With industry partners:
Drew Bewsher
Ethos Urban
Warren Bridson
Ken Granger
WRM Water & Environment
Economic Associates
Jacobs

Technical Evidence Report
Executive Summary and Recommendations
Brisbane River Strategic Floodplain Management Plan

Prepared for the State of Queensland

October 2018

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.

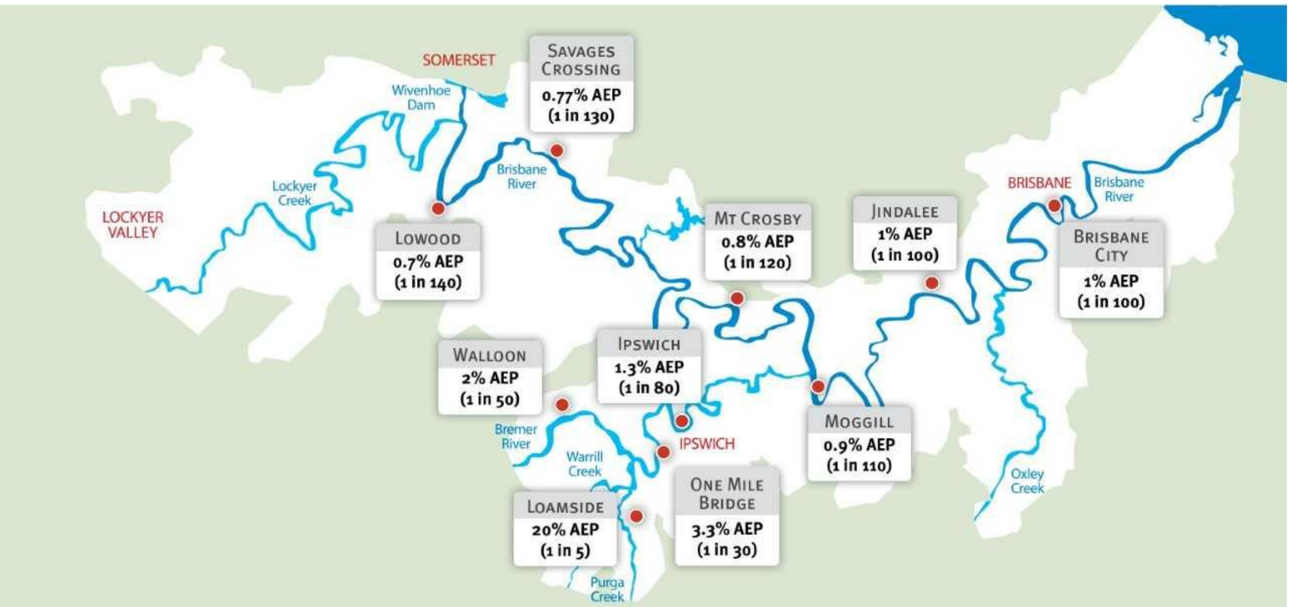


Figure 1 Estimated magnitude (return period) of the 2011 flood

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.

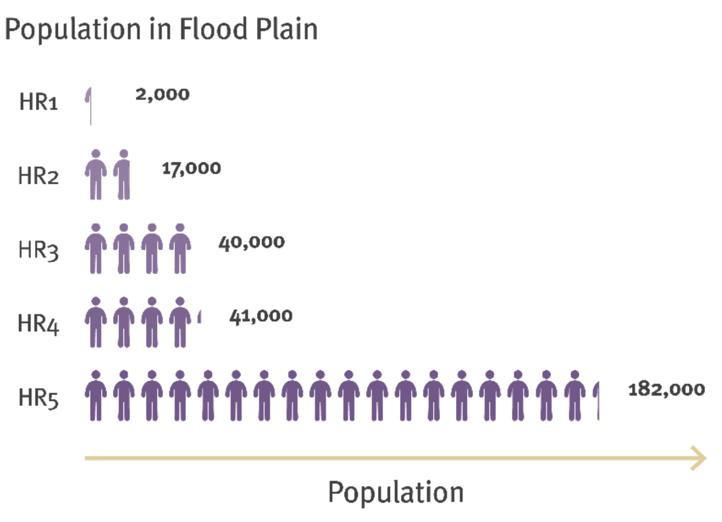
To support the flood exposure assessment, a property dataset was developed. The dataset required a field survey of more than 80,000 properties, which captured the property location, type, building ground and floor level, and a street view photo. The field survey was supplemented with data derived remotely 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.

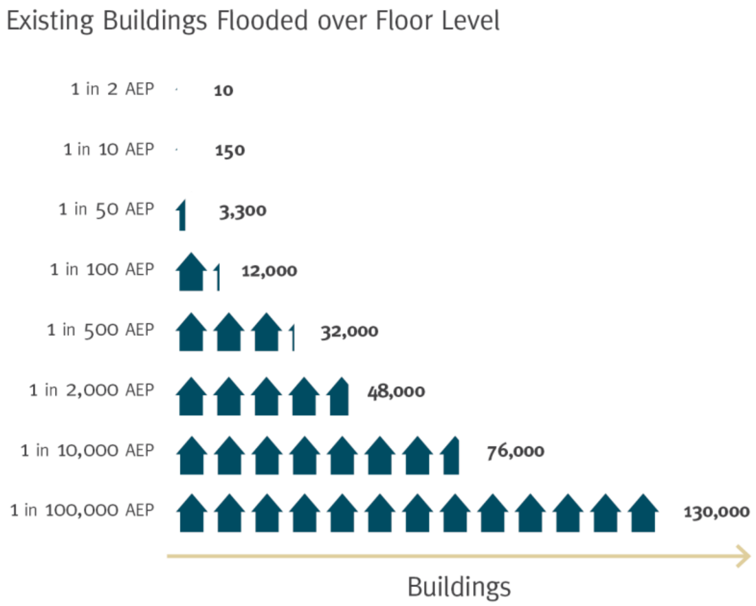
Flood Exposure

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.

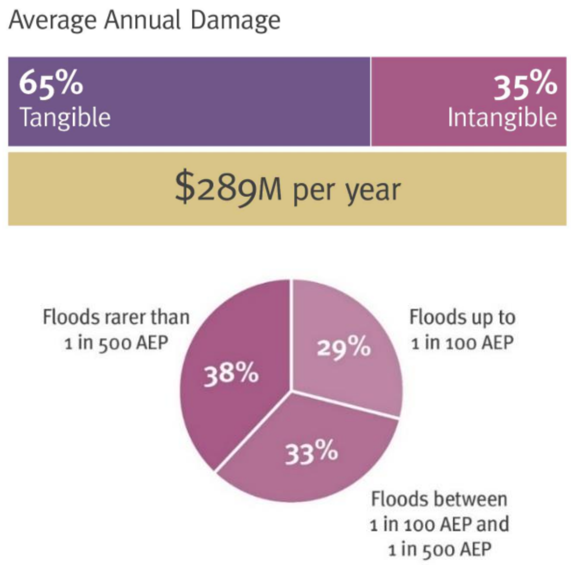
Flood Damage Assessment

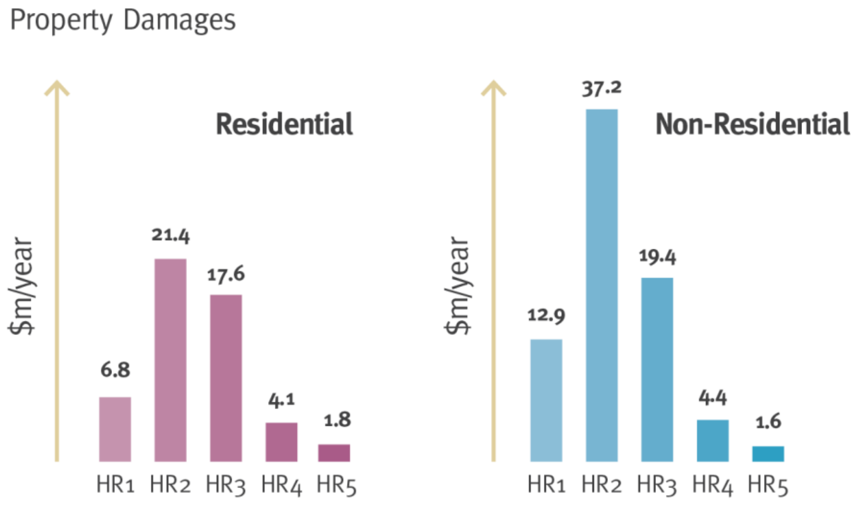
This Technical Evidence Report includes a regional economic framework for the estimation of flood damages in the lower Brisbane River floodplain, for both current and future catchment conditions. This is based on an extensive literature review, which established current best practice in flood damage 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.

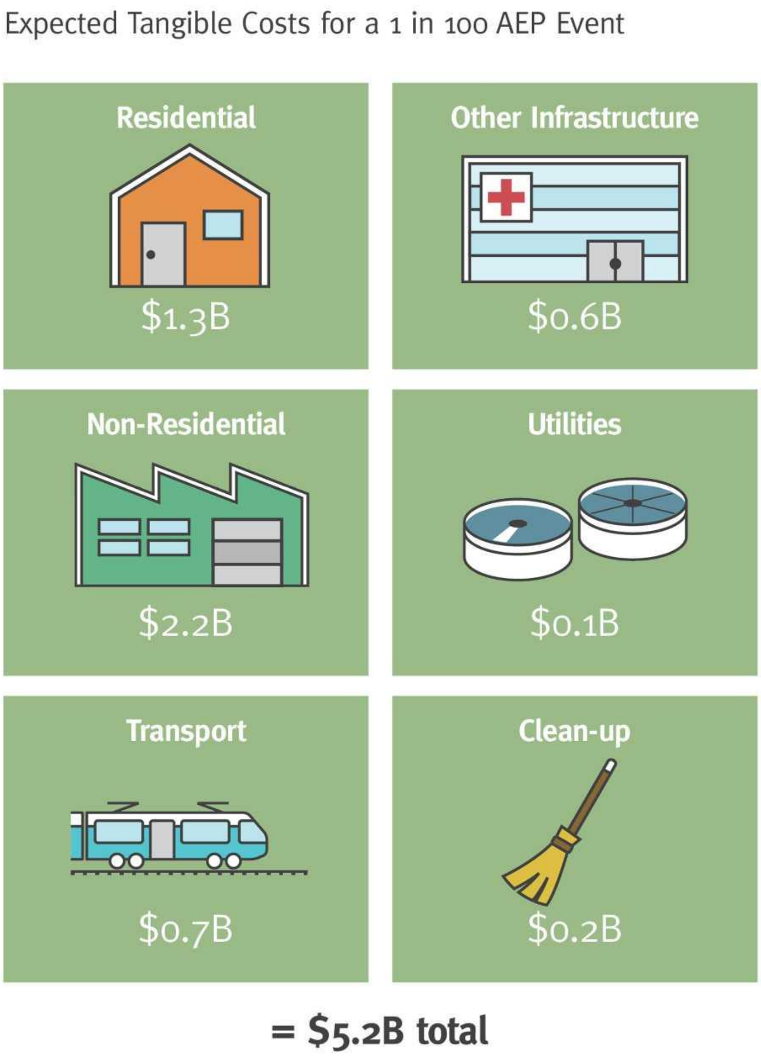
This framework has been used to estimate tangible damages, both direct and indirect, to residential, commercial and industrial properties and public infrastructure. It also establishes intangible damages such as social, environmental, cultural and heritage impacts, for a range of floods ranging from 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).

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.

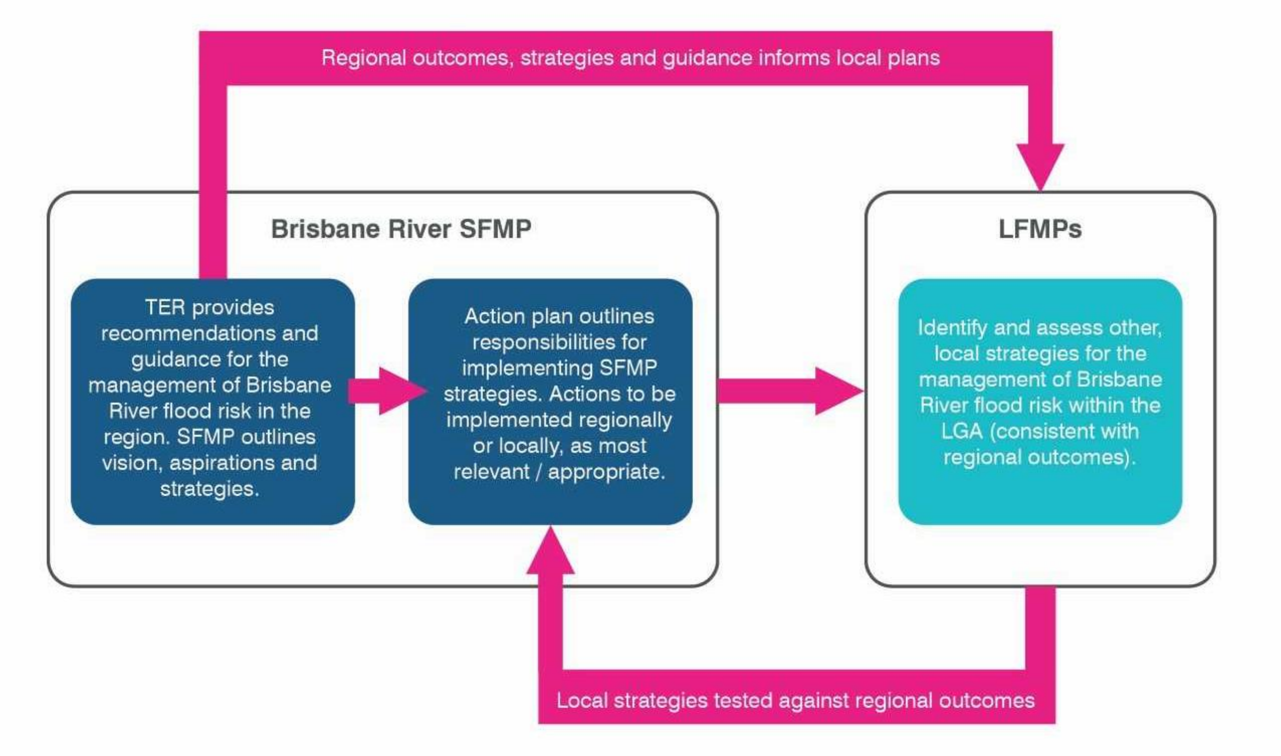
- Continue normal liaison with the Bureau of Meteorology to understand and implement new services and products which are scheduled for release in the near future.

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.

BMT has a proven record in addressing today's engineering and environmental issues.

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Brisbane
Level 8, 200 Creek Street
Brisbane Queensland 4000
PO Box 203 Spring Hill Queensland 4004
Australia
Tel +61 7 3831 6744
Fax +61 7 3832 3627
Email brisbane@bmtglobal.com

Melbourne
Level 5, 99 King Street
Melbourne Victoria 3000
Australia
Tel +61 3 8620 6100
Fax +61 3 8620 6105
Email melbourne@bmtglobal.com

Newcastle
126 Belford Street
Broadmeadow New South Wales 2292
PO Box 266 Broadmeadow
New South Wales 2292
Australia
Tel +61 2 4940 8882
Fax +61 2 4940 8887
Email newcastle@bmtglobal.com

Adelaide
5 Hackney Road
Hackney Adelaide South Australia 5069
Australia
Tel +61 8 8614 3400
Email info@bmtdt.com.au

Northern Rivers
Suite 5
20 Byron Street
Bangalow New South Wales 2479
Australia
Tel +61 2 6687 0466
Fax +61 2 6687 0422
Email northernrivers@bmtglobal.com

Sydney
Suite G2, 13-15 Smail Street
Ultimo Sydney New South Wales 2007
Australia
Tel +61 2 8960 7755
Fax +61 2 8960 7745
Email sydney@bmtglobal.com

Perth
Level 4
20 Parkland Road
Osborne Park Western Australia 6017
PO Box 2305 Churchlands Western Australia 6918
Australia
Tel +61 8 6163 4900
Email wa@bmtglobal.com

London
1st Floor, International House
St Katharine's Way
London
E1W 1UN
Tel +44 (0) 20 8090 1566
Email london@bmtglobal.com

Aberdeen
Broadfold House
Broadfold Road, Bridge of Don
Aberdeen
AB23 8EE
UK
Tel: +44 (0) 1224 414 200
Fax: +44 (0) 1224 414 250
Email aberdeen@bmtglobal.com

Asia Pacific
Indonesia Office
Perkantoran Hijau Arkadia
Tower C, P Floor
Jl: T.B. Simatupang Kav.88
Jakarta, 12520
Indonesia
Tel: +62 21 782 7639
Fax: +62 21 782 7636
Email asiapacific@bmtglobal.com

Alexandria
4401 Ford Avenue, Suite 1000
Alexandria
VA 22302
USA
Tel: +1 703 920 7070
Fax: +1 703 920 7177
Email inquiries@dandp.com

www.bmt.org