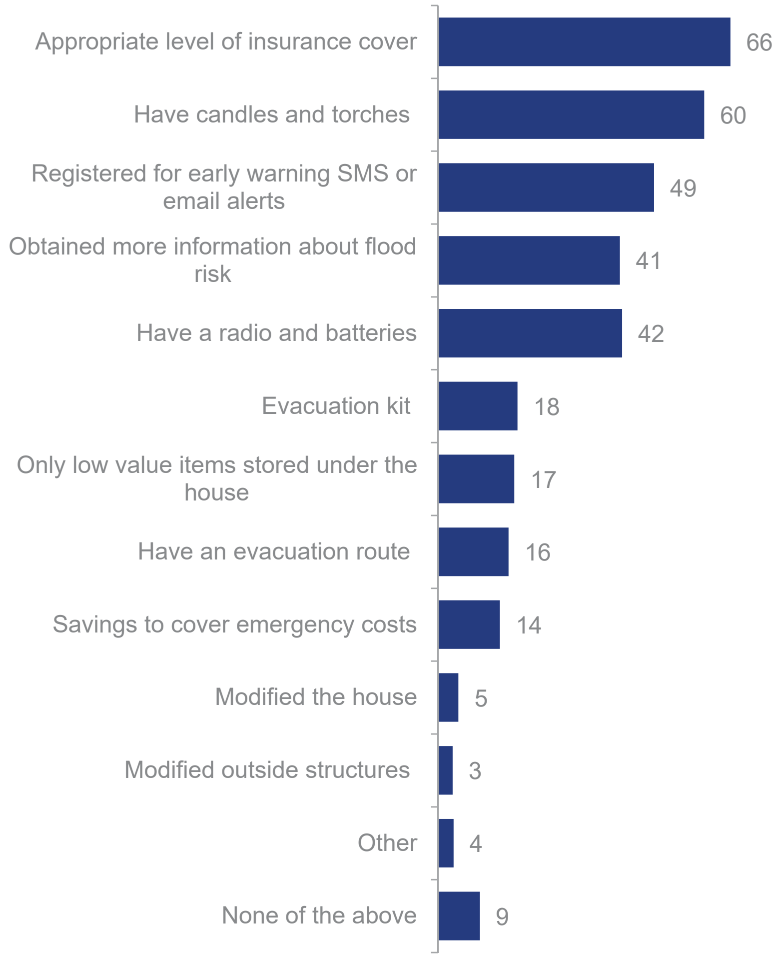
"It's my property and not going anywhere."

"To make sure no one comes to steal anything."

C3c. In the event of a flood that was likely to impact your property, which of the following statements best applies to whether you would evacuate or not? Base: All respondents (n=855)
C4.Thinking at which point you would evacuate, would you say you would evacuate when.... Base: Those who would evacuate (n=762)
C5. Why would you never evacuate your property? Base: Those who would not evacuate (n=68)

Preparation for future flood events

Actions taken to prepare for future flood events (%)

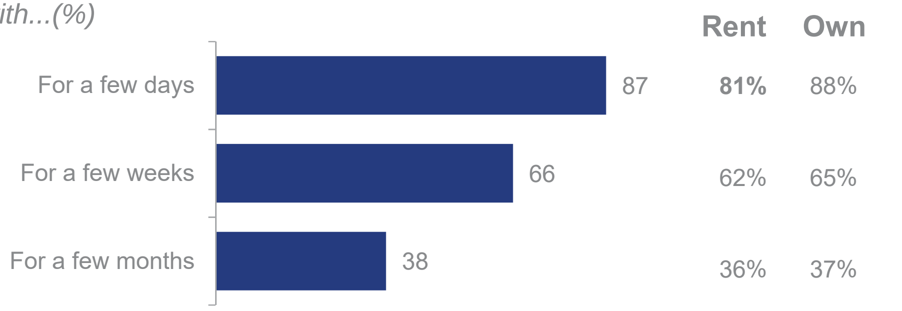


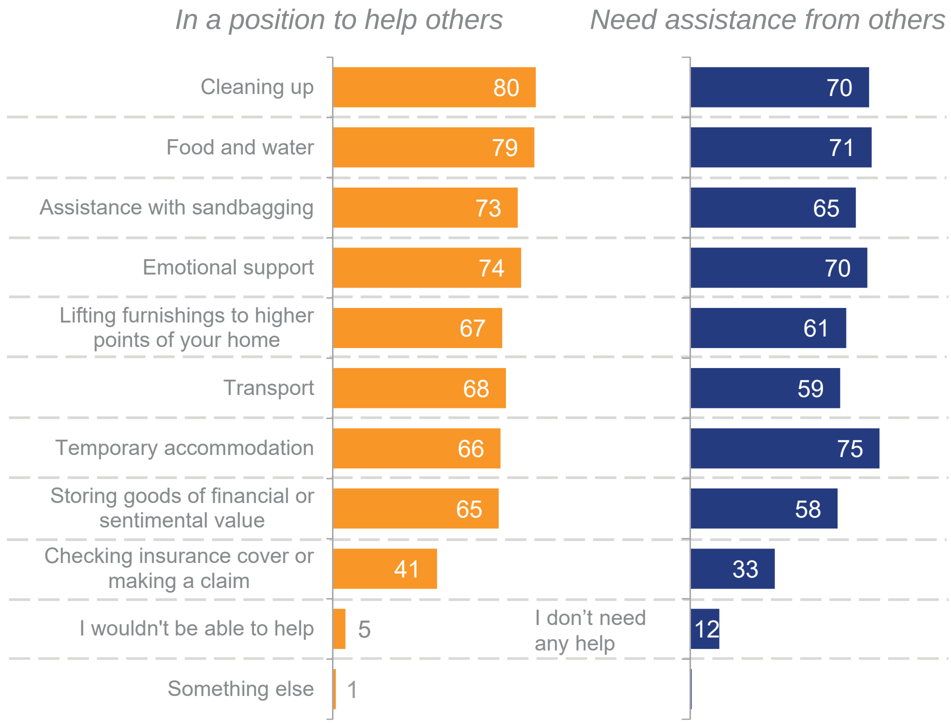
C6. Which of the following ways, if any, has your household prepared for future flood events?
D1Base: All respondents (n=855)

- Two in three (66%) residents state they have insurance cover to prepare for future flood events.
  - Older residents are much more likely to be appropriately insured than younger residents (72% of those aged 61+ compared to 52% of those aged 18-30).
- Older residents are also more likely to have taken practical steps to be ready in their home; 73% have candles and torches ready, 64% have a radio and batteries for loss of power, and 23% have an evacuation kit and evacuation plan (compared to the total).
- Those who have been impacted by a flood event in the past, are significantly more likely to have an evacuation kit (21%), and to have registered for early warning SMS or email alerts (55%) (compared to the total).
- Likewise, those who have lived in the area for less than 5 years, are less likely (when compared to those who have lived in the area more than 5 years) to have take steps to be prepared; 61% have appropriate insurance cover (68% for 5+ years); 52% have candles and torches (64% for 5+ years); 39% have a radio and batteries (47% for 5+ years).

Help & Assistance

If evacuated whether have friends / family to stay with...(%)





- As may be expected, whilst almost nine in ten residents, if evacuated, would have family and friends to stay with for a few days, this decreases for longer periods of need – only around two in five (38%) would have someone to stay with for a few months.
- Interestingly, renters are significantly less likely to have emergency accommodation for *a few days* when compared to those who own their own property (81% renters, vs. 88% for home owners). Results are consistent across renters and property owners for a *few weeks*, and *for a few months.*
- Residents have and are able to contribute to a strong support network in case of an emergency situation.
  - More than nine in ten residents (94%) would be in a position to help others, whilst most residents if required would be able to seek help from family, friends or neighbours if required.

D1. If you had to evacuate your home in an emergency situation, would you have friends of family you could stay with…
D2. Do you have family, friends or neighbours who could assist you with the following?
D3. Would you be in a position to help others with any of the following during a flood event?
Base: All respondents (n=855)

Vehicles in household

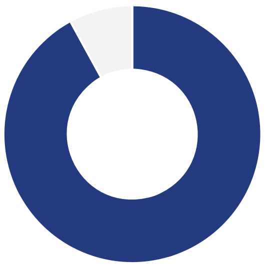
How many vehicles do you have at home?..

34% No vehicles

33% One vehicle

43% Two vehicles

20% Three or more vehicles



93%

Believe they have a sufficient number of vehicles to transport household members / essential possessions in case of emergency

Almost all residents (93%) believe they have enough vehicles to transport all members of their household and essential possessions in the event of an emergency.

The results are consistent across different ages and regions, as well as those who have and haven't been impacted by a flood previously.

D4. How many vehicles are permanently located at your home?
D5. Is this sufficient to transport all members of your household and essential possessions in the event of an emergency?
Base: All respondents (n=855)

What could the Queensland Government do to improve community safety

“Provide regular and consistent information via a variety of communication channels. Be clear about what is known and what is not known. Avoid blanket/catch-all/generic warnings, provide specific warnings.”

“Superior road closed signage. Current signage is the same as road closed signage for construction work which is often not applicable to people residing on the street. Current signage is old, worn, and not flood specific.”

“Centralised source of information and consistent messaging. Release likely flood impact maps in lead up to events, much like the cyclone forecast maps issued by BOM that show likely impacts over time and location.”

“Teach children in primary and high schools flood safety. For example teaching young kids all the dangers associated with floods. Teach them to think straight and be supportive of the adults that are responsible for their safety. Teach them how to be helpful in an emergency and how to minimise panic. Even kids whose properties aren't impacted can panic and worry about the possibilities of flooding within the community.”

“Greater communication to households, have future planned evacuations centres so people will know where to go with out having to rely on any resources for information.. e.g.. I know the local school hall is the evacuation centre for my area.”

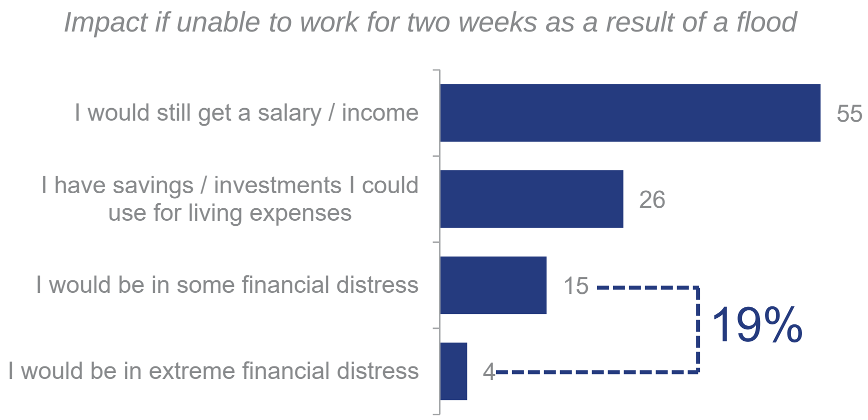
Ensure that all of the major dams are managed correctly and not allowed to remain at precariously high levels for long times. Ensure flood maps are promoted, have awareness campaigns on the importance of moving to higher ground and treating each event seriously. I think the recent action in ex-cyclone Debbie where the Government closed schools for two days was a smart move.

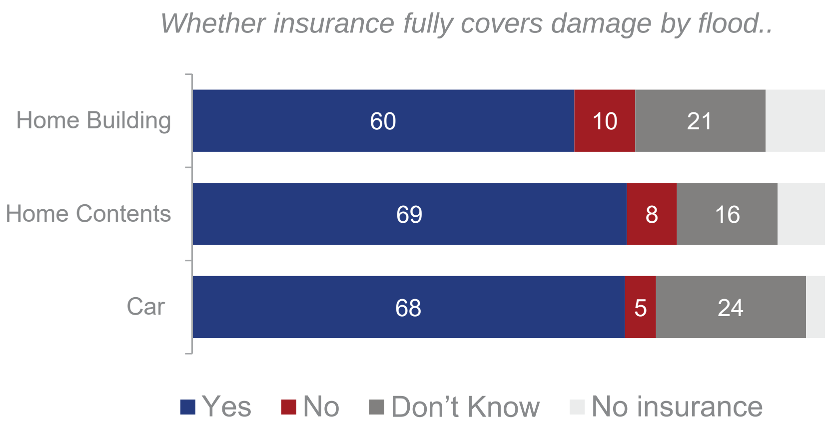
Everything that they are doing already plus following up with offenders from news footage after the event so emergency workers are not put at risk. Offenders who blatantly put themselves and others in danger by their reckless behaviour should be penalised. Also put better lighting in known danger spots where drivers run the risk of inadvertently driving into flooded waterways at night.

C7. What do you think the Queensland Government could do to improve community safety during flood events?
Base: All respondents (n=xxx)

6.
Economic Impact

Financial impact of floods





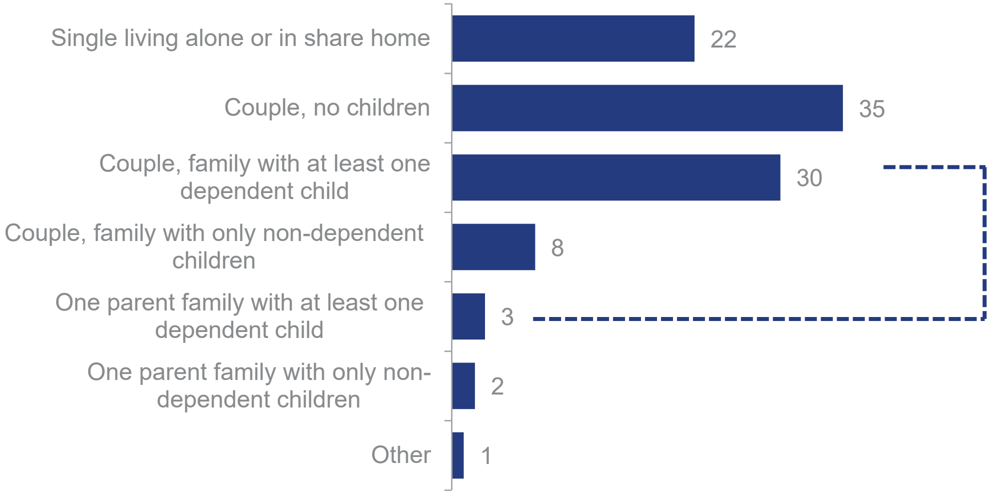
E1. If you were directly impacted by a flood and were unable to go about your usual work or daily activities for two weeks, which of the following best describes your financial situation…
E2. Does your insurance policy cover the full replacement value of assets damaged by flood?
Base: All respondents (n=855)

- One in five residents (19%) would be in financial distress if their work situation were to be negatively impacted by a flooding event for two weeks.
  - A higher proportion of would be in 'some financial distress' (30%) when compared to those who own their house.
- Of some concern is the lack of knowledge about level of insurance cover relating to flood damage. Around one in four state that they don't know if their home building insurance (21%) or car insurance (24%) covers them for full replacement value, whilst one in five (16%) aren't sure about their home contents policy.
  - Younger residents (aged 18-30) and females are more likely to be uncertain as to their insurance coverage.

7.
Demographic Data

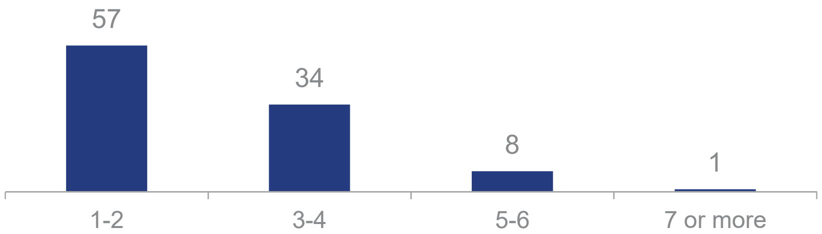
Demographic data (unweighted data)

Household structure



26%
Child under 5 years

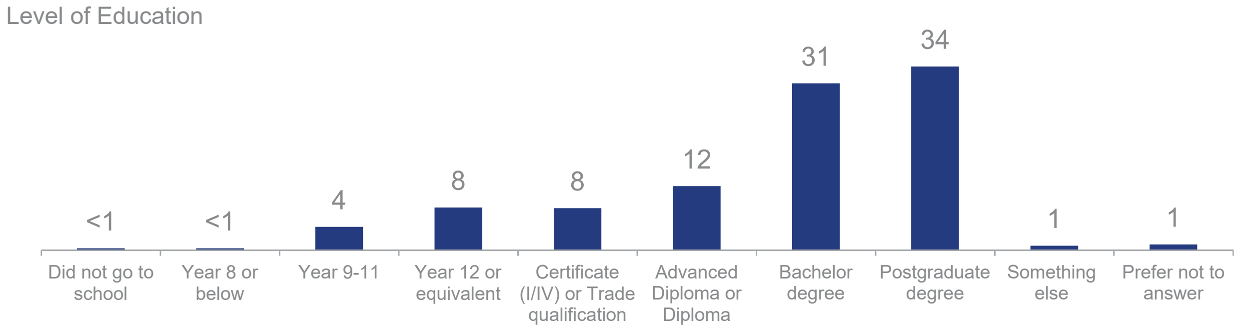
Number of people in household

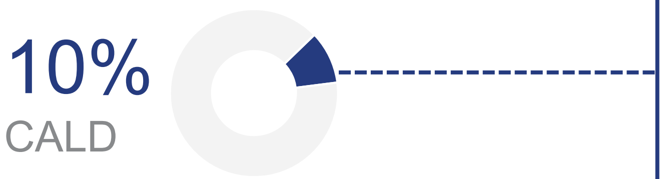


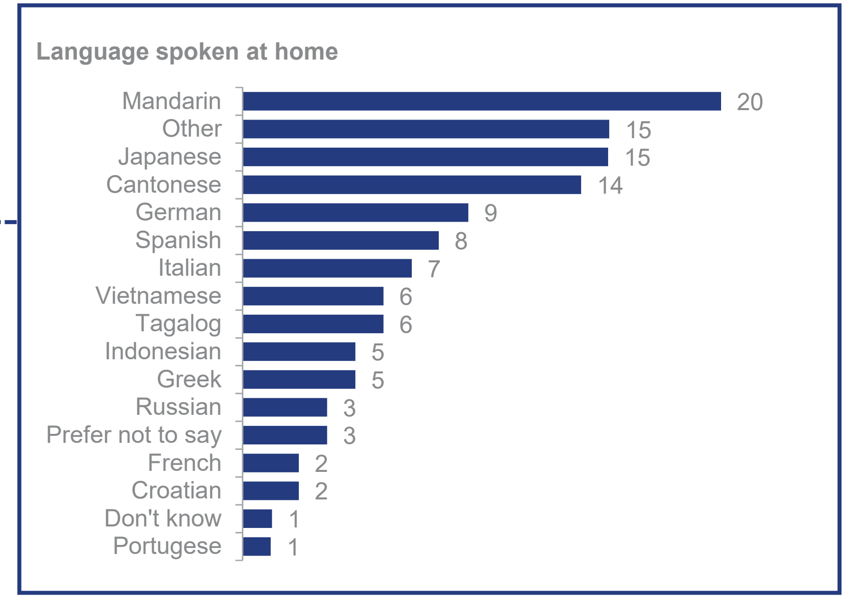
18%
Residents over 65 years

51%
Have a pet

Demographic data (unweighted data)

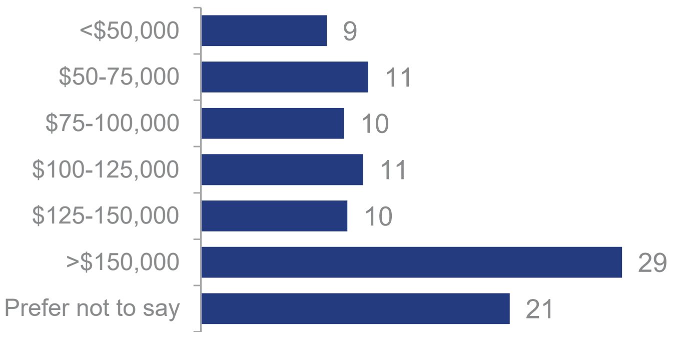




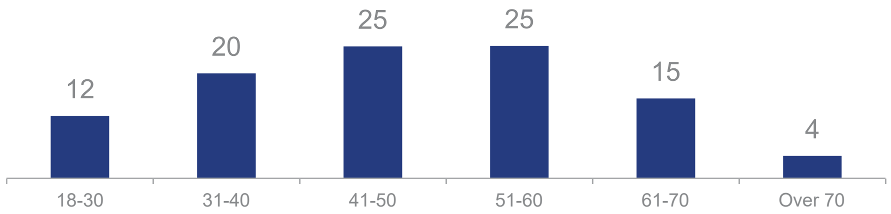


Demographic data (unweighted data)

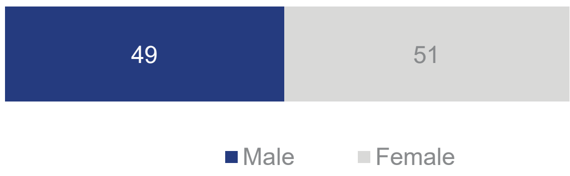
Income



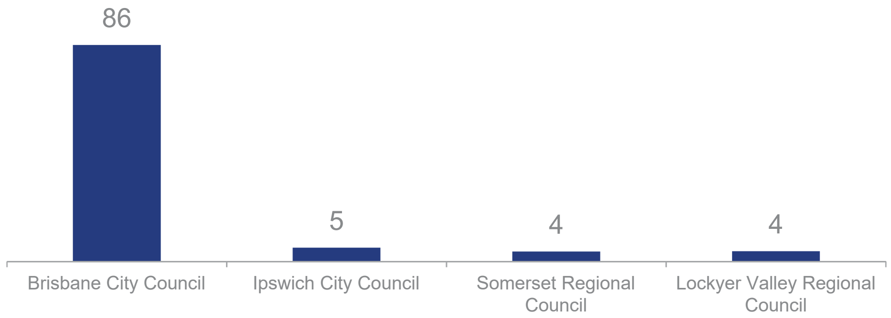
Age



Gender



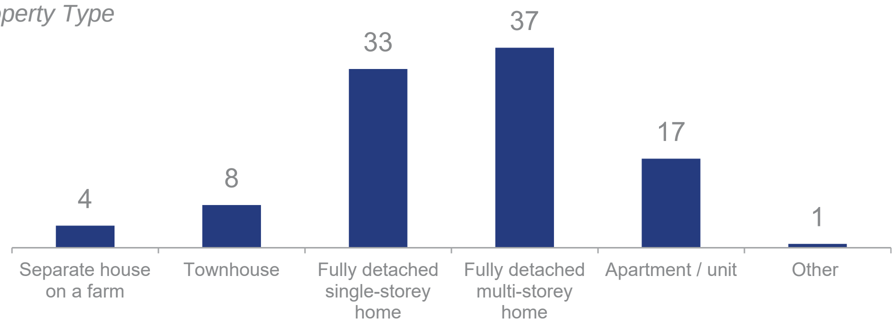
Local Council Area



*Note: data is weighted based on population size of each region

Demographic data (unweighted data)

Property Type



Property Ownership

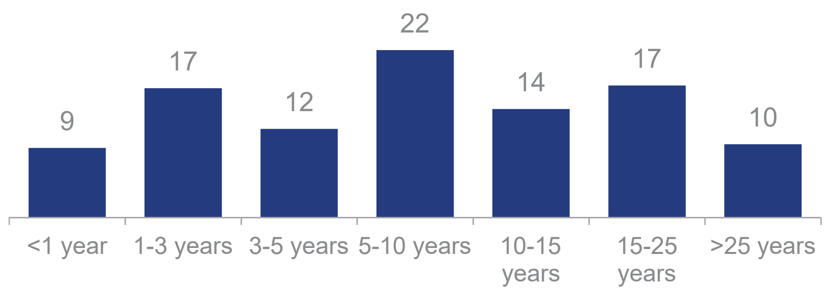
75% **Own their own home**

- 42% currently paying it off
- 32% own outright

22% currently renting

4% other arrangements

Length of residence in Brisbane River Catchment



Thank you

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Queensland Government

Appendix U Market Research Responses by LGA

Market research analysis – by local government area

Undertaken by the Queensland Reconstruction Authority

Introduction

In 2017, Kantar Public was commissioned to undertake research to provide an initial benchmark of community attitudes, awareness and levels of resilience in relation to flood risk within the Brisbane River Floodplain. Kantar Public produced a report that detailed the overall community responses across the catchment.

The Queensland Reconstruction Authority provided an additional layer of analysis by separating out the responses according to the four local governments to identify any key differences in responses based on locality. The following information is a breakdown of the responses according to local government area.

Key findings

1. Responders who said they need to hear from, or check with official sources such as local Council, emergency services, other government sources, before taking preventive action.
   - 52 per cent from Brisbane City Council (Brisbane)
   - 40 per cent from Ipswich City Council (Ipswich)
   - 23 per cent from Lockyer Valley Regional Council (Lockyer Valley)
   - 59 per cent from Somerset Regional Council (Somerset).

2. Percentage of responders who say in the event of a flood they would never evacuate.
   - 6 per cent from Brisbane
   - 4 per cent from Ipswich
   - 37 per cent from Lockyer Valley
   - 29 per cent from Somerset.

3. Comments regarding this response include:
   - *'My fur babies and worried about break ins and theft'*
   - *'I want to be in a position to ensure the security of my property'*
   - *'It's my property and not going anywhere'*
   - *'To make sure no one comes to steal anything'*

4. Percentage of respondents who said they would evacuate if flood warnings specifically named their street (Refer to Figure 11 and Figure 12 for detailed responses).
   - 92 per cent from Brisbane
   - 98 per cent from Ipswich
   - 77 per cent from Lockyer Valley
   - 91 per cent from Somerset.

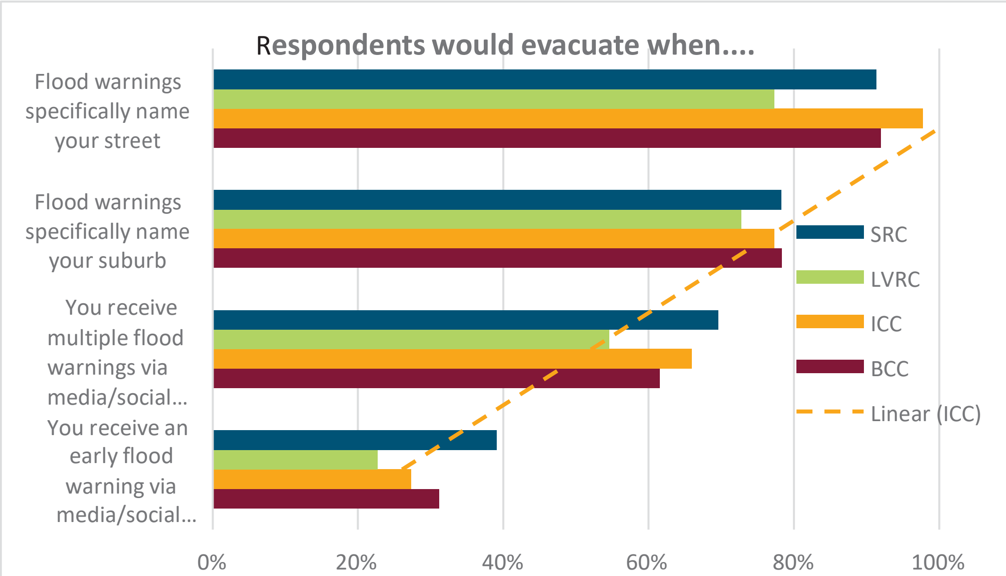


Figure 1: Percentage of people who would evacuate if flood warnings specifically named their street

5. Percentage of respondents who said they would be in some or extreme financial hardship if they were impacted by a flood and were unable to work for two weeks:
   - 17 per cent from Brisbane
   - 26 per cent from Ipswich
   - 20 per cent from Lockyer Valley
   - 35 per cent from Somerset.

6. A large proportion of respondents either did not know what their insurance covered them for or did not have insurance.

	Home insurance (building)				**Home contents insurance**			
	BCC	**ICC**	**LVRC**	**SRC**	**BCC**	**ICC**	**LVRC**	**SRC**
Don't know	22%	13%	9%	6%	17%	11%	6%	6%
Do not have insurance	10%	9%	6%	6%	8%	2%	6%	9%

7. Percentage of respondents who believe they have enough vehicles to transport all members from their household and essential possessions:
   - 89 per cent from Brisbane
   - 96 per cent from Ipswich
   - 94 per cent from Lockyer Valley
   - 94 per cent from Somerset.
8. Percentage of respondents who usually speak a language other than English at home:
   - 11 per cent from Brisbane
   - 6 per cent from Ipswich
   - 3 per cent from Lockyer Valley
   - 6 per cent from Somerset.
9. Percentage of respondents with someone in their household who suffers from or has been diagnosed with a chronic illness or disability:
   - 12 per cent from Brisbane
   - 15 per cent from Ipswich
   - 23 per cent from Lockyer Valley
   - 44 per cent from Somerset.

Risk perceptions

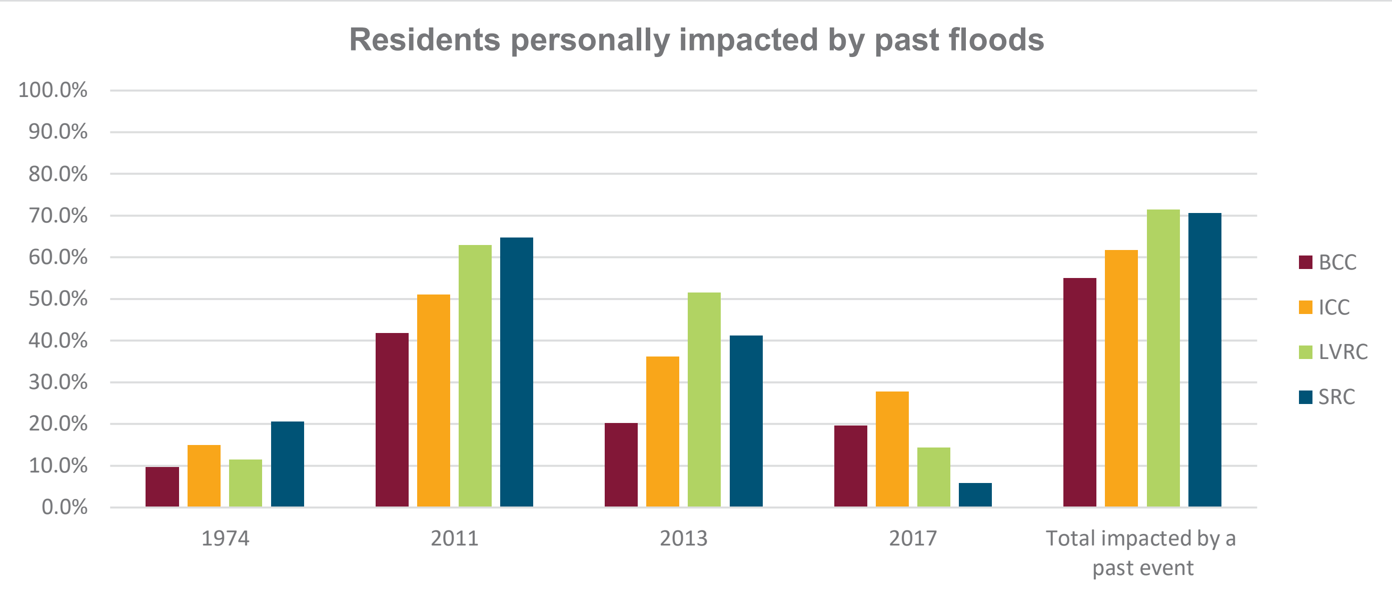


Figure 2: Percentage of people personally impacted by Brisbane flood events

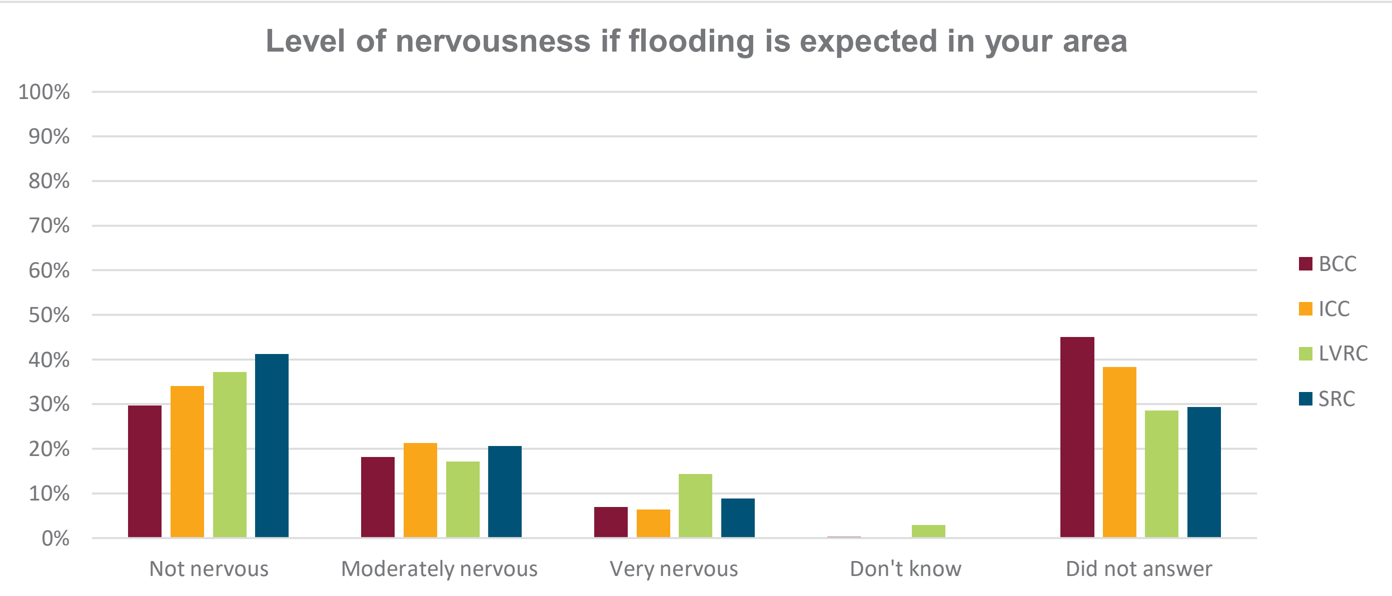


Figure 3: Percentage of respondent's level of nervousness if flooding is expected in their area.

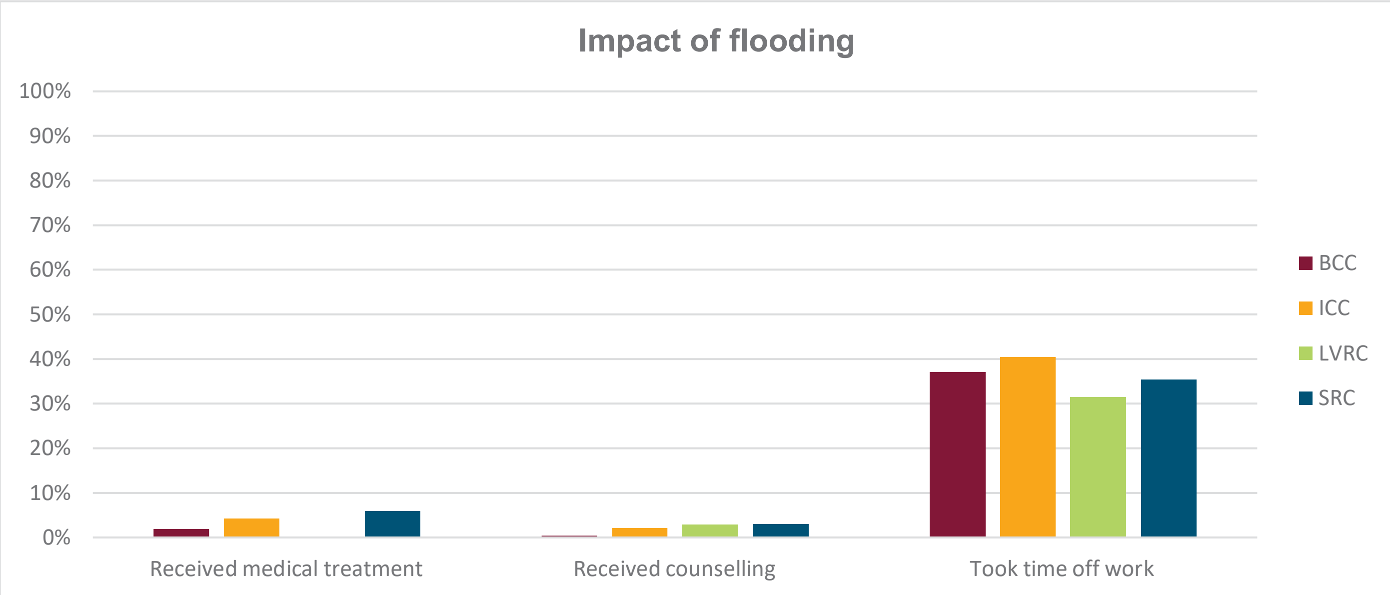


Figure 4: Percentage of people who have been impacted by flooding.

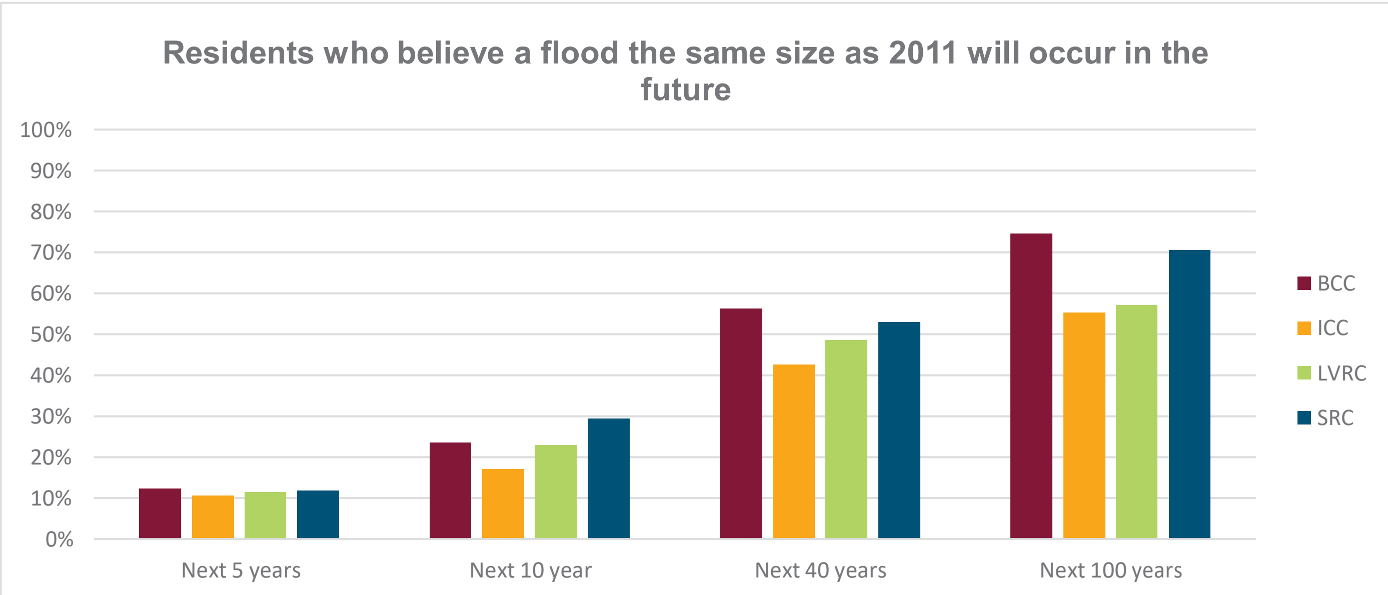


Figure 5: Residents who believe a flood the same size as 2011 will occur in the future

Information sources

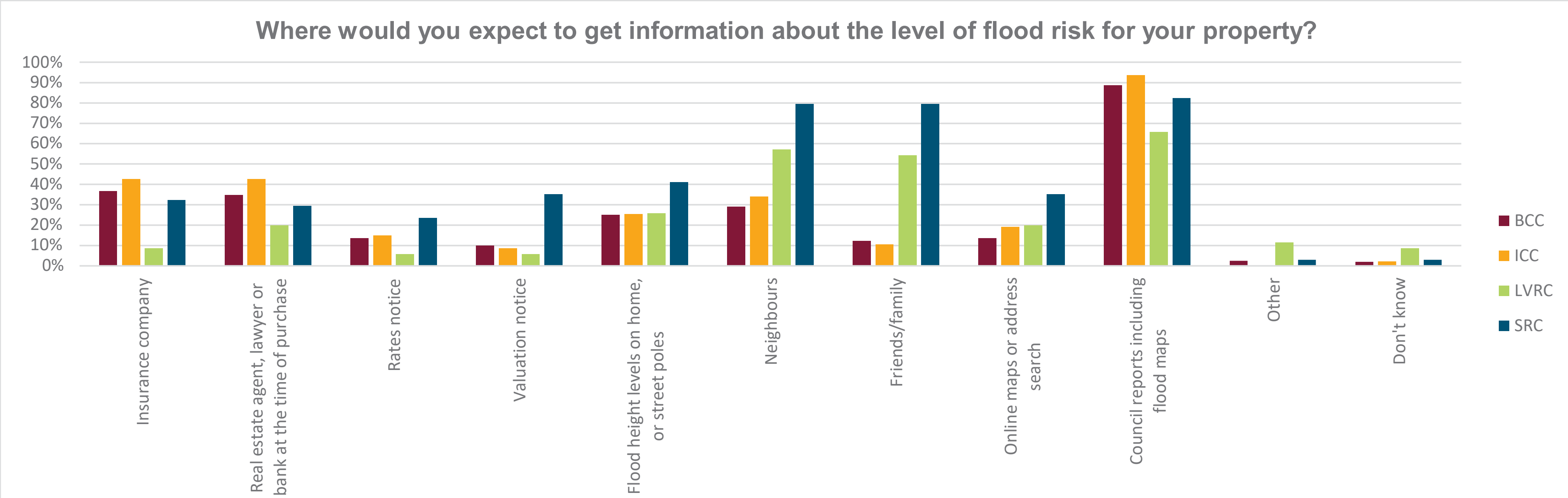


Figure 6: Information sources used to determine personal flood risk

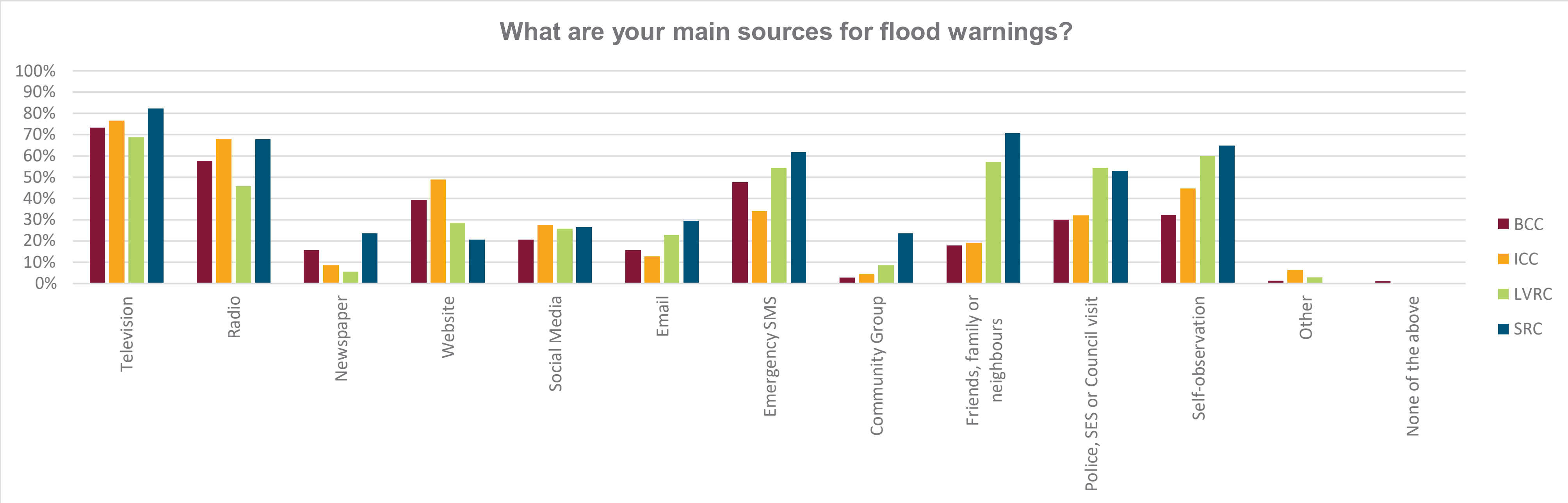


Figure 7: Information sources used for flood warnings.

Responses to flood risk and warnings

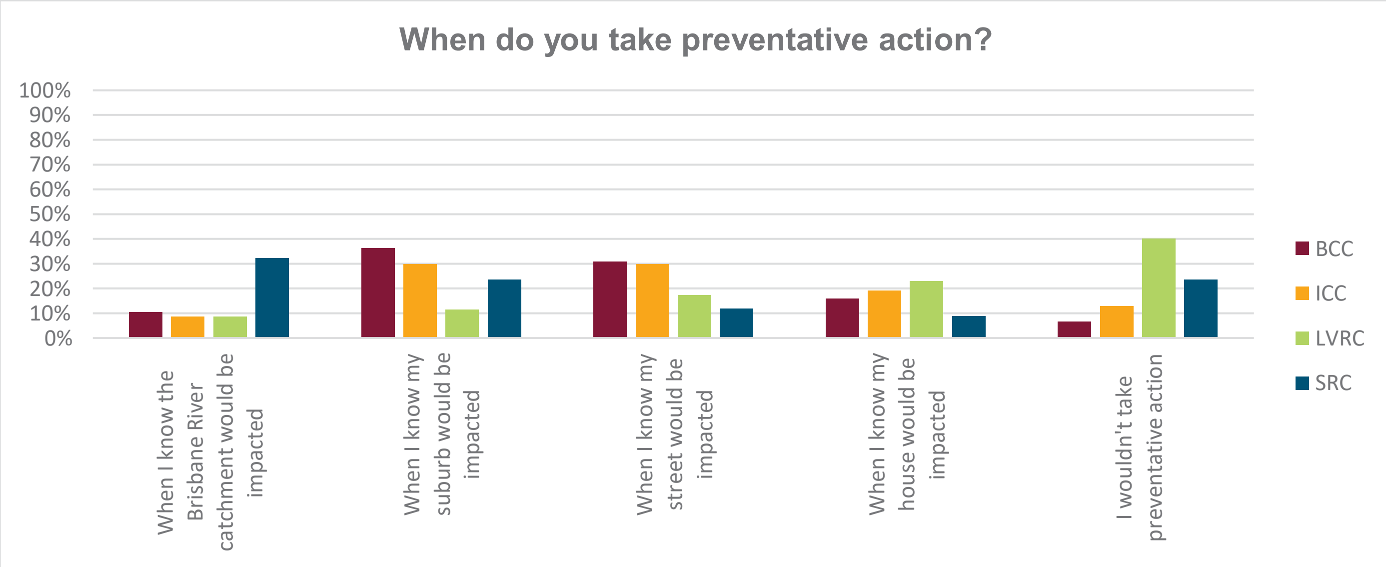


Figure 8: What information people need in order to take preventative action for an imminent flood (such as raising valuables or sandbagging doorways).

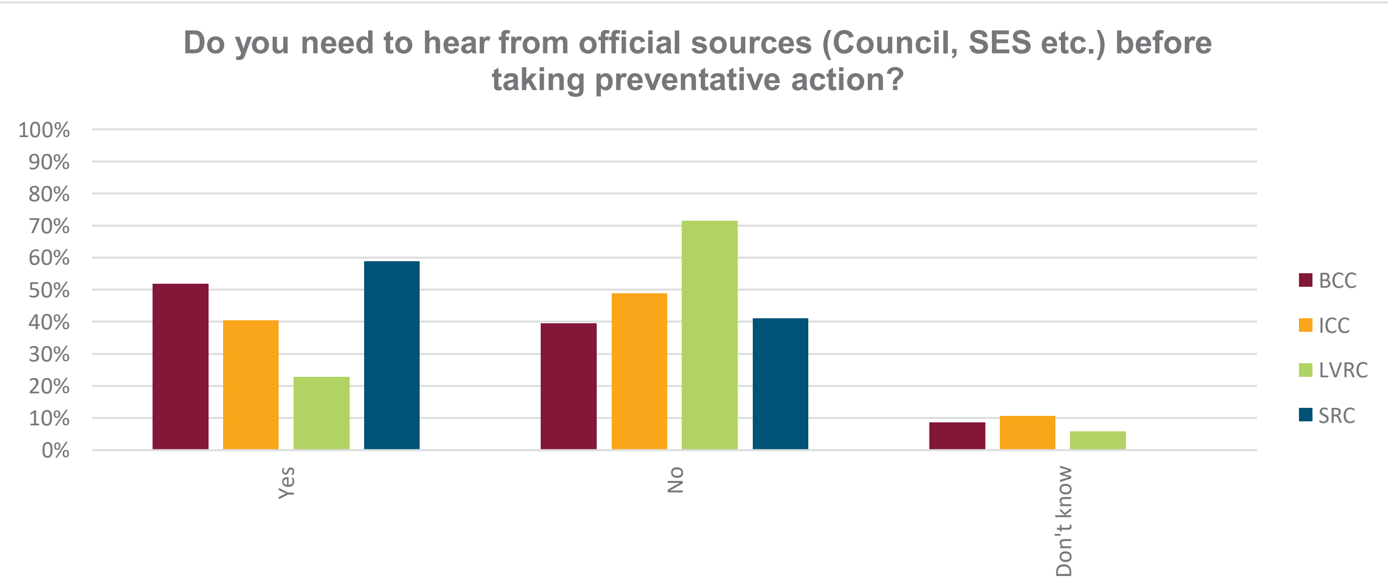


Figure 9: Who people need to hear from about flood warnings before taking preventative action.

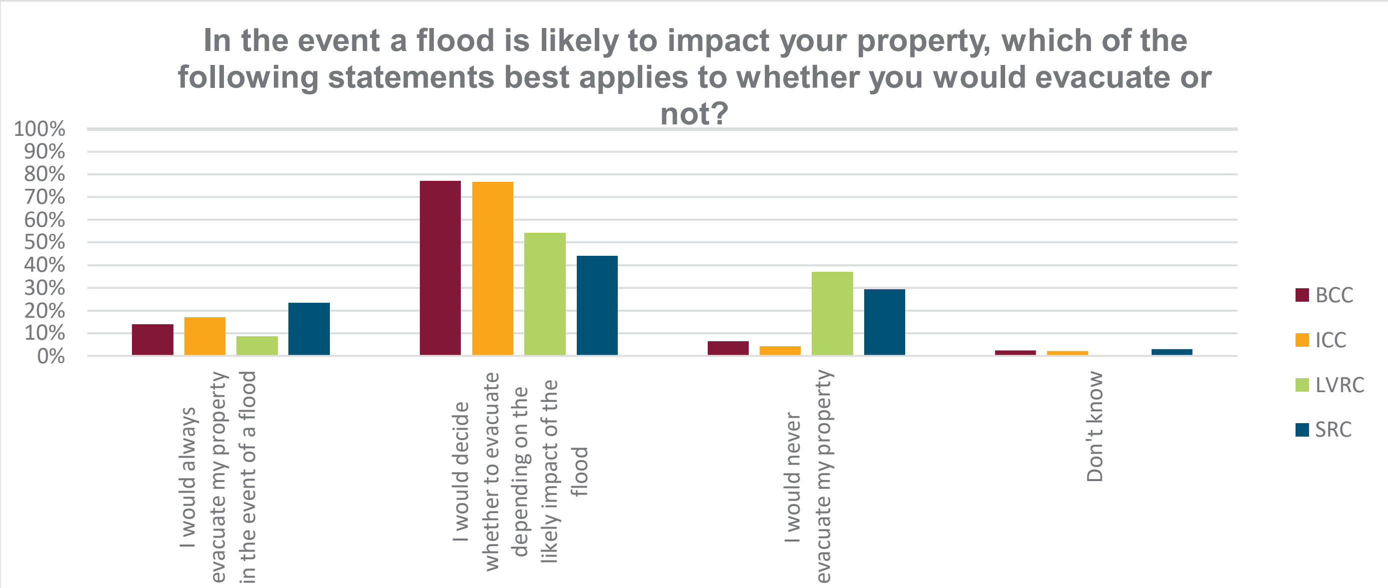


Figure 10: Under what circumstances people are likely to evacuate during a flood

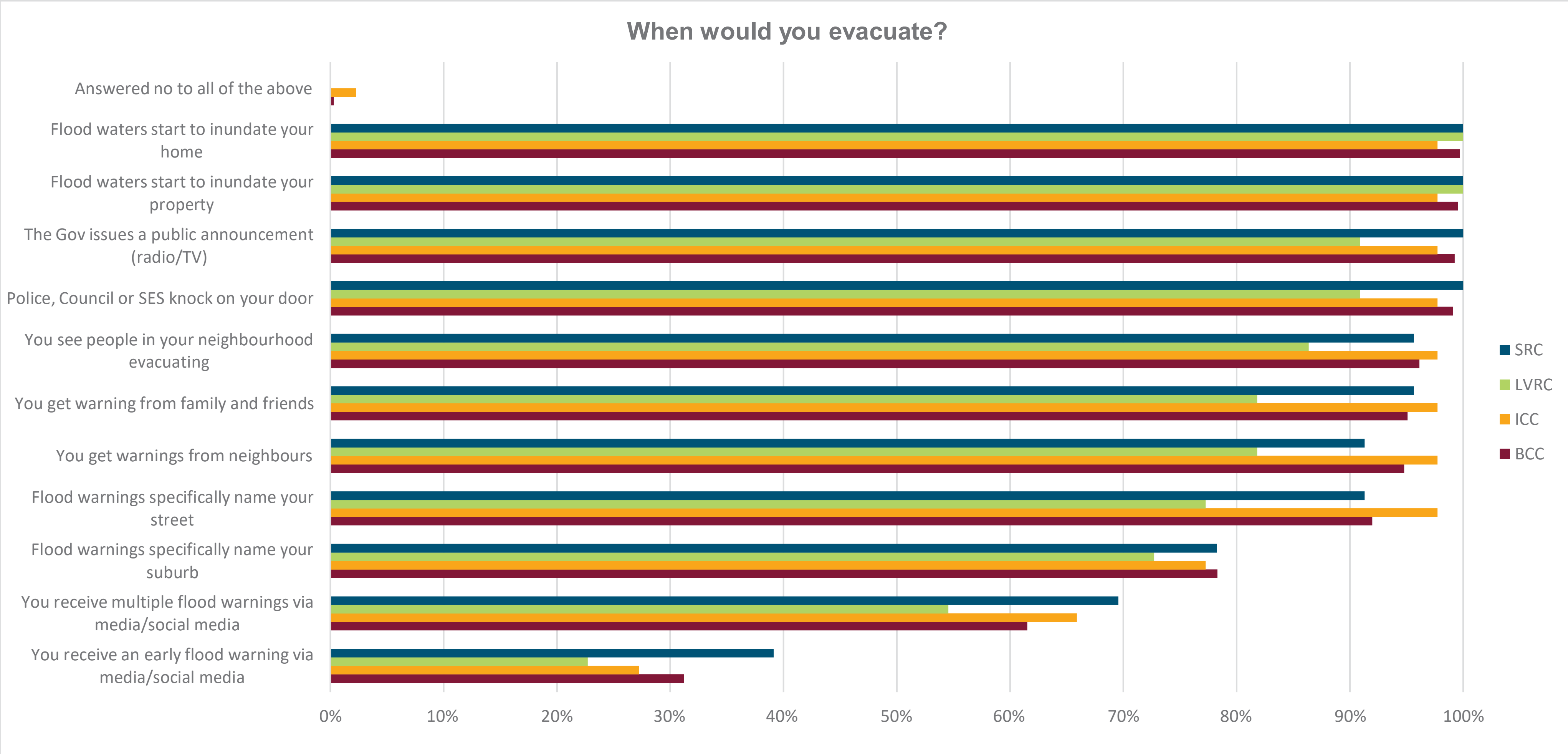


Figure 11: Percentage of people who would evacuate at each point (this was an escalating question i.e. when someone first answered yes the remainder were automatically answered yes). This does not include those who did not answer.

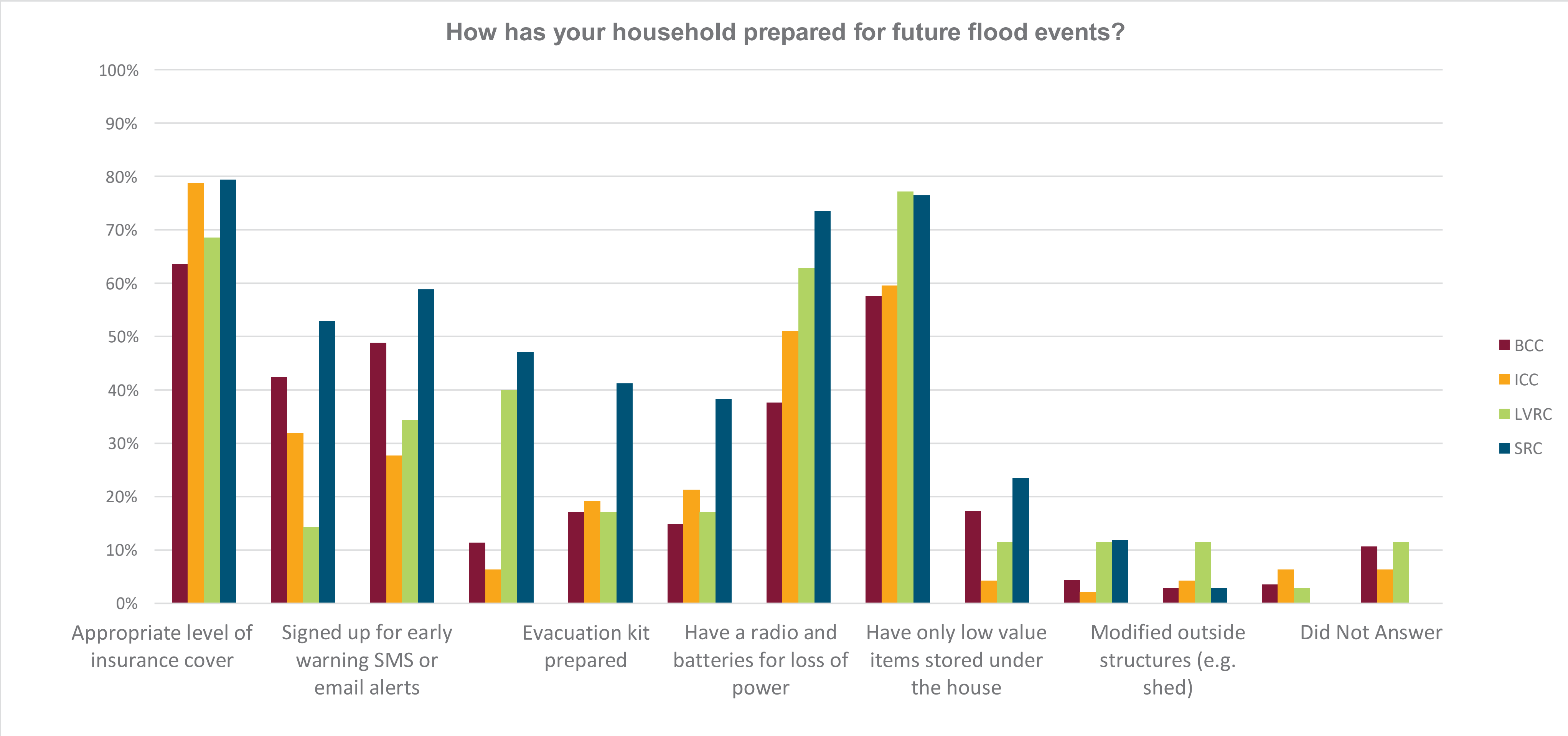


Figure 12: People who have implemented preparation measures for floods

Help and assistance

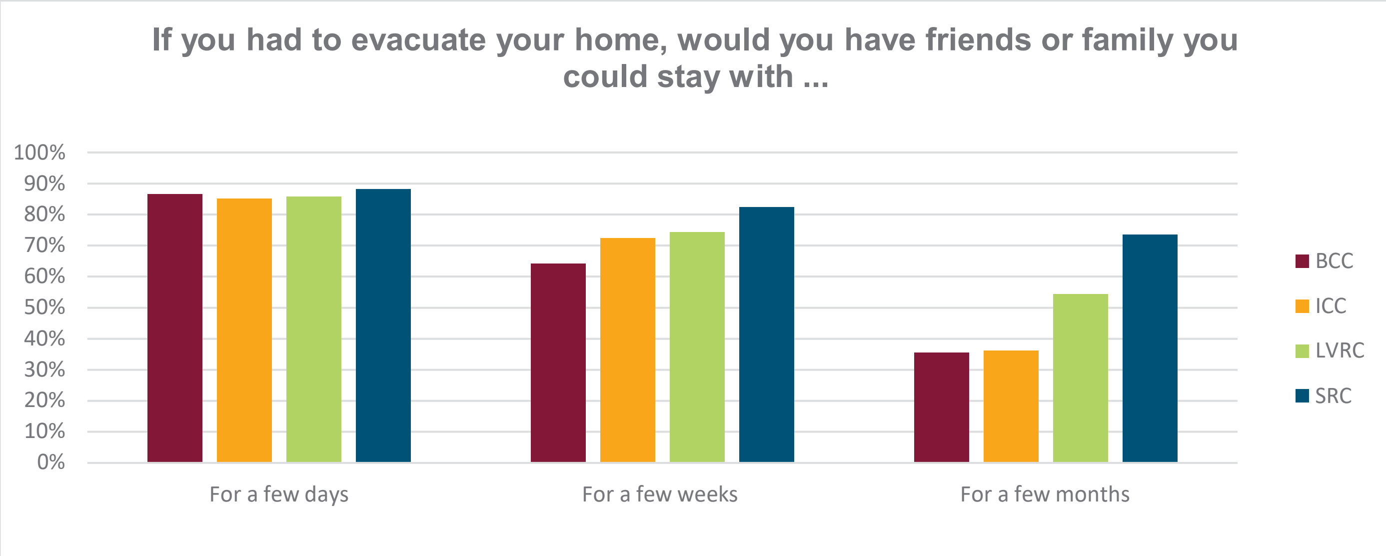


Figure 13: Respondents who have family and friends to stay with in the event of a flood

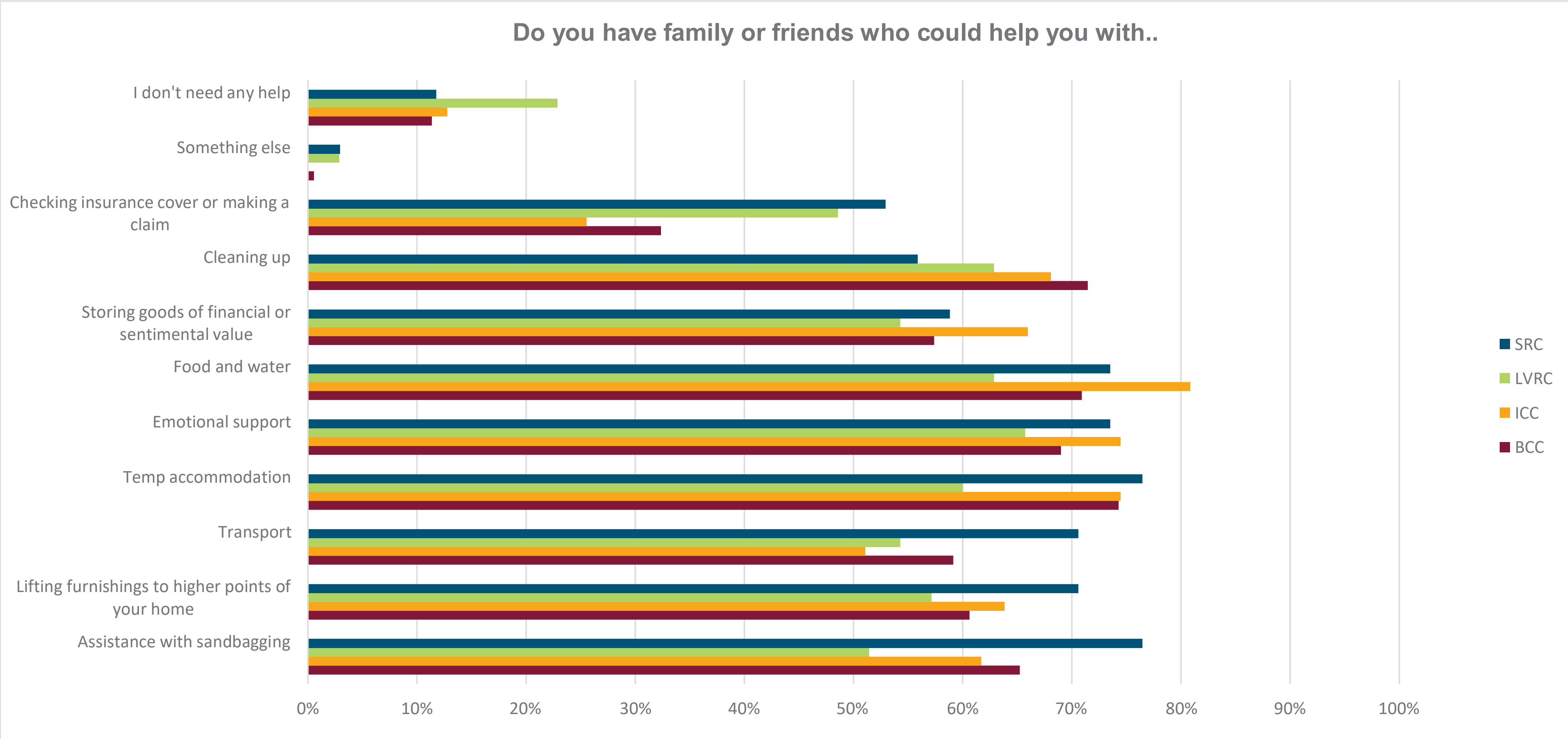


Figure 14: Respondents who have family and friends to help during a flood.

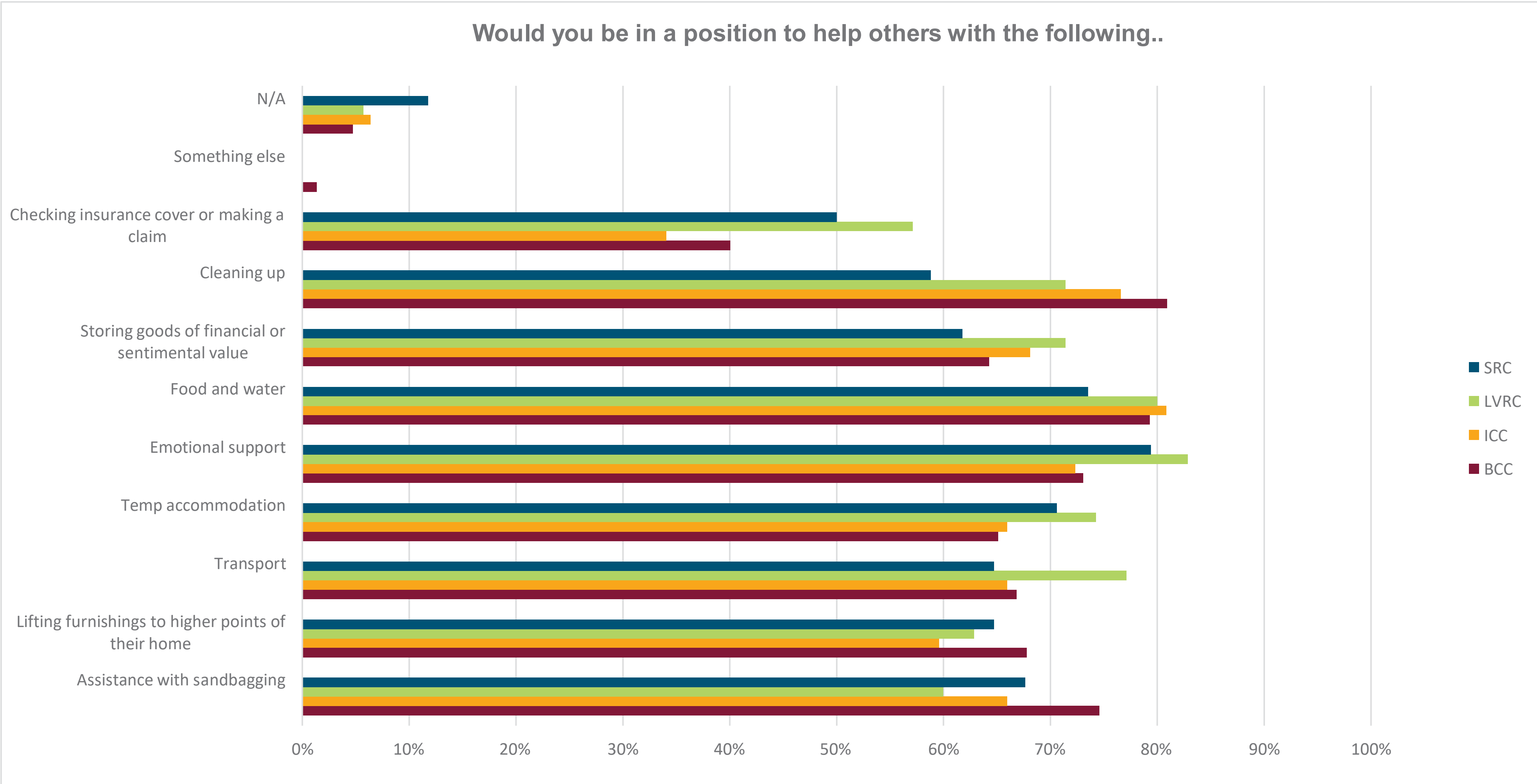


Figure 15: Respondents who say they would be in a position to help others during a flood

Transportation

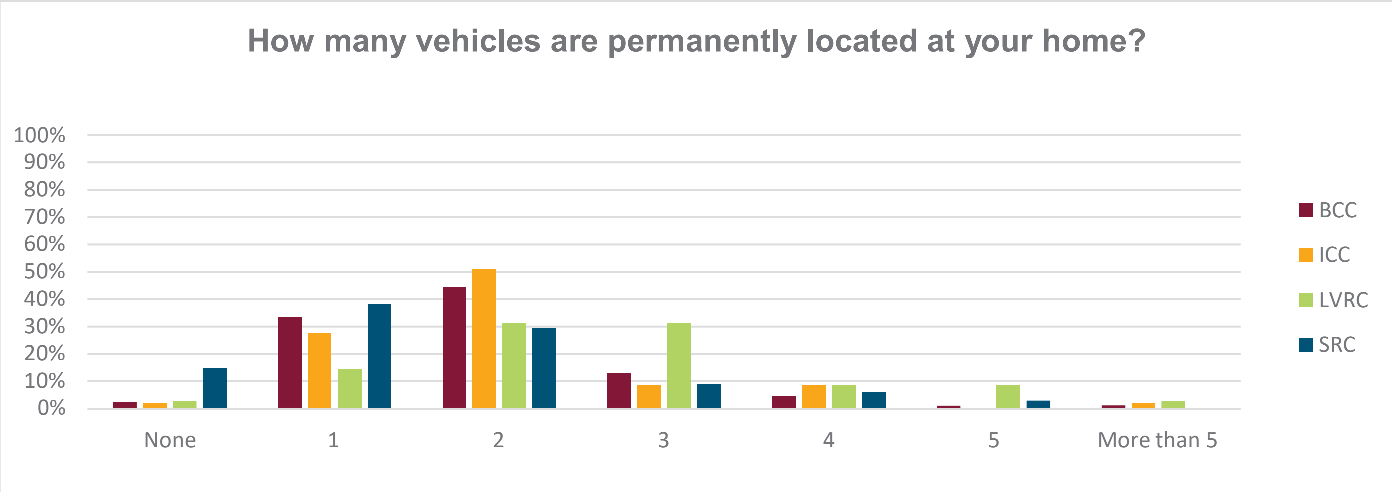


Figure 16: Number of vehicles per household.

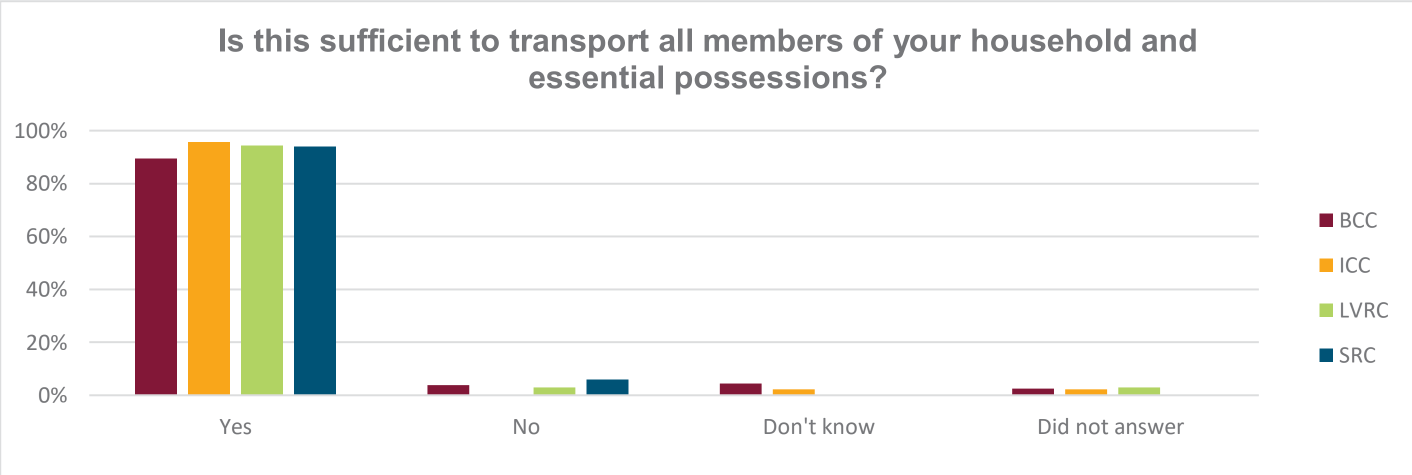


Figure 17: Respondents with sufficient to transport for members of their household and essential possessions

Economic resources

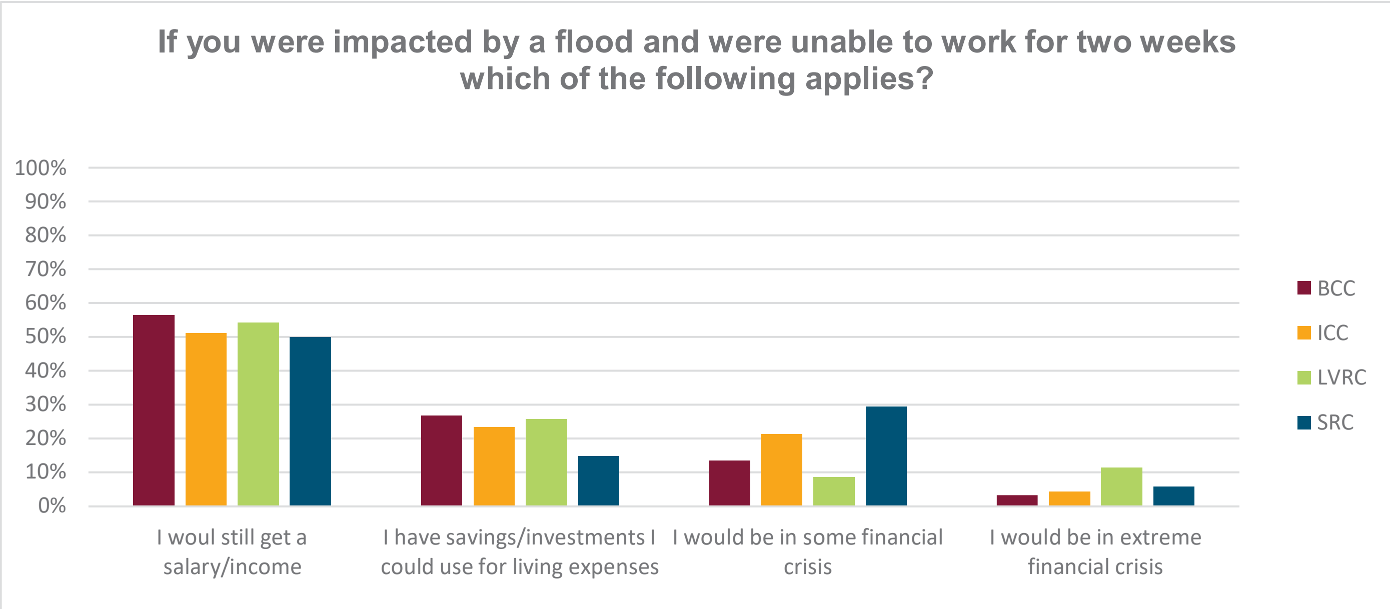


Figure 18: Respondents who may or may not be in financial hardship as a result of a flood

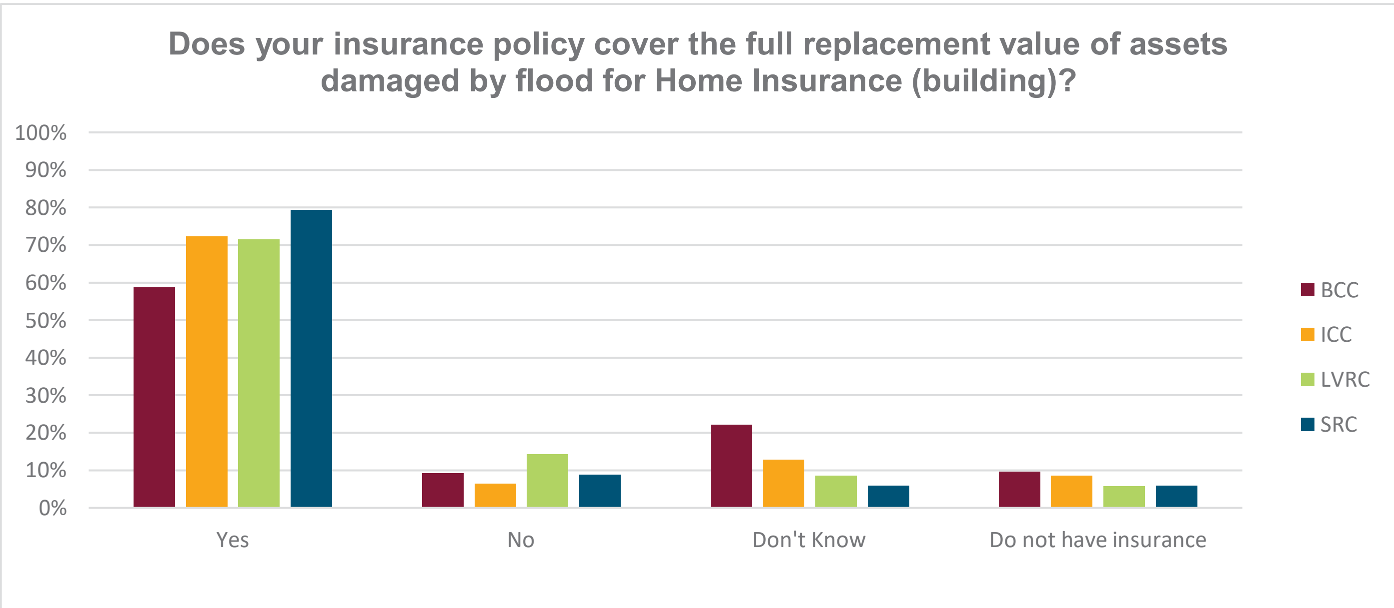


Figure 19: Respondents with adequate insurance to cover the full replacement value of assets damaged by floods

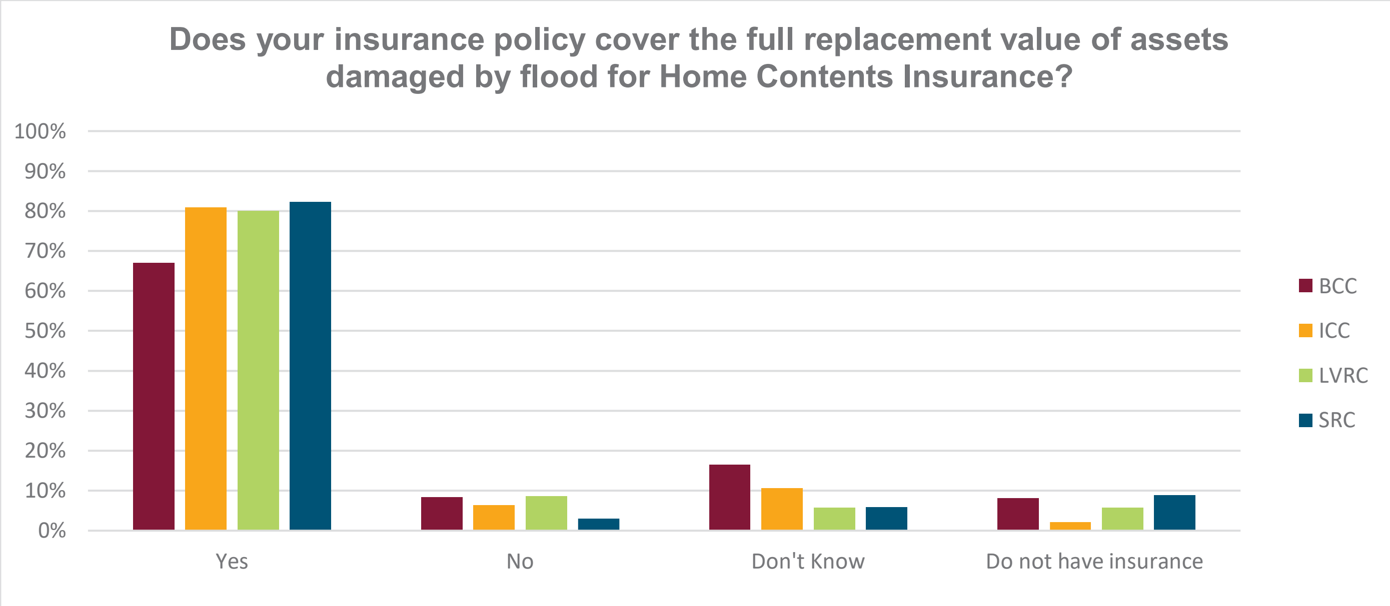


Figure 20: Respondents with insurance that covers the full replacement value of assets damaged by floods

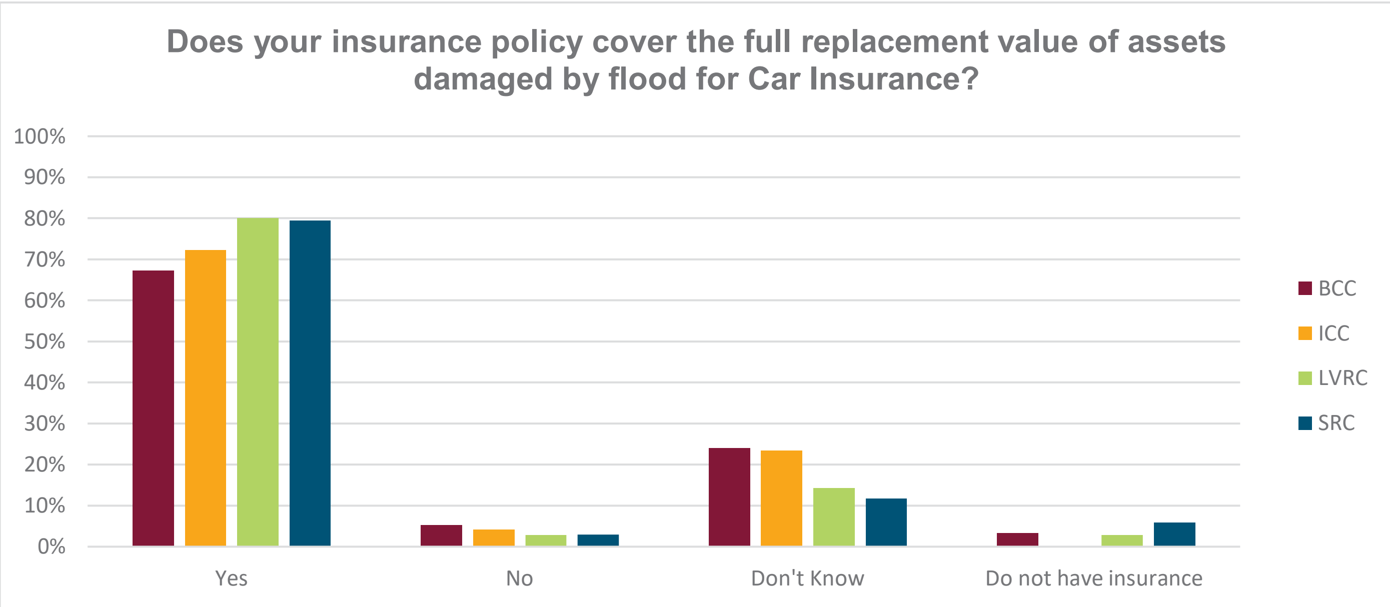


Figure 21: Respondents with insurance that covers the full replacement value of car assets damaged by floods

Demographics

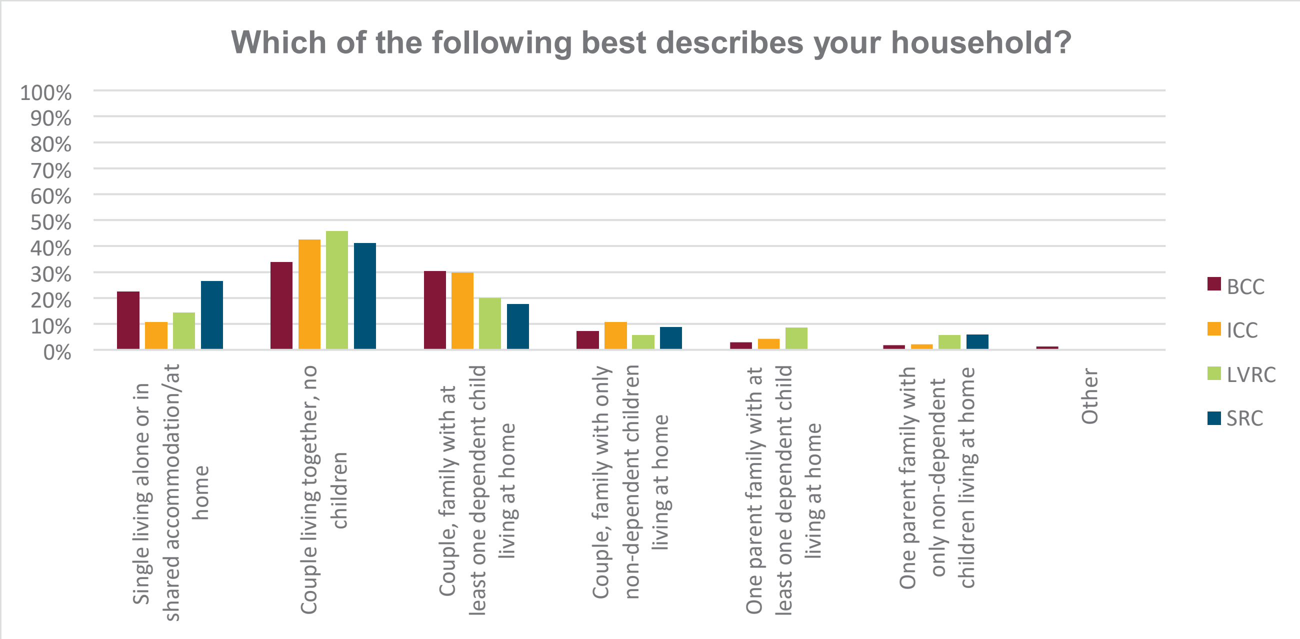


Figure 22: Household structures

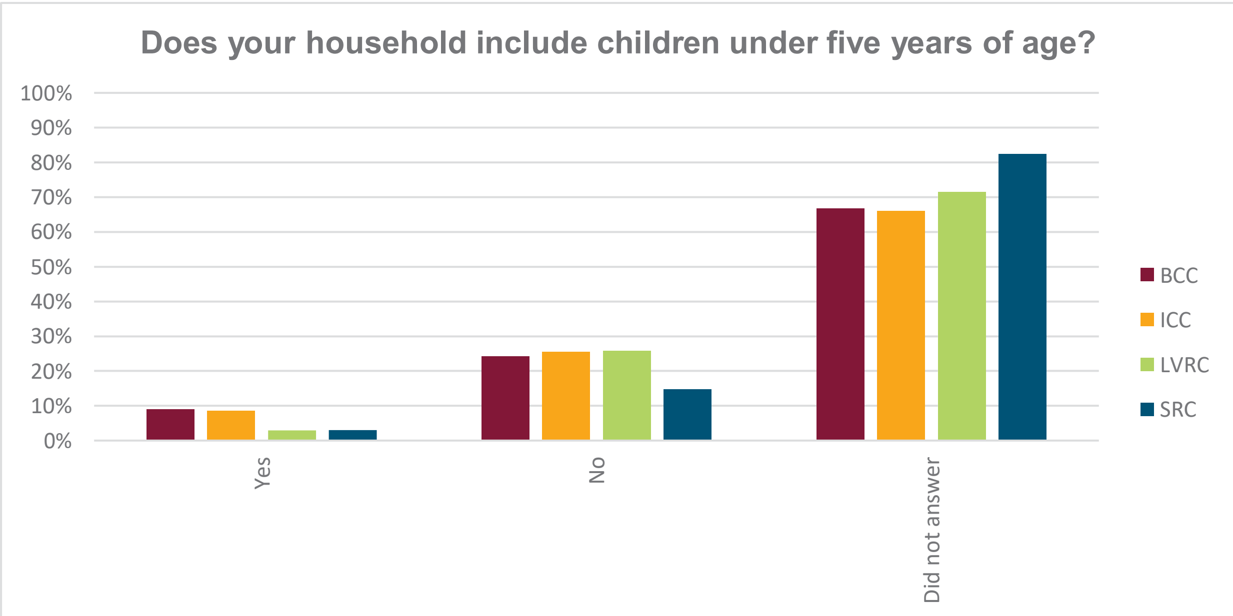


Figure 23: Households with children under five years of age.

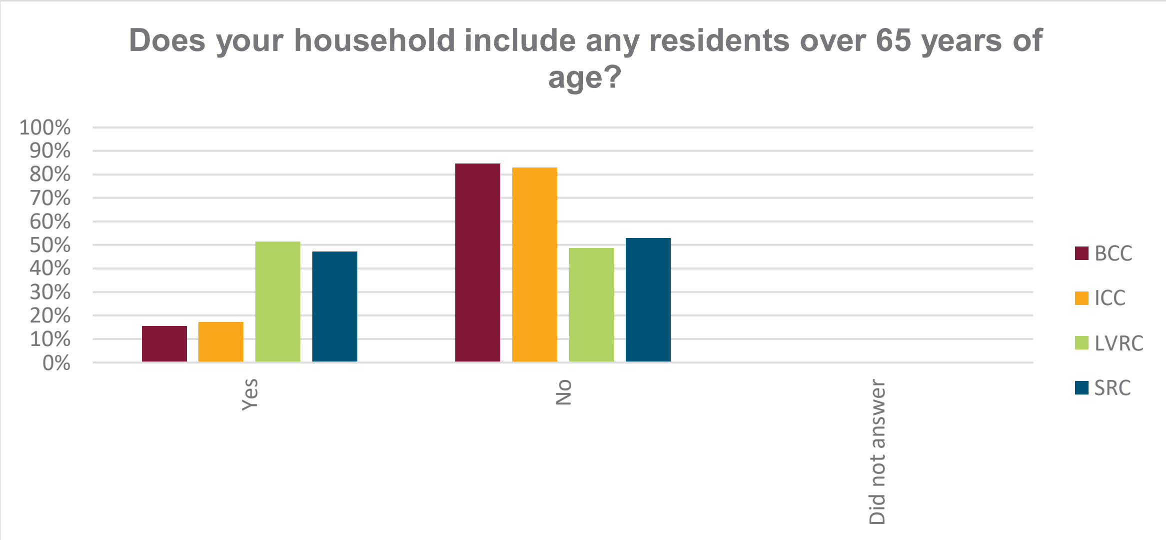


Figure 24: Households with people over 65 years of age

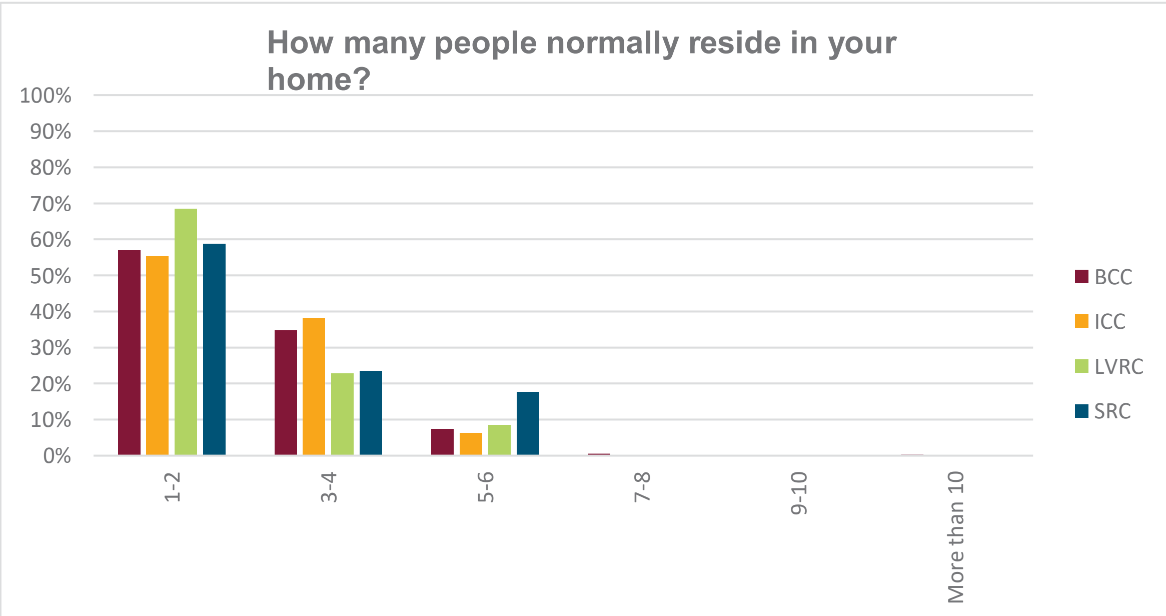


Figure 25: Number of people in a household

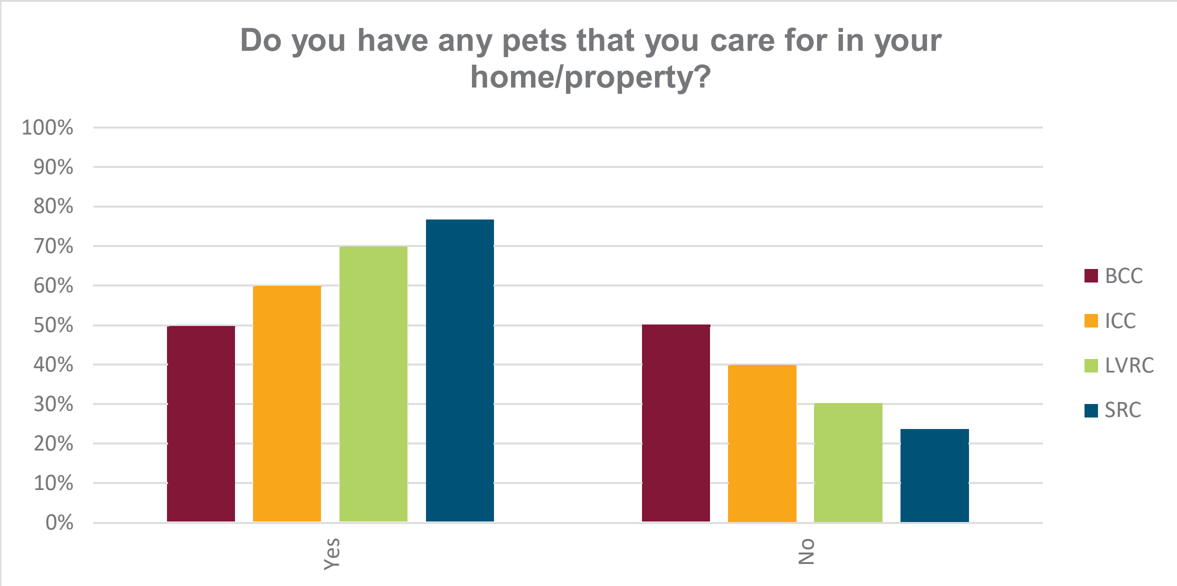


Figure 26: Households with pets

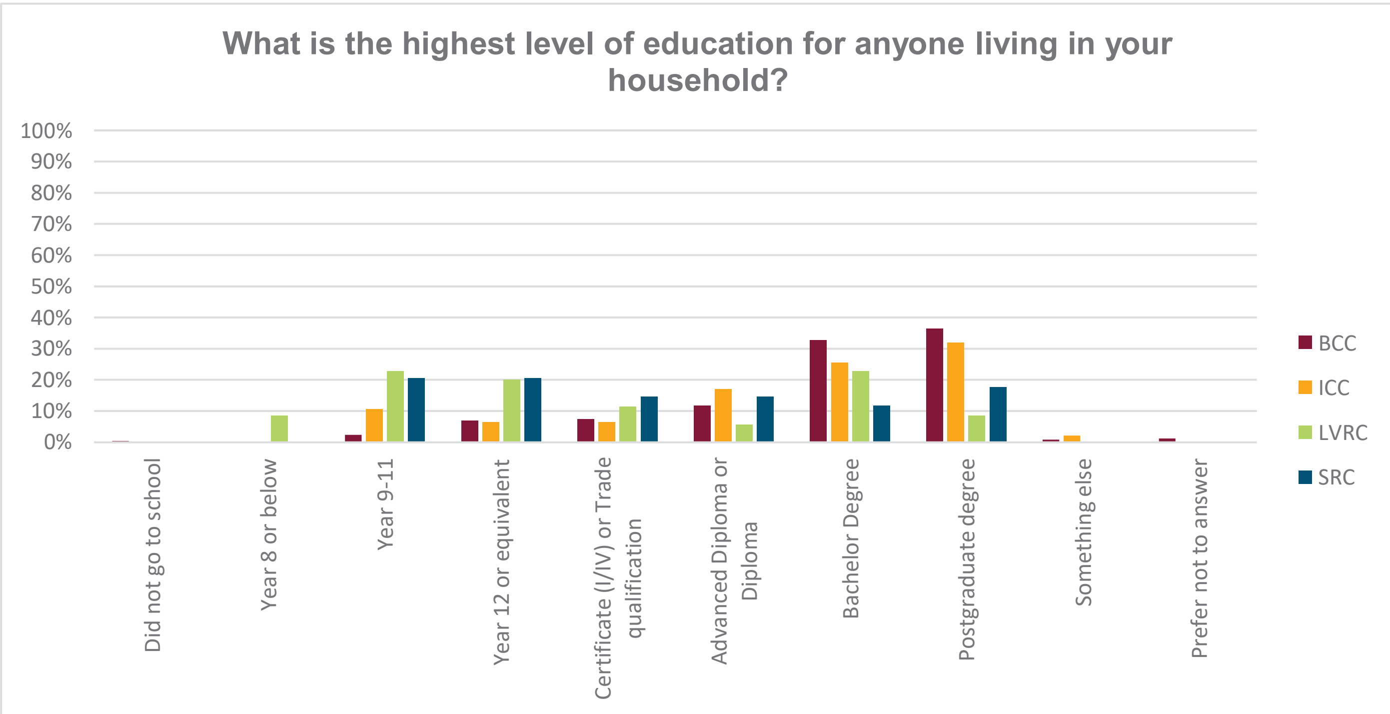


Figure 27: Education level for each respondent

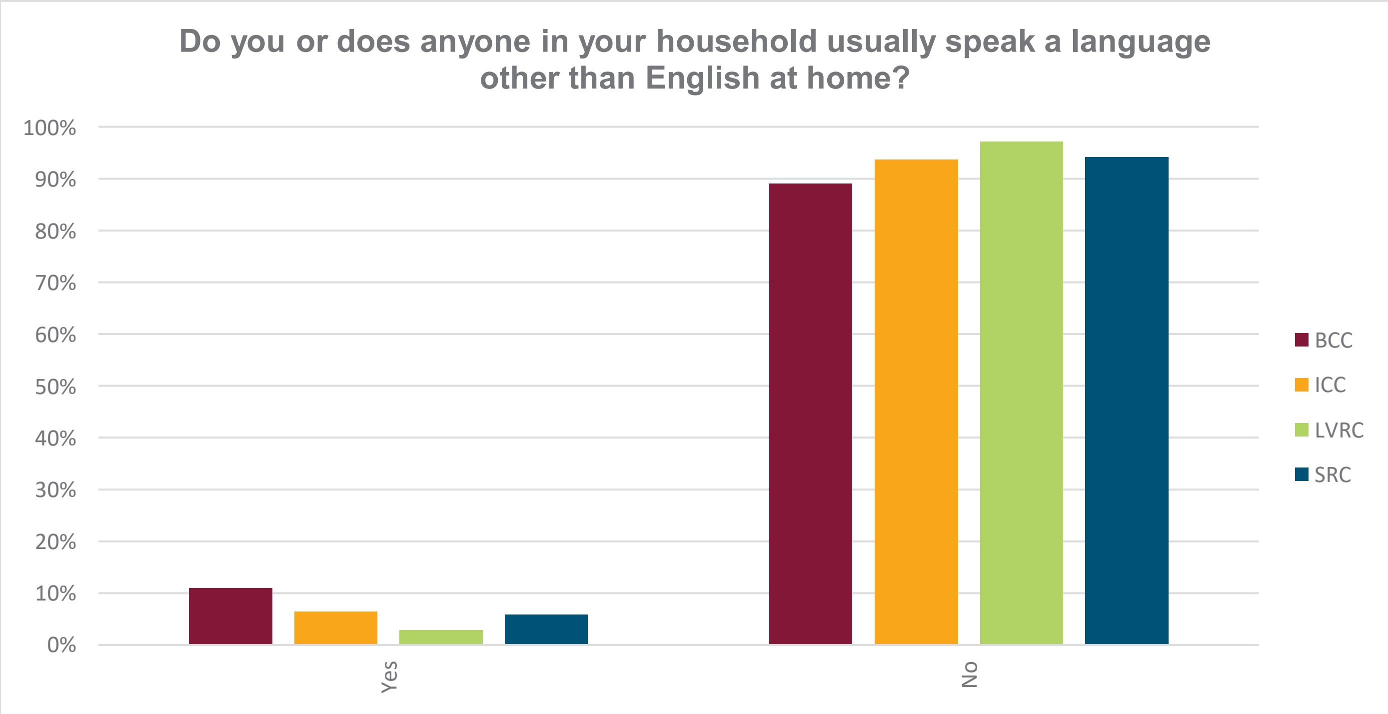


Figure 28: Respondents who speak a language other than English at home

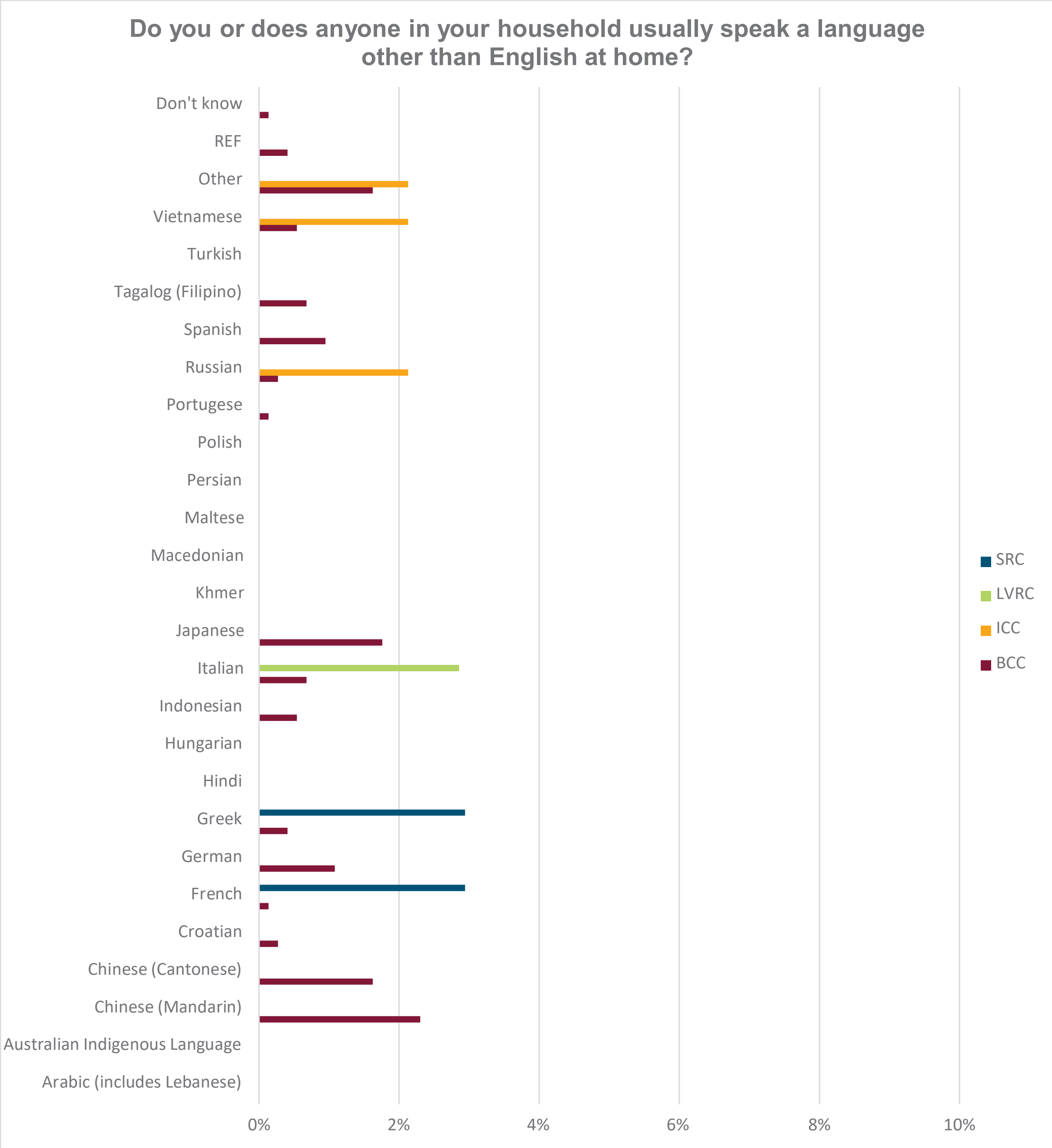


Figure 29: Languages spoken other than English

For those who answered other:
Indonesian, Amharic, Tigrinya, Dutch, Africaans, Swedish, Norwegian, Nepalese, Thai, Serbian, Ukrainian and Sinhalese.

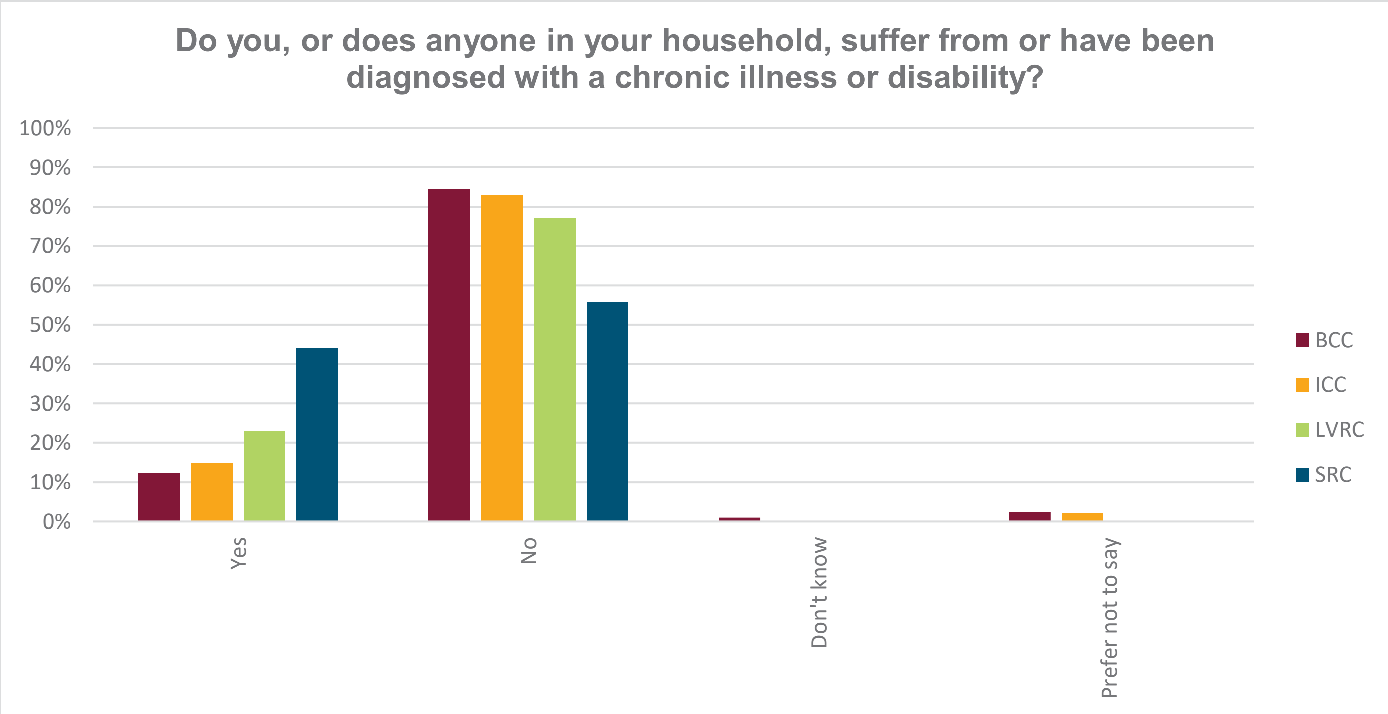


Figure 30: Respondents who have someone in their household who suffers from a chronic illness or disability

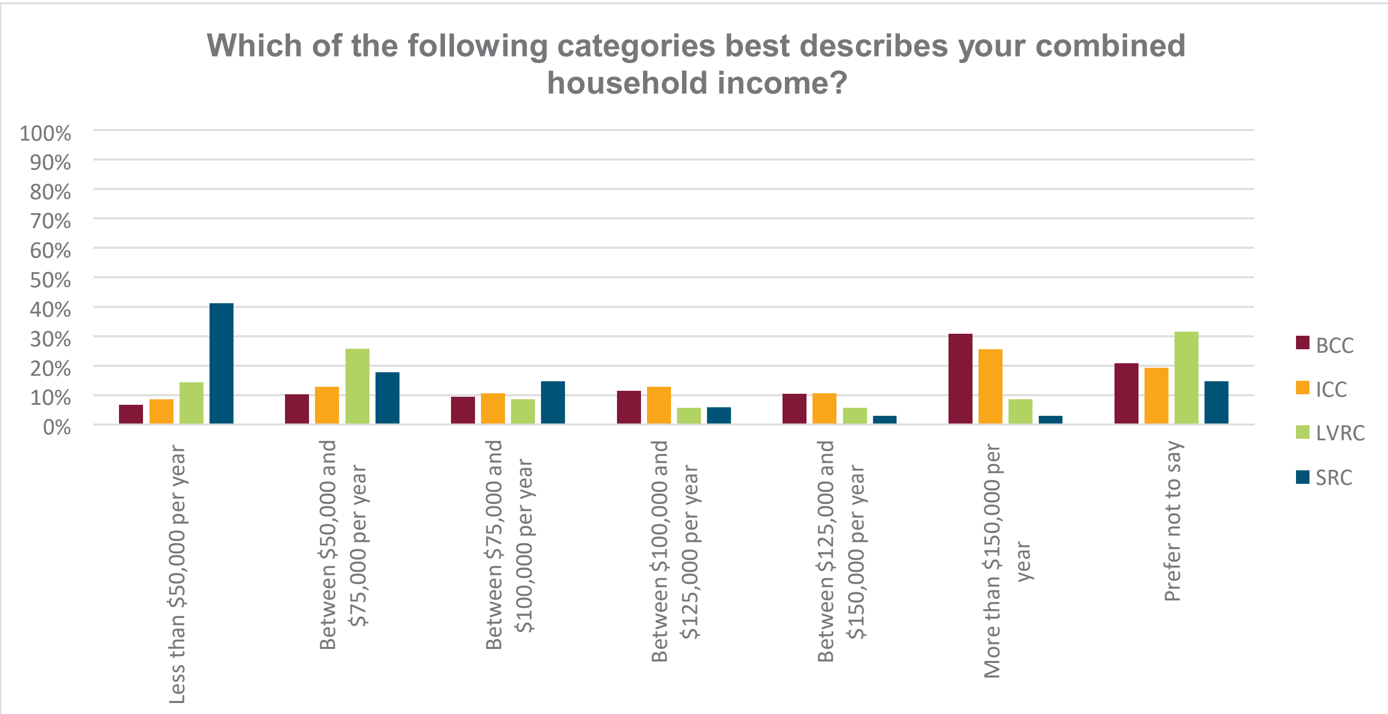


Figure 31: Combined household incomes

Appendix V Community Engagement Summary Report

Strategic Plan - community survey results

Background

In August and September 2017, the community was invited to share their views about the types of options that could be considered for modifying flood behaviour and increasing public awareness and responsiveness to flood risk in the Brisbane River floodplain.

Community displays were held across Brisbane, Ipswich, Somerset and the Lockyer Valley to provide information about the project. This report summarises the 186 responses captured through an online survey, which included responses from people living, working and recreating in the Brisbane River floodplain.

Key findings

Key findings from those surveyed:

- 35 per cent work in a different council area to where they live
- 42 per cent would seek information from more than one council during a flood
- 17 per cent would seek flood information from three or more council areas
- 76 per cent consider 'land use planning and development controls to be most important measures for managing flood risk
- 74 per cent consider 'increasing community safety during floods' to be most important when considering flood management options. This is followed closely by 'reducing the cost of flood damages' at 66 per cent, while only 7 per cent considered 'low establishment costs' to be most important.

Demographic information

The following tables represent the demographics of survey respondents including the local government areas in which they live and work, how long they have lived in the area and their age.

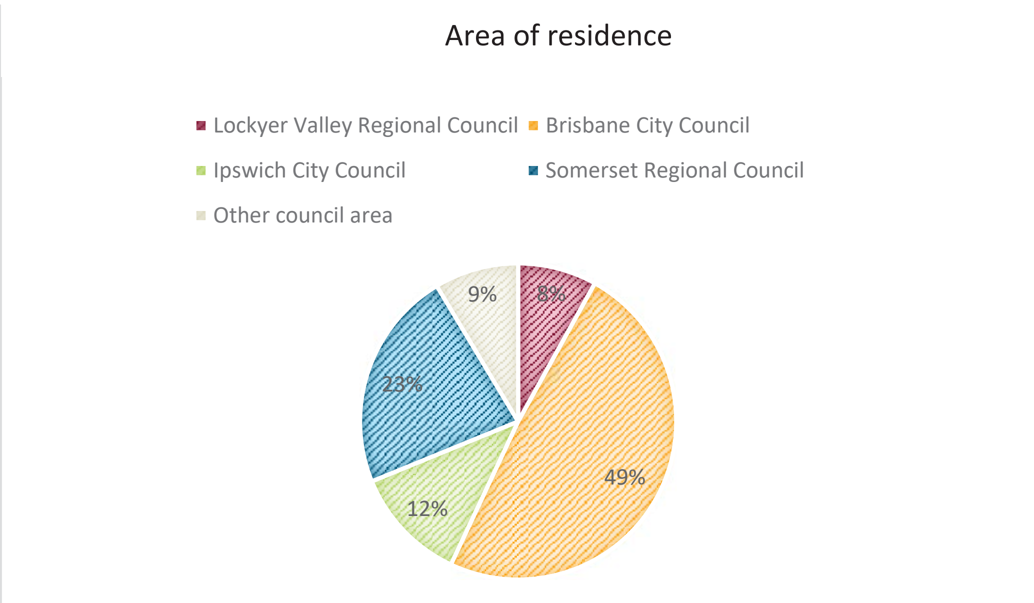


Figure 1: Local government area of residence of people surveyed

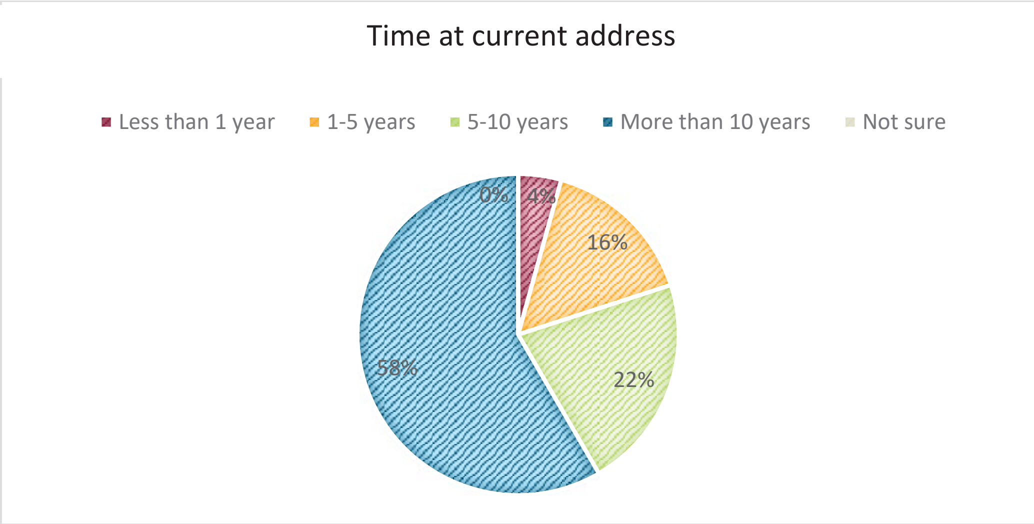


Figure 2: Length of time at current address of people surveyed

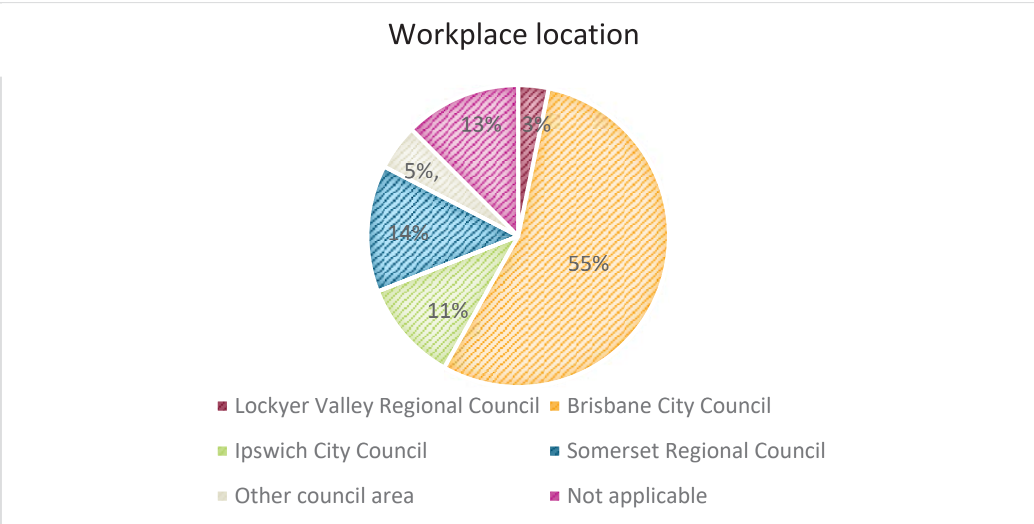


Figure 3: Location of workplace by local government area of people surveyed

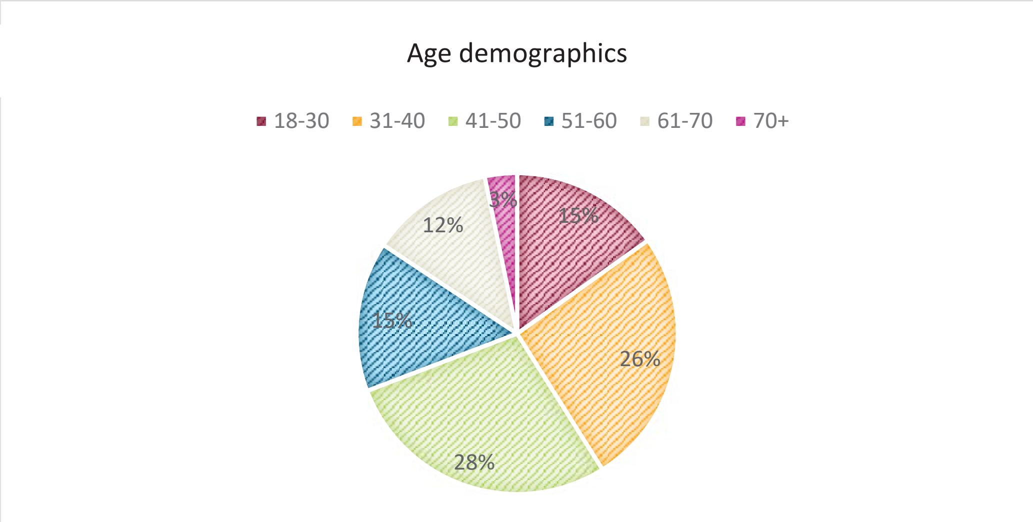


Figure 4: Age demographics

Survey responses

Flood Risk Measures

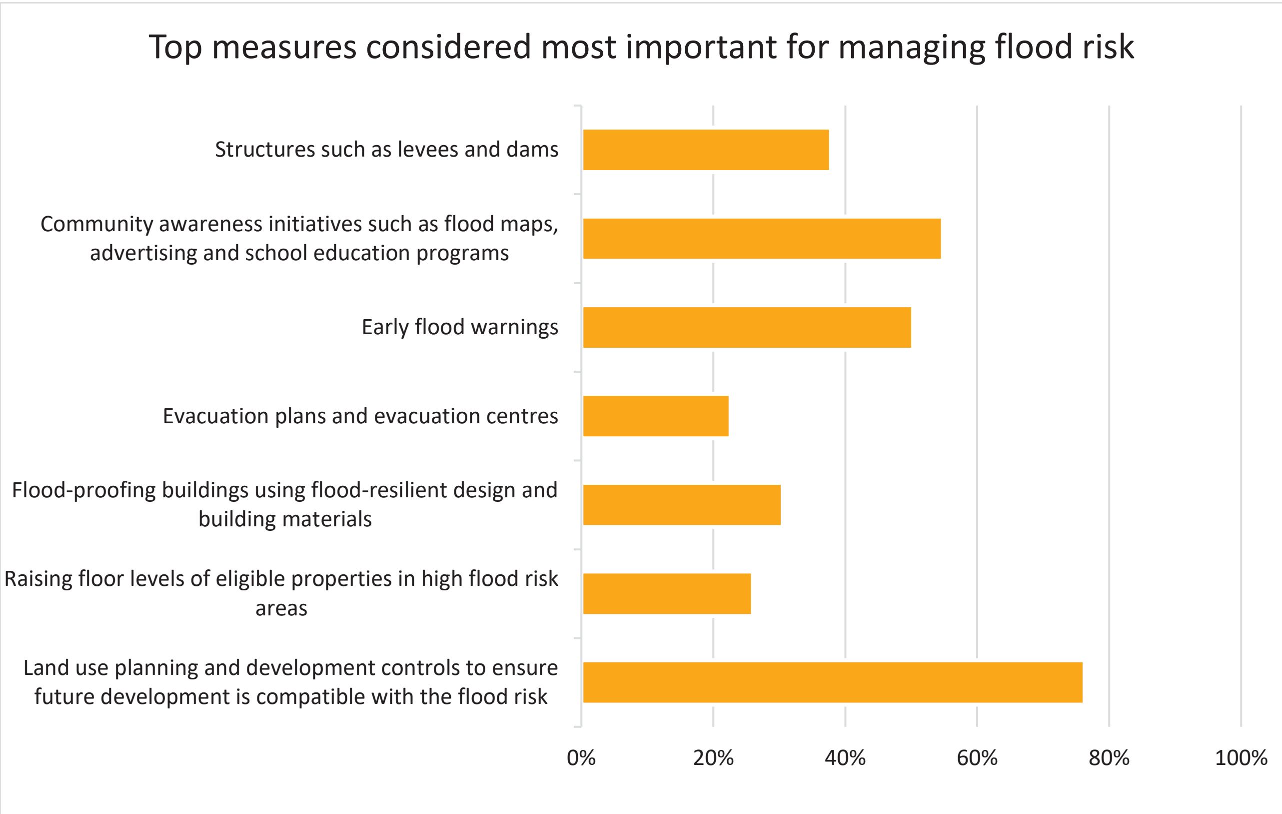


Figure 5: Measures considered most important by the community

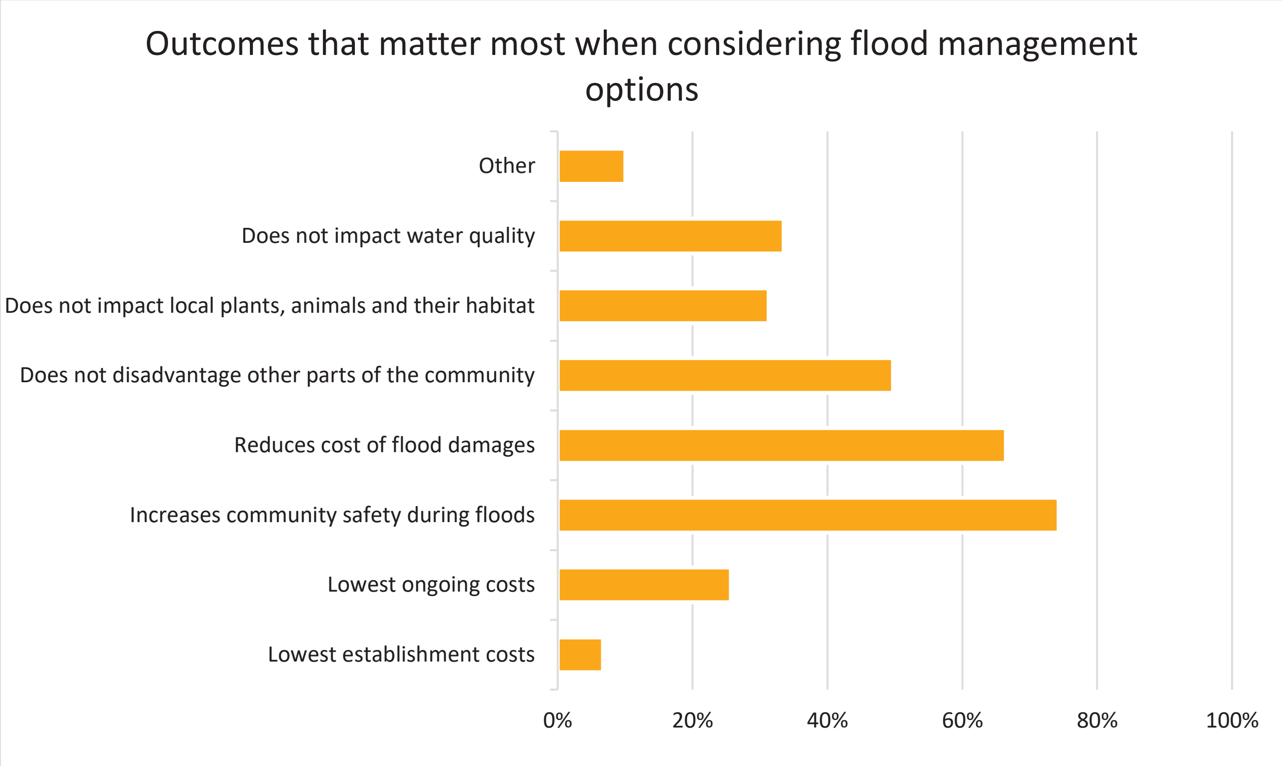
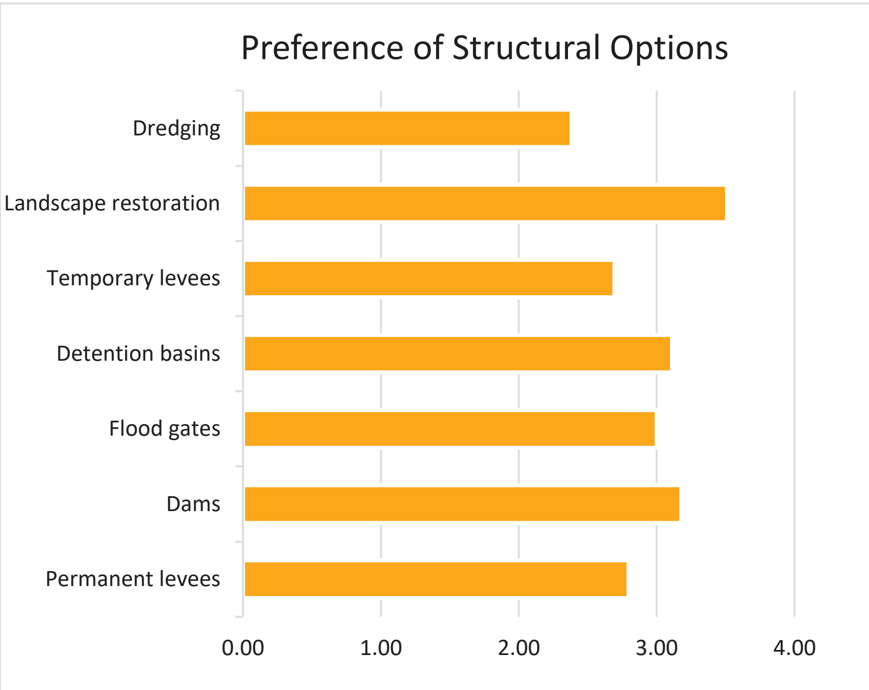


Figure 6: Resilience outcomes considered most important by the community

Structural Mitigation Options



Ranking system applied

Most preferred	5
Preferred	4
Unsure	3
Not preferred	2
Least Preferred	1

Figure 7: Preferred flood mitigation options

Community awareness and resilience - before a flood

76 per cent have viewed council's online flood mapping, with 80 per cent saying the maps provided the information they were looking for.

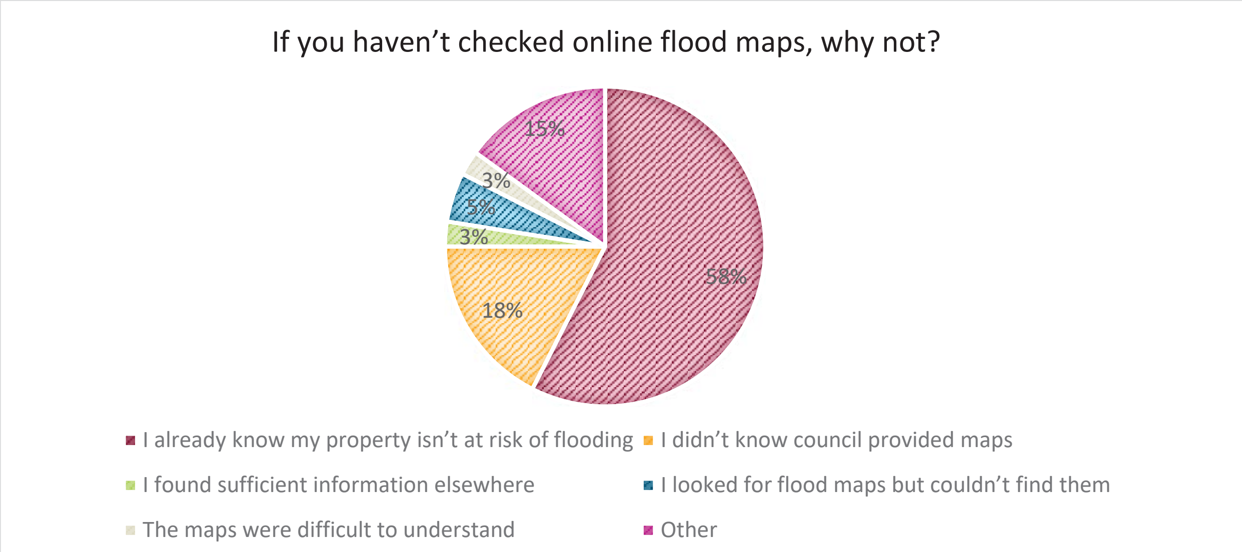


Figure 8: Reasons why people had not viewed online flood maps

Community awareness and resilience – during a flood

42 per cent would seek information from more than one council during a flood. Of these respondents;

- 57 per cent have family and friends in other council areas
- 18 per cent travel through other council areas
- 32 per cent have received conflicting information or advice during a flood.

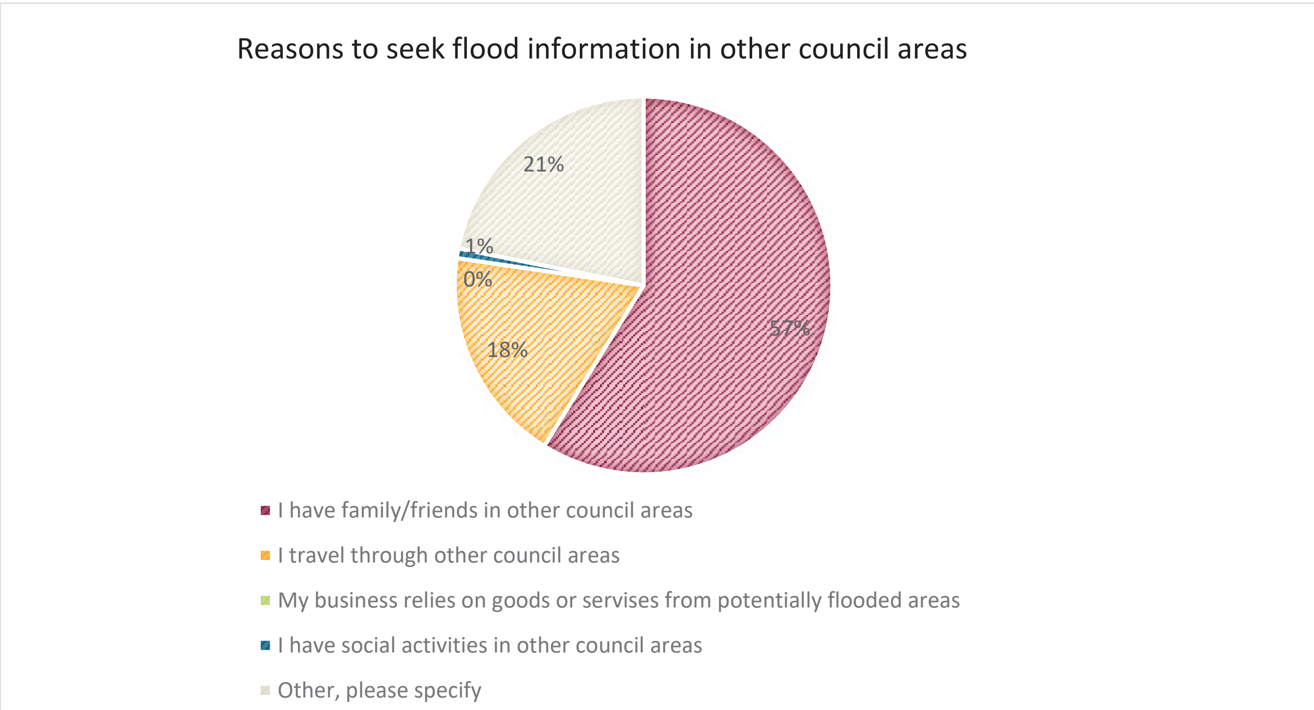


Figure 9: Reasons people seek information in additional local governments

Other local governments you seek flood related information from

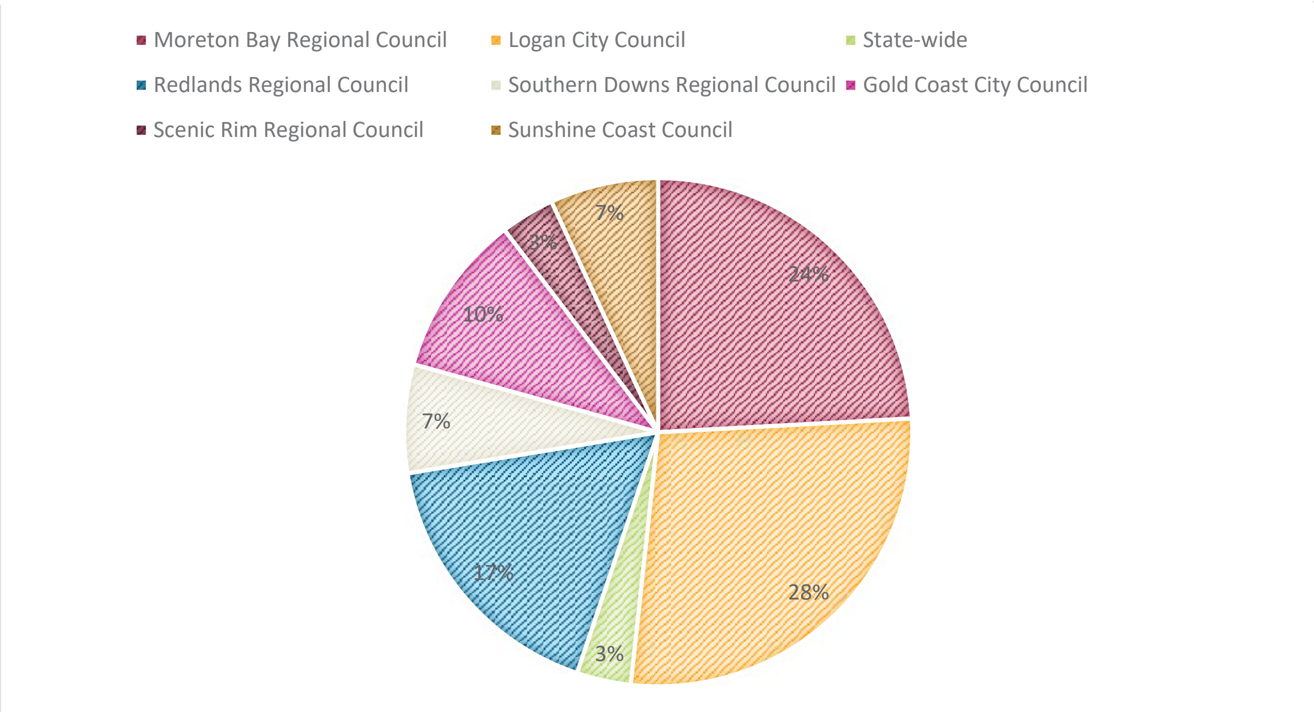


Figure 10: Other local government's people go to for flood information outside their own council

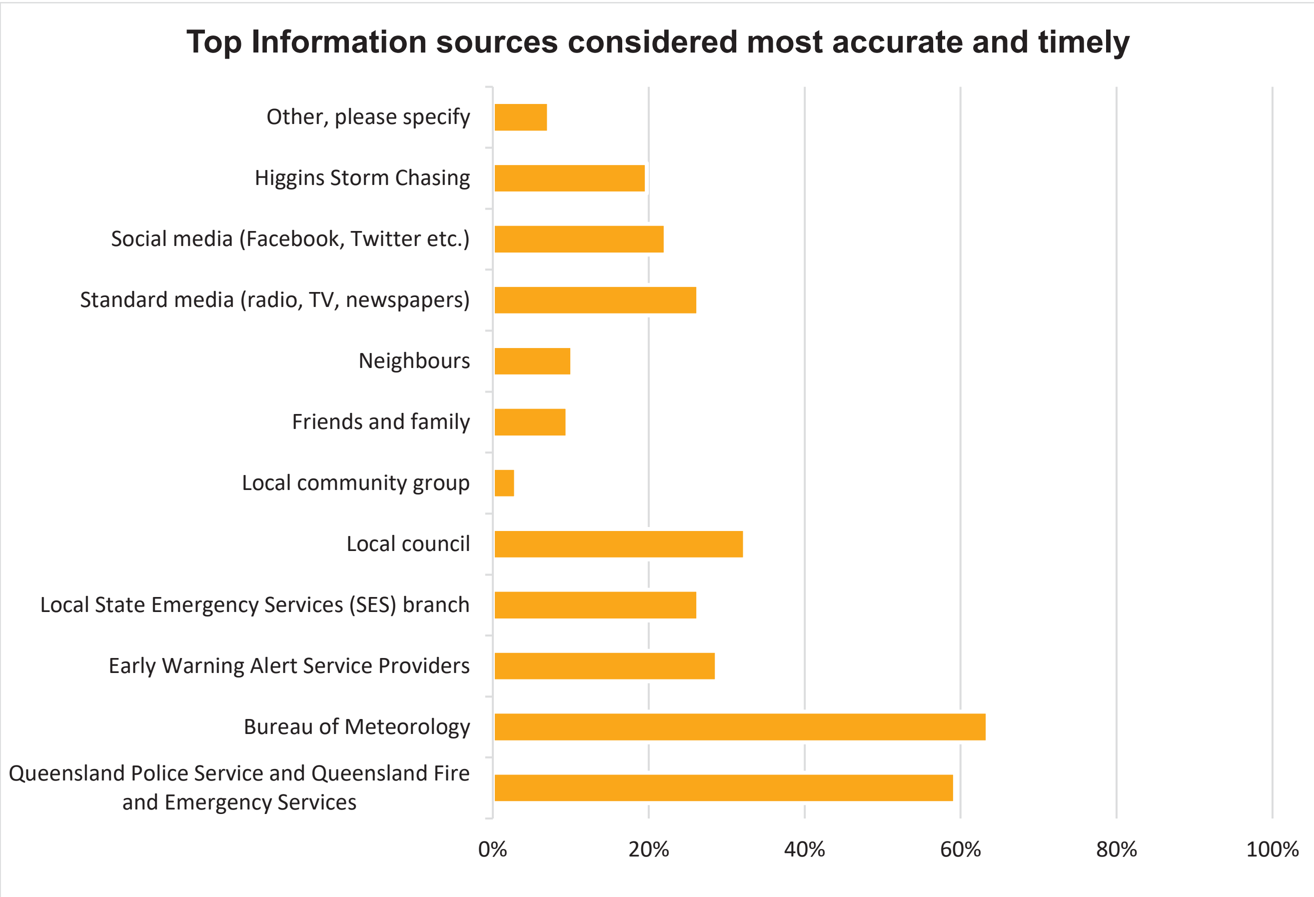


Figure 11: Flood warning sources considered to be most accurate and timely

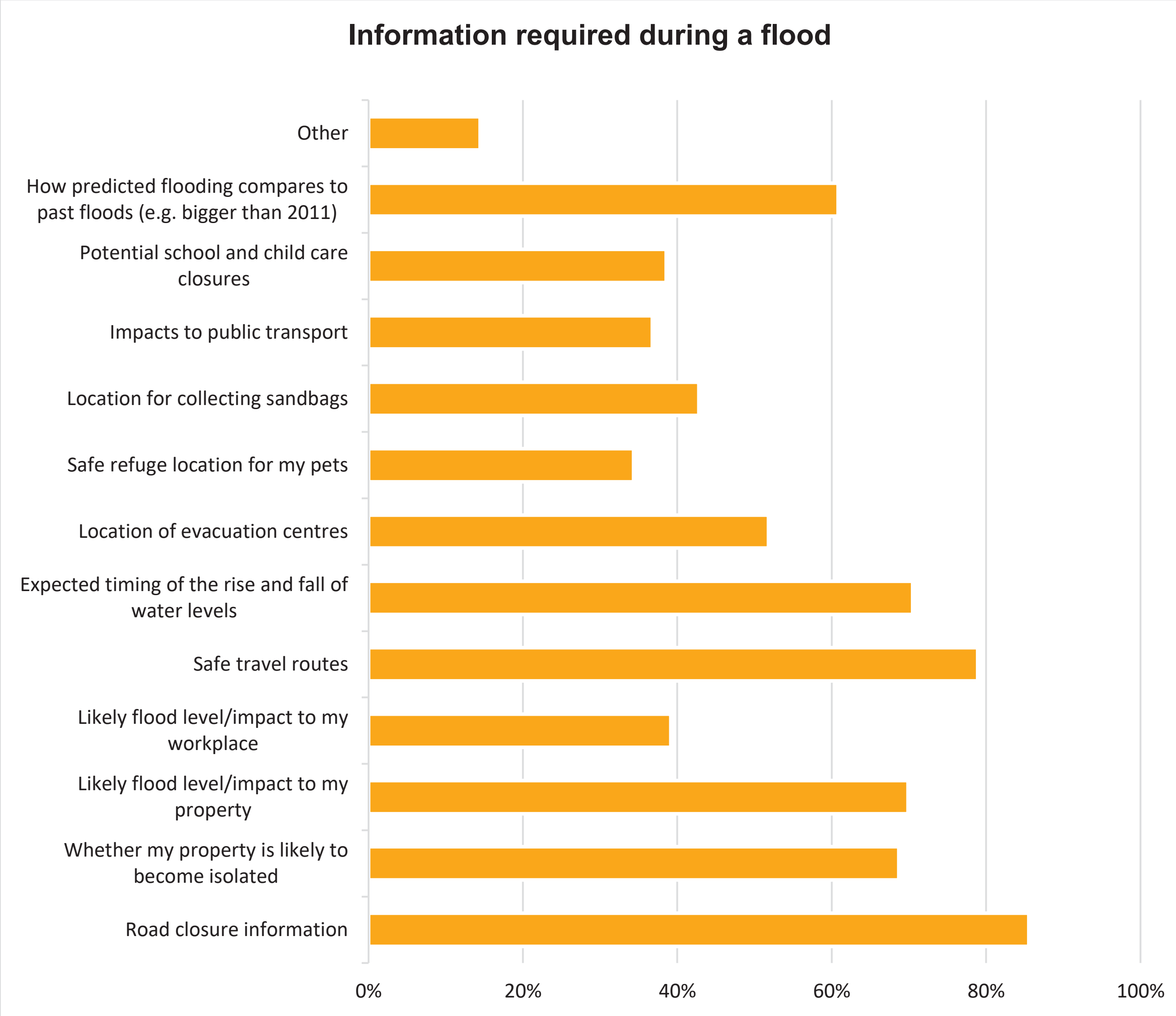


Figure 12: Information considered most important during a flood

Community Awareness and Resilience Activities

27 per cent of responders have previously been involved with a community group or organisation that assists local residents to prepare for and recover from flood impacts. Some of these groups include:

- Church groups
- Australian Army Reserves
- Rural Fire Brigade
- Rotary
- SES
- Neighbourhood communities
- Salvation Army
- Scouts
- Radio stations
- Sporting clubs
- Mud Army.

Level of support for establishing a community champions program to build flood awareness and resilience

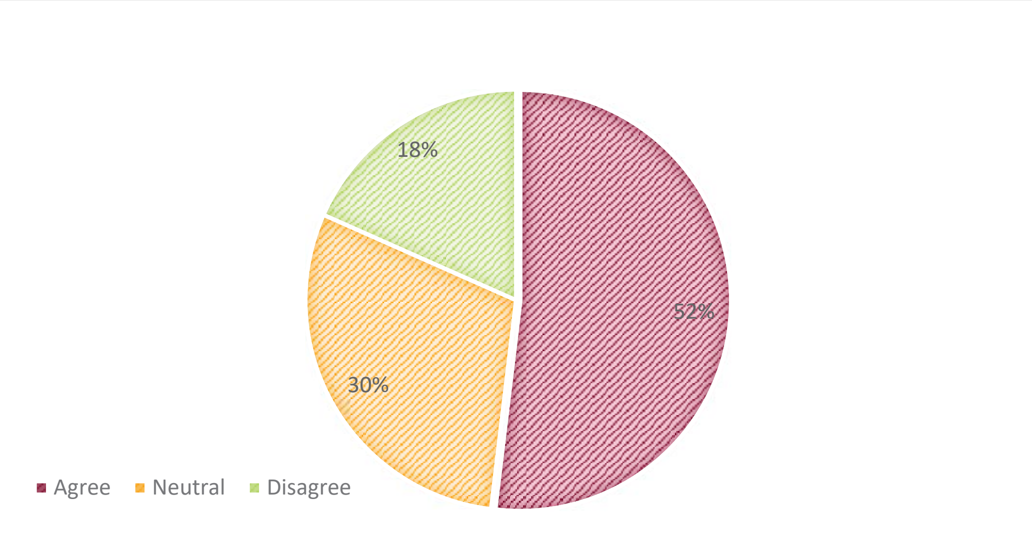


Figure 13: Support for the concept of a community champions program

Appendix W Gap and Opportunity Analysis

A risk informed community	What this means for councils, state governments and organisations	Activities currently being undertaken BCC	ICC	SRC	LVRC	Others	Gaps / opportunities	Related recommendations
Assesses flood risk by seeking comprehensive and local information from trusted sources, and personal or shared lived experience.	Undertakes comprehensive flood risk assessments.	Yes, in LDMP (although this is LGA wide). Also share information to assist others to undertake assessments (as outlined below).	Yes, in LDMP (although this is LGA wide). Also share information to assist others to undertake assessments (as outlined below).	Yes, in LDMP (although this is LGA wide). Also share information to assist others to undertake assessments (as outlined below).	Yes, in LDMP (although this is LGA wide). Also share information to assist others to undertake assessments (as outlined below).	Yes, Seqwater.	**Gap / opportunity:** There is a gap in detailed flood hazard information throughout the catchment for a variety of events / likelihoods including nature of flooding. The BRCFS will help to fill this gap by providing additional data on flood risk to assist councils, organisations and communities undertake risk assessments. **Gap / opportunity:** Increase community involvement in flood risk assessments undertaken by organisations and councils.	8.3.5 Develop a region-wide information and awareness campaign to share the results of the Brisbane River Flood Studies 8.3.6 Provide online mapping for flood awareness purposes 8.3.7 Provide property-scale information to households and organisations 8.4.1 Extending/embedding approach to community resilience in local / detailed Flood Risk Management Strategies 8.4.2 Continue implementation of suite of activities targeting vulnerable communities at a local level 8.4.7 Build on existing continuity planning resources with a local program assisting businesses, organisations and community groups
	Translates flood risk to a community, neighbourhood or household scale.	Flood Awareness Maps and Floodwise Property Reports.	Property reports for 1974 and 2011 flood events available.	Not identified in review.	Not identified in review.	Not identified in review.	**Gap / opportunity:** Provide property-scale flood risk information throughout the catchment including nature of flooding. For example, as well as region-wide mapping, an online platform could generate property-scale reports with tailored preparedness actions based on local risks (including potentially a photo of the property), and direct mail / door knocking could be used to provide this information to specific households (along with supporting materials).	8.3.6 Provide online mapping for flood awareness purposes 8.3.7 Provide property-scale information to households and organisations
	Provides flood risk information using: • Easy to understand language. • Consistency in language, terminology and approach with other organisations providing information for the same community.	Online resources. 'Be Prepared' articles.	Online resources. LDMP includes reference to consistent language.	Online resources. Articles in newsletters.	Online resources. Articles in newsletters.	Get Ready Queensland program offers variety of resources. QFES all-hazard resources.	**Gap / opportunity:** Provide detailed flood hazard information to support households, communities, businesses and community organisations to undertaken risk assessments. **Gap / opportunity:** Develop consistent categories of flood risk and flood risk language throughout the catchment, and explanations of key concepts using easy to understand language.	8.3.4 Develop guidelines for communication and engagement for use by organisations
	• Formats and media channels which are readily accessible to the entire community (including vulnerable or hard to reach communities).	Online resources. Advertising. Newsletters. Social Media. Some resources in multiple languages. Information stalls at events.	Online resources. Advertising. Newsletters. Social media. Information stalls at events.	Online resources. Newsletters. Social media. Information stalls at events.	Online resources. Newsletters. Social media. Information stalls at events.	Advertising (QFES, DOC, Seqwater). Social media. Get Ready resources available in multiple languages. Information stalls at events.	Flood risk information should continue to be provided through various formats and media channels, and communication accessible to vulnerable / hard to reach groups should continue. **Opportunity:** Investigate methods to communicate flood risk that may more effectively trigger attitude and behaviour change.	8.3.4 Develop guidelines for communication and engagement for use by agencies 8.3.7 Provide property-scale information to households and organisations

A risk informed community	What this means for councils, state governments and organisations	Activities currently being undertaken					Gaps / opportunities	Related recommendations
		BCC	ICC	SRC	LVRC	Others		
	Communicates risk and uncertainty.	Online awareness resources / maps communicate risk and likelihood.	Not identified in review.	Not identified in review.	Low to high flood hazard categories explained, however these are in a TLPI.	Not identified in review.	**Gap / opportunity:** Develop explanations of risk and uncertainty in easy to understand language for use in flood information.	8.3.4 Develop guidelines for communication and engagement for use by organisations
	Captures and promotes the sharing of past flood experiences.	Yes, for example, markers / installations in public spaces.	Yes, for example, markers / installations in public spaces.	Yes, for example, book capturing past flood event information.	Yes, for example, book capturing past flood event information.	Not identified in review.	**Opportunity:** Currently undertaken throughout the catchment, however there is an opportunity to include elements which describe / explain flood events in the context of the whole catchment, and incorporate flood memories in community events (for example, River Festival).	8.4.5 Investigate options for sharing flood histories through place-based installations and regional / local community events
Acknowledges that they live in a floodplain, and not all risk can be eliminated.	Assesses the full range of flood risk, up to and including extremely rare events.	Yes, 20% to 0.05% AEP available online.	Not identified in review. Historic events (1974 & 2011) only in flood maps available online.	Yes, in some locations 10% to PMF is available online.	Not identified in review. Provides low to high hazard categories for 'defined flood event' but not range of flood events.	Not identified in review.	**Gap / opportunity:** The BRCFS provides opportunity to build on local studies to include full range of flood events in risk assessments.	8.4.1 Extending/embedding approach to community resilience in local / detailed Flood Risk Management Strategies
	Provides information on the full range of flood risk, emphasising that the future will be different from the past.	Yes, 20% to 0.05% AEP available online.	Not identified in review. Historic events (1974 & 2011) only in flood maps available online. Doesn't emphasise this is not extent of possible floods.	Yes, in some locations 10% to PMF is available online.	Not identified in review. Provides low to high hazard categories for 'defined flood event' but not range of flood events.	Not identified in review.	**Gap / opportunity:** The BRCFS provides opportunity to build on local studies to provide information on the full range of flood events.	8.3.5 Develop a region-wide information and awareness campaign to share the results of Brisbane River Catchment Flood Studies 8.4.1 Extending/embedding approach to community resilience in local / detailed Flood Risk Management Strategies
	Promotes some flooding as desirable.	Not identified in review.	Not identified in review.	Not identified in review.	Not identified in review.	Not identified in review.	**Gap / opportunity:** Promote some flooding as desirable. For example, this could be achieved through development of a regional guideline for communicating flooding as desirable, through an awareness campaign materials developed to share the results of the BRCFS, and celebrating the river through community events (including some flooding).	8.3.4 Develop guidelines for communication and engagement for use by organisations 8.3.5 Develop a region-wide information and awareness campaign to share the results of Brisbane River Catchment Flood Studies
Assesses strengths, capabilities, vulnerabilities and capacity to respond to flood risk.	Involves the community in planning for flood resilience to build capabilities and capacity to respond.	Not identified in review.	Not identified in review.	Not identified in review.	Not identified in review.	Not identified in review.	**Gap / opportunity:** Involve the community in planning for flood resilience. Specifically, involving the community in developing local / detailed Flood Risk Management Strategies through engagement methods, supporting community-led initiatives, and investigating a community champions program.	8.3.3 Develop resilience toolkit to guide local implementations of priority regional resilience activities 8.3.4 Develop guidelines for communication and engagement for use by organisations 8.4.1 Extending/embedding approach to community resilience in local / detailed Flood Risk Management Strategies 8.4.6 Support community -led initiatives using community development approaches and community development training for organisation / council disaster management officers

A risk informed community	What this means for councils, state governments and organisations	Activities currently being undertaken					Gaps / opportunities	Related recommendations
		BCC	ICC	SRC	LVRC	Others		
								8.4.8 Develop guidance for a community champion program to be implemented locally
	Identifies strengths, capabilities, vulnerabilities and capacity of community to respond to flood risk.	Yes, in LDMP (although this is LGA wide).	Yes, in LDMP (although this is LGA wide).	Yes, in LDMP (although this is LGA wide).	Yes, in LDMP (although this is LGA wide).	Department of Communities' vulnerability assessments.	**Gap / opportunity:** Assessments of community strengths, capabilities, vulnerabilities and capacity often not undertaken at the local / neighbourhood level (or not in a formal way). The BRCFS provides a methodology to consider strengths and vulnerabilities for use in local assessments and plans. **Gap / opportunity:** Assessments to be undertaken by community groups, and through community led-initiatives at the local / neighbourhood scale.	8.3.6 Provide online mapping for flood awareness purposes 8.4.1 Extending/embedding approach to community resilience in local / detailed Flood Risk Management Strategies 8.4.2 Continue implementation of suite of activities targeting vulnerable communities at a local level 8.4.6 Support community -led initiatives using community development approaches and community development training for organisation / council disaster management officers 8.4.7 Build on existing continuity planning resources with a local program assisting businesses, organisations and community groups 8.4.8 Develop guidance for a community champion program to be implemented locally
	Provides tailored support, information and capacity building for communities which are vulnerable to flooding or do not have sufficient capacity to respond appropriately.	Various activities targeting vulnerable groups.	Various activities targeting vulnerable groups.	Various activities targeting vulnerable groups.	Various activities targeting vulnerable groups.	Various activities targeting vulnerable groups.	Activities targeting vulnerable / hard to reach groups should continue. **Gap / opportunity:** Undertake evaluations to identify effective activities, share learnings regionally, and coordinate delivery of activities targeting vulnerable groups (if appropriate) between organisations and councils operating throughout the catchment.	8.4.2 Continue implementation of suite of activities targeting vulnerable communities at a local level
Understands that everyone is responsible for working together to reduce flood risk.	Is clear on responsibilities for governance and action.	Yes, in LDMP. Less clear on proactive role for community.	Yes, in LDMP. Less clear on proactive role for community.	Yes, in LDMP. Less clear on proactive role for community.	Yes, in LDMP. Less clear on proactive role for community.	Yes.	**Gap / opportunity:** There are clear responsibilities for governance and action outlined in LDMPs, however these provide less guidance on responsibilities for communication with the community during events (especially through social media), and the role of community organisations / community groups / communities in disaster preparedness / response. Clear roles for communication with the community, and for the community itself, in a flood event should be considered.	8.3.1 Establish a regional group for coordinated flood awareness and resilience 8.3.4 Develop guidelines for communication and engagement for use by organisations 8.4.1 Extending/embedding approach to community resilience in local / detailed Flood Risk Management Strategies

A risk informed community	What this means for councils, state governments and organisations	Activities currently being undertaken					Gaps / opportunities	Related recommendations
		BCC	ICC	SRC	LVRC	Others		
	Empowers the community to manage their own flood risk.	Flood Awareness Maps. Guide for Residents includes resources to undertake household risk assessments.	Property reports for 1974 and 2011 flood events available.	Not identified in review.	Not identified in review.	Get Ready Queensland program offers variety of resources. QFES all-hazard resources.	**Opportunity:** The BRCFS provides an opportunity to build on local studies, and provide additional information on flood risk to the community to inform planning and support empowerment. **Gap / opportunity:** Empowerment of community to manage their flood risk, including involvement in flood risk planning and management.	8.3.6 Provide online mapping for flood awareness purposes8.4.3 Investigate options for facilitating / expanding / utilising volunteer connection and coordination strategies by organisations and councils at a regional level8.4.4 Utilise existing community events / networks to support community resilience8.4.6 Support community - led initiatives using community development approaches and community development training for organisation / council disaster management officers8.4.8 Develop guidance for a community champion program to be implemented locally 8.4.9 Investigate development of education program on flood awareness that aligns with the school curriculum outcomes
	Promotes stakeholder and community participation in the decision-making process.	Not identified in review.	Not identified in review.	Not identified in review.	Not identified in review.	Not identified in review.	**Gap / opportunity:** Stakeholders and community included in decision making process. Specifically in the development of local / detailed Flood Risk Management Strategies, Local Disaster Management Plans, the development of programs to build resilience, and supporting community-led initiatives.	8.4.1 Extending/embedding approach to community resilience in local / detailed Flood Risk Management Strategies 8.3.4 Develop guidelines for communication and engagement for use by organisations 8.4.6 Support community -led initiatives using community development approaches and community development training for organisation / council disaster management officers
An Appropriately Prepared Community	**What this means for councils, state governments and organisations**	**Activities currently being undertaken**					**Gaps / opportunities**	**Related recommendations**
		BCC	**ICC**	**SRC**	**LVRC**	**Others**		
Has the capacity, skills and	Contributes to a risk informed community (see above).	As above					As above	As above

A risk informed community	What this means for councils, state governments and organisations	Activities currently being undertaken					Gaps / opportunities	Related recommendations
		BCC	ICC	SRC	LVRC	Others		
knowledge to prepare, safely respond to and recover from a flood.	Provides ongoing and effective flood awareness and education programs and activities.	Various programs and activities captured in review.	Various programs and activities captured in review.	Various programs and activities captured in review.	Various programs and activities captured in review.	Various programs and activities captured in review.	A range of flood awareness and education programs and activities are undertaken throughout the catchment. **Gap / opportunity:** Undertake evaluations to identify effective activities, share learnings regionally and coordinate delivery of activities if appropriate. **Gap / opportunity:** Additional awareness and education programs and activities which provide deeper engagement / empowerment. **Opportunity:** Utilise the Get Ready Queensland approach to deliver regional flood awareness information that can be referred to by other organisations and councils, and provide funding to tailor information for specific local areas.	8.3.5 Develop a region-wide information and awareness campaign to share the results of Brisbane River Flood Studies 8.3.6 Provide online mapping for flood awareness purposes 8.3.7 Provide property-scale information to households and organisations 8.3.8 Investigate options for sharing location-based alerts / warning data and recovery information 8.4.2 Continue implementation of suite of activities targeting vulnerable communities at a local level 8.4.4 Utilise existing community events / networks to support community resilience 8.4.5 Investigate options for sharing flood histories through place-based installations and regional / local community events 8.4.6 Support community -led initiatives using community development approaches and community development training for organisation / council disaster management officers 8.4.7 Build on existing continuity planning resources with a local program assisting businesses, organisations and community groups 8.4.8 Develop guidance for a community champion program to be implemented locally 8.4.9 Investigate development of education program on flood awareness that aligns with the school curriculum outcomes 8.5.1 Evaluate resilience activities and share learnings 8.5.4 Engage with representatives of peak business / community sector, real estate and insurance bodies to facilitate collaboration
	Builds networks of community leaders/champions with in-depth capacity, skills and knowledge.	Not identified in review.	Not identified in review.	Not identified in review.	Not identified in review.	SES / QFES Rural Fire Brigades.	**Gap / opportunity:** Utilisation of networks of community leaders / champions to support resilience.	8.4.8 Develop guidance for a community champion program to be implemented locally
	Develops systems for appropriate community response (such as coordinating volunteers).	To some extent through Community Support Centres.	Not identified in review.	Not identified in review.	Not identified in review.	Volunteering Queensland developed database of volunteers for organisations to draw on.	**Opportunity:** Opportunity to build on the work of Volunteering Queensland to develop systems to coordinate community response.	8.3.8 Investigate options for sharing location-based alerts / warning data and recovery information 8.4.3 Investigate options for facilitating / expanding / utilising volunteer connection and coordination strategies by organisations and councils at a regional level
Has strong social alliances and networks, including with local leaders and partnerships with emergency services, local authorities and other relevant organisations,	Incorporates community development approaches in resilience building activities wherever possible.	Not identified in review. Potentially in street meets?	Not identified in review.	Not identified in review.	Not identified in review.	Not identified in review.	The review did not identify many examples of community development approaches to resilience building activities, however these are likely to be targeted / small scale and may not have been captured in the review. **Gap / opportunity:** Incorporate community development approaches in resilience building activities wherever possible.	8.4.1 Extending/embedding approach to community resilience in local / detailed Flood Risk Management Strategies 8.4.4 Utilise existing community events / networks to support community resilience 8.4.5 Investigate options for sharing flood histories through place-based installations and regional / local community events

A risk informed community	What this means for councils, state governments and organisations	Activities currently being undertaken					Gaps / opportunities	Related recommendations
		BCC	ICC	SRC	LVRC	Others		
and existing connections. Knows who they can help, and who can help them.	Delivers community resilience building information and activities through existing social networks to reinforce and strengthen these networks.	To some extent, with involvement in community events.Assume some programs delivered through existing community groups.	To some extent, with involvement in community events.Assume some programs delivered through existing community groups.	To some extent, with involvement in community events.Assume some programs delivered through existing community groups.	To some extent, with involvement in community events and backpacker / itinerant worker meet up events.Assume some programs delivered through existing community groups.	To some extent, with involvement in community events, for example, QFES involvement in community events.QFES school program and engagement through existing community groups.	The review did not identify many examples of social networks being used for resilience building activities, however these are likely to be targeted / small scale and may not have been captured in the review. **Gap / opportunity:** Deliver community resilience building information and activities through existing social networks.	8.4.4 Utilise existing community events / networks to support community resilience8.4.5 Investigate options for sharing flood histories through place-based installations and regional / local community events8.4.8 Develop guidance for a community champion program to be implemented locally 8.4.9 Investigate development of education program on flood awareness that aligns with the school curriculum outcomes
	Supports social alliances and networks as a component of various government functions, wherever possible (invests in community development approaches beyond direct flood applications).	Various community development approaches used to support social networks.	Various community development approaches used to support social networks.	Various community development approaches used to support social networks.	Various community development approaches used to support social networks.	Various community development approaches used to support social networks.	**Opportunity:** Continue to invest in community development approaches beyond direct flood applications. Local / detailed Flood Risk Management Strategies can also recognise social alliances / networks as an important element of resilience to embed this approach.	8.4.1 Extending/embedding approach to community resilience in local / detailed Flood Risk Management Strategies
Makes informed decisions and takes appropriate measures to reduce exposure to floods including to potential loss of life, assets, and livelihoods. Appropriately modifies these measures as risks evolve (including considering changing conditions during a flood, future climate, impacts of development or infrastructure, and changing demographics in the community).	Provides timely and relevant information about changing circumstances (hazard, exposure, vulnerability).	EWN, social media	EWN, EM Dashboard, social media	EWN, EM Dashboard, social media	EWN, EM Dashboard, social media	QLD Alerts website, QFES newsroom website, Seqwater EWN, Seqwater freecall number, social media.	**Gap:** Different services available in different local government areas means that users need to register / visit multiple services if accessing information for multiple local government areas. **Opportunity:** Build on success of EM dashboard and EWN to link alerts / warnings throughout the catchment to wherever person is located. Specifically, provide links to neighbouring council dashboards within each dashboard to provide quick access, and continue to develop these dashboards by adding new data sources. **Opportunity:** Use 'open data' approaches to support information sharing, including alerts / warnings based on specific location-based information. Specifically, work with organisations and councils to share data in a consistent format so it can be used in multiple applications (for example, Translink public transport data is available in multiple applications including Google Maps, Moovit App, etc.).	8.3.6 Provide online mapping for flood awareness purposes 8.3.8 Investigate options for sharing location-based alerts / warning data and recovery information

A risk informed community	What this means for councils, state governments and organisations	Activities currently being undertaken: BCC	ICC	SRC	LVRC	Others	Gaps / opportunities	Related recommendations
	Invests in communication systems to provide information to the community, and for the community to communicate with each other and authorities as risks evolve.	Social media accounts	Social media accounts	Social media accounts	Social media accounts	Social media accounts. Self-Recovery App (DOCCSDS), Seqwater App.	**Opportunity**: Clarify communication protocols regarding social media to ensure consistency of messaging and information between providers and platforms. **Opportunity**: Investigate options for sharing location-based data	8.3.8 Investigate options for sharing location-based alerts / warning data and recovery information 8.3.4 Develop guidelines for communication and engagement by organisations
	Facilitates flood resilient urban and rural planning.	Undertaken in other work packages.						
	Facilitates flood resilient built form outcomes.	Undertaken in other work packages.						
	Supports the community in preparation and response measures, including provision of aids (such as sandbags).	Yes	Yes	Yes	Yes	Yes. Self-Recovery App (DOCCSDS)	**Opportunity:** Upskill network of community champions to share their skills with broader community.	8.4.8 Develop guidance for a community champion program to be implemented locally
Plans for continuity (households, businesses and community organisations and institutions), including investing in measures to lesson impacts, being appropriately insured, and developing plans in advance.	Provides templates and guidance materials to assist with planning for continuity, based on research of effective strategies and tailored for specific users such as households, businesses, community groups, and other institutions.	Guide for Business. Videos. Continuity Plan template.	Refer visitors to website to Get Ready resources.	Unclear. Identified as action in LDMP.	Refer visitors to website to Get Ready resources.	Qld Government online resources including Continuity Plan template. Dep Communities preparing toolkit for community organisations.	**Gap / opportunity:** Build on continuity resources already available, and combine with deeper engagement methods (workshops, meetings) to support businesses and organisations to develop continuity plans.	8.3.6 Provide online mapping for flood awareness purposes 8.3.7 Provide property-scale information to households and organisations 8.4.2 Continue implementation of suite of activities targeting vulnerable communities at a local level 8.4.7 Build on existing continuity planning resources with a local program assisting businesses, organisations and community groups 8.4.8 Develop guidance for a community champion program to be implemented locally 8.4.9 Investigate development of education program on flood awareness that aligns with the school curriculum outcomes
	Engages with representatives and peak bodies for businesses and insurance to facilitate provision of relevant information and support.	Writes to peak bodies and industry when new information becomes available.	Not identified in review.	Not identified in review. Identified as issue for State Government in LDMR.	Not identified in review.	Not identified in review.	**Gap / opportunity:** Engage with representatives and peak bodies including business / community sector, real estate and insurance bodies to facilitate collaboration.	8.5.4 Engage with representatives of peak business / community sector, real estate and insurance bodies to facilitate collaboration
Prepares psychologically for potentially traumatic events.	Supports the community to prepare psychologically for potentially traumatic events, informed by research and tailored to suit local community characteristics and past flood experience.	Not identified in review.	Not identified in review.	Not identified in review.	Not identified in review.	Included in the RediPlan emergency planning guides.	**Gap / opportunity:** Research on the applicability of psychological preparedness to flooding. **Gap / opportunity:** Include psychological preparedness in awareness campaigns to support action.	8.5.3 Further research on incorporating psychological preparedness into awareness and resilience campaigns including applicability to flood hazards
An Adaptable Community	**What this means for councils, state governments and organisations**	**Activities currently being undertaken: BCC**	**ICC**	**SRC**	**LVRC**	**Others**	**Gaps / opportunities**	**Related recommendations**
Adjusts response in rapidly changing circumstances including changing flood conditions, infrastructure conditions and	Provides timely and relevant information during floods, including flood warning, identification of potential impacts and recommended response measures.	EWN	EWN, EM Dashboard	EWN, EM Dashboard	EWN, EM Dashboard	EWN	**Opportunity:** Build on success of EM dashboard and EWN to link alerts / warnings throughout the catchment to wherever person is located (as above). **Opportunity:** Use 'open data' approaches to support information sharing, including alerts / warnings based on specific location-based information (as above).	8.3.4 Develop guidelines for communication and engagement for use by organisations 8.3.8 Investigate options for sharing location-based alerts / warning data and recovery information

A risk informed community	What this means for councils, state governments and organisations	Activities currently being undertaken					Gaps / opportunities	Related recommendations
		BCC	ICC	SRC	LVRC	Others		
availability of support.	Provides information across a range of media to ensure system redundancy in changing circumstances.	Online resources. Advertising. Social Media.	Online resources. Advertising. Social media.	Online resources. Social media.	Online resources. Social media.	Advertising (QFES, DOCCSDS, Seqwater). Social media. Self-Recovery App (DOCCSDS), Seqwater App.	**Opportunity:** Guidelines for communication and social media might assist to ensure messages provided across a range of media and reduce some existing confusion around social media sharing.	8.3.4 Develop guidelines for communication and engagement for use by organisations
Draws on community alliances and networks for rapid and effective disaster response.	Establishes communication protocols and clarifies responsibilities for engaging community alliances and networks during flood events.	To some extent through Community Support Centres.	To some extent in LDMP.	To some extent in LDMP through Red Cross.	To some extent in LDMP through community service organisations.	Not identified in review.	**Gap / opportunity:** Inclusion of community organisations and networks in communication protocols, that is, involve the community sector and key community groups / community champions (once these are identified / developed) in two-way communication flow during and after events.	8.3.4 Develop guidelines for communication and engagement for use by organisations 8.4.6 Support community -led initiatives using community development approaches and community development training for organisation / council disaster management officers 8.4.8 Develop guidance for a community champion program to be implemented locally
	Includes community leaders/champions in formal disaster management response planning.	Not identified in review.	Not identified in review.	Not identified in review.	Not identified in review.	Not identified in review.	**Gap / opportunity:** Community involvement in disaster management response planning, that is, involve community stakeholders (community sector, key community groups / community champions once these are identified / developed) in disaster management planning.	8.3.4 Develop guidelines for communication and engagement for use by organisations 8.4.6 Support community -led initiatives using community development approaches and community development training for organisation / council disaster management officers 8.4.8 Develop guidance for a community champion program to be implemented locally
Reassesses and reorganises approaches based on evaluation and learnings.	Undertakes evaluations of resilience building activities and evaluations of flood event response, shares the outcomes of these evaluations, and modifies future activities based on learnings.	Evaluations of awareness campaigns, and survey on flooding and disaster readiness in annual resident survey.	No formal evaluation. Evaluation limited to campaign metrics.	Not identified in review.	Evaluations of awareness campaigns.	Not identified in review.	**Gap / opportunity:** Evaluation of effectiveness of activities in terms of influencing preparedness attitudes and behaviours (evaluation undertaken is generally related to campaign awareness metrics). Funding to undertake evaluations is an issue. Specifically, develop a compendium of evaluated activities as an evidence base and summarise the practical findings in a resilience toolkit to guide resilience activity implementation, develop mechanism to share evaluations within the catchment (for example, a regional group which meets regularly), and share research and best-practice (potentially through existing forums). Investigating funding mechanisms for evaluations will be important.	8.3.1 Establish a regional group for coordinated flood awareness and resilience 8.3.2 Summarise current resilience activities in a compendium 8.3.3 Develop resilience toolkit to guide local implementations of priority regional resilience activities 8.4.1 Extending/embedding approach to community resilience in local / detailed Flood Risk Management Strategies 8.5.1 Evaluate resilience activities and share learnings 8.5.2 Continue to learn from and share best-practice research findings on community resilience activities from around Australia and internationally

A risk informed community	What this means for councils, state governments and organisations	Activities currently being undertaken					Gaps / opportunities	Related recommendations
		BCC	ICC	SRC	LVRC	Others		
Identifies and introduces new resources, tools, technology, and courses of action to improve resilience over time.	Identifies gaps in current activities and develops resources, tools, technologies and courses of action based on best-practice and current research.	Survey on flooding and disaster readiness in annual resident survey.	Not identified in review.	Not identified in review.	Not identified in review.	IGEM Collaboration Zone / DMO Network Forum / Basecamp platform. Other conferences / workshops.	**Opportunity:** The IGEM Collaboration Zone / DMO Network Forum / QGCIO endorsed Basecamp platform to continue to fulfil this role. **Opportunity:** Establish other catchment wide mechanisms to share knowledge and resources specific to flooding in the catchment.	8.3.1 Establish a regional group for coordinated flood awareness and resilience 8.3.2 Summarise current resilience activities in a compendium 8.3.3 Develop resilience toolkit to guide local implementations of priority regional resilience activities 8.5.1 Evaluate resilience activities and share learnings 8.5.2 Continue to learn from and share best-practice research findings on community resilience activities from around Australia and internationally 8.5.3 Further research on incorporating psychological preparedness into awareness and resilience campaigns including applicability to flood hazards

Appendix X Case-Studies

X.1 Monash University and Emergency Management Victoria compendium of community-based resilience building case studies (Victoria)

Emergency Management Victoria (EMV) and Monash University created a compendium of community-based resilience building case studies which was published in 2017. It includes reflections from project managers, including success factors, challenges and recommendations for replication in other settings. The compendium is available online for broad community access.

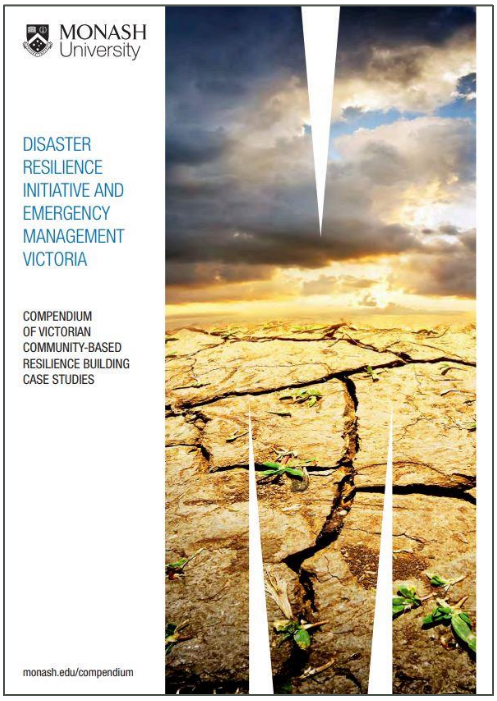


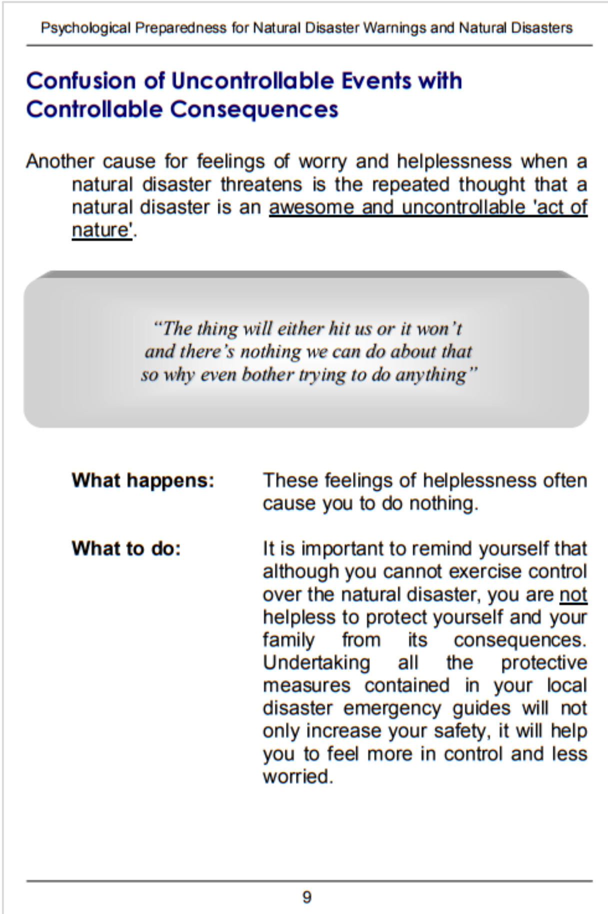
Figure X-1 Compendium of Victorian Community-Based Resilience Building Case Studies

Many of the case studies have not been evaluated by the implementing bodies, and therefore it is difficult to independently assess effectiveness, although many case studies have received awards and are recognised internationally as successful activities.

The broad range of resilience activities included in the compendium suggests that a range of activities can have success for various disaster events (bushfire, flooding, etc.) and in different context / regions.

X.2 Psychological preparedness trial in Cairns (Queensland)

Tropical cyclone warning messages were trialled in Cairns, Queensland during the 1996 / 1997 cyclone season, including Cyclone Justin in March 1997. The trial involved dissemination of psychological preparedness information to enable individuals to better cope with the situation, including in taking actions to prevent and prepare for impacts. The information included a 20-page self-instruction guide on understanding feelings, managing emotions, balancing negative thinking, dealing with anxiety etc.


Psychological Preparedness for Natural Disaster Warnings and Natural Disasters

Confusion of Uncontrollable Events with Controllable Consequences

Another cause for feelings of worry and helplessness when a natural disaster threatens is the repeated thought that a natural disaster is an awesome and uncontrollable 'act of nature'.

"The thing will either hit us or it won't and there's nothing we can do about that so why even bother trying to do anything"

What happens: These feelings of helplessness often cause you to do nothing.

What to do: It is important to remind yourself that although you cannot exercise control over the natural disaster, you are not helpless to protect yourself and your family from its consequences. Undertaking all the protective measures contained in your local disaster emergency guides will not only increase your safety, it will help you to feel more in control and less worried.

9

Figure X-2 Psychological Preparedness Information (Cairns)

The study found that the information reduced levels of concern and increased levels of confidence. In addition, the study found that anxiety can be a barrier for individuals to undertake appropriate preparation steps. Providing disaster awareness material that raises concern about an event, without providing information on how to deal with this concern emotionally, may diminish adaptive response to the risk, or erode existing preparedness motivation and resolve.

X.3 ACOSS Resilient Community Organisations Toolkit (Australia)

The Australian Council of Social Services (ACOSS) developed an online resource for community organisations in association with the Australian Government and the National Climate Change Adaptation Research Facility (NCCARF). The resource includes: an online benchmarking tool to assess the current state of preparedness of the community organisation and to identify areas for improvement; an information resources called 'Six steps to disaster resilience'. The six steps are: Leading resilience; Building networks; Knowing your risks; Managing your risks; Preparing others; and Learning and inspiring; and a disaster plan templates for community organisations.

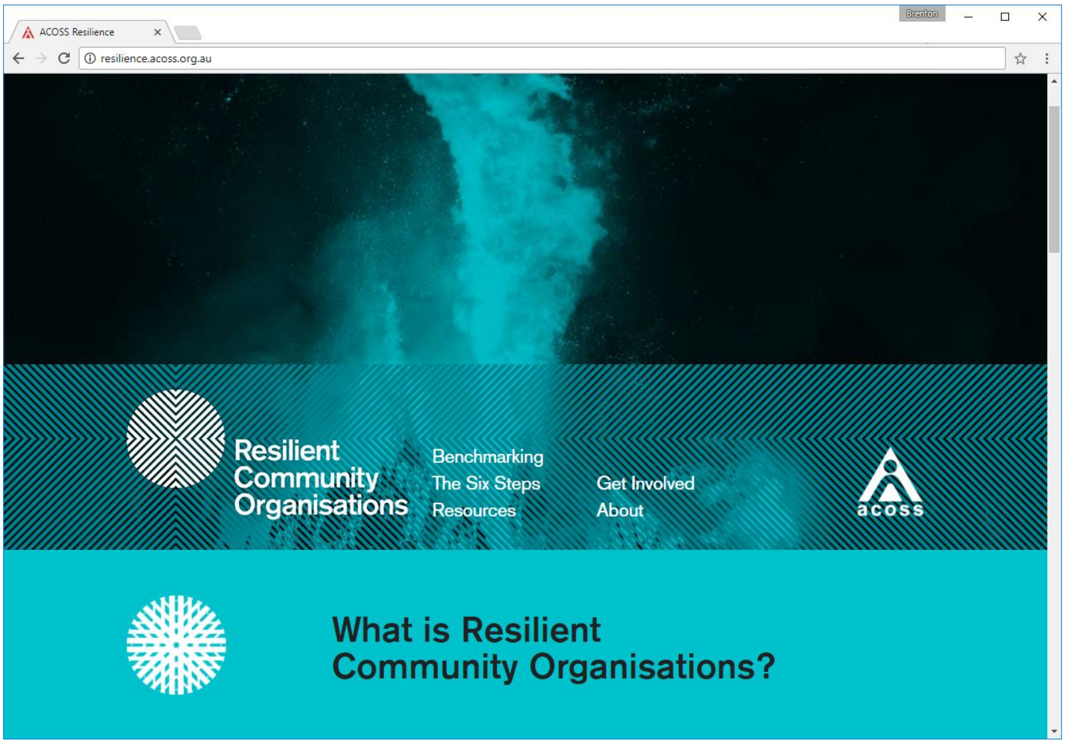


Figure X-3 Resilient Community Organisations Toolkit

The online resource provides the resources and tools for community organisations to consider their own risks, and prepare plans to reduce vulnerability. However, the effectiveness of the online resource as a tool to improve resilience is limited if community organisations do not have the resources to consider their resilience and take appropriate actions. Additional funding, and / or partnerships with State Government organisations / local government (SES / disaster management officers) could assist in supporting the community sector to consider and plan for their resilience as resourcing and knowledge was identified as an issue for implementation.

X.4 Angelsea 'Survive and Thrive' schools program pilot (Victoria)

The 'Survive and Thrive' program was developed by the Country Fire Authority and Anglesea Primary School for local primary school children (Year 4 to Year 6). Children are asked to be educators – leading community-based education and preparedness activities for themselves, family and the community. The program is embedded in school curriculum outcomes, and school timetables with two hours a week throughout the full year dedicated to the program.

Students that have completed the program reflected that they had learnt valuable skills including knowledge of fire and preparedness actions, as well as public speaking, confidence, team work and persistence. Some students noted that they feel safer and not as worried about bushfire impacts. The findings of the evaluation showed participants had increased capacity to respond safely to a bushfire event, as well as an increased sense of safety at school, and children contributed to their family's fire risk and evacuation planning.

The collaborative teaching / learning approach was successful. The program was led by students – what they show interest in, how they learn, what they want to learn about and teach others about.

X.5 Emerald Community House as Centre of Resilience (Victoria)

After bushfires in the Emerald area of the Dandenong Ranges southeast of Melbourne (Ash Wednesday fires in 1983, and fires in 2003), the Emerald Community House started to consider its role in community disaster resilience – and started to consider themselves a 'Centre of Resilience' for the local community.

A steering committee was established to develop a community resilience strategy which was later developed in 2011. The strategy included: embedding resilience components in the centre's strategic plan, goals and objectives, policies and programs; using community development principles to build resilience; developing networks and partnerships to deliver resilience activities; and continuity planning.

Reflecting on learnings from the project, the Centre Manager recommended that:

- Community development training should be promoted for government, organisations and council officers
- Emergency management should be positioned under community development
- Community is lateral, flexible, an fluid, whereas governments and organisations tend to be rigid and hierarchical. Embrace diversity for success,
- Local government should foster community initiatives and creativity.

Traditional emergency management / services volunteers have dismissed the Centre of Resilience activities as being irrelevant, which demonstrates how difficult it can be for communities to take a leadership role in their own resilience even though this is supported / encouraged by government organisations, and undermines confidence in authorities.

Figure X-4 WeatherSmarts Forum at Emerald Community House (WeatherSmarts is a new community approach to preparedness for various weather events)

X.6 BoCo Strong: Community Powered Resilience (Colorado, USA)

Boulder is a city in Colorado USA with a population of around 300,00. After severe flooding in 2013 (1 in 1,000-year flooding with the county receiving 80% of its average annual rainfall in six days), local government, community and non-profit groups gathered to document lessons learnt in the recovery effort. They recognised how vital connections were to recovering including:

- *Getting to know our neighbours meant that we have first responders right next door.*
- *Connecting to non-profits around the county allowed us to access resources when we didn't have what we needed.*
- *Familiarising ourselves with local government and policy makers meant that we could advocate for any changes that needed to be made.*

BoCo Strong Steering Committee was established as a sub-committee of the flood recovery group but soon developed separately. The committee received grant funding in 2015, and hired three project coordinators to: develop a 'resilience network': a network of organisations working on resilience; develop a community organisations disaster network to coordinate non-government response and recovery efforts; deliver a resilience leadership program to engage and empower community leaders from flood affected areas; and assess resilience and provide recommendations for future work.

The committee has since developed into a range of initiatives including participation in the 100 Resilient Cities program and Resilient Together website. Covering broader resilience agenda including environmental, social and economic shocks and stresses.

X.7 BC Climate Action Toolkit (British Columbia, Canada)

The BC Climate Action Toolkit is an activity delivered by the Green Communities Committee (GCC) – made up of The Province of BC's Ministry of Community, Sport and Cultural development; and The Union of British Columbia Municipalities. The GCC's intent is to provide climate action support to local governments through practical ideas and advice on climate change actions to support broader local government actions. One of the key aims of the activity was to avoid re-creating huge volumes of content, but rather to synthesise and summarise existing content in a context which is useful and meaningful for local government implementation. Tools, plans and guidance are the product of existing and new work by experts who have been working inside or with local governments. The tools are delivered under five key banners:

(1) **Planning and implementation** – information about a wide range of plans, policies, projects and processes is provided under 'what' and 'how' banners (i.e. *what* is the policy about, *what* information do local governments need to know etc. and *how* do local governments implement the policy).

(2) **Guides** – relevant and current guidelines that should inform activity design and implementation

(3) **Programs** – a list of current programs (including details and links to the program) that might intersect or overlap with proposed activities, thereby improving coordination and collaboration

(4) **Training** – information about training options provided by governmental and non-governmental bodies which the local governments can use to improve their knowledge and skills

(5) **Funding** – details about potential funding sources that local governments can access to help implement climate action activities

X.8 Youth Looking Beyond Disasters (International Forums)

Youth Looking Beyond Disasters is a series of three international forums organised by United Nations Educational, Scientific and Cultural Organisation (UNESCO) between 2012 and 2013. The forum series sought to build disaster resilience by engaging with young people; a demographic which is often left out of the disaster discourse. The forums were designed around the shared responsibility to resilience approach that is seen in the National Disaster Resilience Strategy, and Queensland Disaster Resilience Strategy, and promoted a participatory approach to community-led resilience building; a critical element of community flood resilience identified in this study's literature review.

Following the forums, a Looking Beyond Disaster Toolkit was created to support young people who want to enhance the disaster resilience of their community. The toolkit provides easy to understand support and instruction for enthusiastic, but non-expert youths to take a leadership role in improving disaster resilience in their community.

X.9 Public Utility Board installations and signage (Singapore)

The Public Utility Board (PUB) is Singapore's National Water Agency, responsible for the management of water infrastructure and awareness of water processes, risks etc. Throughout Singapore, and particularly at key locations, they have undertaken installations providing information to the public in a range of ways. Three example locations are described below:

- **Marina Barrage** is a dam in Singapore, at the confluence of major rivers and at the island edge. The barrage provides water supply and flood control to the CBD area of Singapore, but also acts as a tourist attraction. The barrage is open for public access, and is supported by a large information centre known as the Sustainable Singapore Gallery.

Figure X-5 Sustainable Singapore Gallery Exhibit

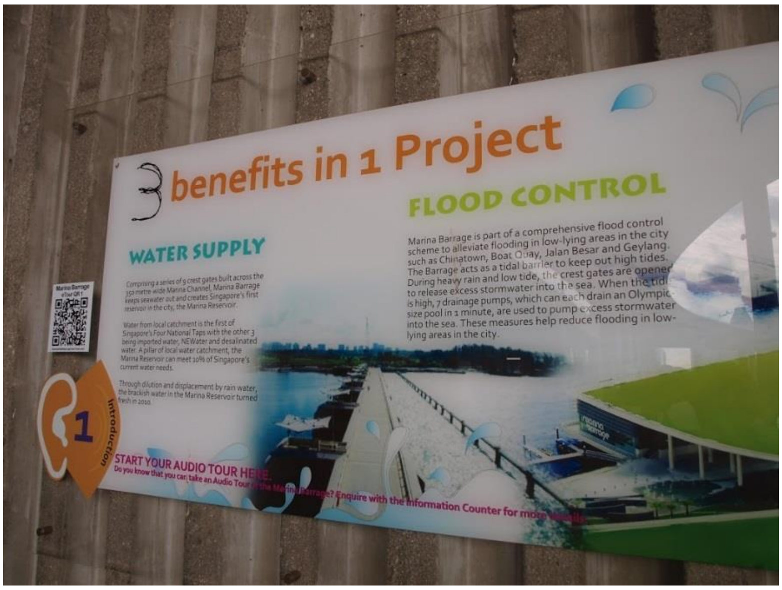


Figure X-6 Operation Information Sign

Figure X-7 Raindrop Mascot at Marina Barrage

- **Bishan Park** is a public park that formerly contained a large, concrete lined channel. As part of river restoration works, the channel was removed and naturalised, creating a space which engages and encourages the community to interact with the water, while also providing ample signage recognising the residual flood risk, and supporting signage with sirens, life preservers etc.

Figure X-8 Overview of Bishan Park showing Informative Sign and Life Preserver

Figure X-9 Flood Warning and Evacuation Sign, Bishan Park, Singapore

- **Lower Seletar Reservoir** is a reservoir in the north-eastern part of Singapore, including a community park. The park includes numerous informative and engaging features, including an interactive play area representing the water infrastructure of the island, and a pictorial 'view back through time' of water management in Singapore.

Figure X-10 Lower Seletar Reservoir Water Play Area

Figure X-11 Water Play Area Signage

Figure X-12 View Back Through Time

These three locations are distributed around Singapore and include a range of place-based markers with various levels of engagement and information, and targeted at different audiences (e.g. young / adult, tourist / local). As a suite, the installations provide a comprehensive understanding of the various water management operations and structures around the country. The rain drop mascot provides a sense of continuity between the locations, highlighting that although the signs and installations are spread throughout the country, they belong to the same campaign.

X.10 City of Yarra Keep Cool / Stay Healthy in the Heat (Victoria)

The City of Yarra, in the inner eastern and northern suburbs of Melbourne, developed a Keep Cool campaign targeted at culturally and linguistically diverse (CALD) community members living in social and public housing in 2015-16. Council developed and led the campaign, and partnered with 25 different organisations and community groups to deliver the campaign. The campaign involved:

- Engaging directly with targeted groups using activities they were already attending (English language classes, migrant centres)
- Partnering with service providers trusted by CALD groups to deliver the campaign materials (pharmacists, Red Cross, VicDeaf, Victorian Aboriginal Health Service, etc.)
- Developing and distributing CALD-tailored resources to assist resilience building (home thermometer, posters) (an example is included below)
- Bus advertising in multiple languages.

Figure X-13 Beat the Heat Poster in Italian

City of Yarra created and delivered the specific and targeted campaign, including engagement with the community to understand required content of messaging, and developed the campaign materials, and then used existing networks and partner organisations / businesses to deliver messages to target groups.

X.11 Operation Bushfire Blitz / Fire Ready Victoria street meetings (Victoria)

Operation Bushfire Blitz was a program of neighbourhood street meetings in Victoria delivered by the Country Fire Authority. The program was first implemented in the late 1990s and early 2000s in high bushfire risk localities with a history of lives and properties lost to bushfire. Around 1,400 small community meetings were delivered by around 55 'community consultants' from volunteer fire brigades. These consultants were given a two-day training session and lesson plan to guide presentations, including topics such as:

- Bushfire risk
- Personal and family safety
- Home preparation
- Helping neighbours
- Risk identification and practical solutions

- Planning what to do on high risk days
- What residents can expect from the fire brigade
- Community Fireguard – the ongoing community group program of the CFA.

Meetings also included a street walk, and lasted around 1-1.5 hours.

While meetings included dissemination of information from the fire brigade volunteer, elements contributing to the success of the meetings included that they involved a dialogue between attendees, and between attendees and the CFA, and information was targeted to local areas. The program was also part of a suite of programs and activities.

Bushfire knowledge was highest amongst those who had attended meetings in the current year and in past years, above those who had attended only in the current year OR in past years, and those that had not attended a meeting. Possible elements of the program contributing to improved awareness / knowledge / readiness could have included:

- Increased trust and credibility of fire agency
- Two-way communication in meetings (although not all meetings included extensive discussion)
- Sense of obligation resulting from commitment of fire agency to program
- Positive reinforcement of presenter to actions
- Peer influence, hearing others discuss their preparations / plans
- Inspiration effect of discussion and new information
- Trained volunteers as presented as they had knowledge/empathy with local community and brigade
- Contributed to community development beyond fire safety.

X.12 Street FireWise program (NSW)

The Street FireWise program was a bushfire community education program running from 2000 to 2003 in the Blue Mountains region of New South Wales. The area is a high bushfire risk region comprising 26 towns and townships – experiencing an average of 14 bushfires per year (range 2-40). The program was delivered as a 90-minute street corner meeting on a Saturday presented by volunteers of the Rural Fire Service brigade.

The meetings were thought to increase awareness and understanding of bushfire risk because interactive meetings supported:

- Ability to build on existing resident knowledge
- Change misconceptions and introduce new ideas
- Contextualise issue to local context.

The meetings also supported understanding of how residents can contribute to mitigation, and clear understanding of the role of the local fire brigade.

Community meetings were seen as one element in the change process. The meetings were seen to build on existing resident thinking and action by re-examining existing plans and strategies, and facilitating discussions with families, friends and neighbours to contribute to empowerment and self-reliance.

The meetings were successful, however attendance started to decline towards the end of the program and it was stopped after 2003. This is not necessarily a failure of the program. It could reflect a successful program if it provided the community education it was designed to deliver and this is when attendance started to decline. However it does suggest that the same program implemented each year over a number of years may slowly start to have reduced effectiveness and therefore may need to be refreshed (with new content aimed at further progressing the target community's journey towards thorough preparedness), the specific method changed to target different people within the community (for example, from a street meeting, to other method targeting people who would not be able to attend a street meeting on a Saturday, for example, young families, older people, disabled people, perhaps busy professional people), or perhaps held less often with other methods / activities utilised in intermediate periods.

X.13 Mansfield community planning and resilience leadership program (Victoria)

Since 2010, 12 small communities in the Mansfield Shire (north east of Melbourne) have developed their own community plans. These were developed as community planning processes which themselves contributed to building existing levels of resilience. Community resilience was a key objective of the community plans and found that community resilience was supported by common elements such as: leadership; networks; knowledge and ready access to information; infrastructure for social activities; a strong volunteer base; and partnerships with other communities and organisations.

Community resilience leadership program was developed and delivered by a community development practitioner. 22 community members participated, representing 8 communities. Participants were involved in 20 contact hours including workshops; peer to peer learning; guest speakers and emergency services panel session, covering topics such as: disaster planning, response and recovery cycle; individual and collective strengths; leadership styles and temperaments; project planning; communities in crisis; roles of emergency services and organisations; and review and evaluation.

The program helped build collaborative connections between organisations and community members.

X.14 Managers of spontaneous emergency volunteers (SEVs) pilot program (Victoria)

The Managers of Spontaneous Emergency Volunteers pilot program was implemented in the G21 Region (City of Greater Geelong, Borough of Queenscliff, Colac Otway Shire, Golden Plains Shire and Surf Coast Shire) in 2014-15. The pilot program involved recruiting, training, supporting, deploying and debriefing a 'workforce' of volunteer managers of emergency volunteers. This included development of best-practice training and professional development materials, establishment of a central register (managed by Volunteering Victoria) of experienced managers (including deployment history), development of an online Resource Centre to house resources that support management of volunteers, communication program to stay in contact with managers, and ongoing research and evaluation of the program. The volunteer managers attended a full-day training course including provision of handbooks, video case studies and other materials.

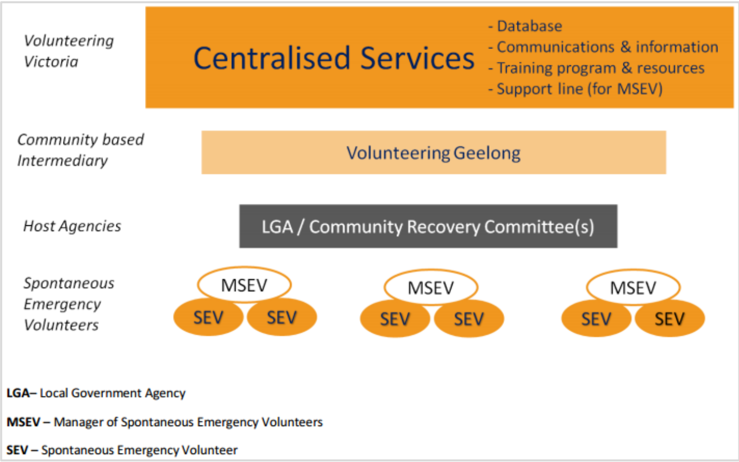


Figure X-14 Managers of volunteers coordinate smaller groups of volunteers under direction of host organisations

A number of risks and issues were identified which were not fully appreciated / understood before the pilot such as:

- Lack of clarity around legal / insurance protections / duty of care etc.
- LGAs do not recognise their role / were not interested in having a role in managing volunteers
- Longer term effects of psychological trauma on volunteer managers
- Difficulty in maintaining connection with managers over time.

Other findings included:

- Local governments are not all the same – with different focuses, funding, challenges, capabilities and capacities in emergency risk management. Many local governments did not consider or prioritise management of SEVs in their emergency management plans
- Long-term engagement and relationship building is required to build confidence in the managers of volunteers concept
- Volunteer managers involved in the program were enthusiastic about being part of an ongoing network supporting continuous learning and knowledge sharing
- Important to development deployment case studies to communicate tangible examples of the role to all stakeholders
- Additional work is required to encourage collaborating and working towards a common goal in an emergency setting.

The pilot found that structures to support volunteering after a disaster event are complex and ongoing work is required to integrate volunteering and volunteer management in local government / stakeholder emergency management frameworks to support implementation; and disaster management authorities / local governments need to embrace initiatives that support community resilience if pursuing community resilience is an objective (this may involve giving away some of the control of disaster response).

X.15 Woronora Flood Preparedness Strategy awareness activities (NSW)

An awareness campaign was implemented between 1999 and 2003 as part of a flood preparedness strategy for the Woronora River, south of Sydney. The awareness activities targeted a small area with around 500 households possibly impacted by flood, based on local flood study outputs. The awareness activities implemented included:

- Simple categories of flood: flood information categorised flood height into green, blue, yellow and red categories (with green being a less significant / more common flood, and red being a more significant / less common flood)
- Two flood signs with ‘Are you ready?’ messaging
- Painted colour bands on street sign posts (17 sign posts)
- Individually printed labels in electrical fuse boxes showing floor level of house in relation to flood category placed by SES volunteers
- Flood kit (with booklet, children’s colouring sheet, fridge magnet and brochure)
- Public meeting before distribution of kit
- Implementation of standard emergency warning signal
- Media releases.

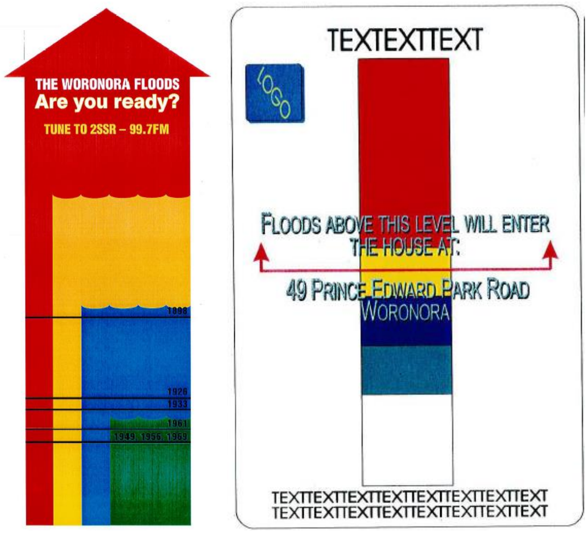


Figure X-15 Managers of volunteers coordinate smaller groups of volunteers under direction of host organisations

A survey of residents after the campaign suggested that while respondents had received the information and some could recall the different categories of flood, their attitude to flood risk had not changed (would rely on their own observations of rainfall to assess risk, would rely on evacuation by boat as a response to flooding) and they had not been affected enough to take preparedness actions (for example to create a flood emergency kit). The personal delivery of the flood kit and label for electrical fuse box by members of the SES were seen as successful elements of the program in creating deeper levels of engagement with materials.

The causal path from knowledge, to attitude change, to behaviour change is weak, that is, additional knowledge does not always influence behaviour change. Additional actions to encourage attitude and behaviour change would therefore be encouraged to move residents from knowledge of flood risks to preparedness, which may require emotional appeals.

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