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Soil Associations of Batavia Downs

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Land Resources Branch

Queensland Department of Primary Industries

Queensland Government Technical Report

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Department of Primary Industries
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ABSTRACT

This report describes the soils and landforms of Batavia Downs, a grazing holding of some 200,000 hectares in the northern part of Cape York Peninsula and comments on the land suitability for more intensive management.

The land resources of Batavia Downs were surveyed at 1:250,000 using free survey with air photo interpretation and ground observations and then mapped into soil associations within soil landscapes which are recurring patterns of soils, landform and geology. The mapping code reflects each of the three components.

Chemical analysis on selected samples showed that all soils are acid except for a brown clay which is alkaline at depth. In general all soils require phosphorus fertiliser for stylo pasture. One deep sample from the brown clay group returned high EC levels. More investigation of soil salt levels is required before clearing is undertaken.

The results of the investigation are available as:

- tabulated and written information;
- mapped information (location, soil landscape and land suitability maps); and
- a Geographic Information System which contains the above information as well as more information available for analysis and further updating.

Suitability analysis to assist whole property planning was performed for two land uses, sowing through existing vegetation and clearing for more intensive pasture improvement. The basis for the decisions are detailed in the text.

Approximately 140 000 ha is suitable with minor or moderate limitations for sowing through the existing tree cover. Much of this land is near the existing homestead.

Clearing and cultivation prior to pasture establishment impose extra costs and less suitable land is available (82 000 ha) for this purpose since the range of limitations is greater.

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Unique map area record file[1]

[1] *Not included in report but can be accessed through the Director, Land Resources Branch, Queensland Department of Primary Industries*

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1. INTRODUCTION

Batavia Downs (Figure 1) was first selected as a cattle property in 1882 by James Burne. There were subsequently a number of ownership changes until in 1987 it came under the control of the Queensland Department of Primary Industries (QDPI). The property has since been destocked under the brucellosis and tuberculosis eradication campaign (BTEC) and a manager appointed.

The QDPI is currently evaluating a number of options for future use of the property. The most likely outcome of that evaluation will include the following uses:

- establishment of a "model" of the Department's management recommendations for the Cape York Peninsula. In brief this consists of handling cattle on smaller areas behind wire, pasture improvement on the more suitable land, supplementation and improved cattle husbandry techniques;
- subdivision of Batavia Downs into smaller, more easily managed units;
- a site for QDPI research in pasture improvement and cattle husbandry; and
- delineation of areas with need or potential for conservation, horticulture or tourism.

This development requires a property management plan. The first step is a land resource assessment and this report describes the soils and landforms of Batavia Downs and comments on the suitability of these lands for various purposes. The vegetation resource has been mapped separately (Neldner and Clarkson 1991)

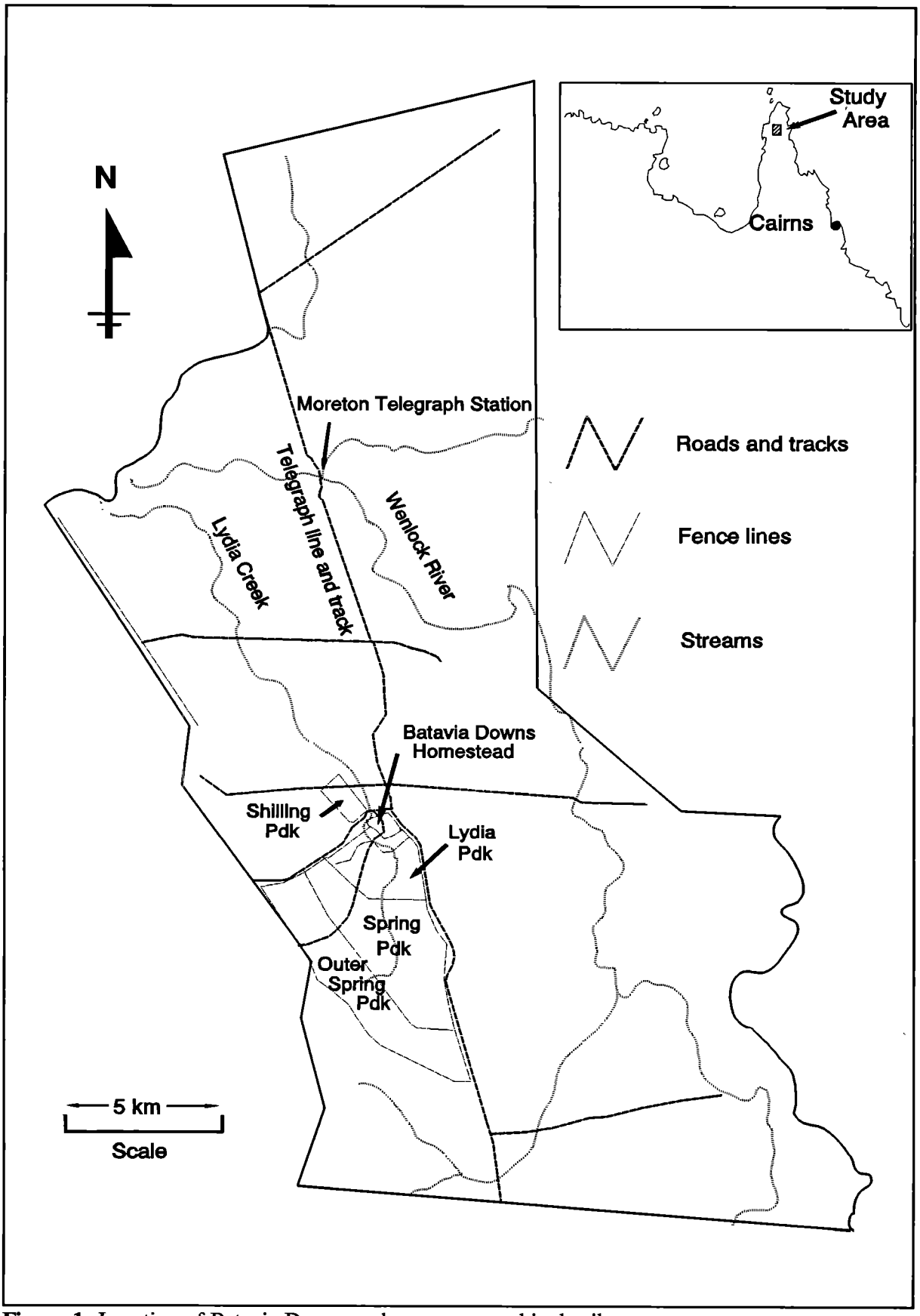

Figure 1 Location of Batavia Downs and some geographic details

2. THE ENVIRONMENT OF BATAVIA DOWNS

2.1 Vegetation

The vegetation of Batavia Downs has been surveyed by two officers of Botany Branch of QDPI (Neldner and Clarkson 1991).

In brief, most of the property is covered by open woodland with *Eucalyptus tetrodonta, Eucalyptus nesophila, Eucalyptus leptophleba* and *Eucalyptus clarksoniana* frequently occurring species. There are small areas of grassland with scattered *Eucalyptus papuana*; and vine forests occur along major creeks and rivers and in small pockets. There has been minimal clearing on the property. The grass layer is dominated by *Heteropogon* and *Aristida* species with *Dicanthium* species on cracking clay soils. There has as yet been only minor introduction of exotic pasture species. Fire has been used by both aborigines and europeans as a management tool usually on at least an annual basis.

2.2 Climate

The climate of Batavia Downs is dominated by the summer monsoon which brings substantial falls of rain over the months January to April (Figure 2). Prior to that period, early summer rainfall accompanies the moist on-shore air stream from the east.

The dry season, typically May to October, is sufficient to dry most creeks in the area with only the Wenlock River, which originates in the Iron Range area to the east, running all year.

Temperatures are warm to hot with significant periods of temperatures exceeding 35°C each year (Figure 3). No frosts are recorded at Batavia Downs.

Cyclones occur sporadically and unpredictably chiefly during the summer months. They may have significant detrimental effects through direct wind damage and stream rises. They also bring beneficial falls of rain. Winds during the dry season are predominantly easterly changing to the north-west as the monsoonal trough exerts its influence.

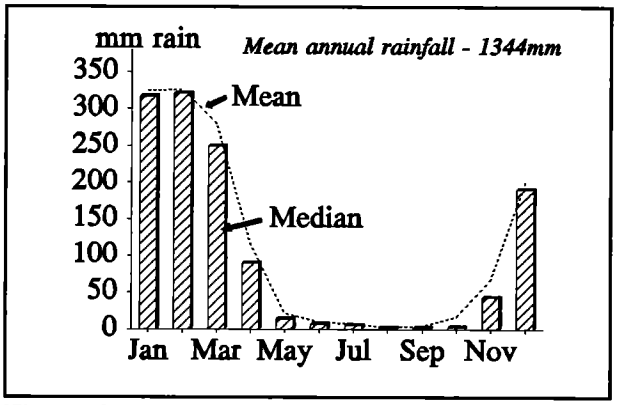

Figure 2 Median and mean monthly rainfall at Moreton Telegraph Station

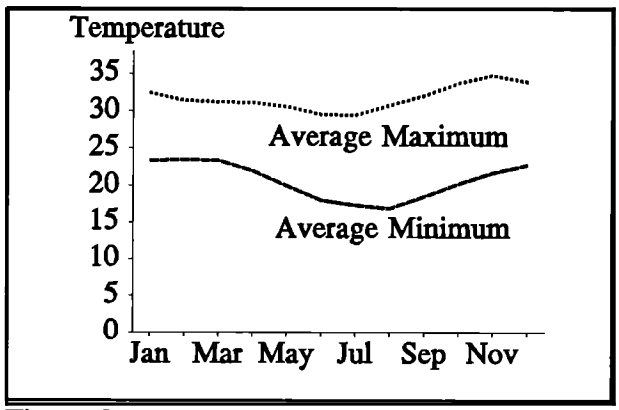

Figure 3 Mean monthly maximum and minimum temperatures (°C) at Moreton Telegraph Station

2.3 Geology

Most of Batavia Downs lies within the Merluna Plain which has developed on sediments of the Rolling Downs Group and the Bulimba Formation (Willmott and Powell 1977; Figure 4). The

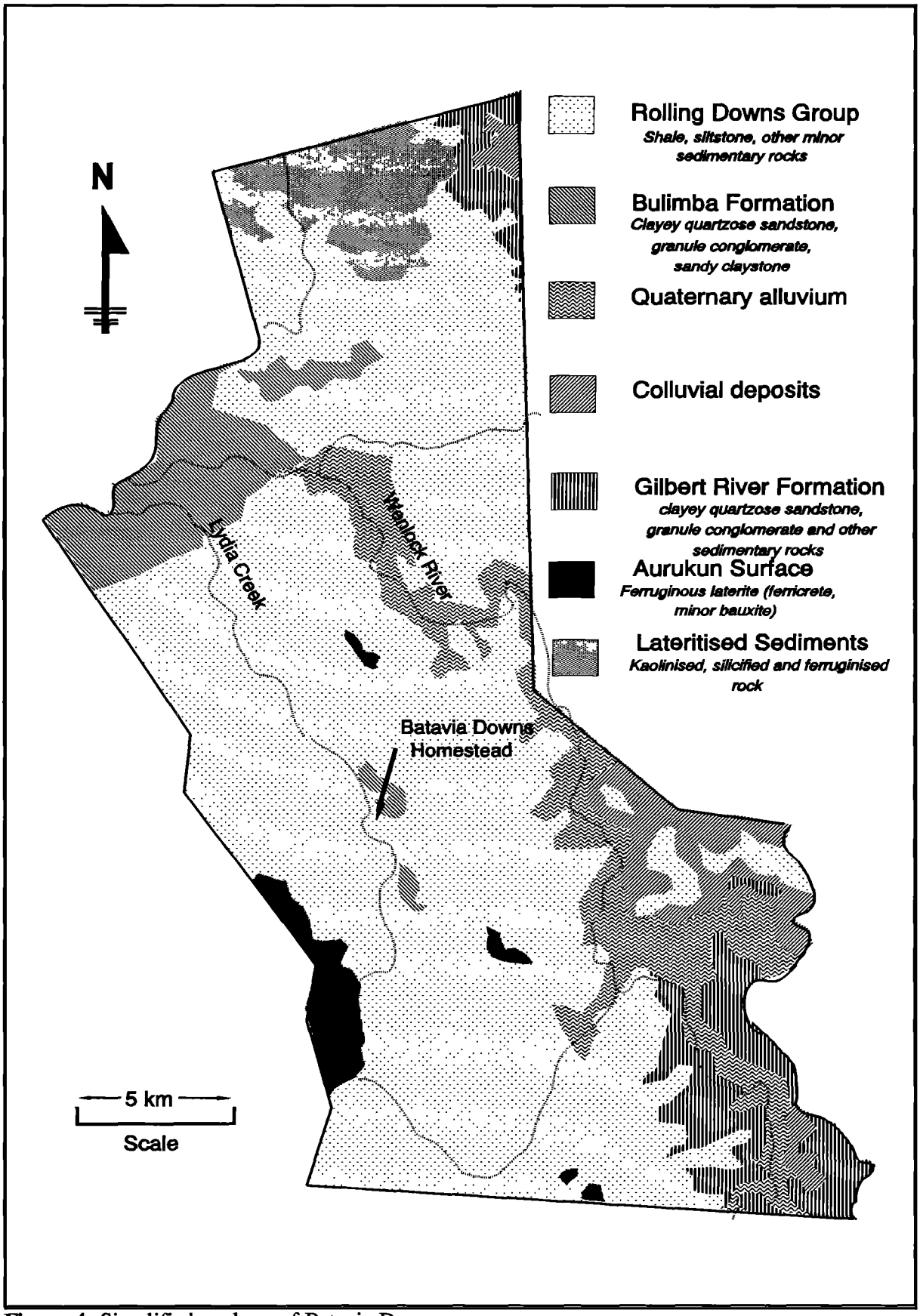

Figure 4 Simplified geology of Batavia Downs

Rolling Downs Group covers more than 80% of Batavia Downs with the Bulimba formation much of the remainder. There are relatively few exposures of either, however. Most of the surface of this plain has been formed by erosion of the lateritic Tertiary Aurukun Surface a product of deep weathering of the two sedimentary series mentioned above. The Embley Range is the largest remnant of this Surface. Further lateritisation occurred after dissection and on Batavia Downs this is most clearly evident in the north east.

The west of the property comprises the Glennie Tableland and the Olive-Pascoe Lowlands. The latter is a dissected elevated area formed by dissection of the Aurukun Surface which overlaid the argillaceous sediments of the Rolling Downs Group and the sandstones of the Gilbert River Formation. The southern part of this unit is the hilliest on the property. The Olive-Pascoe Lowlands occupy a small part of Batavia Downs in the north-east. They are a result of headward erosion by the Olive River into the Glennie Tableland and associated physiographic units.

2.4 Water resources

2.4.1 Surface water

The only permanent stream on Batavia Downs is the Wenlock River which enters the property on the south-east and exits in the north-west (Figure 1). There are a number of billabongs adjacent to the present course of the Wenlock River which contain significant amounts of water throughout the year. Waterholes are associated with a number of the major creeks which despite the fact that they are dry for much of the year have substantial channels reflecting the heavy monsoonal rainfall. Use of the Wenlock and other creeks in cattle management is hampered by the thick vine forest which grows on the levees of even the minor streams. More intensive management would require fencing of the more substantial of these areas.

There are at least two permanent or semi-permanent springs coming out of the Tertiary Embley Range on the western boundary. These flow for about two kilometres. Water quality is unknown.

2.4.2 Sub-surface water

Underground water at a relative shallow depth and of suitable quality for stock is available over much of Batavia Downs. QWRC records indicate that of two bores investigated for the QDPI, one had a depth of 6.6m and the other 12.7m. An earlier bore established during seismic investigations was recorded as having flowed and was capped with concrete.

Chemical data are available on three currently active bores (Table 1).

While these results indicate reasonable quality for stock use, the high levels of sodium rule out use for small scale irrigation from this source.

Table 1 Chemical analysis of bore water samples from Batavia Downs

	Yard Bore	Shilling Bore	Batavia 2	Critical Values[1]
EC (μS/cm)	975	750	740	
Chlorides (mg/l)	356	76	251	
Total hardness (mg/l)	40	90	55	
Alkalinity (mg/l)	155	310	145	
Dissolved Ions (mg/l)	611	582	487	9000
SAR	13.3	6.0	8.2	
Residual alkali (meq/l)	2.3	4.4	1.8	
Ca^{++}	8	12	10	
Mg^{++}	5	15	7	400
Na^{+}	193	131	140	
HCO_3^-	189	378	177	
$CO_{3=}$	0	0	0	
Cl^-	216	46	152	
F^-		0.1		2
pH	7.4	7.3	7.2	

1. Critical values are for beef cattle and are derived from Gill (1984)

3. SOILS AND SOIL LANDSCAPES

3.1 Soil associations

The land resources of Batavia Downs were surveyed using free survey with air photo interpretation and ground observations. Observations were sufficiently frequent to justify mapping at 1:250 000. The patterns identified in the landscape were then mapped into soil associations, a recurring pattern of soils, landform and geology. The mapping code reflects each of the three components.

Table 2 is a listing of the soil landscape units identified on Batavia Downs with their areas. Great soil group names have been used throughout the study but almost all of the soils described on Batavia Downs differ in some respects from the Stace *et al.* (1968) definitions. The xanthozem is the most notable case. Consequently descriptions of typical examples of the soils are given in Section 3.2.

The relative occurrence of the major and associated soils is variable and clearly have an effect on the suitability of each mapping unit for particular purposes. These data for individual units are included in the GIS which is described in Section 4.1. Nevertheless in most cases the characteristics of the dominant soil determine the suitability of the whole unit. These characteristics are described in the Section 3.2.

Table 2 Soil associations of Batavia Downs

Mapping code*	Major Great Soil Group#	Associated soils	Area (ha)
	Soils of the undulating to rolling hills (H) on sedimentary rocks[1] (S)		
LHS	Lithosol (L)	Earthy sand	3850
	Soils of the undulating low hills (L) on sedimentary rocks[1] (S)		
RELS	Red earth (RE)	Yellow earth earthy sand	2670
YELS	Yellow earth (YE)	grey earth red earth earthy sand	9450
ESLS	Earthy sand (ES)	red earth yellow earth	2230
	Soils of the gently undulating to undulating rises (R) on sedimentary rocks[1] (S)		
RERS	Red earth (RE)	Yellow earth Earthy sand	13450
YERS	Yellow earth (YE)	Red earth Earthy sand	33350
ESRS	Earthy sand (ES)	Yellow earth Red earth	3190

Table 2 (continued)

Mapping code*	Major Great Soil Group#	Associated soils	Area (ha)
GERS	Grey earth (GE)	Yellow earth	5040
	Soils on the gently undulating rises (R) on claystone colluvia▲ (C)		
BCRC	Brown clay (BC)	Xanthozem	5920
XRC	Xanthozem (X)	Brown clay	16330
	Soils of the level to gently undulating plains (P) on sedimentary rocks§ (S)		
GEPS	Grey earth (GE)	Yellow earth Podsol	38720
YEPS	Yellow earth (YE)	Grey earth Podsol	18170
REPS	Red earth (RE)	Podsol Yellow earth	2200
ESPS	Earthy sand (ES)	Podsol	1640
	Soils of the gently undulating plains and rises (P) on tertiary lateritic remnants (R)		
REPR	Red earth (RE)	Yellow earth Earthy sand	27820
YEPR	Yellow earth (YE)	Grey earth Red earth Earthy sand	4440
	Soils of the alluvial plains (AP)		
PAP	Podsol (P)		11310
	Miscellaneous units		
S	Seasonal or permanent swamps		360
I	Ironstone ridges		530

* *The first one or two letters of the mapping code refer to the major great soil group, the second last letter refers to the landform and the last to the geological substrate.*

\# *Great Soil Group after Stace et al. (1968), A Handbook of Australian Soils.*

¶ *These sediments form part of the Gilbert River Formation of Willmott and Powell (1977)*

§ *These sediments form part of the Rolling Downs Group of Willmott and Powell (1977)*

▲ *The colluvia was derived from elements of the Bulimba Formation of Willmott and Powell (1977)*

In Figure 5, relative elevation diagrams are drawn of west-east transects from the north, central and southern part of the study area. These are not accurate representations of reality but were drawn to include all landscapes (though not all dominant soils) so that an impression can be gained of how the mapped units relate to each other.

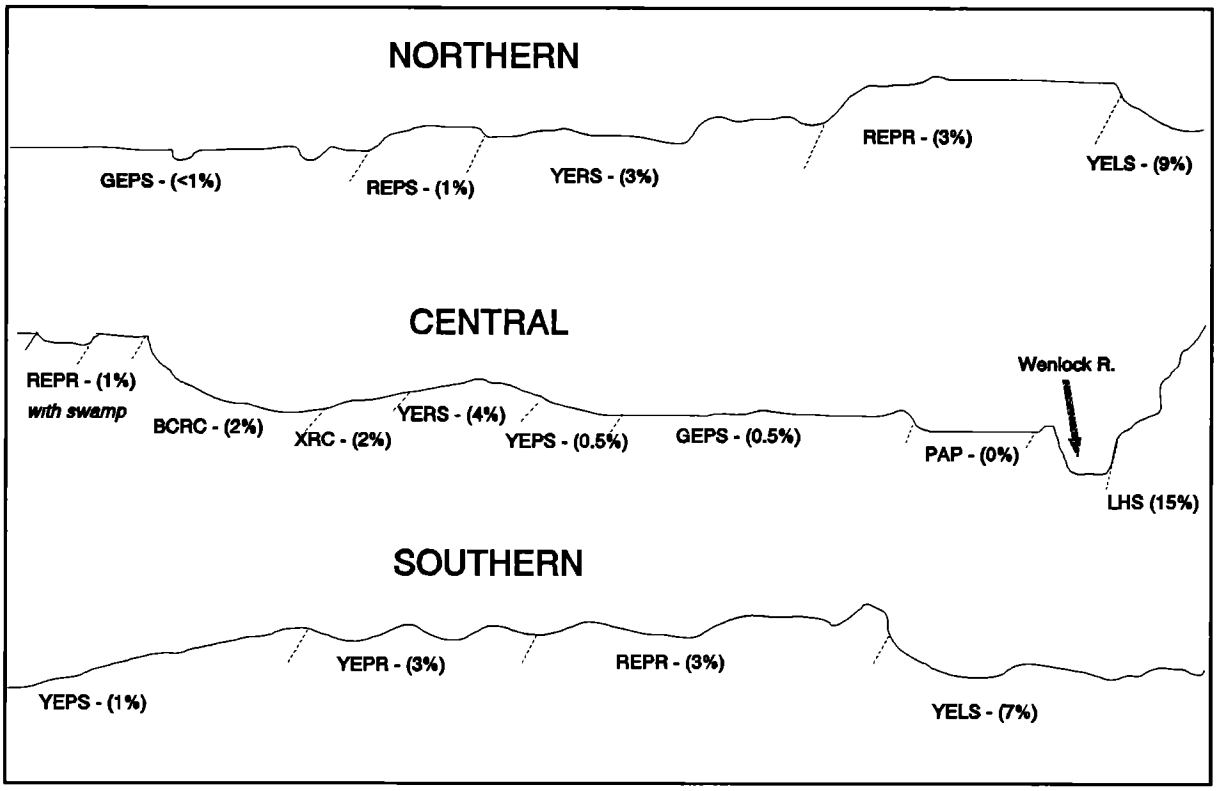

Figure 5 Idealised west-east transects to show the relationship between soil associations on Batavia Downs. Indicative slopes are given for each soil association.

3.2 Descriptions of soil attributes

3.2.1 Soil morphology

Red Earth

These soils are concentrated in the north and east of the property and are for the most part a soil cap on a tertiary laterite surface.

They occur on gently undulating plains and rises and typically are covered with a tall open forest dominated by *Eucalyptus tetrodonta.*

They are deep, highly permeable and well drained soils. Surface textures range from fine sandy loams to sandy clay loams and are loose to firm rather than hardsetting. Slightly more than half the profiles examined were gradational; the remainder were duplex. They are whole coloured throughout the profile with very few segregations. They have an acid soil reaction trend and a low to moderate PAWC (for the purposes of the discussion in this report, low PAWC would include values less than 100mm of water in the top metre; moderate values would range from 100 to 160 and high values would exceed this. The range in profile features is described in Appendix I and an example is described in some detail in Table 3.

Table 3 Site and profile description of a red earth on Batavia Downs

GREAT SOIL GROUP: Red earth **SUBSTRATE MATERIAL:** Tertiary laterite

SITE NO: 38
SOIL ASSOCIATION: REPR (Similar soils are also dominant in RELS, RERS, REPS)
A.M.G. REFERENCE: 700 600 mE 8 579 500 mN ZONE 54 **SLOPE:** 2%

PRINCIPAL PROFILE FORM: Dr4.61 **LANDFORM PATTERN TYPE:** Gently undulating rises

VEGETATION:
STRUCTURAL FORM: Very tall woodland
DOMINANT SPECIES: *Eucalyptus tetrodonta, E. hylandii, E. nesophila*

PROFILE MORPHOLOGY:
CONDITION OF SURFACE SOIL WHEN DRY: Firm

HORIZON	DEPTH	DESCRIPTION
A_1	0 to .06 m	Dark reddish brown (5YR3/2) moist; fine sandy loam; massive.
A_2	.06 to .19 m	Dark reddish brown (5YR3/4) moist; fine sandy loam; massive.
A_3	.19 to .41 m	Reddish brown (2.5YR4/6); fine sandy loam; massive.
B_{21t}	.41 to .61 m	Dark reddish brown (2.5YR3/6) moist; clay loam, fine sandy; massive; very few medium manganiferous nodules.
B_{22t}	.61 to 1.35 m	Dark reddish brown (2.5YR3/6) moist; light clay; very few medium pebbles, subangular sedimentary rocks; weak 2-5 mm angular blocky structure; very few medium ferromanganiferous nodules.

Yellow Earth

These are the most prevalent of Batavia soil types and occur throughout the property. They are found both on the Tertiary laterite surface and on weathered sandstones. The landforms are usually gently undulating plains and rises which are covered by tall open woodland dominated by *E. tetrodonta.*

They are deep, moderately permeable and imperfectly to moderately well drained. Surface textures range from loamy fine sand to clay loam fine sandy and are usually hardsetting. Some profiles are mottled at depth and most have 10% or more of deeper horizons composed of iron and manganese nodules. They have an acid to neutral soil reaction trend and a low to moderate PAWC. A range of profile features is described in Appendix I and an example is described in some detail in Table 4.

Table 4 Site and profile description of a yellow earth on Batavia Downs

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GREAT SOIL GROUP: Yellow earth **SUBSTRATE MATERIAL:** Tertiary laterite

SITE NO: 23

A.M.G. REFERENCE: 678 500 mE 8 596 900 mN ZONE 54
SLOPE: 0.5%

SOIL ASSOCIATION: YEPR (Similar soils are also dominant in YELS, YERS, YEPS)

PRINCIPAL PROFILE FORM: Dy4.62 **LANDFORM PATTERN TYPE:** Level plain

VEGETATION:
STRUCTURAL FORM: Tall woodland
DOMINANT SPECIES: *E. tetrodonta, E. hylandii, E. cullenii*

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Firm

HORIZON	DEPTH	DESCRIPTION
A_1	0 to .09 m	Brownish black (10YR3/1) moist; loamy fine sand; massive; very few medium ferruginous nodules.
A_2	.09 to .20 m	Greyish yellow-brown (10YR4/2) moist; fine sandy loam; massive; very few medium ferruginous nodules.
B_{2tn}	.20 to 1.15 m	Yellow (10YR6/5) moist; fine sandy clay; massive; very many coarse ferruginous nodules.

Grey Earth

These soils are concentrated in an east-west band north of the homestead. They occur on level alluvial plains in drainage depressions or along broad drainage lines. The vegetation is usually a mid-high open woodland with *E. clarksoniana* and an understorey of *Melaleuca viridiflora.*

These are very poorly drained soils with a high watertable for prolonged periods of the wet season. Surface textures range from fine sandy loam to sandy clay loam fine sandy and are hardsetting. There is commonly a high concentration of ferromanganiferous nodules in the B horizon and mottles throughout. There is always a bleached A_2 horizon and in some cases the bleaching extends to the surface. The soils are acid with a low PAWC. A range of profile features is described in Appendix I and an example is described in some detail in Table 5.

Table 5 Site and profile description of a grey earth on Batavia Downs

---

GREAT SOIL GROUP: Grey earth **SUBSTRATE MATERIAL:** Alluvium

SITE NO: 14
A.M.G. REFERENCE: 681 400 mE 8 605 400 mN ZONE 54
SLOPE: 1%
SOIL ASSOCIATION: GEPS (Similar soils are also dominant in GERS)

PRINCIPAL PROFILE FORM: Gn2.94 **LANDFORM PATTERN TYPE:** Level plain

VEGETATION:
STRUCTURAL FORM: Mid-high woodland
DOMINANT SPECIES: *E. clarksoniana, M. viridiflora*

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hardsetting

HORIZON	DEPTH	DESCRIPTION
A_1	0 to .03 m	Greyish yellow-brown (10YR4/2) moist; sandy clay loam, fine sandy; massive.
A_{2cb}	.03 to .19 m	Dull yellowish brown (10YR5/3) moist, dry conspicuously bleached; sandy clay loam, fine sandy; massive.
B_{21}	.19 to .45 m	Dull yellowish orange (10YR6/3) moist; common coarse distinct yellow mottles; fine sandy clay; massive.
B_{22n}	.45 to .56 m	Dull yellowish orange (10YR6/3) moist; common coarse distinct yellow mottles; fine sandy clay; many medium ferromanganiferous nodules.

Brown Clay

These cracking clay soils appear to have formed on weathering claystones and mudstones presumably of marine origin. They occur in the south west portion of the property as footslopes off tertiary lateritic plateaux. Trees are confined to isolated specimens of *E. papuana* with a substantial body of grass dominated by Dicanthium species. Bare patches occur sporadically.

They are deep, slowly permeable and poorly drained soils. The shrink-swell features of the dominant clay results in large cracks during the dry season and the formation of deep melonhole gilgai. The soil surface is characterised by seasonal cracking and a weak to firm crust with a medium clay texture. The soils usually have a fine mottle throughout much of the solum and fine ferromanganiferous nodules occasionally occur. They are alkaline below about 1.4 m and have a high PAWC. Layers of gravel are common. A range of profile features is described in Appendix I and an example is described in some detail in Table 6.

Table 6 Site and profile description of a brown clay on Batavia Downs

GREAT SOIL GROUP: Brown clay **SUBSTRATE MATERIAL:** Weathered claystone colluvia
SITE NO: 41 **SLOPE:** 0.9 %
A.M.G. REFERENCE: 680 700 mE 8 587 000 mN ZONE 54
SOIL ASSOCIATION: BCRC

PRINCIPAL PROFILE FORM: Ug5.35 **LANDFORM PATTERN TYPE:** Level plain
VEGETATION:
STRUCTURAL FORM: Mid-high isolated trees
DOMINANT SPECIES: *Eucalyptus papuana*

TYPE OF MICRORELIEF: Normal gilgai
VERTICAL INTERVAL: 0.40 m **HORIZONTAL INTERVAL:** 6 m
SURFACE COARSE FRAGMENTS: Very few coarse pebbles, subangular sedimentary rocks

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Periodic cracking, self mulching

HORIZON	DEPTH	DESCRIPTION
A1	0 to .09 m	Brownish black (10YR2/2) moist; medium clay; strong 2-5mm granular.
B21n	.09 to .55 m	Yellowish brown (10YR5/6) moist; common medium distinct red mottles; medium heavy clay; moderate 5-10mm angular blocky; many medium ferromanganiferous nodules.
B22	.55 to .99 m	Dull yellowish orange (10YR6/3) moist; many medium distinct orange mottles; medium heavy clay; moderate 20-50mm prismatic secondary, parting to moderate 10-20mm angular blocky primary.
B23	.99 to 1.45 m	Light grey (10YR7/1) moist; many fine distinct orange mottles; heavy clay; strong 10-20mm lenticular.

Xanthozem

These soils occur as a fringe around areas of brown clay soils or interspersed with them on gently undulating rises but they do not exhibit seasonal cracking. The vegetation, a tall open woodland is dominated by *E. leptophleba.*

These are deep moderately permeable, imperfectly drained soils. The soil surface is invariably hardsetting and has a clay loam to light clay texture. Nodules and mottles may be present in the structured B horizon.

The soils are acid and have a moderate PAWC. A range of profile features is described in Appendix I and an example is described in some detail in Table 7.

Table 7 Site and profile description of a xanthozem on Batavia Downs

GREAT SOIL GROUP: No suitable group. Affinities with xanthozem.
SUBSTRATE MATERIAL: Sedimentary colluvia

SITE NO: 64

A.M.G. REFERENCE: 678 000 mE 8590 900 mN ZONE 54
SOIL ASSOCIATION: XRC
SLOPE: 4.2%

PRINCIPAL PROFILE FORM: Uf4.43 **LANDFORM PATTERN TYPE:** Undulating rises

VEGETATION:
STRUCTURAL FORM: Tall open woodland
DOMINANT SPECIES: *Eucalyptus leptophleba, E. clarksoniana*

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A_1	0 to .07 m	Brownish black (10YR3/2) moist; light clay; very few medium pebbles, rounded quartz; weak < 2 mm granular structure.
A_2	.07 to .26 m	Brown (10YR4/4) moist; few fine distinct red mottles; light clay; moderate < 2 mm angular blocky structure.
B_1	.26 to .60 m	Bright yellowish brown (10YR7/6) moist; common fine distinct red mottles; light clay; moderate < 2mm angular blocky; common medium ferromanganiferous nodules.

Earthy Sand

Earthy sands occur intermixed with yellow earths and more rarely with red earths on sandstone rises or laterite surfaces. These are usually gently undulating rises with tall open woodland. Common species include *E. nesophila* and *E. tetrodonta*.

They are deep or moderately deep, well drained soils with loose sandy surfaces. They are whole coloured, acid soils with a very low PAWC. A range of profile features is described in Appendix I and an example is described in some detail in Table 8.

Table 8 Site and profile description of a earthy sand on Batavia Downs

GREAT SOIL GROUP: Earthy sand **SUBSTRATE MATERIAL:** Sandstone

SITE NO: 46

A.M.G. REFERENCE: 687 500 mE 8645 800 mN ZONE 54
SOIL ASSOCIATION: ESRS (Similar soils are also dominant in ESLS, ESPS)
SLOPE: 1%

PRINCIPAL PROFILE FORM: Uc4.21 **LANDFORM PATTERN TYPE:** Gently undulating rises

VEGETATION:
STRUCTURAL FORM: Very tall woodland
DOMINANT SPECIES: *E. nesophila, E. tetrodonta*

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Loose

HORIZON	DEPTH	DESCRIPTION
A_1	0 to .10 m	Brownish black (7.5YR3/2) moist; fine sandy loam; massive.
A_3	.10 to .27 m	Dark brown (7.5YR3/3) moist; loamy fine sand; massive.
B_1	.27 to 1.02 m	Bright reddish brown (5YR5/6) moist; loamy fine sand; massive.
2B	1.02 to 1.38 m	Red (2.5YR5/7) moist; clay loam, fine sandy; massive.

Podsol

Podsols occur in small areas sporadically over the property but are concentrated on level alluvial plains of the Wenlock River in the east. They are covered by a dense low heath with *Melaleuca viridiflora* emergent.

These are deep, poorly to imperfectly drained soils with loose sandy surfaces. The more poorly drained sites have a concentration of nodules at the base of the A horizon. They are acid with a very low PAWC. A range of profile features is described in Appendix I and an example is described in some detail in Table 9.

Table 9 Site and profile description of a podsol on Batavia Downs

GREAT SOIL GROUP: Podsol

SUBSTRATE MATERIAL: Alluvium

SITE NO: 18

A.M.G. REFERENCE: 696 500 mE 8 600 300 mN ZONE 54
SOIL ASSOCIATION: PAP

SLOPE: 0.0%

PRINCIPAL PROFILE FORM: Uc2.21

LANDFORM PATTERN TYPE: Level plain

VEGETATION:
STRUCTURAL FORM: Mid-high woodland
DOMINANT SPECIES: *Melaleuca viridiflora, Asteromyrtus lysicephala, A. symphiocarpa, Banksia dentata, Melaleuca arcana.*

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Loose

HORIZON	DEPTH	DESCRIPTION
A_1	0 to .23 m	Brownish grey (10YR4/1) moist; loamy fine sand; single grain.
A_{2cb}	.23 to 1.30 m	Brownish grey (10YR6/1) moist, dry conspicuously bleached; fine sand; single grain.
B_1	1.30 to 1.40 m	Greyish yellow-brown (10YR6/2) moist; fine sand; single grain.

Lithosol

While isolated occurrences of lithosols occur throughout the sheet, the largest areas are concentrated in the south-eastern corner on the weathered sandstones of the undulating to rolling hills.

They are shallow stony soils which erode readily when disturbed due to the steep slopes. They tend to have a neutral soil reaction trend and a very low PAWC. No chemical data were collected for these soils. A range of profile features is described in Appendix I and an example is described in some detail in Table 10.

Table 10 Site and profile description of a lithosol on Batavia Downs

GREAT SOIL GROUP: Lithosol **SUBSTRATE MATERIAL:** Sandstone
SITE NO: 29
A.M.G. REFERENCE: 684 300 mE 8 598 100 mN ZONE 54
SOIL ASSOCIATION: LHS **SLOPE:** 3%
PRINCIPAL PROFILE FORM: Um1.41 **LANDFORM PATTERN TYPE:** Gently undulating rises

VEGETATION:
STRUCTURAL FORM: Tall woodland
DOMINANT SPECIES: *E. tetrodonta, E. hylandii*

SURFACE COARSE FRAGMENTS: Few coarse pebbles, rounded gravel

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A_1	0 to .05 m	Dark brown (10YR3/4) moist; sandy clay loam; few coarse pebbles, rounded gravel; massive.
AC	.05 to .25 m	Dull yellowish brown (10YR5/4) moist; sandy clay loam; many coarse pebbles, rounded gravel; massive.

3.2.2 Soil Chemistry

Methods

Samples were collected from the surface (0-10cm) of up to 27 profiles of each of the main great soil groups - yellow earth, red earth, grey earth, brown clay, xanthozem and earthy sand and from the subsoils (in most cases from the 50-60cm layer but it varied depending on horizonation) of all but the last two soils. These were analysed for pH, electrical conductivity, chloride, bicarbonate extractable phosphorus, nitrate nitrogen and sulphate sulphur. The methods used were those published in Bruce and Rayment (1982).

Results

The means and standard deviations of six chemical attributes for the major soils are listed in Table 11. The pH of most soils were slightly acid in the surface becoming more acid with depth. The exception was the brown clay which at depths greater than 1.4 m was alkaline. The level of nitrate nitrogen measured in the laboratory was uniformly low. Although NO3-N will vary through the year and indeed within soil samples as they are dried, handled and stored, it is reasonable to assume that field levels will be consistently low.

Table 11 Means and standard deviations of six chemical properties for the major Batavia soils *(These analyses were performed at the laboratories of Agricultural Chemistry Branch, Queensland Department of Primary Industries)*

Soil type		No.	Depth	pH	EC mS/cm	Cl(ppm)	P Bicarb	NO^3-N ppm	SO^4-S ppm
Yellow earth (YE)	Mean		Surf	6.05	0.025	14.65	1.62	1.96	7.08
			Subsurf	5.68	0.007	2.17	2.33	1.00	34.17
	S.D.	27	Surf	*0.28*	*0.012*	*11.22*	*0.70*	*3.74*	*3.65*
		6	Subsurf	*0.19*	*0.003*	*1.83*	*1.06*	*0.00*	*25.77*
Red earth (RE)	Mean		Surf	6.09	0.033	15.54	2.38	1.92	6.08
			Subsurf	5.57	0.007	3.33	1.33	1.00	25.33
	S.D.	13	Surf	*0.27*	*0.015*	*7.20*	*0.96*	*1.50*	*1.89*
		3	Subsurf	*0.12*	*0.003*	*3.21*	*0.58*	*0.00*	*15.53*
Grey earth (GE)	Mean		Surf	5.93	0.021	11.75	1.88	1.00	4.63
			Subsurf	5.45	0.008	1.00	2.50	1.00	16.50
	S.D.	8	Surf	*0.19*	*0.005*	*4.30*	*1.46*	*0.00*	*1.77*
		2	Subsurf	*0.21*	*0.005*	*0.58*	*1.53*	*0.58*	*11.54*
Brown clay (BC)	Mean		Surf	6.04	0.05	25.63	3.25	1.00	12.25
			Subsurf	7.02	0.19	163.80	1.20	1.00	16.00
	S.D.	8	Surf	*0.26*	*0.02*	*8.37*	*1.28*	*0.00*	*1.28*
		5	Subsurf	*1.06*	*0.37*	*346.73*	*0.45*	*0.00*	*22.01*
Xanthozem (X)	Mean		Surf	5.93	0.03	17.00	2.33	1.00	15.67
	S.D.	3	Surf	*0.15*	*0.003*	*3.46*	*1.15*	*0.00*	*3.79*
Earthy sand (ES)	Mean		Surf	5.83	0.02	13.75	1.50	1.25	4.25
	S.D.	4	Surf	*0.35*	*0.004*	*4.57*	*0.58*	*.025*	*2.06*

Phosphorus status

Mean bicarbonate-extractable phosphorus levels for each of the major soils are plotted in Figure 6. All are very low. Only some surface values of the brown clay exceeded 3 ppm, the point below which stylo pastures require phosphorus fertilisation.

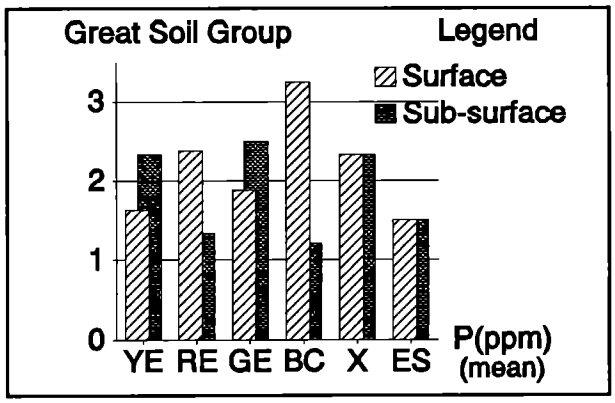

Figure 6 Bicarbonate extractable phosphorus in Batavia Downs soils

Sulphur status

The earth soils had relatively low sulphate sulphur levels in the surface but the increase in the subsoil is large enough to suggest that a profile mean weighted as suggested by Probert and Jones (1977) would exceed the critical value of 4 ppm (Figure 7). The earthy sand was also low in sulphur in the surface but unfortunately no data were available for the subsoil. It may be responsive to sulphur. Sulphate levels in the brown clay and xanthozem are probably adequate for tropical legumes.

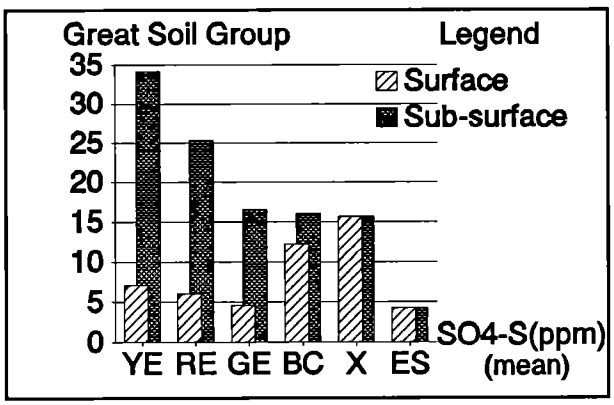

Figure 7 Sulphate sulphur in Batavia Downs soils

Salinity

Most of the soils collected had very low levels of both electrical conductivity and chloride. (The levels of chloride and electrical conductivity were highly correlated). The major exception was the brown clay (Figure 8). The plot for this soil covers values over a range of subsoil depths. There is only one value from the 1.4 - 1.5 m depth (0.843 $mScm^{-1}$ on a 1:5 H_2O sample and chloride content of 784 ppm). The scale of the survey and the time available did not allow more intensive sampling at depth in these soils. This particular value is sufficiently high to suggest, however, that management should allow for the presence of salt in the subsoil of the brown clays.

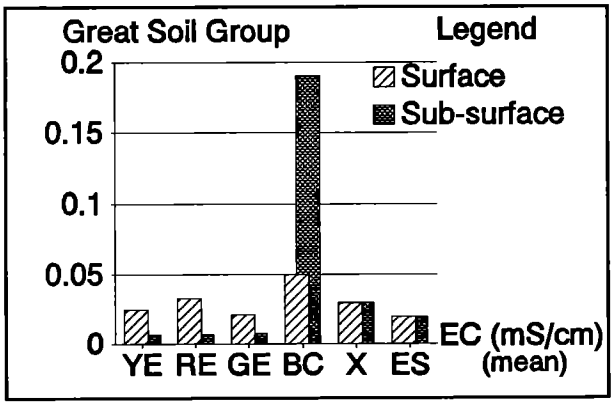

Figure 8 Electrical conductivity in Batavia Downs soils

Discussion

For all soils except the earthy sands, the major limiting nutrient is likely to be phosphorus which will need to be applied to tropical legumes for adequate growth. Sulphur levels are adequate. Other studies in the region have suggested that potassium, zinc and possibly calcium become limiting as the major phosphorus limitation is alleviated. The economic returns of this added fertilisation has yet to be determined.

The earthy sands probably require both phosphorus and sulphur fertilisation suggesting the use of single superphosphate rather than phosphate enriched fertilisers.

The presence of salt in the subsoil of the brown clay needs further investigation. Until then the following management practices are necessary:

- land upslope and part of the same catchment should not be cleared or thinned. This includes the Embley Range and other smaller laterite plateaus in the area.

- The existing tree cover on the brown clays and associated Xanthozems should be left undisturbed.

4. ASSESSMENT OF LAND SUITABILITY

The following section describes the process of assigning suitability classes to the mapped soil associations. As with the physical resource assessment, the reliability of the analysis depends on the intensity of observation and measurement and on the validity of the decision rules adopted. This assessment was designed to provide a guide to suitability for the property as a whole. Small areas within the mapping units, which may be significant at a local scale, may differ in suitability to that of the unit as a whole.

4.1 Methodology

This project used the geographic information system approach described in Grundy and Bryde (1989). While this methodology will not be detailed in this report, it briefly consists of establishing a data base related to each soil landscape mapping unit (or Unique Mapping Area - UMA). This data base lists the soil landscape attributes in terms of limitations for the defined land uses - sowing of introduced legume species through the existing tree cover or sowing into cultivated and cleared land - and relates it to the two land uses . For each limitation, the data base lists a land suitability subclass which is then compared with the range of other subclasses to derive an overall land suitability class (LSC) for each of the two land uses. Land suitability classes range from 1 (suitable with negligible limitations) to 5 (unsuitable). Classes 1 to 3 are suitable. The decision matrix used is detailed in Appendix II and the definitions of the LSCs in Appendix III. The limitations used in this study were:

- Plant available water capacity as estimated by field texture;
- Soil wetness as estimated by field morphology;
- Soil erodibility as estimated by slope and surface characteristics;
- Regrowth potential which varies between species and forest type;
- Existing vegetation; and
- Intake/outflow potential or the potential capacity for secondary saline seepage which is related to geomorphology and soil drainage characteristics.

Nutritional limitations were included as a blanket limitation since all soils were similarly low in phosphorus and would require fertilisation to overcome deficiencies. A land suitability subclass of 2 was imposed across the survey area.

4.2 Potential land uses and their requirements

Assessment of land suitability requires a matching of the requirements of the land use (e.g. the nutritional requirements of individual species or the physical requirements of a particular cattle management system) to the attributes of the land (e.g. soil wetness, vegetation or slope). This process would normally include the management option of grazing native pasture which has been the predominant practice on Cape York Peninsula. The constraints of brucellosis and tuberculosis control, escalating mustering costs and improved cattle husbandry elsewhere have combined to make this option untenable in the long term. Land must be fenced, smaller areas must therefore be used and greater productivity obtained from those areas. Thus, while grazing native pastures (perhaps with supplementation) will remain in use for some time on the Peninsula, this study only deals with more intensive systems.

4.2.1 Introduction of legumes into uncleared land

This system will usually involve the reduction of the bulk of ground herbage through fire or grazing at the end of the dry season and aerial seeding of the legume species, seca stylo (*Stylosanthes scabra*), Carribean stylo (*Stylosanthes hamata* cv. verano) and Glenn joint vetch (*Aeschynomene americana*). Fertiliser inclusion depends on the fertility status of the soil (uniformly low in the case of Batavia Downs). The published environmental requirements of these species are listed in the Pasture Manual (Anon. 1990)

Clearly the species involved require moisture from the soil and some degree of freedom from long periods of wetness or inundation. No attempt was made to separate the individual species with respect to these requirements and the subclasses assigned reflect a conservative average requirement.

The erosion risk with this system reflects not only the nature of the soil landscape and the climate but also the management regime. This analysis assumes optimal management which will allow the retention of native grasses throughout the year.

Since no clearing or thinning of these trees is involved, within the constraint of soil attributes, the thicker the tree coverage, the less suitable the land for this use. There is also a concern that with increased grazing pressure and cooler, less frequent fires, *Acacia* and other volunteer species will become more prevalent and reduce the productivity of the land. Although this has yet to be substantiated, some soil landscape units seem more suitable to the growth of *Acacia* under-stories.

The effect of this system on saline seepage should be minimal although there may be long term effects if succession of the existing forest is hampered by the grazing regime and changes in the management of fire.

4.2.1 Clearing and pasture improvement

This system involves the clearing of land and the sowing of introduced species into cultivated soil. The range of legumes will be similar to that in the less intensive system but one or more grass species will be included from *Brachiaria decumbens, B. humidicola* and *Heteropogon gayanus*.

Clearing :

- will exacerbate the seasonal wetness effects on some soils;
- may accelerate erosion;
- will involve a commitment to long term control of regrowth which is worse for some species and communities than others; and
- may contribute to secondary salinity in particular landscapes.

Cultivation will increase the risk of erosion in some soils and in the brown clays may bring more dispersive materials to the surface through the inversion of the surface and the exposure of soil materials higher in sodium. Crusting and scalded areas are already apparent.

5. RESULTS

The results of this project can be grouped into three:

- **Tabulated and written information** which is contained in this report.
- **Mapped information** which includes:
  - A transparent location map which can be overlaid on the coloured thematic and soils maps to correlate land information with such features as roads and fences;
  - A soil landscape map which summarises the information gained about the base resource; and
  - Land suitability maps which indicate the distribution of the different classes of land or particular features of the land;
- **A Geographic Information System** which contains the maps and UMA database. The information presented in this report is only a selection from the system and it is available for further analysis or as a base for further updating as in detailed property planning.

5.1 Areas of suitable land

Table 12 Areas of land in the five Land Suitability Classes for two land uses on Batavia Downs

Land Suitability Class	Sowing through trees	Clearing and cultivation
2	39 610	
3	99 610	82 330
4	47 560	56 120
5	13 890	62 220

Classes 2 and 3 are suitable. As Figures 9 amd 10 indicate much of the more suitable land for sowing without clearing is near the existing homestead and fencing. The class 2 land includes brown clays, xanthozems and yellow earths. The areas of red earths tend to be class 3 due to the denser vegetation. Areas in the north which would otherwise be class 3 are class 4 due to the presence of poisonous cycads.

There is no class 2 land for clearing. Clearing and cultivation impose costs (due to regrowth, cost of clearing or erosion in most cases) which management of the land must recognise and account for. Much of the class 3 land near the homestead includes yellow earths while red earths cover the bulk of this land elsewhere. The brown clays and xanthozems are class 4 for clearing and cultivation solely due to the potential for salting (Figure 11). This will not impose a major impediment to use of the brown clay since the scattered nature of the trees will not preclude intensive pasture improvement by sowing through the existing trees. The xanthozems are included in class 4 as a conservative measure in the absence of sufficient information. They occur with the brown clays and may have salt at depth. We would recommend a program of deep sampling to at least 2 metres before this land is cleared.

This report has not addressed more intensive uses such as agriculture and horticulture. Information could be produced if that were required at a later stage.

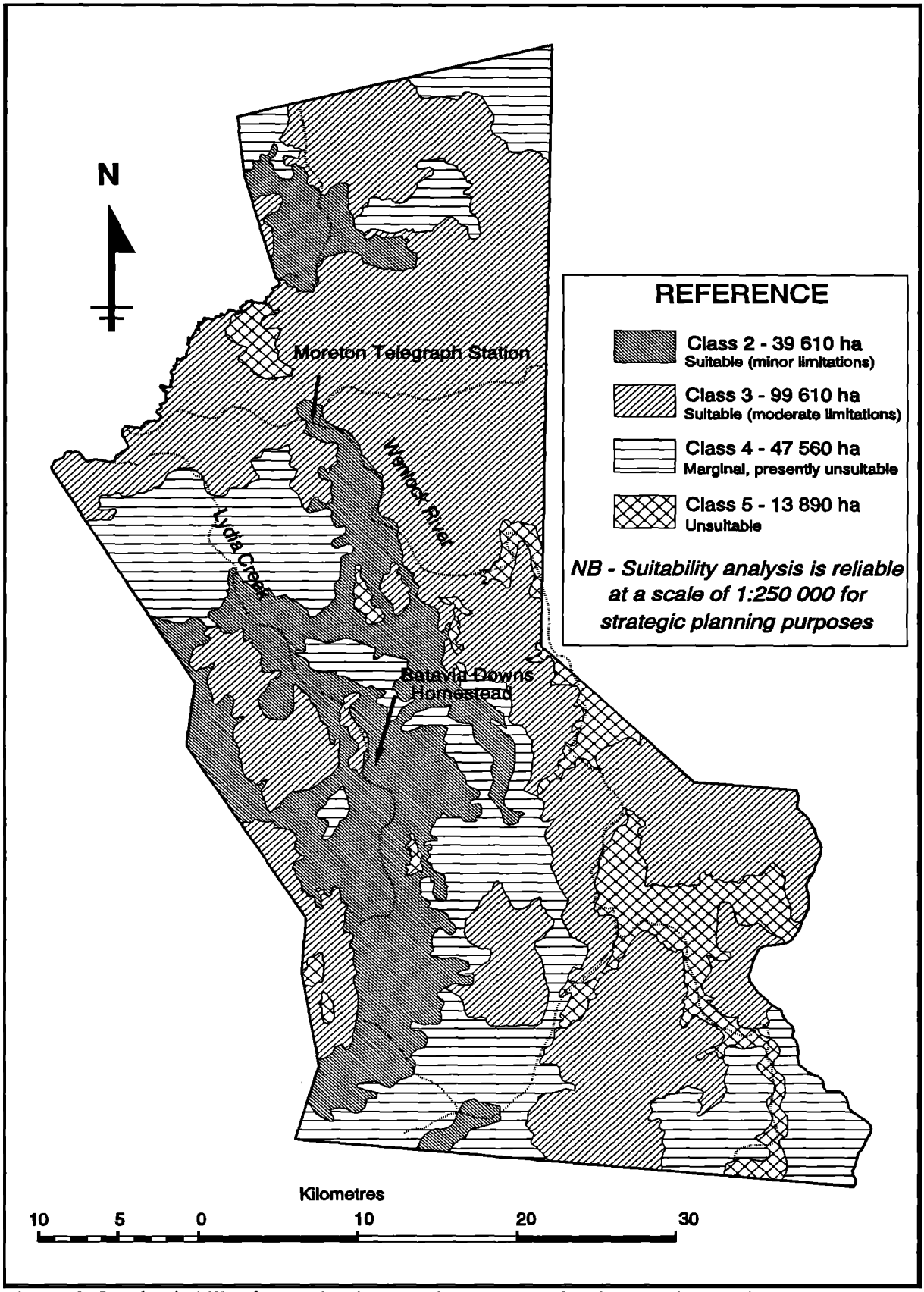

Figure 9 Land suitability for sowing improved pasture species through the existing tree cover at Batavia Downs

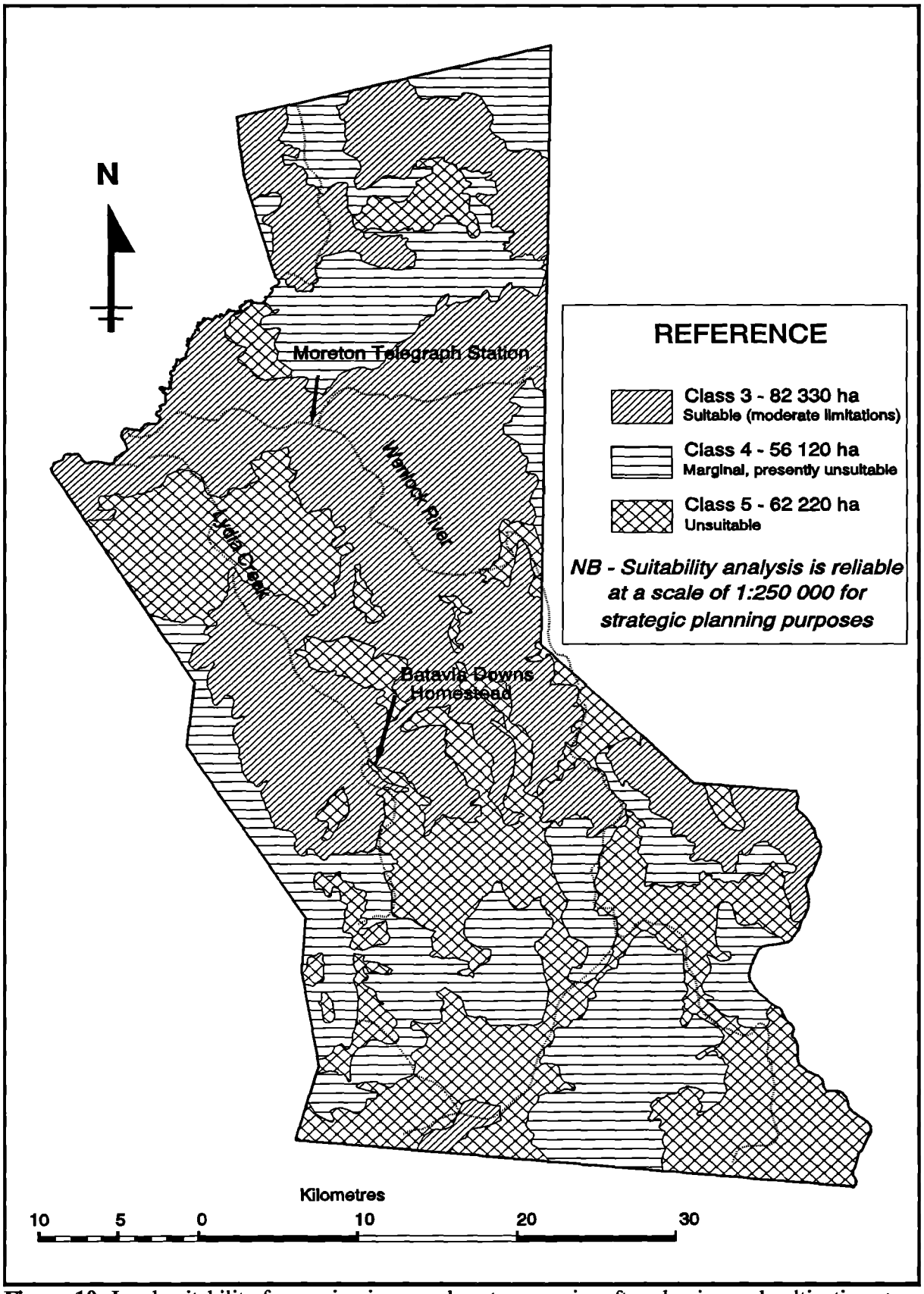

Figure 10 Land suitability for sowing improved pasture species after clearing and cultivation at Batavia Downs

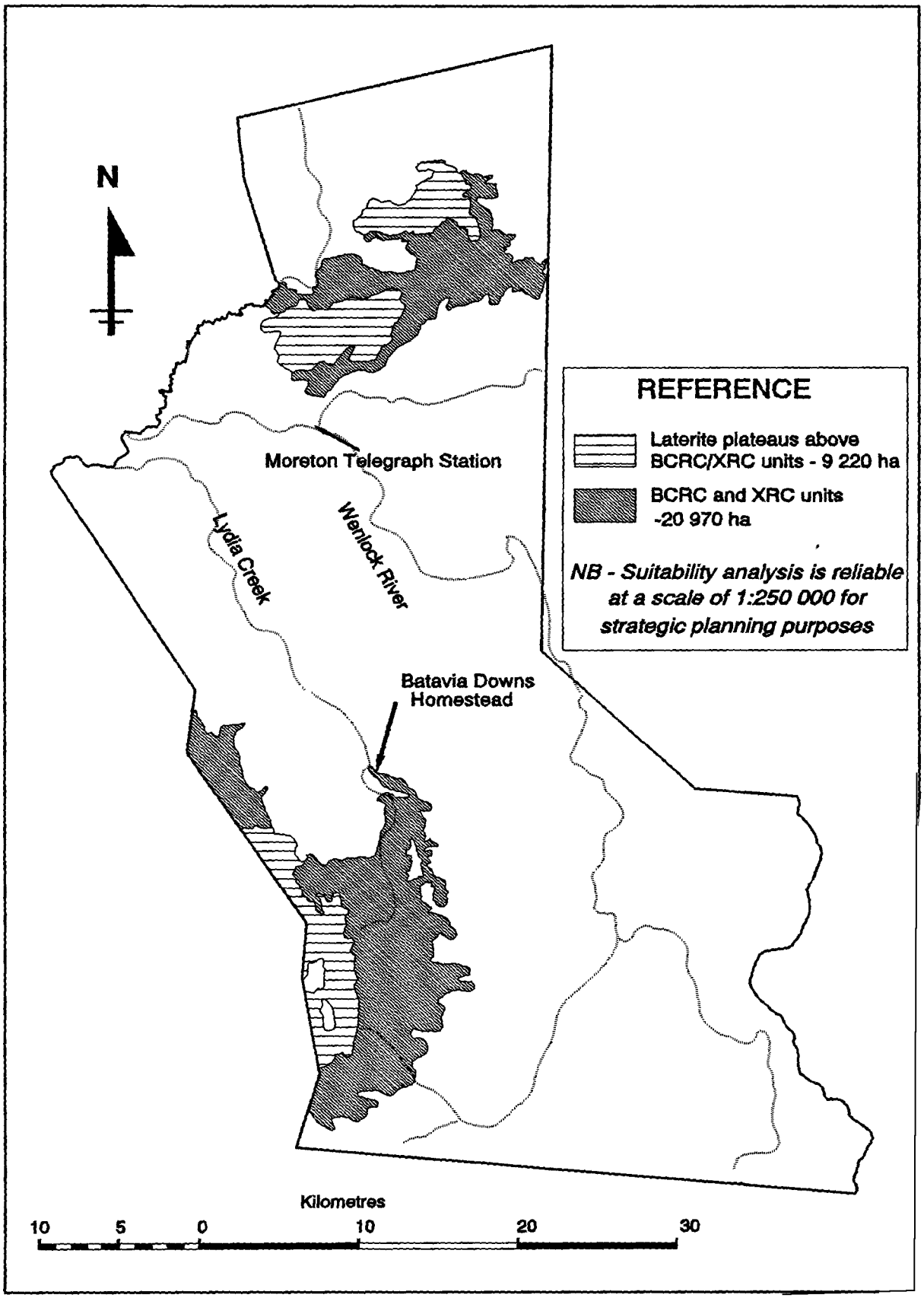

Figure 11 Areas of Batavia Downs where clearing is not recommended until the potential for induced salinity is investigated

6. ACKNOWLEDGMENTS

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- Peter McKeague, Agriculture Branch, for advice on land use and pasture technology;
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APPENDIX I
RANGE OF ATTRIBUTES OF BATAVIA DOWNS SOILS

GREAT SOIL GROUP: Red Earth **SOIL ASSOCIATIONS:** REPR, RELS, RERS, REPS

PRINCIPAL PROFILE FORMS: Gn 2.11, Gn 2.12, Gn 2.14, Dr 4.61.

VEGETATION:

STRUCTURAL FORM: Tall to very tall woodland.

DOMINANT SPECIES: *Eucalyptus tetrodonta, E. hylandii, E. nesophila, E. crebra.*

PROFILE MORPHOLOGY:

HORIZON	LOWER DEPTHS	DESCRIPTION
A1	0.04 to 0.18m	Dark, red brown or red; fine sandy loam to sandy clay loam; apedal; acid.
A2	0.11 to 0.32m	(where present) Red or red brown, fine sandy loam to sandy clay loam; apedal; acid.
A3/B1	0.17 to 0.41m	(where present) Red or red brown; sandy clay loam to clay loam; apedal; acid.
B21	0.32 to 0.75m	Red; clay loam fine sandy to light clay; apedal; acid to neutral.
B22	0.60 to 1.35m	Red; clay loam fine sandy to light clay; apedal; few medium ferruginous nodules; acid to neutral.

GREAT SOIL GROUP: Yellow earth **SOIL ASSOCIATIONS:** YEPR, YELS, YERS, YEPS.

PRINCIPAL PROFILE FORMS: Gn 2.24, Gn 2.21, Gn 2.64, Gn 2.61, Dy 2.61, Dy 4.62.

VEGETATION:

STRUCTURAL FORM: Tall woodland

DOMINANT SPECIES: *Eucalyptus tetrodonta, E. hylandii E. nesophila, E. clarksoniana, Melaleuca viridiflora.*

PROFILE MORPHOLOGY:

HORIZON	LOWER DEPTHS	DESCRIPTION
A1	0.03 to 0.12m	Dark, grey or brown; fine sandy loam to sandy clay loam fine sandy; apedal; acid.
A2	0.10 to 0.40m	Brown, yellow brown or grey, bale dry; fine sandy loam to sandy clay loam fine sandy; apedal; acid.
B1	0.15 to 0.45m	(where present) Yellow brown to yellow; sandy clay loam to clay loam sandy; apedal; acid.
B21	0.26 to 0.90m	Mottled or whole coloured yellow or yellow brown; sandy clay loam to light medium clay; apedal; few to common medium ferromanganiferous nodules; acid to neutral.
B22	0.40 to 1.10m	Mottled or whole coloured yellow; clay loam sandy to light clay; apedal; common to very many ferromanganiferous nodules; acid to neutral.

GREAT SOIL GROUP: Grey earth **SOIL ASSOCIATIONS:** GEPS, GERS.
PRINCIPAL PROFILE FORMS: Gn 2.94, Dg 2.61, Dg 4.82, Gn 2.84.
VEGETATION:
STRUCTURAL FORM: Mid-high woodland.
DOMINANT SPECIES: *E. clarksoniana, Melaleuca viridiflora*

PROFILE MORPHOLOGY:

HORIZON	LOWER DEPTHS	DESCRIPTION
A1	0.04 to 0.16m	Grey; fine sandy loam to sandy clay loam fine sandy; apedal; acid.
A2	0.19 to 0.31m	Grey or yellow brown, dry conspicuously bleached; sandy loam to sandy clay loam fine sandy; apedal; acid.
B21	0.39 to 0.55m	Yellow mottled, grey or yellow brown; clay loam sandy to light clay; apedal; acid.
B22	0.50 to 0.74m	Yellow mottled, grey; clay loam to light clay; apedal; few to many medium ferromanganiferous nodules; acid.

GREAT SOIL GROUP: Brown Clay **SOIL ASSOCIATIONS:** BCRC
PRINCIPAL PROFILE FORMS: Ug 5.34, Ug 5.35, Ug 5.32.
VEGETATION:
STRUCTURAL FORM: Tall isolated trees
DOMINANT SPECIES: *Eucalyptus papuana, E. leptophleba.*

PROFILE MORPHOLOGY:

HORIZON	LOWER DEPTHS	DESCRIPTION
A1	0.04 to 0.12m	Dark; light to medium heavy clay; strongly pedal; acid.
B21	0.23 to 0.55m	Mottled dark, yellow brown or yellow; medium to medium heavy clay; strongly pedal; acid.
B22	0.60 to 1.11m	Mottled brown, yellow brown or yellow; medium heavy to heavy clay; strongly pedal; acid.
B23	1.45 to 1.80m	Mottled yellow, yellow brown or grey; medium heavy to heavy clay; strongly pedal; neutral to alkaline.

GREAT SOIL GROUP: Xanthozem **SOIL ASSOCIATIONS:** XRC
PRINCIPAL PROFILE FORMS: Gn 3.71, Uf 6.34, Uf 4.43.
VEGETATION:
STRUCTURAL FORM: Tall open woodland
DOMINANT SPECIES: *Eucalyptus leptophleba, E. clarksoniana*

PROFILE MORPHOLOGY:

HORIZON	LOWER DEPTHS	DESCRIPTION
A1	0.04 to 0.09m	Dark; clay loam to light clay; pedal; acid.
A2	0.15 to 0.26m	(where present) Brown, pale dry; light clay; pedal; acid.
B1	0.21 to 0.60m	Mottled brown to yellow; light clay; pedal; acid.
B2	0.50 to 0.75m	Mottled yellow or yellow brown; light to light medium clay; pedal; few to common medium ferromanganiferous nodules; acid.

GREAT SOIL GROUP: Earthy sand **SOIL ASSOCIATIONS:** ESRS, ESLS, ESPS.
PRINCIPAL PROFILE FORMS: Uc 5.22, Uc 4.21, Uc 2.21
VEGETATION:
STRUCTURAL FORM: Very tall woodland
DOMINANT SPECIES: *Eucalyptus tetrodonta, E. nesophila, E. hylandii, E. crebra*

PROFILE MORPHOLOGY:

HORIZON	LOWER DEPTHS	DESCRIPTION
A1	0.05 to 0.12m	Dark or grey; loamy sand to fine sandy loam; apedal; acid.
A2	0.27 to 0.47m	Grey brown or yellow-brown; (occasionally conspicuously bleached dry) loamy fine sand to loamy sand; apedal; acid.
A3/B1	0.49 to 1.02m	(where present) Yellow brown to red brown; loamy fine sand; apedal; acid.
B2	0.95 to 1.50m	Yellow brown; loamy sand to fine sandy loam; apedal; acid.

GREAT SOIL GROUP: Podsol — **SOIL ASSOCIATIONS:** PAP

PRINCIPAL PROFILE FORMS: Uc 2.21

VEGETATION:

STRUCTURAL FORM: Mid-high woodland.

DOMINANT SPECIES: *Melaleuca viridiflora, Asteromyrtus lysicephala, A. symphyocarpa, Banksia dentata.*

PROFILE MORPHOLOGY:

HORIZON	LOWER DEPTHS	DESCRIPTION
A1	0.06 to 0.23m	Brown to grey; loamy fine sand; apedal, acid.
A2 acid.	1.10 to 1.30m	Grey, dry conspicuously bleached; fine sand; apedal;
B	1.40 to 1.50m	Grey; fine sand; apedal; acid.

GREAT SOIL GROUP: Lithosol — **SOIL ASSOCIATIONS:** LHS

PRINCIPAL PROFILE FORMS: Um 1.42, Uc 2.12.

VEGETATION:

STRUCTURAL FORM: Tall woodland

DOMINANT SPECIES: *Eucalyptus tetrodonta, E. hylandii.*

PROFILE MORPHOLOGY:

HORIZON	LOWER DEPTHS	DESCRIPTION
A1	0.02 to 0.05m	Grey or brown; loam fine sandy to clay loam; common to many medium pebbles rounded gravel; apedal; acid.
AC	0.25 to 0.35m	Yellow brown; loam fine sandy to clay loam; common to many medium pebbles rounded gravel; apedal; acid.

APPENDIX II

LAND SUITABILITY LIMITATIONS AND SUITABILITY SUB-CLASSES

WATER HOLDING CAPACITY LIMITATION	Suitability sub-class	
	Trees[¶]	Cultiv[§]
Units dominated by brown clays	1	1
Units dominated by xanthozems	2	1
Units dominated by yellow and red earths	2	2
Units with mixtures of earthy sands and earths OR dominated by grey earths	3	3
Units dominated by earthy sands or podsols	5	5

ERODIBILITY LIMITATION			Suitability sub-class	
			Trees	Cultiv
Soils with loose, fine sandy surfaces:				
•	level to very gently inclined	(0-3%)	1	2
•	gently inclined	(3-10%)	2	4
•	moderately inclined or greater	(>10%)	4	5
Soils with hardsetting surfaces:				
•	level to very gently inclined	(0-3%)	2	2
•	gently inclined	(3-10%)	3	4
•	moderately inclined or greater	(>10%)	4	5
Brown clays			1	3

¶ - *Trees* - Sowing through the existing vegetation

§ - *Cultiv* - Sowing into cleared and prepared ground

WETNESS LIMITATION	Suitability sub-class	
	Trees	Cultiv
Permeability/Drainage classes		
highly permeable/well drained	1	1
highly permeable/moderately well drained	1	1
moderately permeable/moderately well drained	1	1
moderately permeable/imperfectly drained	2	3
moderately permeable/poorly drained	4	5
moderately permeable/very poorly drained	4	5
slowly permeable/imperfectly drained	3	4
slowly permeable/poorly drained	4	5

REGROWTH LIMITATION	Suitability sub-class	
	Trees	Cultiv
Tall open forest and woodland dominated by *E. tetrodonta*	2	3
Woodland dominated by *E. leptophleba*	2	2
Woodland with significant *M. viridiflora*	1	3
Others	1	1

EXISTING VEGETATION LIMITATION	Suitability sub-class	
	Trees	Cultiv
Tall open forests	3	2
Woodland	2	2
Forests with cycads	4	2
Heath	4	2
Melaleuca forests	4	2
E. papuana/grassland communities	1	2

SALINITY (INFLOW/OUTFLOW) LIMITATION	Suitability sub-class	
	Trees	Cultiv
Laterite plateaus above BCRC and XRC units	1	5
BCRC and XRC units	1	5
Other	1	1

NUTRIENT LIMITATION

All soils have a low level of available phosphate and are therefore assigned a nutrient sub-class of 2.