Government of **Western Australia**
Department of **Water**

Waterway assessment for the lower Lockhart River: Caroline Gap to Old Beverley Road

Water resource management series
Looking after all our water needs

Report no. WRM 54
December 2008

Government of **Western Australia**
Department of **Water**

Waterway assessment for the lower Lockhart River: Caroline Gap to Old Beverley Road

This project is funded by the Avon Catchment Council and the state and Australian governments through the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality.

Department of Water

Water resource management series

Report No. WRM 54

December 2008

Prepared by
Viv Read & Associates in association
with BlueSands Environmental for
Department of Water

Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone +61 8 6364 7600
Facsimile +61 8 6364 7601
www.water.wa.gov.au

December 2008

ISSN: 1326-6934 (pub)
ISSN: 1835-3592 (pdf)

ISBN: 978-1-921468-97-1 (pub)
ISBN: 978-1-921468-98-8 (pdf)

Acknowledgements

The survey and plan have been prepared with considerable contributions from many people and organisations. The project was managed by Kate Gole, Natural Resource Management Officer with the Department of Water, Swan–Avon Region.

Comments on the draft report were provided by Kate Gole, Martin Revell and Bernard Kelly of the Department of Water in Northam.

All adjacent landholders gave permission for access to the lower Lockhart River for this assessment.

Michael Hayden, Manager, Merredin Aboriginal Project Inc., provided information about the values of the Nyaki Nyaki Nyungar people relevant to the study area.

Additional information about recent changes in the condition of the river and about social history was provided by Alan and Eva Cole, landholders in the Shire of Kellerberrin.

The project was undertaken by Viv Read & Associates in association with BlueSands Environmental (Lucy Sands).

Cover photo: Lockhart River.

All photos taken by Viv Read unless otherwise stated.

Foreword

This waterway assessment for the lower Lockhart River was initiated by the Department of Water to provide benchmark information about the condition of the river. This information enables the Western Australian government to work with the community to protect and improve the environmental and social values of our river systems.

The assessment provides continuity of waterway planning processes for the Avon River and its major tributaries. It is also linked to management of the Swan River estuary.

Findings of the assessment show that, while it is substantially degraded in some areas, the lower Lockhart River has many locations with high conservation value. Some areas are described as being in near pristine condition. Significant Aboriginal heritage values and European historic values are also associated with this section of the river.

There are many challenges to the effective management of river systems in the Avon River basin. The impacts of salinity, sedimentation and excessive nutrients on water quality and riparian vegetation are difficult to control but these challenges can be met by consistent good management of the river environment and adjacent catchments. The Department of Water, in partnership with the Avon Catchment Council, will use this report as an important step in successfully managing the lower Lockhart River.

The project is jointly funded by the state and Australian governments through the Department of Water and the Avon Catchment Council, as part of the Avon Rivercare Program.

Martin Revell
Program Manager, Swan–Avon Region
Department of Water

Contents

Appendices

Tables

Figures

Maps

Summary

This assessment of the lower Lockhart River has been undertaken to provide benchmark information about the valley floor environment. This will guide management of the river, and enable comparisons to be made in the future.

The Lockhart River system is a major tributary of the Avon River. It has a catchment area of 28 400 km^2, which is 24 per cent of the area of the Avon River basin. The waterway is within an ancient landform with subdued features. It is a sluggish river with a channel gradient of only 0.027 per cent (23 m fall in the 86 km length of the study area).

Annual streamflow is measured at the Kwolyn Hill gauging station. The location of the station (reference code 615012) is shown on Map 2. Streamflow information has been reliably recorded for over 30 years. The annual average flow is more than four times greater than that measured for the Yilgarn River. The lower Lockhart River is highly saline, with an average salinity greater than 33 000 mg/L (similar to that of sea water). There have been five significant high flow events in the past 30 years. The most significant recorded flood event was during January 2000. Salinity is significantly reduced following high flow events.

The area assessed extends from the Caroline Gap, between Mt Caroline and Mt Stirling where the Yilgarn and Lockhart rivers converge, upstream to the Old Beverley Road. The assessment method was to select 11 representative sites and undertake a reconnaissance-scale survey at each site.

The width of the valley floor within the study area varies from a relatively narrow 0.5 km to over 3 km wide. The micro-morphology of the valley floor is highly variable. The river channel is moderately well defined at some sites although it is most commonly highly scalloped or indented (small bare deflation areas within the valley floor that detain flood waters and commonly are sites of groundwater discharge).

Dune systems occur within the valley floor. These vary in height, up to approximately 2 m. They are important as they provide protection from rising saline groundwater for natural vegetation. The more elevated dunes generally support higher quality vegetation communities that are at less risk of salinity-related degradation.

Two sites surveyed have natural vegetation in near pristine condition (LLR06 and LLR07). Three sites have more than 20 per cent assessed to be in excellent condition (LLR05, LLR07 and LLR08). The conservation values of these sites is considered to be very high.

In contrast, there are two sites where more than 90 per cent of the vegetation was assessed as completely degraded (LLR09 and LLR10). One other site (LLR11) is considered to be completely degraded for more than 50 per cent of the area. This is the Wandjagill Nature Reserve adjacent to the Old Beverley Road. The assessment

indicates that this site is rapidly becoming more degraded.

Site degradation is due primarily to rising groundwater and associated salinity processes. The margins of currently bare areas of the valley floor are most at risk. The melaleuca-dominated vegetation communities are in significant decline in these locations.

Management response actions are proposed. These focus on ongoing monitoring of resource condition and increasing community understanding of the environmental and social values (including Aboriginal heritage sites and European historic values) and of the threatening processes that are occurring. Some preventative actions can be taken on-site, including controlled or no grazing in high conservation value areas. Other proposed management actions are best integrated with catchment management actions to reduce high peak streamflow events, where feasible, to control groundwater rise.

1 Introduction

Department of Water has undertaken waterway condition assessments of the Avon River, and many of its major tributaries, and further assessments are planned. The results provide benchmark information for future assessment of changes in river condition, enable planning of management actions for river recovery and engage local community interest in river management and recovery.

This waterway assessment provides a site-based survey for the lower Lockhart River from the Caroline Gap to the Old Beverley Road, a distance of approximately 86 km.

A new survey method has been developed for the lower-rainfall areas of the zone of ancient drainage within the Avon River basin. This includes the lower Lockhart River. The method is better suited to the waterway characteristics that occur in the relatively subdued landscape within this zone, which include low gradients, relatively low annual streamflows, occasional high flood events and poorly defined stream channel patterns that may be distributed across broad, indistinct floodplains.

The method used is based on surveying representative sites, rather than a continuous longitudinal assessment.

1.1 Purpose and scope of the assessment

The purpose of the survey is to describe the waterway, salt lake and floodplain characteristics, riparian vegetation and other associated remnant vegetation and to assess the threatening processes that are affecting vegetation condition.

The assessment aims to provide a snapshot of the current riparian condition and management needs of the waterways and associated floodplains of the lower Lockhart River in the zone of ancient drainage by:

- describing the nature of the waterway and floodplain
- identifying and describing areas of riparian vegetation, and areas of remnant vegetation closely linked to riparian vegetation
- identifying threatening processes that are impacting on riparian vegetation condition.

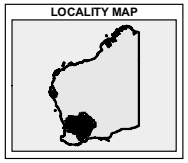
Priority actions for waterway and floodplain management are also recommended.

The scope of the waterway assessment is for the lower Lockhart River from the Caroline Gap to the Old Beverley Road, a distance of approximately 86 km. At a landscape scale, the waterway assessment recognises the ecological processes and management implications that occur in adjoining hill slopes and tributary catchments. However detailed management of these areas is considered to be beyond the scope of this plan.

There are a number of threats to the riparian ecosystems in the broad floodplains of the zone of ancient drainage. They include:

- salinity and waterlogging
- land clearing, resulting in the direct loss of riparian vegetation and fragmentation of remnant vegetation
- restriction of the passage of saline flood flows by road crossings, causing localised flooding and waterlogging problems
- increased streamflow, causing erosion and sedimentation in tributaries
- invasion of pest species
- fire risk
- dumping of rubbish in floodplain areas.

Map 1 Location of the lower Lockhart River study area within the Avon River basin



LEGEND

- Major town/city
- Town
- Major road
- River
- Avon River basin boundary
- Subcatchment boundaries

N

0 25 50 75 100

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requestee: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_series\B41480002\mxd\Map01_Avon_River_Basin_and_Subcatchments.mxd
Date: April 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:

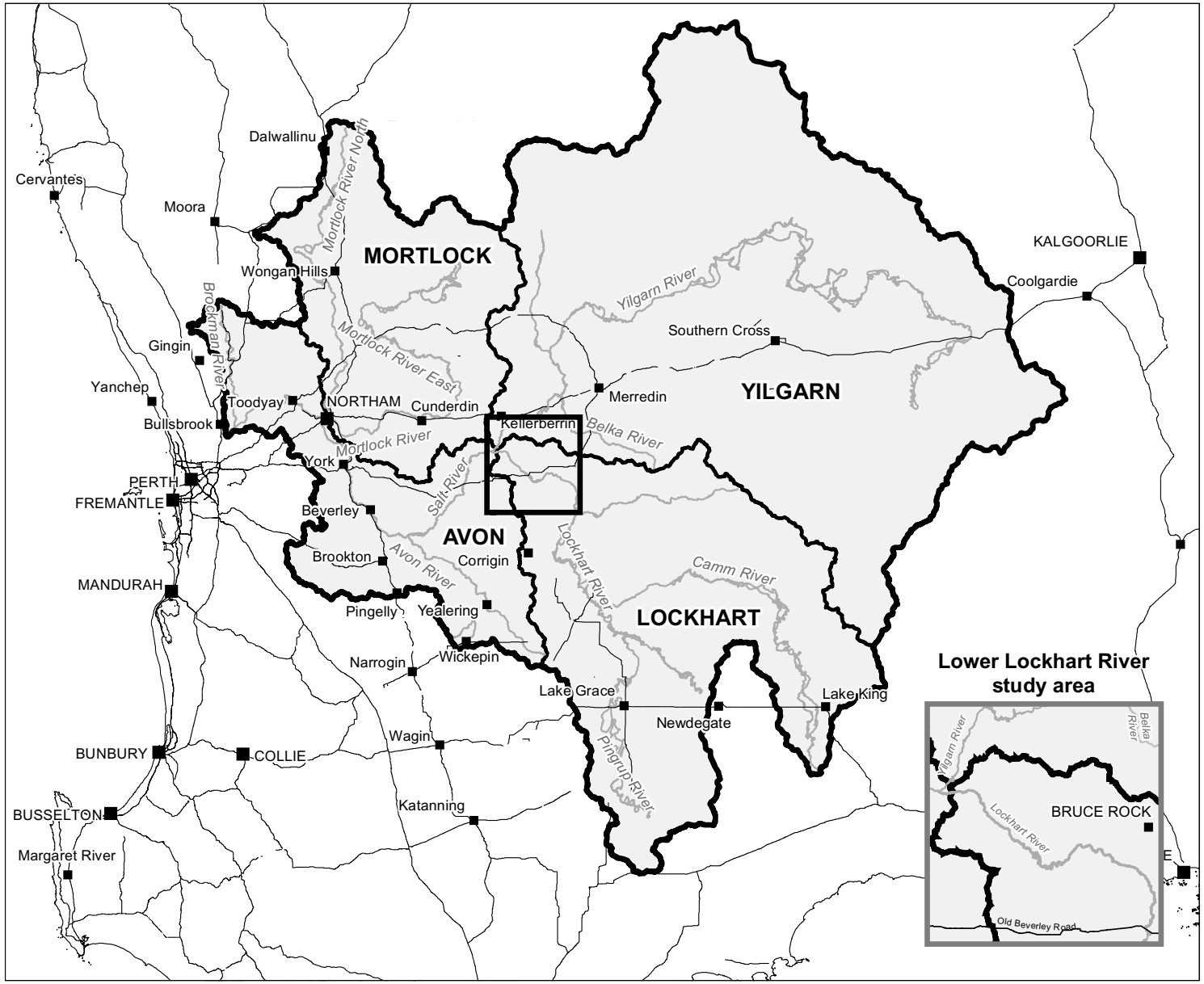
Towns – Landgate – 2004
Roads, 1M – Geoscience Australia – 2002
WA coastline – Geoscience Australia – 2001
Hydrographic catchments – DoW – 2005

Department of Water
Government of Western Australia

This map is a product of the Department of Water Spatial Analysis section and was completed in April 2008.

This map was produced with the intent that it be used for Avon River Recovery Plans at the scale of 1:3 000 000.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.



Lower Lockhart River study area

Map 2
Lower Lockhart River study area

N

0 2 4 6 8
Kilometres

LEGEND

Road network
- Main road
- Local road
- Track

River network
- Major waterway
- Lake

Boundaries
- Lockhart River catchment
- LGA boundary
- Nature reserve

Other
- Town
- Gauging station

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requested by: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_Series\B4148\0002_LowerLockhart\mxd\Map02_Lower_Lockhart_Study_Area_A3.mxd
Date: July 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:

Towns - Landgate - 2007
Road centrelines - Landgate - 2007
Hydrography, linear (Hierarchy) - DoW - 2007
Local govt authorities - Landgate - 2004

Department of Water
Government of Western Australia

This map is a product of the Department of Water (Measurement and Water Information Branch), and was completed in July 2008.

This map was produced with the intent that it be used for the Lower Lockhart River mapping project at the scale of 1:210 000.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

2 Overview of the lower Lockhart River

The Lockhart River catchment is one of four major subcatchments of the extensive Avon River basin.

The subcatchments are:

- the Lockhart River catchment, which drains an area of approximately 28 400 km^2 (24 per cent of the Avon River basin). It originates near Newdegate and flows north-west through Kondinin, Corrigin and Bruce Rock to the Caroline Gap. The catchment also includes the Pingrup River, which originates at Chinocup Lake south of Lake Grace, and the Camm River, which originates at Lake King.
- the Yilgarn River catchment, which drains an area of approximately 55 900 km^2. It originates north-east of Southern Cross from Lake Seabrook and Lake Deborah and flows to the south-west past Merredin to its confluence with the Lockhart River at the Caroline Gap, south of Kellerberrin.
- the Mortlock River system, which drains an area of approximately 16 770 km^2. The Mortlock River system consists of the Mortlock River, Mortlock River North, Mortlock River East and Mortlock River South and joins the Avon River at Northam.
- the Avon River catchment, which drains an area of approximately 15 500 km^2, and includes the Salt River, Avon River South Branch, Dale River, Mackie River, Toodyay Brook, Brockman River and Wooroloo Brook catchments.

The Yilgarn and Lockhart rivers converge at the Caroline Gap (between Mt Caroline and Mt Stirling) to form the Salt River which flows to the Yenyening Lakes. Discharge flow from the lake system joins streamflow from the Upper Avon catchment. The Mortlock River catchment discharges to the Avon River at Northam.

The Yilgarn, Lockhart and part of the Mortlock River system drain the broad valleys of the zone of ancient drainage in the east while the Upper Avon drains into the rejuvenated Avon River in the west of the Avon River basin.

2.1 Location, land use and tenure

The lower Lockhart study area includes the salt lakes, channels and floodplain of the Lockhart River from the Caroline Gap at Glenluce Rd, approximately 86 km upstream to the Old Beverley Rd, west of Narembeen. Map 1 shows the location of the study area within the Avon River basin and Map 2 shows the extent and features of the study area.

Almost the entire lower Lockhart study area is within the Shire of Bruce Rock. A small area near the confluence with the Yilgarn River is in the Shire of Kellerberrin.

Eleven survey sites have been identified by the Department of Water as being representative of the lower Lockhart River floodplain (refer to maps 3 to 13). The area for each site ranges from 96 ha to 760 ha. Site codes, names, approximate size and coordinates (eastings and northings based on the GDA 94 datum) are provided in Appendix 1.

Land use and tenure for each of the sites is shown in the table below.

Table 1 Land use and tenure for the survey sites

Tenure	Sites	Land use
Private landholding	LLR01, LLR04, LLR08, LLR09, LLR10	Livestock grazing and partial cropping incorporated within whole farming system.
Nature reserve (DEC)	LLR03, LLR06, LLR07, LLR11	Managed by DEC for conservation values.
Crown reserve	LLR05	Managed by the Shire of Bruce Rock for public recreation.
Unallocated Crown land	LLR02	

2.2 Aboriginal values and influence

The landscapes of the lower Lockhart River have been home to the Nyaki Nyaki Nyungar people for thousands of years. *Budjar* is the Nyungar word for country and encompasses everything associated with the land, including attachment, cultural, physical and spiritual aspects. Traditionally, Nyungar people knew their *Budjar* intimately. *Budjar* not only provided them with their needs and wants but connected them spiritually to their inheritance and obligations to the land.

In traditional times Nyungar people lived in complete harmony with the land, waterways and sky. The six seasons, described by the prevailing weather conditions, indicated the best times to hunt particular animals and gather certain plants and medicines.

Waterways were, and still are, sacred places. They are important for spiritual reasons and because they provided water and foods – water birds, eggs, fish, plants and medicines. The adjacent woodlands also provided food and medicines.

There are three significant Aboriginal sites identified along the lower Lockhart River (Department of Indigenous Affairs 2008).

These are listed in Table 2.

Table 2 Significant Aboriginal sites along the lower Lockhart River

Kwolyin/Kapbunglin	Yarding Siding	Kokerbin Rock
Site ID: 5068	Site ID: 5722	Site ID: 5706
Permanent register	Permanent register	Permanent register
Open access	Open access	Open access
Ceremonial site	No site type information	Ceremonial site/artefacts
No gender restriction	No gender restriction	No gender restriction

2.3 European values and influence

European settlement has influenced the Shire of Bruce Rock since the early 1900s when land was cleared for rural settlement and agriculture. Development of the railway system through the Wheatbelt by 1912 provided benefit to the rural communities within the Bruce Rock Shire (Ewers 1959). This enabled rapid expansion of agriculture within the district.

Current farming systems are crop dominant based on rotations with leguminous pastures. Salinity is the most significant threat to productive agricultural area (Leoni and Murphy-White 2006).

The rural towns of Bruce Rock and Shackleton are significant within the study area. Other towns were proposed for Ardath and Kwolyin.

Lakes within the lower Lockhart River system provide recreational areas for local communities, including water skiing. The Shackleton Lakes are within a public reserve vested with the Shire of Bruce Rock for recreational purposes.

2.4 Climatic information

The Bureau of Meteorology does not record climatic information for Bruce Rock, but there are long-term records for the towns of Kellerberrin and Narembeen. Bruce Rock is midway between these two towns.

A summary of climatic information for Kellerberrin and Narembeen is provided in Appendix 2. The average annual rainfall is approximately 300 mm. The highest record for Kellerberrin is 661 mm (in 1963) and the lowest is 167 mm (in 1994). For Narembeen, the highest is 589 mm (in 1974) and the lowest is 174 mm (in 1972). Both locations have an approximate average of 50 days annually with more than 1 mm rainfall and approximately 8 days with more than 10 mm rainfall (Bureau of Meteorology, 2008).

High rainfall variability and the occasional occurrence of drought are characteristics of the lower Lockhart River environment. Climate change is predicted to lower winter rainfall and increase the incidence of summer storm events. This would increase rainfall variability and probably increase the frequency of winter drought.

2.5 Geomorphology and soils

The lower Lockhart River occurs within the geomorphic area described as the zone of ancient drainage (Lantzke 1992). Landscapes within this area are characterised by broad valley floors which contain salt lakes (playas) and braided, discontinuous stream channels bordered by lunettes (wind-blown sediment deposits), and flat to undulating saline plains (Commander et al. 2001).

The landscape units shown in Figure 1 provide a basis for describing the landscapes of the lower Lockhart River (Lantzke 1992). The *Merredin* unit contains the broad floodplain alluvial soils. The *Baandee* unit contains salt lakes, the river channel and associated local landforms. The *Nangeenan* unit is often referred as 'morrel country' with powdery calcareous soils. The *Belka* unit has the lenses of deep sands that occur in the valley floor.

On the adjacent lower slopes, the *Collgar* unit contains duplex texture profile soils with the hard-setting sandy loams of the *Booraan* unit further upslope. The *Ulva* unit has deep sandy soils of the undulating sandplain that occur above lateritic pavement with occasional exposure of cliff-faced pavement 'breakaways'.

The *Steep Rocky Hills* unit occurs as granite outcrops (for instance, in Kokerbin Nature Reserve). The associated *Danberrin* unit has relatively shallow soils with frequent rock outcropping. The landscapes of Mt Caroline and Mt Stirling are sequences of these two units.

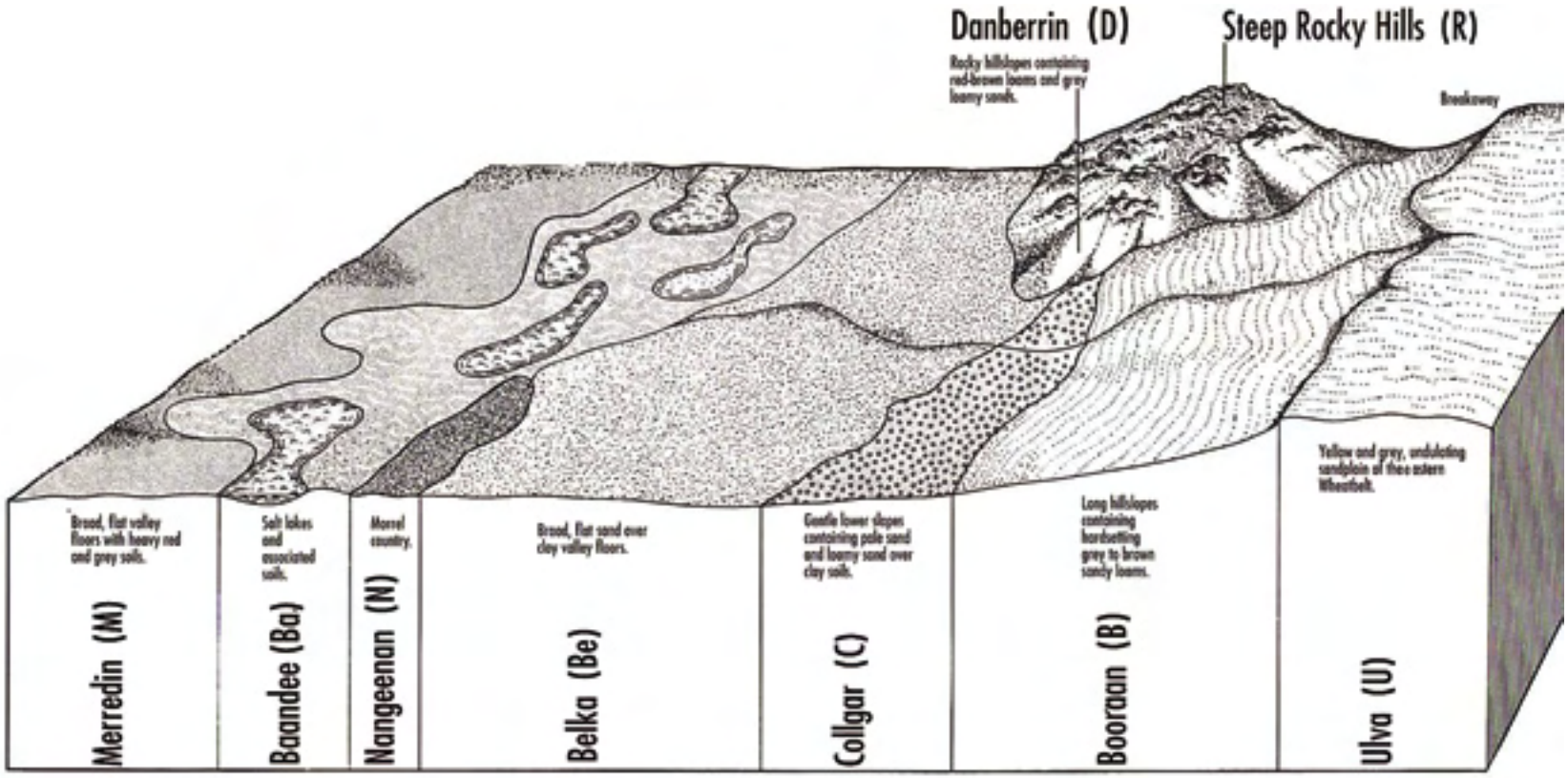
Landform in the zone of ancient drainage is the result of an extensive period of weathering, erosion and depositional processes. It is now relatively stable.

Within the study area the lower Lockhart River flows north from the Old Beverley Road then re-orientates west-north-west with one major southerly meander. The river tends to the west just before its confluence with the Yilgarn River.

The gradient of the lower Lockhart River is relatively gentle. Figure 2 shows the downstream elevation to be 228 m AHD increasing to an elevation of 251 m AHD over a distance of 86 km. The average channel gradient is 0.027 per cent. The spot height elevations for the study area measured at approximately 2 km intervals are provided in Appendix 3.

The lower Lockhart River channel and floodplain is generally described as being of the *Merredin* landscape unit, which contains the broad floodplain alluvial soils, and the *Baandee* landscape unit which contains salt lakes, the river channel and associated local landforms.

The lower Lockhart River is a broad, subdued drainage system that is characteristic of the zone of ancient drainage. The streamflow channel of the lower Lockhart River is poorly defined, discontinuous and frequently alters form. The main stream channel meanders through complex systems of salt lakes and drainage indentations.



SOIL LANDSCAPE UNIT	Merredin	Baandee	Nangeenan	Belka	Collgar	Danberrin	Steep Rocky Hills	Booraan	Ulva
MAJOR SOIL TYPES	Red-brown sandy loam over clay valley soil. Red clay valley soil. Grey clay valley soil Grey to brown cracking clay.	Salt lake and channels. Soils fringing the salt lakes.	Powdery surfaced calcereous soil.	Deep sandy surfaced valley soil. Shallow sandy surfaced valley soil.	Loamy sand over clay	Rocky red-brown loamy sand/sandy loam. Brownish grey granitic loamy sand. Red-brown doleritic clay loam.	Steep rocky hill soils.	Sandy loam over clay. Shallow hardsetting grey sandy loam over clay. Loamy sand over clay.	Yellow gradational loamy sand. Deep yellow sand. Pale sand over gravel/loamy sand. Deep pale sand. Shallow mottled zone. Deep yellow acid sand.
VEGETATION	Salmon gum Gimlet	Barley grass Bluebush Saltbush Samphire Bare ground	Morrel	Salmon gum York gum White gum Gimlet	Mallee species	York gum Jam Sheoak White gum Salmon gum	Jam York gum Sheoak White gum	Salmon gum White gum Mallee Gimlet	Banksia Sandplain pear Tammar Sandplain mallee Woodjil Flame grevillea Christmas tea

Figure 1 *Soil landscape units of the zone of ancient drainage Source: adapted from Lantzke, 1992*

The floodplain of the lower Lockhart River is not clearly defined by either river terracing or a change in the slope of adjacent landscapes. It is likely that floodwaters are largely contained within the drainage features and natural retention capacity of the valley floor.

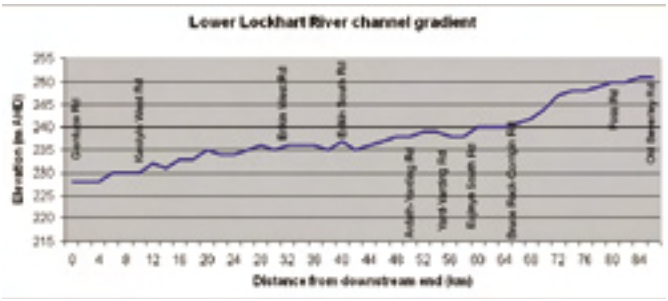


Figure 2 *Channel profile of the lower Lockhart River*

2.6 Broad valley-floor tributaries

Tributaries of the lower Lockhart River occur as broad valley floors with intermittent streamflow. Fifteen tributaries are identified within the study area. Map 2 shows the location of these. Nine occur north of the river and six are to the south. Three of the tributaries have local names, the others are identified by code.

Table 3 gives information about the length, the fall and the average gradient of the tributaries. The 'headwater position' is estimated as the start of the third order channel. The tributary length varies from approximately 3 km (Tributary C) to over 20 km (Youablin Creek). Most tributaries have a channel gradient of less than 0.5 per cent. Two tributaries (Dadenning Creek and Tributary I) are relatively short and steep.

Table 3 Lengths and gradients of tributaries of the lower Lockhart River

Tributary	**Confluence elevation** (m AHD)	**Headwater elevation** (m AHD)	**Distance** (km)	**Gradient**
Tributary A	232	245	3.6	0.39
Dadenning Creek	233	278	7.0	0.64
Tributary B	232	264	10.5	0.31
Tributary C	235	267	11.0	0.29
Tributary D	235	261	7.0	0.38
Tributary E	236	285	22.0	0.22
Lockwood Gully	239	278	16.8	0.24
Tributary F	236	297	18.2	0.33
Tributary G	240	255	3.0	0.48
Tributary H	243	275	6.8	0.46

Tributary I	240	272	3.4	0.91
Tributary J	241	283	15.8	0.26
Tributary K	244	286	9.6	0.43
Youablin Creek	248	311	20.7	0.30
Tributary L	249	310	13.2	0.45

2.7 Hydrology

2.7.1 Streamflow

Streamflow in the Lockhart River is measured at a permanent Department of Water gauging station located on Kwolyn East Road, immediately upstream of Site LLR02 (Kwolyn Hill gauging station, reference code 615012). Reliable information is available for the period from 1975 to the time of the survey. The location of the station is shown on Map 2.

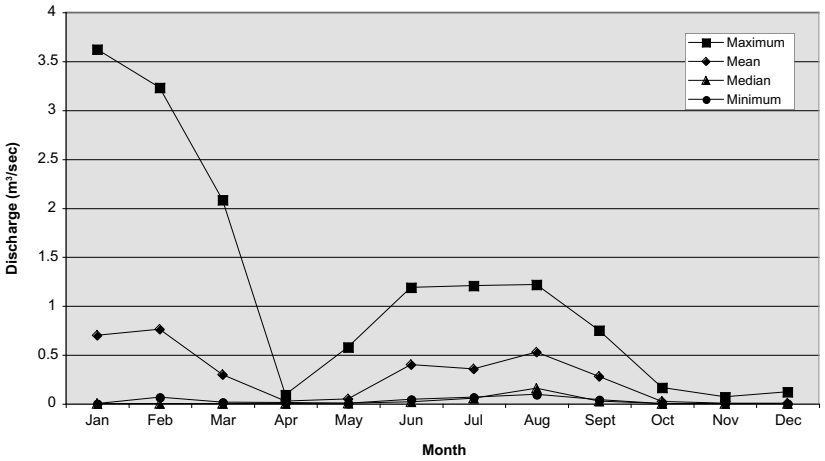
Photo 1 *Kwolyin gauging station*

The average annual total flow for the Lockhart River is 13 GL[1]. This compares with 4 GL for the Yilgarn River, 137 GL for the Avon River at Northam and 353 GL for the Avon River at Walyunga, where the Swan River commences on the lower slopes of the Darling Scarp (Department of Environment 2005).

The annual flow of the Lockhart River varies considerably, from the lowest measured flow of 0.27 GL in 2002 through to the maximum measured flow of 87 GL, in 2000).

[1]GL 1 gigalitre = 1x103 megalitres (ML) = 1x106 kilolitres (kL) = 1x109 litres (L)

The average maximum, minimum, mean and median monthly streamflow as measured at Kwolyn Hill gauging station are shown in Figure 3.



Source: Department of Water streamflow records

Note: 1.0 m3/s = 1000 L/s

Figure 3 *Average monthly stream discharge for the Lockhart River at the Kwolyn Hill gauging station between 1975 and 2007*

2.7.2 Floods

Major floods have occurred during summer and autumn due to cyclonic influence on weather patterns. High streamflows (>10 m^3/s) were recorded in March 1978, June 1989, January and February 1990, January and February 2000 and February 2003. These events have contributed to the high mean discharge for January, February and March shown in Figure 3.

A significant cyclonic rainfall event occurred over 21–22 January 2000, with rainfall in excess of 100 mm over a large area from east of Hyden to Beverley. This event was estimated to have an average recurrence interval of 1 in 8 years (using all records since 1970), and an average recurrence interval of 1 in 20 years for summer events (Water and Rivers Commission 2000).

2.7.3 Water quality

Streamflow salinity in the Lockhart River is very high. For the period 1993–2000, the average salinity was 33 900 mg/L (seawater is approximately 35 000 mg/L). This compares with 22 500 mg/L for the Yilgarn River, 6700 mg/L for the Avon River at Northam and 4900 mg/L for the Avon River at Walyunga for the same period (Department of Environment 2005). This salinity is some 60 per cent greater than for the period 1983–92 when it averaged 21 200 mg/L. However there is considerable variation within each period.

The average annual salt load from the Lockhart River for the 1993–2000 period was 99 000 t. Annual average salt load is closely related to streamflow. In the flood year of 2000, a total of 300 000 t of salt was discharged in 87 GL of flow. This compares with

2 t in 0.27 GL of flow for 2002.

The Lockhart River is the most saline continuously monitored waterway in Western Australia (Department of Environment 2005). It is probably the most saline river in all of Australia and possibly the world.

Monitoring at Kwolyn Hill gauging station shows total nitrogen to range from 0.2 mg/L to 4.4 mg/L and total phosphorus from 0.01 to 0.8 mg/L based on occasional spot sampling between June 1997 and September 2007.

The river's pH ranged from 3.2 (acidic) to 8.7 (slightly alkaline) but is most commonly slightly acidic.

Detailed water quality information is provided in Appendix 4.

2.8 Vegetation

The *Australian terrestrial biodiversity assessment* (Sattler and Creighton 2002) provides a national review of terrestrial biodiversity based on the interim biogeographic regionalisation of Australia (IBRA) framework (Environment Australia 2000). The subregions are grouped within bioregions on the basis of common landforms, vegetation, geology and soils. The lower Lockhart River occurs within the Avon Wheatbelt 1 (AW1 – Ancient Drainage) IBRA sub-region.

The distribution of natural vegetation has been mapped from what remains in reserves, on private land and beside roads (Beard 1980). The lower Lockhart River study area occurs within the Mount Caroline vegetation system of the Avon botanical district (Beard 1980). Vegetation communities are closely associated with valley floor landscape units as shown in the table below.

Table 4 Vegetation communities and valley floor landscape units

Landscape unit	Dominant vegetation
Merredin	Melaleuca thickets grading into woodlands of York gum (*Eucalyptus loxophleba*), salmon gum (*Eucalyptus salmonophloia*), gimlet (*Eucalyptus salubris*) and morrel (*Eucalyptus longicornis*) over melaleuca species and succulents.
Baandee	Salt lakes generally devoid of vegetation and fringed by salt-tolerant species such as samphire (*Halosarcia species*), saltbush (*Atriplex* species) and bluebush (*Maireana* species).
Nangeenan	Salmon gum (*Eucalyptus. salmonophloia*) and gimlet (*Eucalyptus salubris*) with some *Eucalyptus gracilis* and Wandoo (*Eucalyptus wandoo*)

Figure 4 shows a typical topographical sequence with commonly occurring natural vegetation associations.

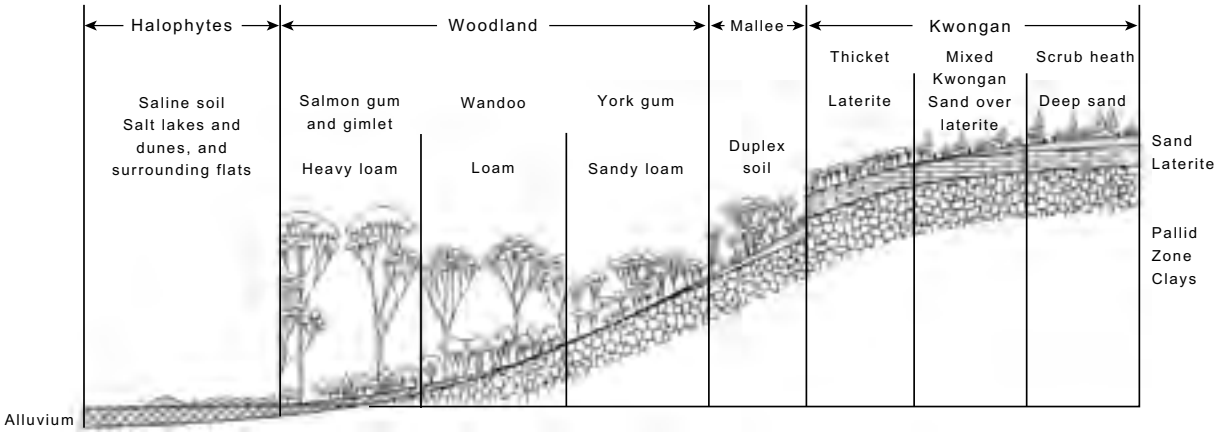


Figure 4 *Natural vegetation associations with soils and landform in the Avon River basin (adapted from Beard, 1990)*

Hopkins et al. (2001) have described vegetation associations based on the previous mapping of Beard (1980). The conservation status for those that occur in the lower Lockhart survey sites are shown in Table 5.

Table 5 Vegetation associations for the lower Lockhart survey sites

Vegetation association	Description	Pre-European extent ha*	Current extent ha*	Percentage remaining*	Percentage protected in reserves*	Conservation status**
8	Medium woodland, salmon gum and gimlet	1 238 672	675 472	54.5	37.8	Least concern
125	Bare areas, salt lakes	3 940 746	3 536 922	89.8	7.0	Least concern
141	Medium woodland, York gum, salmon gum and gimlet	676 791	250 256	37.0	5.8	Depleted
356	Succulent steppe with open woodland, eucalypt over saltbush	5 080	2 362	46.5	2.9	Depleted
631	Succulent steppe with woodland and thicket, York gum over *Melaleuca thyoides* and samphire	125 212	46 336	37.0	10.4	Depleted

Vegetation association	Description	Pre-European extent ha*	Current extent ha*	Percentage remaining*	Percentage protected in reserves*	Conservation status**
694	Shrublands, scrub-heath on yellow sandplain banksia-xylomelum association in the Geraldton Sandplain and Avon Wheatbelt Region	403 915	68 872	17.1	52.8	Vulnerable
951	Succulent steppe with sparse woodland and thicket, York gum and Kondinin blackbutt over tea-tree thicket and samphire	32 427	10 020	30.9	21.6	Depleted
955	Mosaic: shrublands; Scrublands, scrub-heath (SE Avon)/ shrublands: *Allocasuarina campestris* thicket	155 719	11 316	7.3	9.6	Endangered
1049	Medium woodland, wandoo, York gum, salmon gum, morrel and gimlet	759 623	23 779	3.1	12.0	Endangered
1053	Shrublands, *Melaleuca uncinata* thicket with scattered York gum	16 300	2 587	15.9	28.9	Vulnerable

**Source: Shepherd et al. 2002*

***Source: Department of Natural Resources and Environment 2002*

Endangered — less than 10 per cent of pre-European extent remains

Vulnerable — between 10 per cent and 30 per cent of pre-European extent remains

Depleted — between 30 per cent and 50 per cent of pre-European extent remains

Least concern — more than 50 per cent of pre-European extent remains

Native vegetation has been extensively cleared for agriculture in the Shire of Bruce Rock. In 1995, there was 7.8 per cent vegetation cover remaining, 4.2 per cent on private land and 3.6 per cent in public reserves (Weaving 1995).

The potential for salinity to affect biodiversity values in the Wheatbelt of Western Australia was assessed by systematic biological surveys (Keighery et al. 2004). Four survey sites for this assessment have locations from the biological survey either within the sites or on adjacent land, as shown in the table below.

Table 6 Biological survey sites that occur within lower Lockhart River survey sites

Lower Lockhart River survey site	Biological survey location code
LLR04	KL01 (located off-site)
LLR05	SPS088
LLR06	SPS084, KL03, KL28, KL29
LLR11	SPM009, SPS085 (both located off-site)

2.9 Management of natural resources

The Avon Catchment Council (ACC) is the peak natural resource management body in the Avon River basin. The *Avon River basin natural resource management strategy* (Avon Catchment Council 2005a) and *Avon investment plan* (Avon Catchment Council 2005b) provide directions and priorities for investment to improve the condition of water, land, vegetation and other landscape assets.

The Ballardong NRM Working Group has completed *Ballardong Noongar Budjar: Healthy country – healthy people* (2006) which provides a perspective on 'Caring for Country' and involving the Ballardong people in natural resource management in the Avon River basin. The document outlines how the Aboriginal community of the Avon region will work in partnership with the Avon Catchment Council to improve the condition of the natural environment.

The Avon Natural Diversity Alliance is an alliance between the Department of Water, Department of Environment and Conservation, Greening Australia Western Australia and WWF–Australia to deliver some of the diversity projects identified in the *Avon investment plan*. The Avon Rivercare Project focuses on management of waterways and lakes within the region.

This waterway assessment for the lower Lockhart River is one of a series for the zone of ancient drainage in the Avon River basin. Other assessments have been completed for reaches of the Salt River (Department of Water 2008a) and Yilgarn River (Department of Water 2008b).

3 Description of methods

The waterway assessment method has been developed to assess the condition of waterways in the zone of ancient drainage in the Avon River basin (Department of Water 2007). This method differs from that used for the zone of rejuvenated drainage (the more dissected landscape of the main Avon River channel and its immediate tributaries). The geomorphology of landscapes within the zone of ancient drainage is characterised by broad valley floors with a generally poorly defined floodplain and stream channels that are braided, discontinuous and punctuated with chains of salt lakes.

The survey method used for this assessment is based on studying representative sites, rather than surveying the entire length of the river. It is designed to be a rapid process that enables larger areas to be surveyed efficiently. The focus of assessment is on the condition of riparian vegetation.

3.1 Defining the study area

The study area for the lower Lockhart River includes the channel, salt lakes and floodplain of the river for a distance of 86 km upstream from the confluence with the Yilgarn River at the Caroline Gap, a narrowing geomorphic saddle between Mt Caroline and Mt Stirling located respectively in the Shires of Kellerberrin and Quairading (see Map 2).

The upstream limit to the study area is defined by the Old Beverley Road, which is also the southern boundary of the Wandjagill Nature Reserve. The Lockhart River continues upstream to Newdegate with several major tributaries, including Wakeman Creek and the Camm and Pingrup rivers. Separate waterway assessments will be required for each of these.

3.2 Site selection

Eleven sites were selected as being representative of the condition of the lower Lockhart River. The selected sites met the following criteria:

- represented the full range of geomorphologic features within the study area, for example salt lakes, areas of braided channels and areas with more defined channels
- had high environmental, social or cultural values, such as nature reserves and lakes used for water skiing
- contained vegetation communities in good or degraded condition.

Sites were selected using aerial photography.

Detailed information for each survey site is provided in Appendix 5. The survey sites are shown in maps 3 to 13.

3.3 Survey methods

To ensure consistency, information collected during the site surveys was recorded on a survey form, which is included in Appendix 6.

The survey information obtained for each site consisted of:

- floodplain features
- riparian vegetation
  - vegetation association
  - structure and cover
  - native species occurrence (richness)
  - weeds species occurrence
  - vegetation cover
  - disturbance factors
  - linkage to protected remnant vegetation
- aquatic vegetation
  - dominant type
  - disturbance factors
- native fauna
- water quality
- threatening processes
- site management needs.

3.3.1 Assessing riparian vegetation

The description of riparian vegetation is modified from a survey method developed by Keighery in 1994.

In this method, vegetation associations (Hopkins et al. 2001; Beard 1980) are recorded for each site based on survey information and landholder or other observations. This provides an indication of the original vegetation that occurred. Vegetation associations have been mapped at a scale relevant to regional planning and management for Western Australia.

An estimate of cover within a set of cover classes is made for each vegetation strata at the survey site. The dominant species for each stratum are recorded.

The percentage of the survey site that falls within vegetation condition categories is recorded based on vegetation structure, the impact of disturbance and the capacity for regeneration. The vegetation condition rating categories are shown in Table 7.

Table 7 Vegetation condition categories

Condition	Description
Revegetation	–
Pristine	No obvious signs of disturbance
Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species
Very good	Vegetation structure altered, obvious signs of disturbance
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances, retains basic vegetation structure or ability to regenerate
Degraded	Basic vegetation structure severely impacted by disturbance, regeneration to good condition requires intensive management
Completely degraded	Vegetation structure no longer intact and the area is without/almost without native species

Source: adapted from Keighery, 1994

3.3.2 Field survey methods

Survey sites were accessed by vehicle. Aerial photos were used to plan a walking survey as an informal transect to assess variation in geomorphology and vegetation condition at the site. At some of the larger sites, there was more than one transect.

The field surveys were undertaken between 27 August and 29 August 2007.

The field survey was planned using 1:20 000 scale colour aerial photographs, property boundaries and roads.

The location of walking transects and of significant observations was recorded using a global positioning system (Magellan GPS 315).

A standardised survey form was used to record information survey information (Appendix 6).

Stream salinity was measured at each survey site where there was surface water available using a Hanna HI 8733 conductivity meter. All samples were taken from static water. Survey site LLR08 had no surface water available for sampling.

Plants and weeds were identified in the field and confirmed with relevant reference documents.

Disturbance factors were recorded according to their threat level (high, medium or low). Details of significant threatening processes at each site were noted.

Birds and other animals were identified by sightings and calls.

Photo-points were established for each site with public road access. The baseline information and photos for these sites is contained in Appendix 7. Sites LLR01 and LLR10 did not have public road access so photo points were not established.

3.4 Contact with landowners and managers

Letters were sent by the Department of Water to all landholders and managers with properties within the study area. This was to let them know the purpose of the survey and, where relevant, to request their permission for entry to their properties during the survey.

Landholders were contacted by phone one to two days prior to the survey.

Landholders were interviewed to find out any anecdotal or recorded information about the survey site that might be useful.

4 Survey results for each site

This section provides a detailed record of the results of the survey. The following information is given for each site:

- the coordinates of the centre of the site
- a description of the main characteristics of the site, including:
  - its area
  - the form of the waterway
  - the dominant types of vegetation
- the condition of the vegetation
- management considerations.

Section 5 summarises the survey results for the whole length of the river.

4.1 Site descriptions

4.1.1 LLR01 — Coles

Central site coordinates

E 565959, N 6480540

Site description

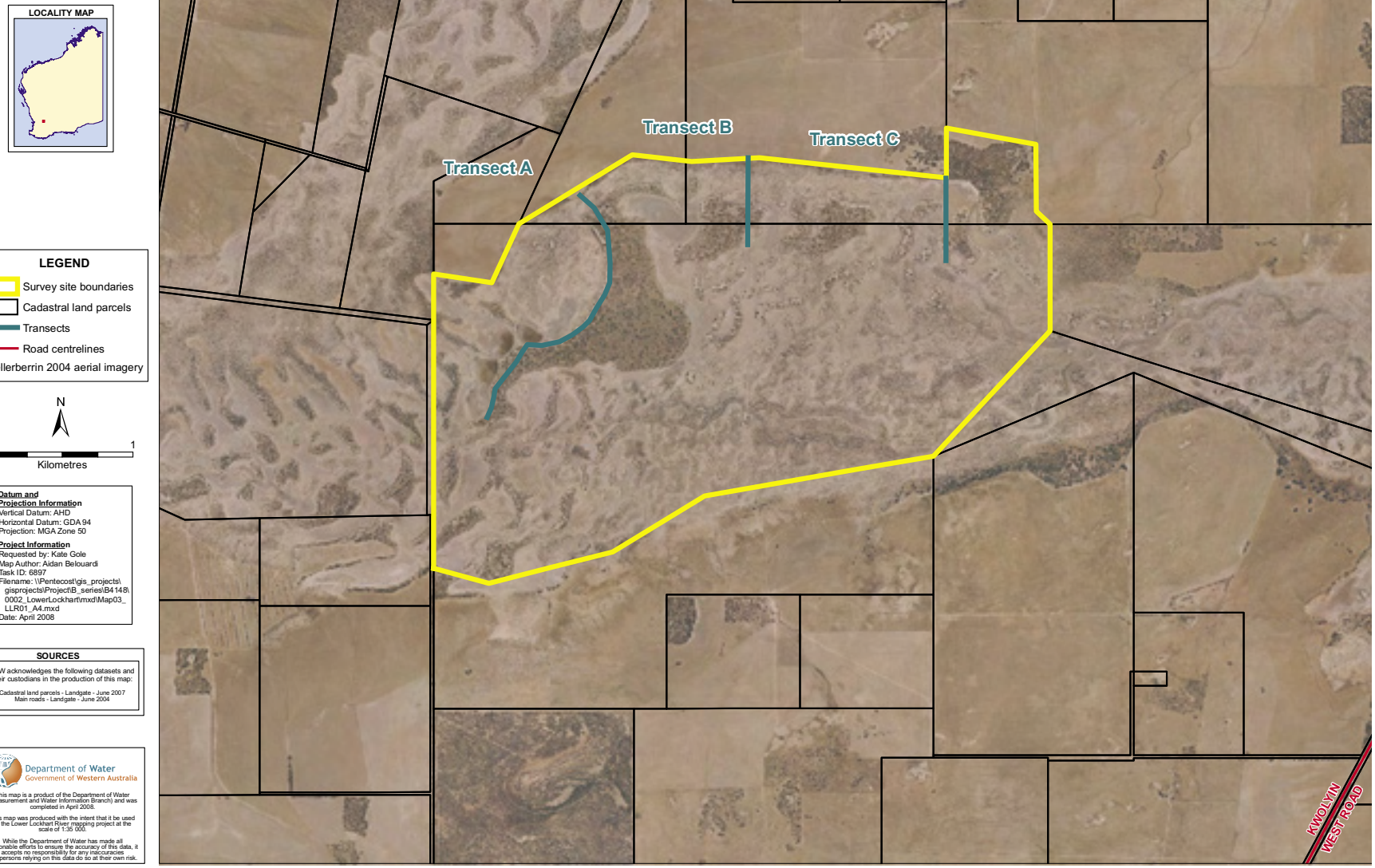
This survey site is relatively large (approximately 822 ha) and is privately-owned. It is located immediately upstream from the confluence of the Lockhart River with the Yilgarn River (confluence position reference: E 564539, N 6480133). The site is fenced and contains natural riparian vegetation communities (Map 3).

The riparian zone is a broad valley floor with braided drainage. A high proportion of the site is bare scalded lakebed with occasional intermittent streamflow. There is a main channel meandering east to west across the southern portion of the site. The bare areas are considered to have high groundwater discharge.

The dominant vegetation communities of the sandy rises are eucalypt woodland (*Eucalyptus loxophleba*) and melaleuca thickets with a predominantly halophyte shrub and ground cover. There is only limited understorey vegetation.

There are two declared rare flora species identified at this site. These require protection under the *Wildlife Conservation Act (1950)*. The two species are *Roycea pycnophylloides* and *Frankenia parvula*.

Map 3
Survey site
LLR01 Cole's



LOCALITY MAP

LEGEND

- Survey site boundaries
- Cadastral land parcels
- Transects
- Road centrelines

Kellerberrin 2004 aerial imagery

N

0 1

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requested by: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_series\B414\0002_LowerLockhart\mxd\Map03_LLR01_A4.mxd
Date: April 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:

Cadastral land parcels - Landgate - June 2007
Main roads - Landgate - June 2004

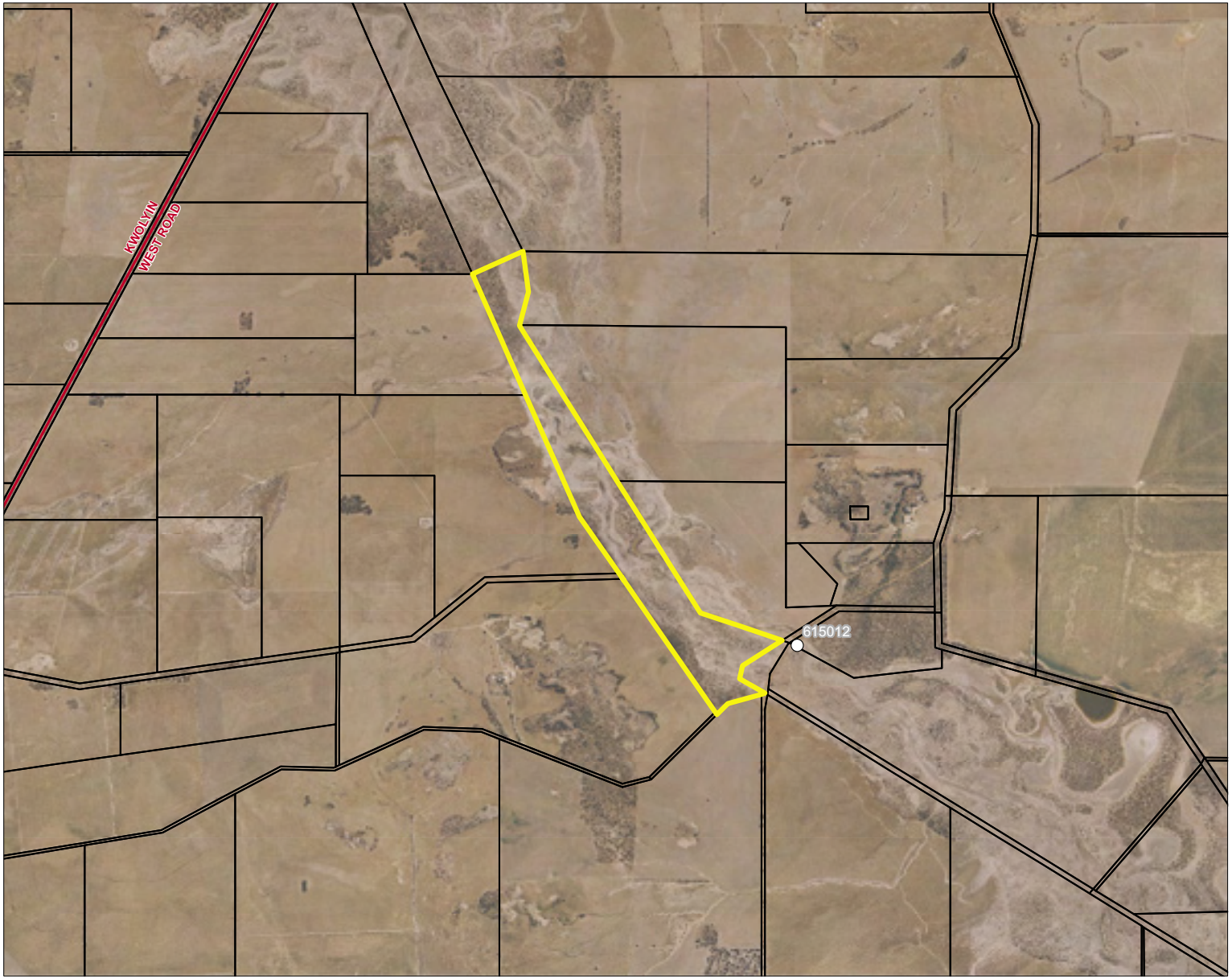
Department of Water
Government of Western Australia

This map is a product of the Department of Water (Measurement and Water Information Branch) and was completed in April 2008.

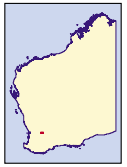
This map was produced with the intent that it be used for the Lower Lockhart River mapping project at the scale of 1:35 000.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Map 4 Survey site LLR02 Unallocated Crown land



LOCALITY MAP



LEGEND

- Survey site boundaries
- Cadastral land parcels
- Stream gauging site

Kellerberrin 2004 aerial imagery

N

0 1

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requested by: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_series\B4148\0002_LowerLockhart\mxd\Map04_LLR02_A4.mxd
Date: April 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:

Cadastral land parcels - Landgate - June 2007
Main roads - Landgate - June 2004
Kellerberrin aerial image - Landgate - 2004

Department of Water
Government of Western Australia

This map is a product of the Department of Water (Measurement and Water Information Branch) and was completed in April 2008.

This map was produced with the intent that it be used for the Lower Lockhart River mapping project at the scale of 1:35 000.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Photo 2 *Lunette vegetation adjacent to the Yilgarn River west of the site (Transect A)*

Photo 3 *York gum (*Eucalyptus loxophleba*) woodland with halophyte scrub understorey (Transect A)*

Photo 4 *Patchy melaleuca thicket on sandy interfluvial sandy rises (Transect B)*

Photo 5 *Increasing salt affected areas on the margin of a scald (Transect C)*

There is private remnant vegetation immediately north of the site which is in effect a part of the same drainage system. Significantly, the Glenluce Nature Reserve is adjacent to the site and the Nangeen Hill, Mt Caroline and Mt Stirling nature reserves are within 8 km to the south and west.

Condition assessment

Due to the larger area of this site, assessment was undertaken at three north-south transects: Transect A – the western end, Transect B – central, and Transect C – eastern end (Map 3).

The vegetation condition assessment for this site is shown in the table below.

Table 8 LLR01 — Coles vegetation condition assessment

Vegetation condition	Percentage of site
Pristine	0
Excellent	0
Very good	30
Good	40
Degraded	30
Completely degraded	0

Remnant vegetation at this site remains in relatively good condition although the effect of salinity is slowly increasing on melaleuca thickets on the margins of broad lakes and on adjacent agricultural land.

Other than for salinity, the threat level at this site remains relatively low.

Management considerations

The condition of fencing on the northern side is in places poor and requires replacement. The current farm practice is to graze the site approximately one year in seven.

The identified threatened plant species require site specific management.

4.1.2 LLR02 — Unallocated Crown land

Central site coordinates

E 572132, N 6475505

Site description

This site consists of some 96 ha of unallocated Crown land extending approximately

1.6 km upstream from East Kwolyin Road (Map 4). The Kwolyn Hill gauging station (reference code 615012) is immediately upstream of this site. This gauging station provides the only long-term streamflow and water quality information for the Lockhart River.

The site is dominated by the broad meandering channel of the valley floor. Groundwater discharge is substantial at this site. The river channel and floodplain are narrow (approximately 0.5 km wide) compared with the generally broad valley floor of the lower Lockhart River. This is the narrowest section of river within the survey site. It is a site that is constricted by extensive bedrock outcroppings north and south of the upstream end of the study area. Most surface flow is contained within defined stream channels and the capacity available for retaining floodwaters is limited.

Riparian vegetation is sparse with halophyte shrubland being dominant. There is fragmented woodland development on sandy interfluves. There is one area adjacent to Stones Road, south in the site, that is elevated from the valley floor. This contains York gum (*Eucalyptus loxophleba*) and red morrel (*Eucalyptus longicornis*) woodland remnants.

There are some areas of remnant vegetation on granite outcrops on private land near the site. Kwolyin Nature Reserve is immediately upstream of this site. Other significant nature reserves are 5 to 8 km distant.

Power line infrastructure traverses the site. Kwolyin East Road forms the eastern site boundary. This road has box culverts of substantial capacity.

Condition assessment

The vegetation condition assessment for this site is shown in Table 9.

Table 9 LLR02 — Unallocated Crown land vegetation condition assessment

Vegetation condition	Percentage of site
Pristine	0
Excellent	0
Very good	10
Good	80
Degraded	10
Completely degraded	0

Vegetation at the site is generally in good condition. While there is significant groundwater seepage in the valley floor, this is considered to be primarily from adjacent extensive sand lenses so it is relatively fresh. Due to the bedrock constriction, it is unlikely that there is significant deeper groundwater discharge so the potential threat from increasing salinity at this site is relatively low.

A constructed road within the river bed is used for coarse rubbish disposal. The type

Photo 6 *Recent boundary fencing north of the site*

of rubbish is considered to be innocuous although unsightly.

Management considerations

The site is well fenced.

Rubbish deposition at the site should be discontinued.

4.1.3 LLR03 — Kwolyin Nature Reserve

Central site coordinates

E 574556, N 6473537

Site description

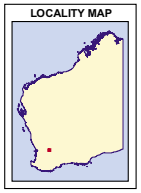
This site is a significant valley floor nature reserve (approximately 341 ha) located immediately upstream of survey site LLR02 (Map 5). The main features of this site are the meandering main channel systems in the south and a series of lakes and backwater-scalded areas. Approximately half of the site consists of moderately elevated interfluves with woodland vegetation. There is a relatively small area of diverse woodland in the north-west of the site. The value of this area is complemented by adjacent private remnant vegetation that links extensive bedrock outcropping to the valley floor system.

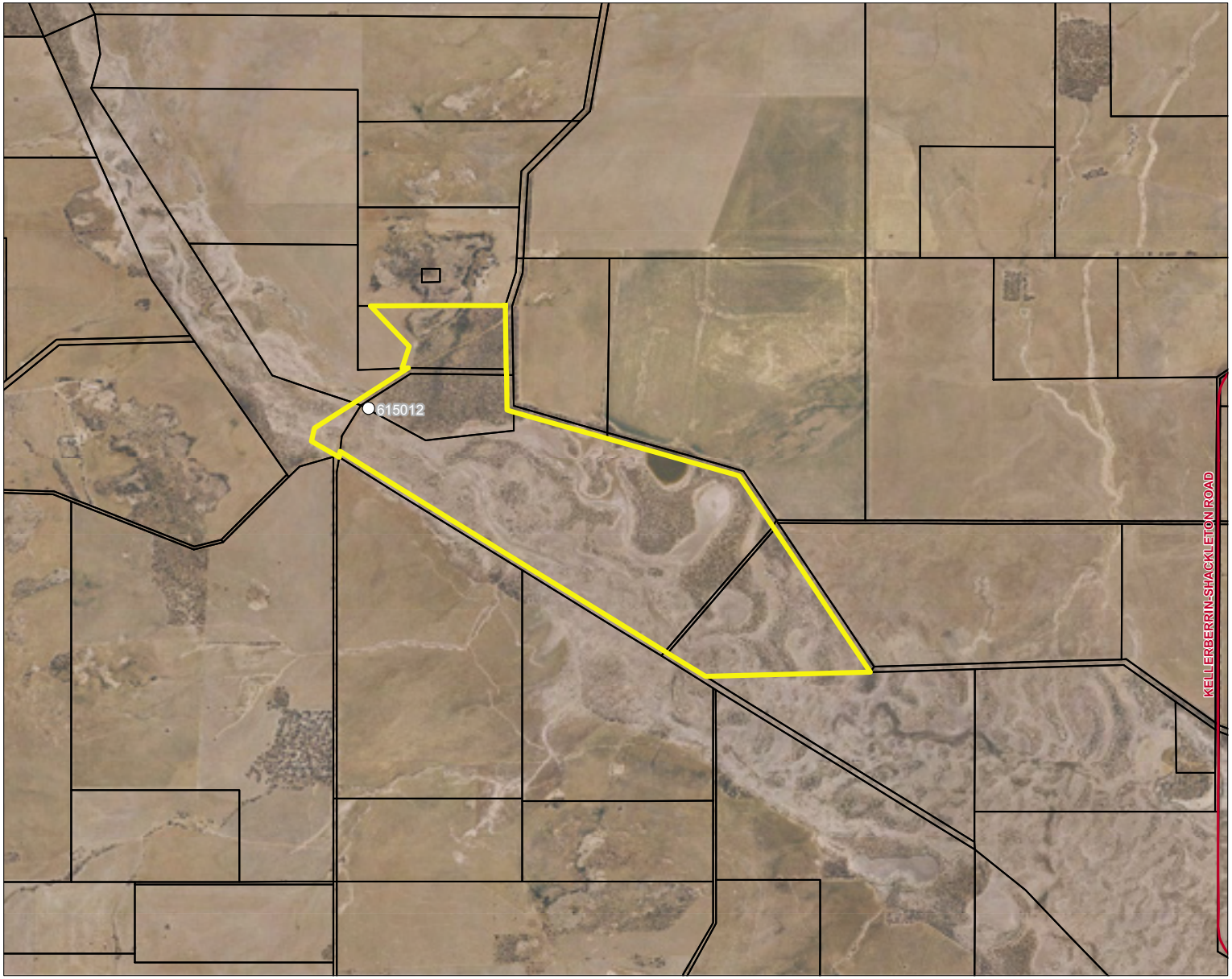
The broad stream channel and scalded areas are likely to have a high level of saline

Photo 7 *Road construction and rubbish at the upstream end of the site*

Photo 8 *Box culvert structures for Kwolyin East Road*

Map 5 Survey site LLR03 Kwolyin Nature Reserve





LEGEND

- Survey site boundaries
- Cadastral land parcels
- Stream gauging site

Kellerberrin 2004 aerial imagery

N

0 1

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requested by: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_series\B4148\0002_LowerLockhart\mxd\Map05_LLR03_A4.mxd
Date: April 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:

Cadastral land parcels - Landgate - June 2007
Main roads - Landgate - June 2004

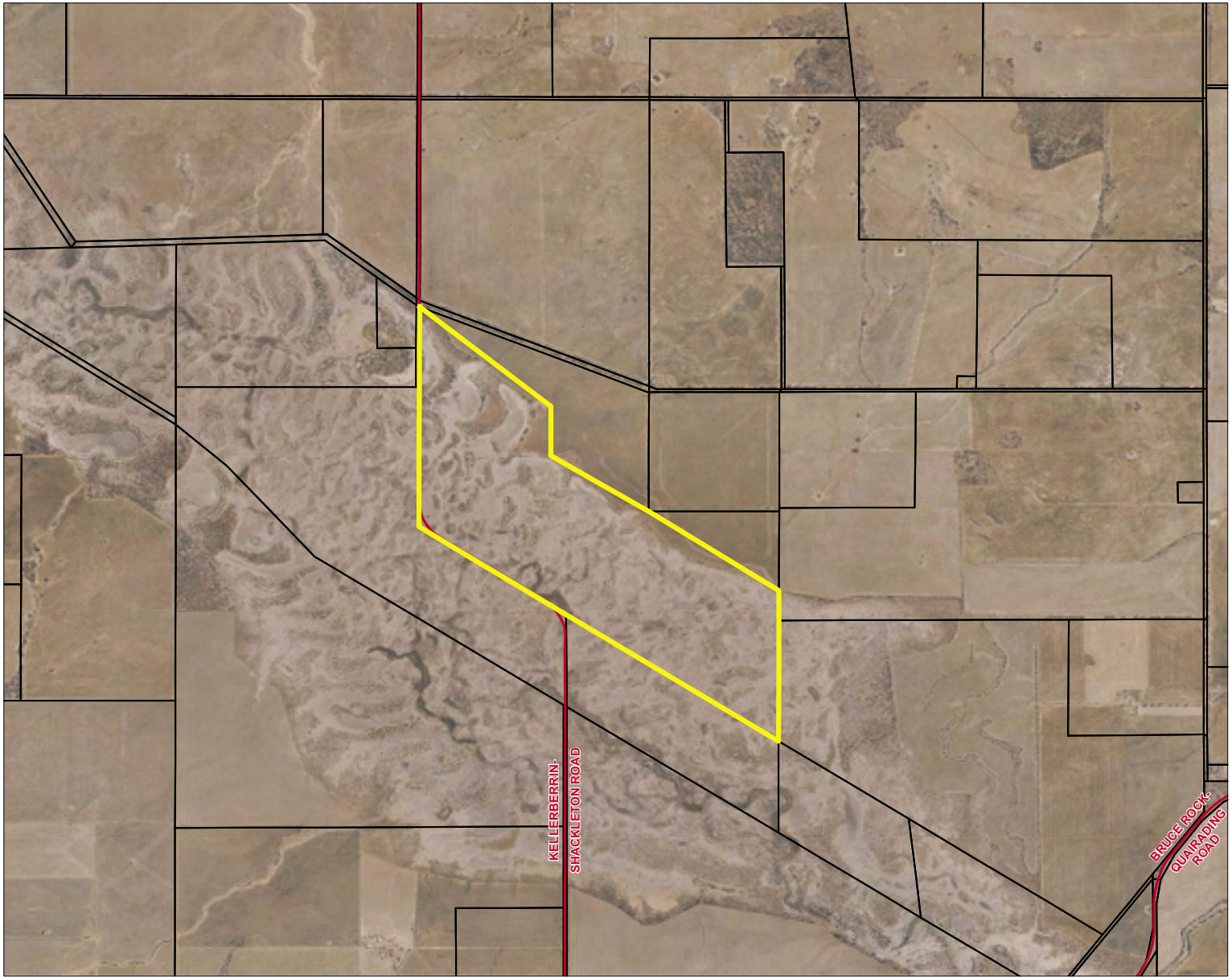
Department of Water
Government of Western Australia

This map is a product of the Department of Water (Measurement and Water Information Branch) and was completed in April 2008.

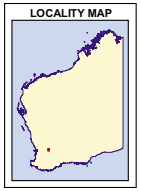
This map was produced with the intent that it be used for the Lower Lockhart River mapping project at the scale of 1:35 000.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Map 6 Survey site LLR04 Venemore's



LOCALITY MAP



LEGEND

- Survey site boundaries
- Cadastral land parcels
- Transects
- Road centrelines

Kellerberrin 2004 aerial imagery

N

0 1

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requested by: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_series\B4148\0002_LowerLockhart\mxd\Map06_LLR04_A4.mxd
Date: April 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:

Cadastral land parcels - Landgate - June 2007
Main roads - Landgate - June 2004

Department of Water
Government of Western Australia

This map is a product of the Department of Water (Measurement and Water Information Branch) and was completed in April 2008.

This map was produced with the intent that it be used for the Lower Lockhart River mapping project at the scale of 1:35 000.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Photo 9 *Healthy mallee woodland located on the sandy interfluves*

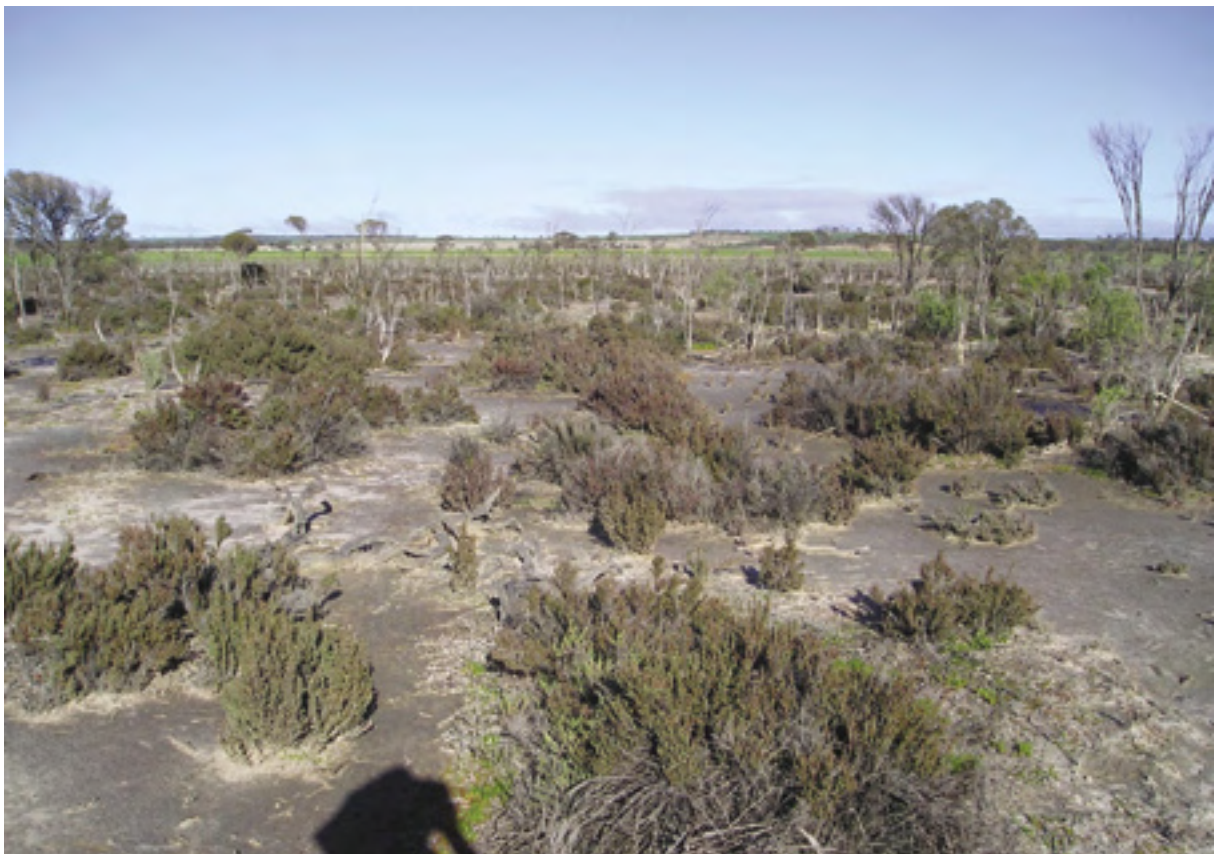


Photo 10 *Transitional vegetation in response to salinity*

Photo 11 *Recent regeneration on the sand margin of saline scalds*

Photo 12 *Groundwater discharge in the broad valley floor*

groundwater discharge. There is a significant tributary contribution from the north of the site (Tributary C) and a smaller tributary from the south.

The Kwolyn Hill gauging station (reference code 615012) is located in this site adjacent to Kwolyin East Road which is the western site boundary.

Condition assessment

The vegetation condition assessment for this site is shown in the table below.

Table 10 LLR03 — Kwolyin Nature Reserve vegetation condition assessment

Vegetation condition	Percentage of site
Pristine	0
Excellent	10
Very good	0
Good	20
Degraded	70
Completely degraded	0

The valley floor system is substantially degraded due largely to increasing saline groundwater discharge. The location of this site upstream from a geological constriction, caused by bedrock protrusion immediately downstream of the site. The two tributaries to this site increase the potential for salinity. The confluences of these tributaries are considered to be the areas of greatest salinity risk.

The major impact of rising groundwater and salinity at this site is the transition from melaleuca-dominant vegetation to samphire shrubland (Photo 10). The elevated sandy fringes to the scalded areas are capable of healthy regeneration (Photo 11).

The area of high quality woodland adjacent to Kwolyin East Road is not considered to be at risk to salinity due to its location down slope from an extensive area of rock outcrop which provides seasonally fresh groundwater throughflow. This vegetation is significant as it represents a transitional ecosystem linking bedrock exposure to the valley floor.

Management considerations

Boundary fencing south of the site is in good condition and north of the site it is in moderate condition.

4.1.4 LLR04 — Venemore's

Central site coordinates

E 579486, N 6470248

Site description

This site is a privately-owned area of valley floor adjacent to the Kellerberrin–Shackleton Road (Map 6). It is approximately 341 ha in area. It occurs at a location where the valley floor is more than 2.5 km wide. However, the site is restricted to approximately one third of the valley floor. South of the site is Crown Reserve 24505 (Shackleton Reserve). The reserve also is not the full width of the valley floor. The main flow channel of the river is located primarily on private land south of the reserve.

A substantial proportion of the site is scalded bare areas, some occurring in a scalloped formation. All of these bare areas are interconnected – there are no separated lake systems – and they fill by backflow, during periods of high streamflow, and by localised inflow. Box culverts allow connecting streamflow to occur under Shackleton Road (Photo 13). There is likely to be a high level of saline groundwater discharge to scalded areas within this site.

The site is located upstream of Tributary C and downstream from Tributary E. On the southern side, the confluence of Tributary D, although not directly on this site, influences a broad area of the valley floor.

The predominant vegetation is samphire (Photo 14). This is transitional from a former melaleuca-dominated vegetation association (Photo 15). The sandy interfluves have small isolated areas of woodland vegetation. There is very little structural complexity in the remaining vegetation so the habitat value of this site is low. Few bird species were recorded at this site.

Condition assessment

The vegetation condition assessment for this site is shown in Table 11.

Table 11 LLR04 — Venemore's vegetation condition assessment

Vegetation condition	Percentage of site
Pristine	0
Excellent	2
Very good	8
Good	80
Degraded	10
Completely degraded	0

Vegetation on the elevated sandy interfluves has remained in relatively good condition although it is limited in area. A large proportion of the site is naturally occurring samphire flats and these areas resemble natural conditions. Rising groundwater and salinity have caused decline in the melaleuca-dominated fringing vegetation.

The broad valley floor exposed to occasionally high streamflow has relatively high erosion risk (Photo 16).

Photo 13 *Box culvert on the Shackleton Road*

Photo 14 *Samphire flats*

Photo 15 *Transitional vegetation from melaleuca to samphire*

Photo 16 *Broad eroded valley floor*

Agricultural land north of the site has generally shallow soils over bedrock outcroppings so it is unlikely that salinity will extend from the valley floor.

Management considerations

The fencing on the northern boundary adjacent to agricultural land is in good condition. Fencing adjacent to Shackleton Road on the southern side is in moderate condition.

Revegetation of an area near the northern boundary of this site with a range of saltbush species (*Atriplex spp.*) has degenerated significantly.

4.1.5 LLR05 — Crown reserve 22131 (Shackleton Lakes)

Central site coordinates

E 583688, N 6465569

Site description

Crown reserve 22131 is generally known as the Shackleton Lakes (Map 7). The approximately 370 ha reserve is vested with the Shire of Bruce Rock for recreation and is used for water skiing, picnic and horse riding. However it also has high conservation value.

The survey site occurs at the downstream end of the only major meander in the lower Lockhart River section. The meander is almost certainly geologically controlled. The same geological control appears to also influence the orientation of major tributaries to this site along a north-east, south-west alignment.

The valley floor is approximately 3 km wide. It is similar in form and condition both upstream and downstream of this site. There is no clearly defined stream channel. Instead, it is understood that flow occurs through a series of interconnected lakes in the central part of the site. There are peripheral lakes that are probably connected by groundwater processes.

Tributary E to the north of the site and Lockwood Gully to the south are both broad saline valley floor systems which may have significant hydrological influence on the site. It is likely that groundwater discharge to the lakes and other scalded areas within the site is.

The extensive areas of interfluve are well elevated and have healthy woodland vegetation dominated by white-leaved mallee (*Eucalyptus albida*) (Photo 17). The lower understorey is diverse including extensive areas of *Lepidosperma* species and

Lomandra effusa (Photo 18). A coarse fibrous macrophyte occurs in some of the lakes.

Condition assessment

The vegetation condition assessment for this site is shown in Table 12.

Table 12 LLR05 — Crown Reserve 22131 (Shackleton Lakes) vegetation condition assessment

Vegetation condition	Percentage of site
Pristine	0
Excellent	20
Very good	15
Good	65
Degraded	0
Completely degraded	0

Vegetation at the site is mostly in good condition due to the relatively high elevation of the areas of woodland. The high potential for salinity in adjacent areas is unlikely to significantly affect these elevated areas.

The hydroperiod of the lakes and water receiving areas has altered due to changes in surface water inundation and higher groundwater discharge. These changes are affecting lake ecosystems, which can be seen by the changes in riparian vegetation communities from melaleuca-dominated to samphire-dominated shrublands (Photo 19).

Streamflow is retained by the spacious receiving water bodies within the reserve so no significant soil erosion and sediment deposition is occurring.

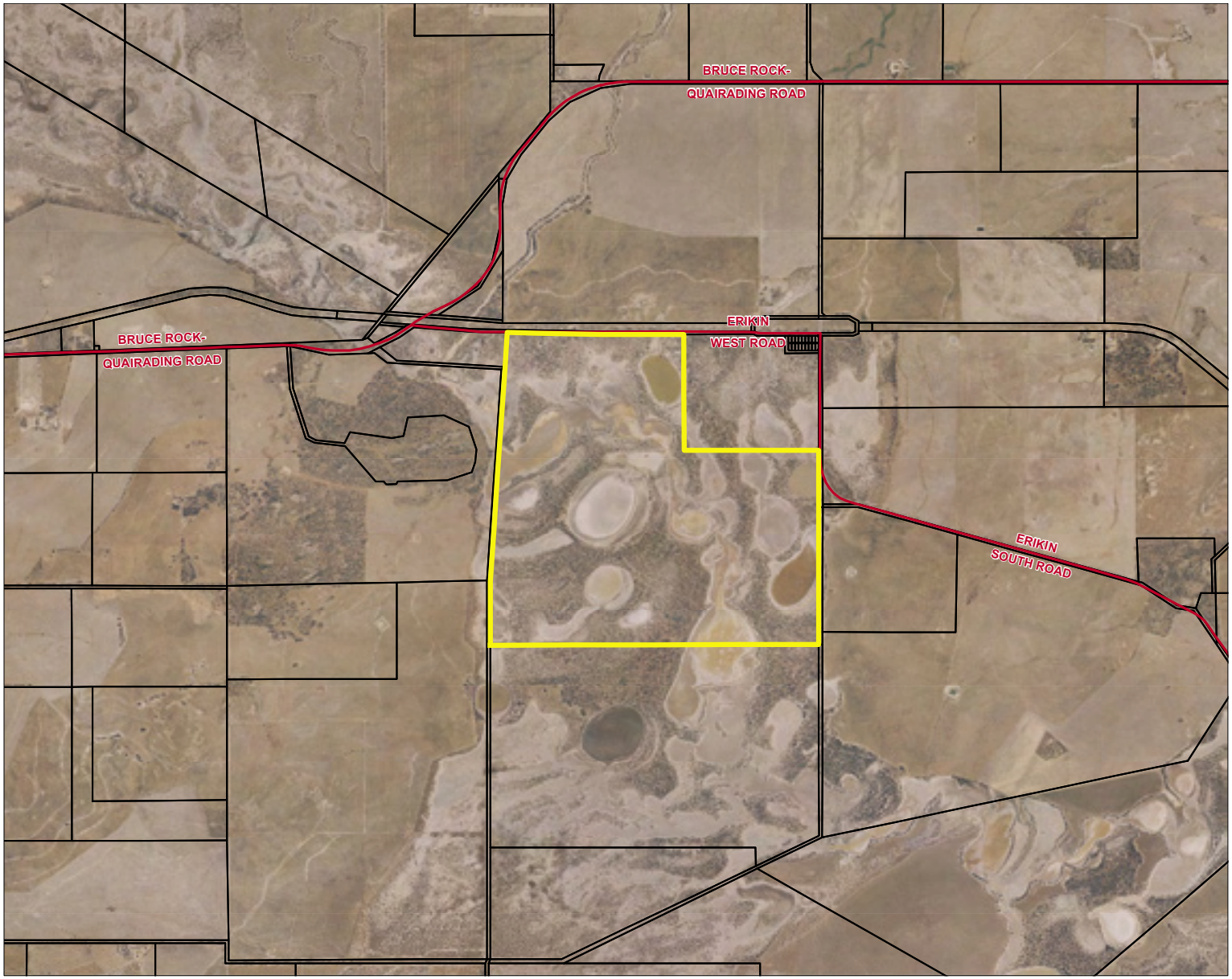
Management considerations

The site is used for recreation, including water skiing, although the impact on the site is relatively low. There is some risk from fire which could affect vegetation and conservation values. Access by horses to the area increases the risk of weeds within the site.

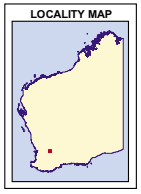
Rubbish has been deposited recently within the reserve in a small uncontrolled area off Erikin South Road. A former rubbish disposal site off Erikin West Road, which included disposal to a lake, has been partially rehabilitated.

The boundary fencing is currently adequate.

Map 7 Survey site LLR05 Crown Reserve 22131



LOCALITY MAP



LEGEND

- Survey site boundaries
- Cadastral land parcels
- Road centrelines

Kellerberrin 2004 aerial imagery

N

0 1

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requested by: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_series\B4148\0002_LowerLockhart\mxd\Map07_LLR05_A4.mxd
Date: April 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:

Cadastral land parcels - Landgate - June 2007
Main roads - Landgate - June 2004

Department of Water
Government of Western Australia

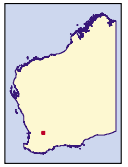
This map is a product of the Department of Water (Measurement and Water Information Branch) and was completed in April 2008.

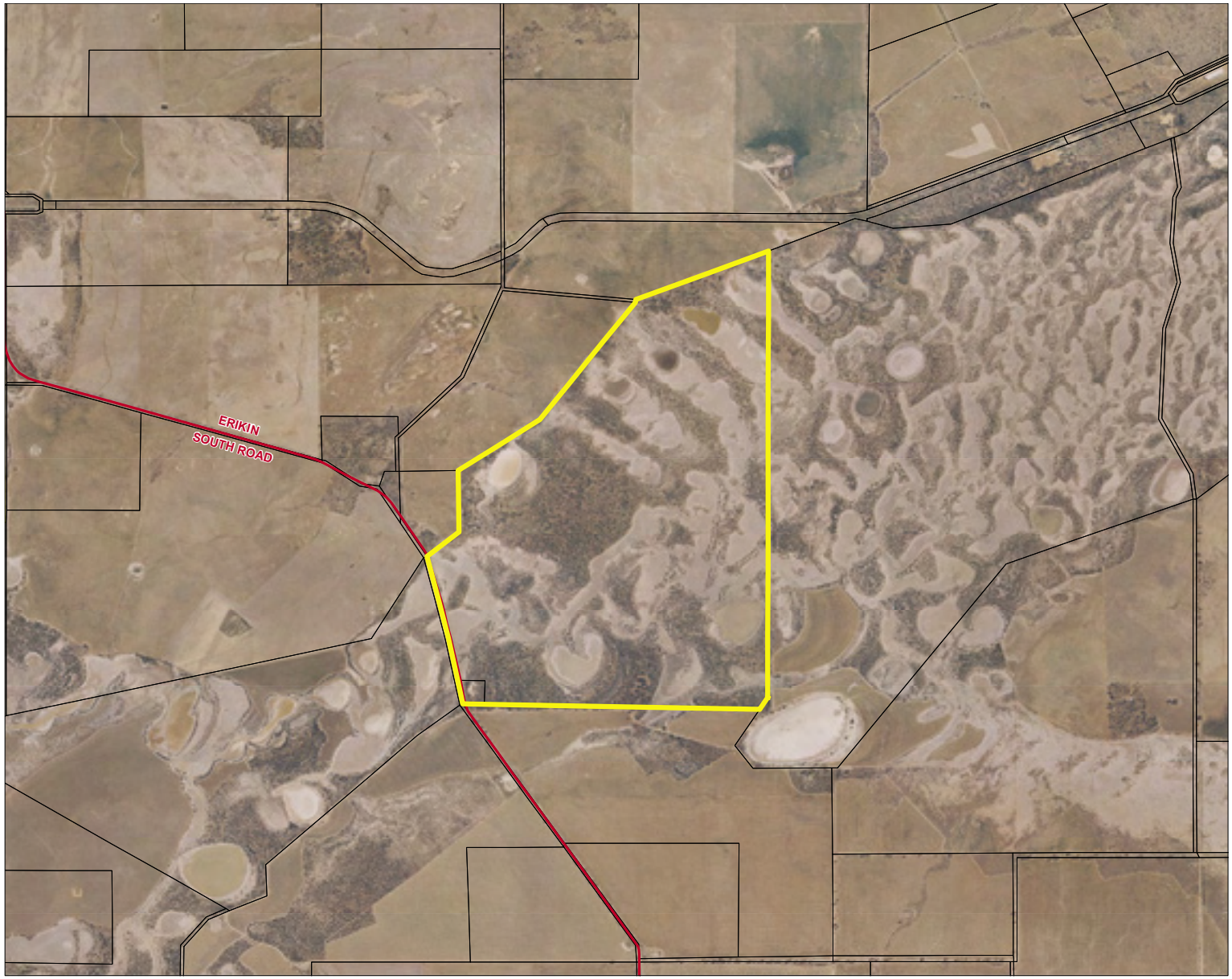
This map was produced with the intent that it be used for the Lower Lockhart River mapping project at the scale of 1:35 000.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Map 8 Survey site LLR06 Mokami Nature Reserve

LOCALITY MAP





LEGEND

- Survey site boundaries
- Cadastral land parcels
- Road centrelines

Kellerberrin 2004 aerial imagery

N

0 1

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requested by: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_series\B4148\0002_LowerLockhart\mxd\Map08_LLR06_A4.mxd
Date: April 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:

Cadastral land parcels - Landgate - June 2007
Main roads - Landgate - June 2004

Department of Water
Government of Western Australia

This map is a product of the Department of Water (Measurement and Water Information Branch) and was completed in April 2008.

This map was produced with the intent that it be used for the Lower Lockhart River mapping project at the scale of 1:35 000.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Photo 17 *Access track through mallee woodland*

Photo 18 Lepidosperma *species within woodland on elevated sandy interfluve*

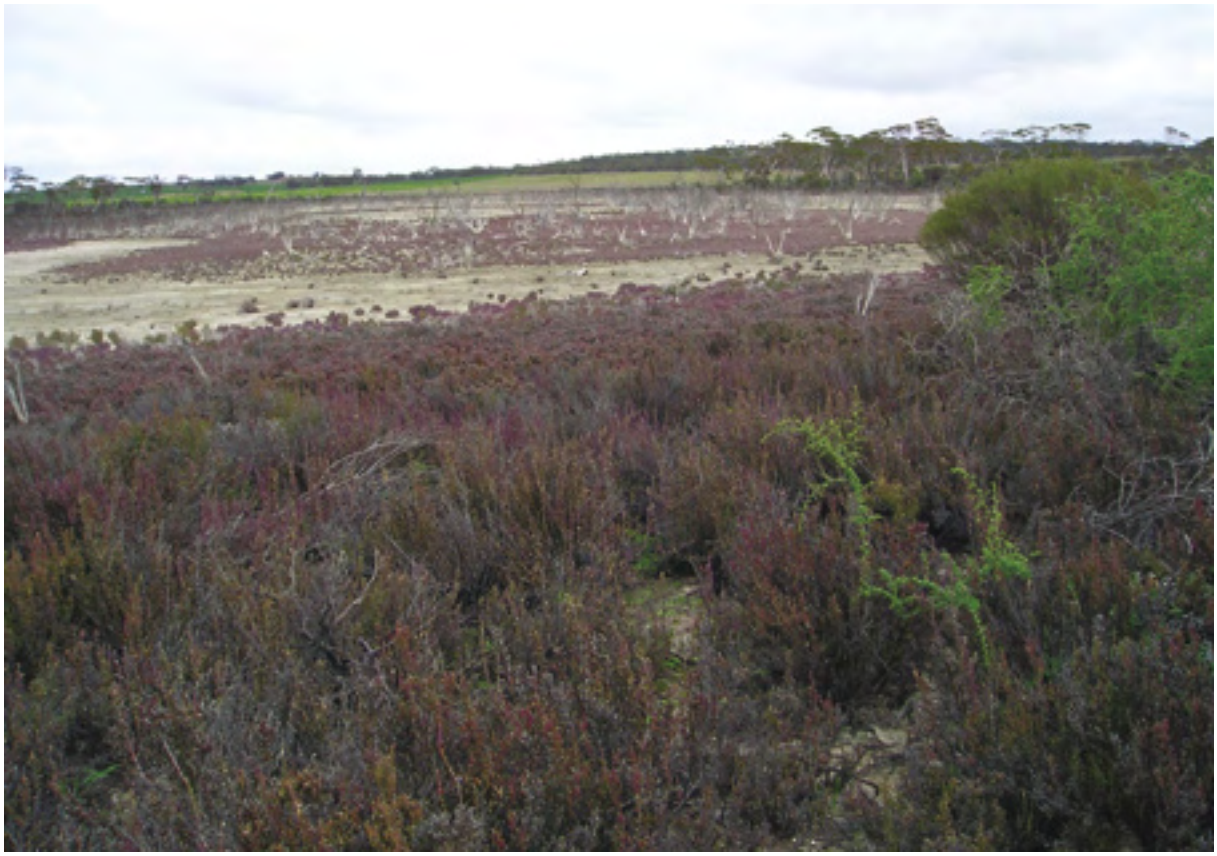


Photo 19 *Change in lake vegetation*

Photo 20 *Former rubbish disposal into a lake*

Photo 21 *Samphire fringing vegetation*

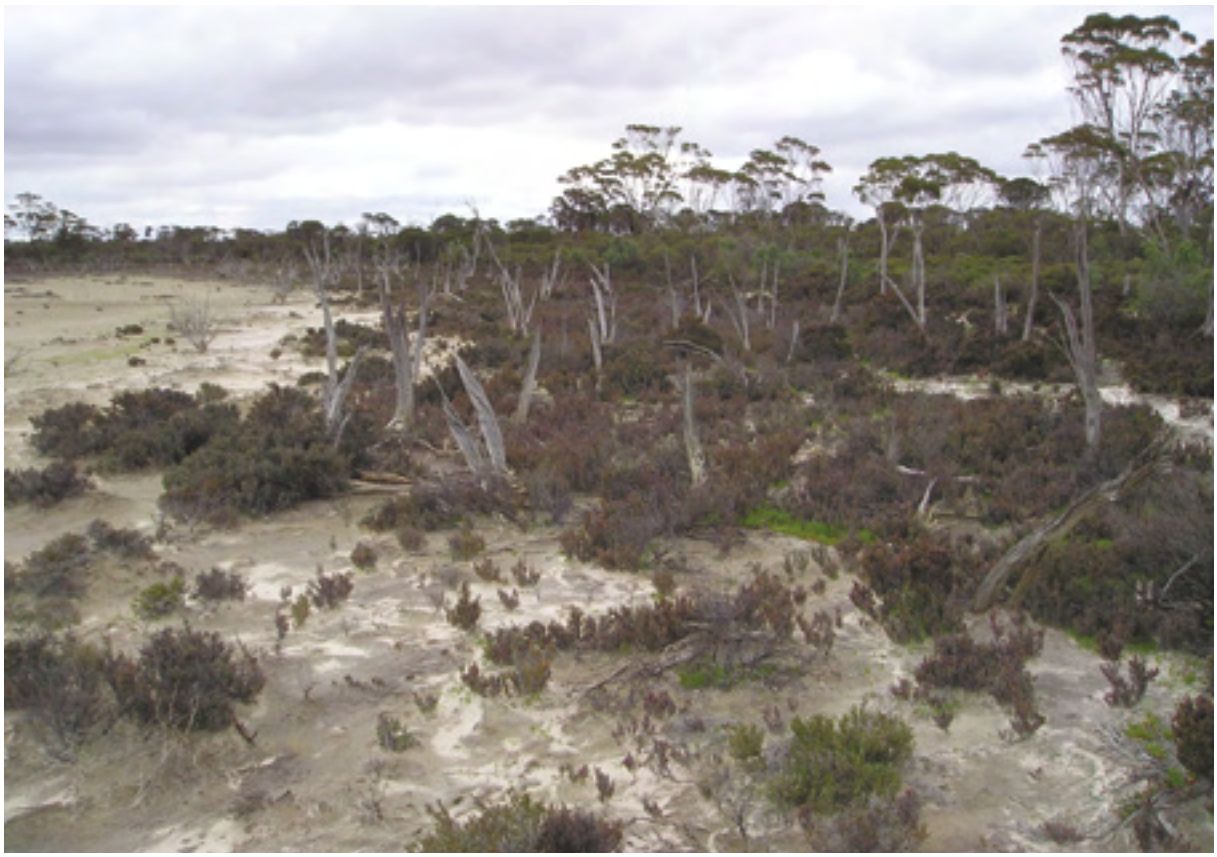


Photo 22 *Melaleuca stags indicating significant hydrological change*

Photo 23 *Box culverts on Erikin South Road*

4.1.6 LLR06 — Mokami Nature Reserve

Central site coordinates

E 588412, N 6464531

Site description

Mokami Nature Reserve is 475 ha in area and is vested with the Department of Environment and Conservation (Map 8). It is located upstream of the major meander in the lower Lockhart River. The site includes the full width of the valley floor, which is generally greater than 2.5 km.

There is a main streamflow channel that occurs in the southern portion of the site although this occurs through a series of interconnected lakes. There is an additional series of elongated lakes that are not directly connected with the main streamflow channel. These appear to have been formed through progressive periods of deflation caused by prevailing wind.

Tributary F is a very broad and poorly defined drainage system with influence on the site from the south.

There are extensive areas of woodland. These occupy more than half of the site. Most of this area is dominated by salmon gum (*Eucalyptus salmonophloia*) and there are areas of white-leaved mallee (*Eucalyptus albida*).

The western boundary is Erikin South Road which also provides a service corridor for water supply and telecommunications.

Condition assessment

The vegetation condition assessment for this site is shown in the table below.

Table 13 LLR06 — Mokami Nature Reserve vegetation condition assessment

Vegetation condition	Percentage of site
Pristine	20
Excellent	5
Very good	5
Good	65
Degraded	5
Completely degraded	0

The site is generally in good condition with 20 per cent of the area assessed as in near pristine condition. Woodland vegetation is located on elevated interfluve dunes and is unlikely to be significantly affected by groundwater rise or salinity.

The hydroperiods of the lakes and other water receiving areas have altered as a result of changes to the catchment water balance, which has affected fringing vegetation (Photo 22).

Management considerations

Wire and other rubbish has been deposited in the south-west corner of the reserve.

Fencing on the northern boundary is poor while on the southern boundary it is in good condition.

Erikin South Road has high-capacity box culverts and the road would perform as a floodway during occasional flooding.

4.1.7 LLR07 — Yarding Nature Reserve

Central site coordinates

E 593114, N 6467532

Site description

Yarding Nature Reserve (Crown Reserve 27108) is an area of approximately 231 ha vested with the Department of Conservation and Environment. The site includes the full width of the valley floor which is generally greater than 2 km (Map 9).

The site has a complex drainage system with a high level of indentation (irregular shape at the margins). The main flow channel is not well defined as it has frequently migrated across the valley over a long period of time. It is currently located north in the site where there are a series of small lakes interconnected with ox-bow formations.

A significant feature is the extensive lens of deep sand north of the reserve that intrudes into the site (Photo 24). The vegetation differs from the valley floor ecosystem and includes *Banksia prionotes*. The highly permeable sandy soils influence the hydrology and condition of the adjacent lake systems.

The many elevated interfluvial areas are small and poorly connected. They have remnants of woodland vegetation.

Crown reserve 38522 is located to the west of the site and almost adjacent to it.

Condition assessment

The vegetation condition assessment for this site is shown in the table below.

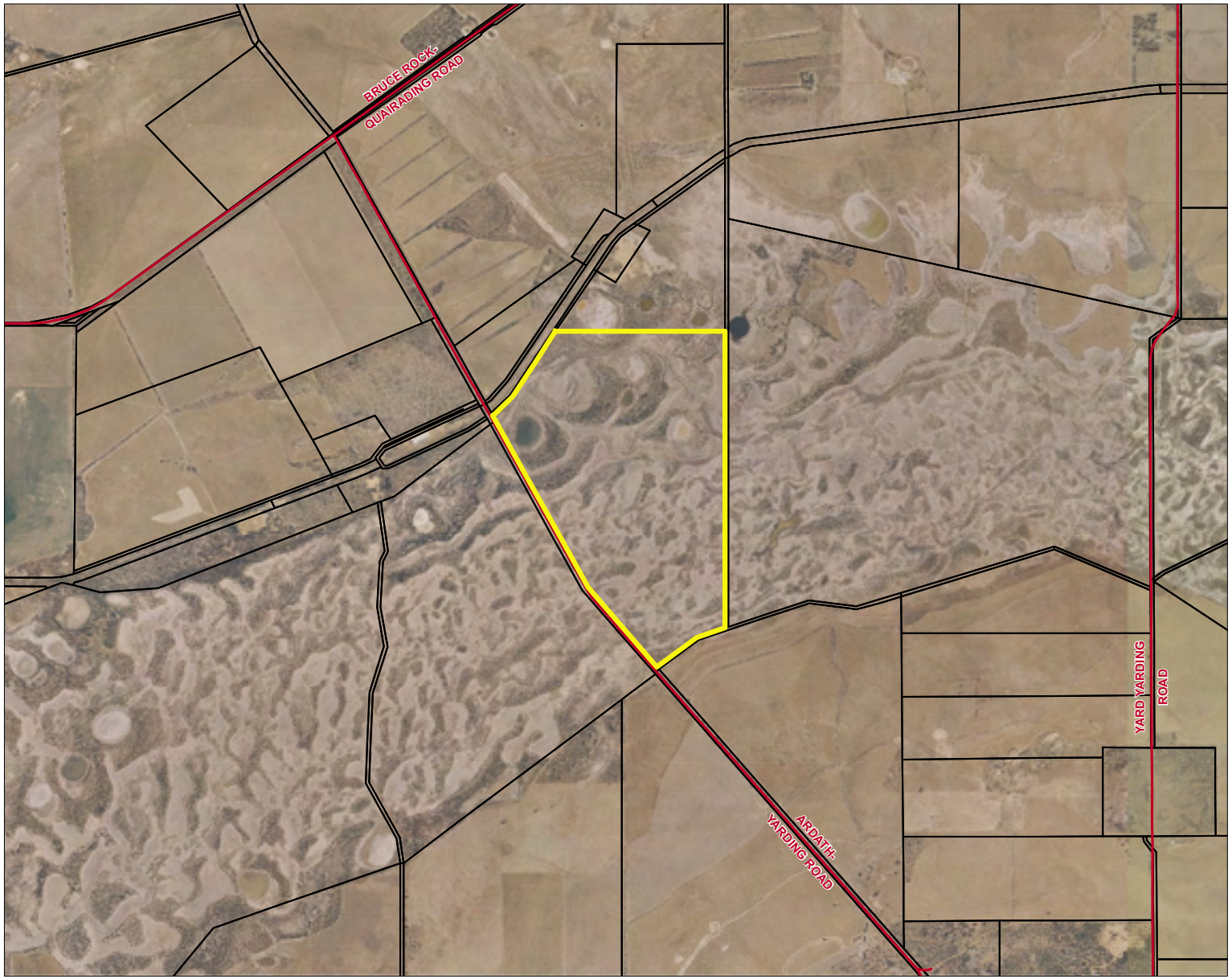
Table 14 LLR07 — Yarding Nature Reserve vegetation condition assessment

Vegetation condition	Percentage of site
Pristine	10
Excellent	20
Very good	10
Good	10
Degraded	50
Completely degraded	0

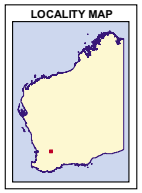
The fringing vegetation in the north of the reserve is highly diverse and in excellent or near pristine condition. Some of the small dunes also have vegetation in good condition. Sandplain vegetation is at risk to plant disease and there is vegetation dieback that may be caused by the pathogen *Phytophthora cinnamomi*.

The water receiving lakes and indentations have been altered by rising groundwater and salinity (Photo 25). The transition is towards samphire-dominant vegetation on the margins of the water bodies and decline in melaleuca-dominated vegetation communities. An estimated 50 per cent of the site is degraded valley floor.

Map 9 Survey site LLR07 Yarding Nature Reserve



LOCALITY MAP



LEGEND

- Survey site boundaries
- Cadastral land parcels
- Road centrelines

Kellerberrin 2004 aerial imagery

Bruce Rock-Muntadgin 2001 aerial imagery

N

0 1

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requested by: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_series\B4148\0002_LowerLockhart\mxd\Map09_LLR07_A4.mxd
Date: April 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:
Cadastral land parcels - Landgate - June 2007
Main roads - Landgate - June 2004
Aerial imagery - Landgate - 2001 and 2004

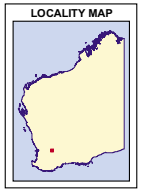
Department of Water
Government of Western Australia

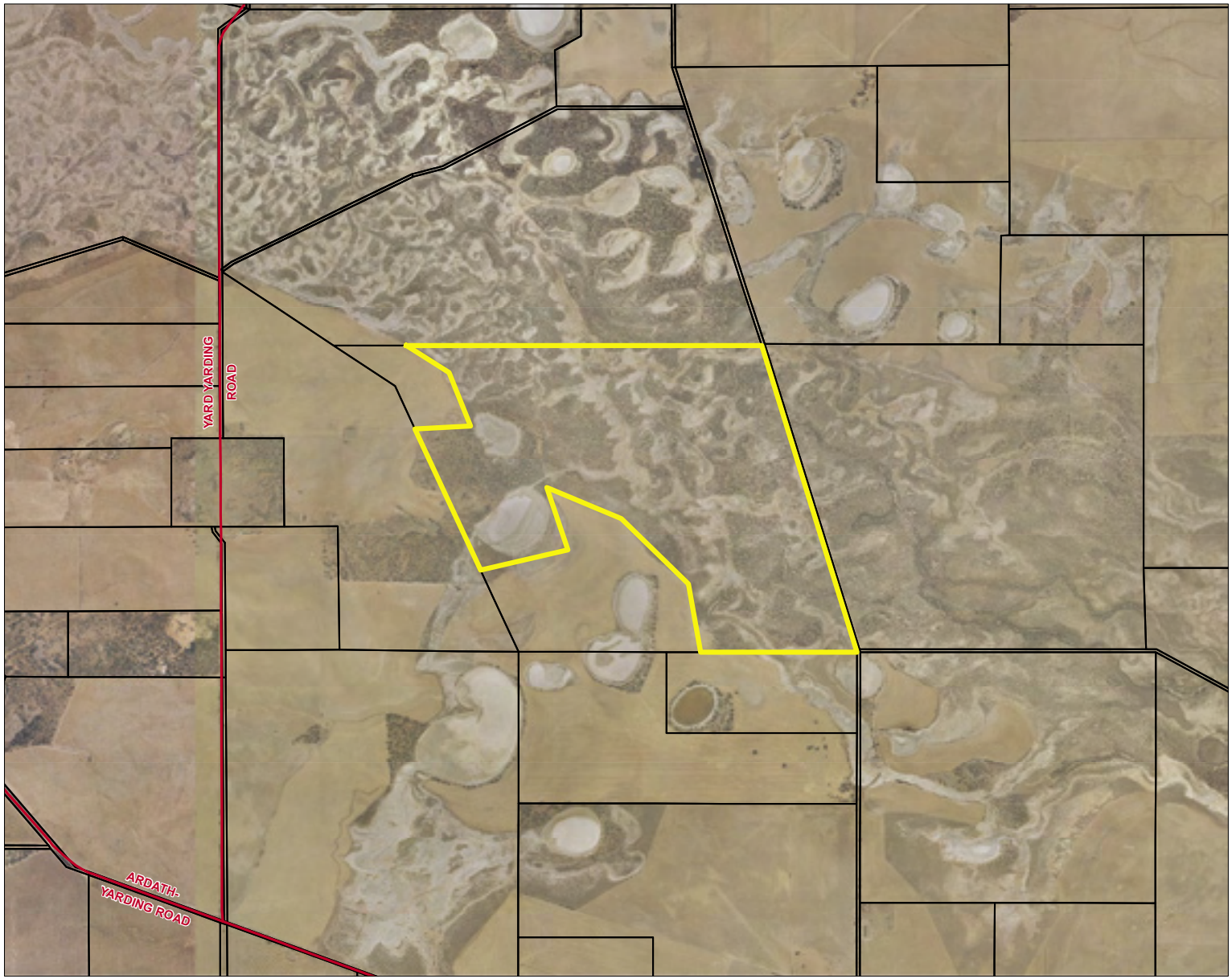
This map is a product of the Department of Water (Measurement and Water Information Branch) and was completed in April 2008.

This map was produced with the intent that it be used for the Lower Lockhart River mapping project at the scale of 1:35 000.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Map 10 Survey site LLR08 Strange's





LEGEND

- Survey site boundaries
- Cadastral land parcels
- Road centrelines

Kellerberrin 2004 aerial imagery

Bruce Rock-Muntadgin 2001 aerial imagery

N

0 1

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requested by: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_series\B4148\0002_LowerLockhart\mxd\Map10_LLR08_A4.mxd
Date: April 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:
Cadastral land parcels - Landgate - June 2007
Main roads - Landgate - June 2004
Aerial imagery - Landgate - 2001 and 2004

Department of Water
Government of Western Australia

This map is a product of the Department of Water (Measurement & Water Information Branch) and was completed in April 2008.

This map was produced with the intent that it be used for the Lower Lockhart River mapping project at the scale of 1:35 000.

Photo 24 *Small lake adjacent to a lens of deep sand*

Photo 25 *Salt-affected fringing vegetation*

Photo 26 *Transitional samphire vegetation of the broad valley floor*

Photo 27 *Box culverts on the Ardath–Yarding Road*

Streamflow velocity is contained by the complex drainage pattern so that soil erosion and sediment deposition are minimised.

Management considerations

The pathogen *Phytophthora cinnamomi* may occur at this site and there is a risk of the disease spreading into high conservation value vegetation. The evidence of dieback is associated with the access road used for sand extraction north of the reserve.

There is a diversion bank downstream from the reserve constructed to control streamflow.

4.1.8 LLR08 — Strange's

Central site coordinates

E 598936, N 6465294

Site description

This approximately 469 ha site consists of privately owned land that extends the full width of the valley floor (Map 10). The valley floor and adjacent landscape is of subdued relief. The broad valley floor system is approximately 3.5 km wide. The main flow channel crosses the eastern site boundary (Eujinyn South Road) north in the site then re-orientates to flow north (Photo 28).

The site is influenced by significant tributaries from the north (Tributary I) and south (Tributary H). Both of these contributing drainage systems have poorly defined streamflow channels through a series of interconnected lake systems. Two of the lakes in the Tributary H system occur within the site. All other tributary lakes are within land cleared for agriculture and are associated with a high salinity risk.

This site is distinctive as it has a greater proportion of woodland area than bare drainage area. Dominant species of the woodland vegetation are Kondinin blackbutt (*Eucalyptus kondininnensisi*) and red morrel (*Eucalyptus longicornis*). The shrubland understorey is predominantly halophytes (samphire, saltbush and bluebush). While the dune systems that support woodland vegetation are extensive, the elevation of these dunes is not substantial.

There are a series of private remnants and public reserves west of the site. One immediately adjacent to the site is on shallow bedrock and adds significantly to the conservation value of the lake system at the west end of the site (Photo 29).

Condition assessment

The vegetation condition assessment for this site is shown in Table 15.

Table 15 LLR08 — Strange's vegetation condition assessment

Vegetation condition	Percentage of site
Pristine	0
Excellent	0
Very good	20
Good	40
Degraded	40
Completely degraded	0

Valley floor vegetation at the site has altered considerably due to salinity and waterlogging and is at risk of further change. The dominant species are in transition from melaleuca vegetation to samphire due largely to rising groundwater and salinity at the site (Photo 29). The combination of hydrological influence from the two tributaries, with the low relief of woodland dunes, indicates the potential for significantly increased salinity impact at this site.

Management considerations

The site is fenced, some recently, to control grazing at the site (Photo 30). The site is vulnerable to high grazing pressure and a less intensive grazing system would be beneficial.

The effect of salinity on adjacent agricultural land has the potential to increase. Adjacent lake systems on the southern side have been connected to reduce inundation (Photo 31). The current works should not have a significant effect on the valley floor within this site.

4.1.9 LLR09 — Crook's

Central site coordinates

E 604755, N 6462936

Site description

This approximately 359 ha site is privately owned and is located across the valley floor east of the Bruce Rock–Corrigin Road and west of the railway line. The site is 2.6 km in width while the valley floor is approximately 3 km wide at this location (Map 11).

This location is characterised by broad eroded drainage areas. The main channel flows through the northern portion of the site (Photo 32).

Other than small areas of remnant vegetation in patches near the northern site boundary (Photo 33), there is no remaining woodland vegetation. Farm land affected

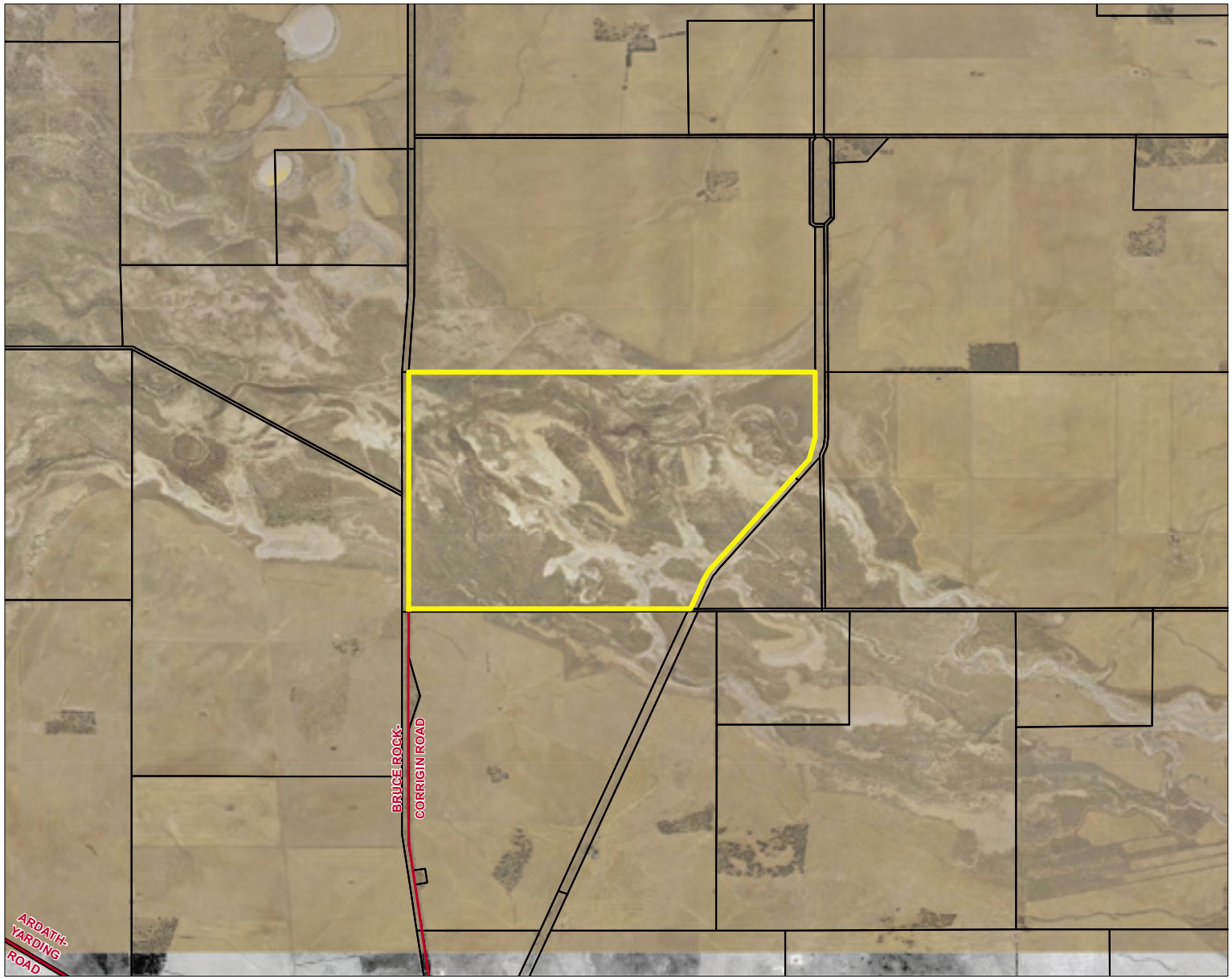
Photo 28 *Floodway for main flow channel*

Photo 29 *Lower grazing pressure on halophytes north of the site*

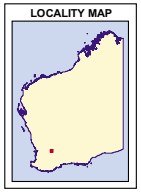
Photo 30 *New fencing on the southern boundary of the site*

Photo 31 *'W-drain' constructed for surface water management*

Map 11
Survey site
LLR09 Crook's



LOCALITY MAP



LEGEND

- Survey site boundaries
- Cadastral land parcels
- Road centrelines

Kellerberrin 2004 aerial imagery

Kellerberrin-Southern Cross 1999 aerial imagery

N

0 1

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requested by: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_series\B4148\0002_LowerLockhart\mxd\Map11_LLR09_A4.mxd
Date: April 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:

Cadastral land parcels - Landgate - June 2007
Road centrelines - Landgate - June 2004
Aerial imagery - Landgate - 1999 and 2001

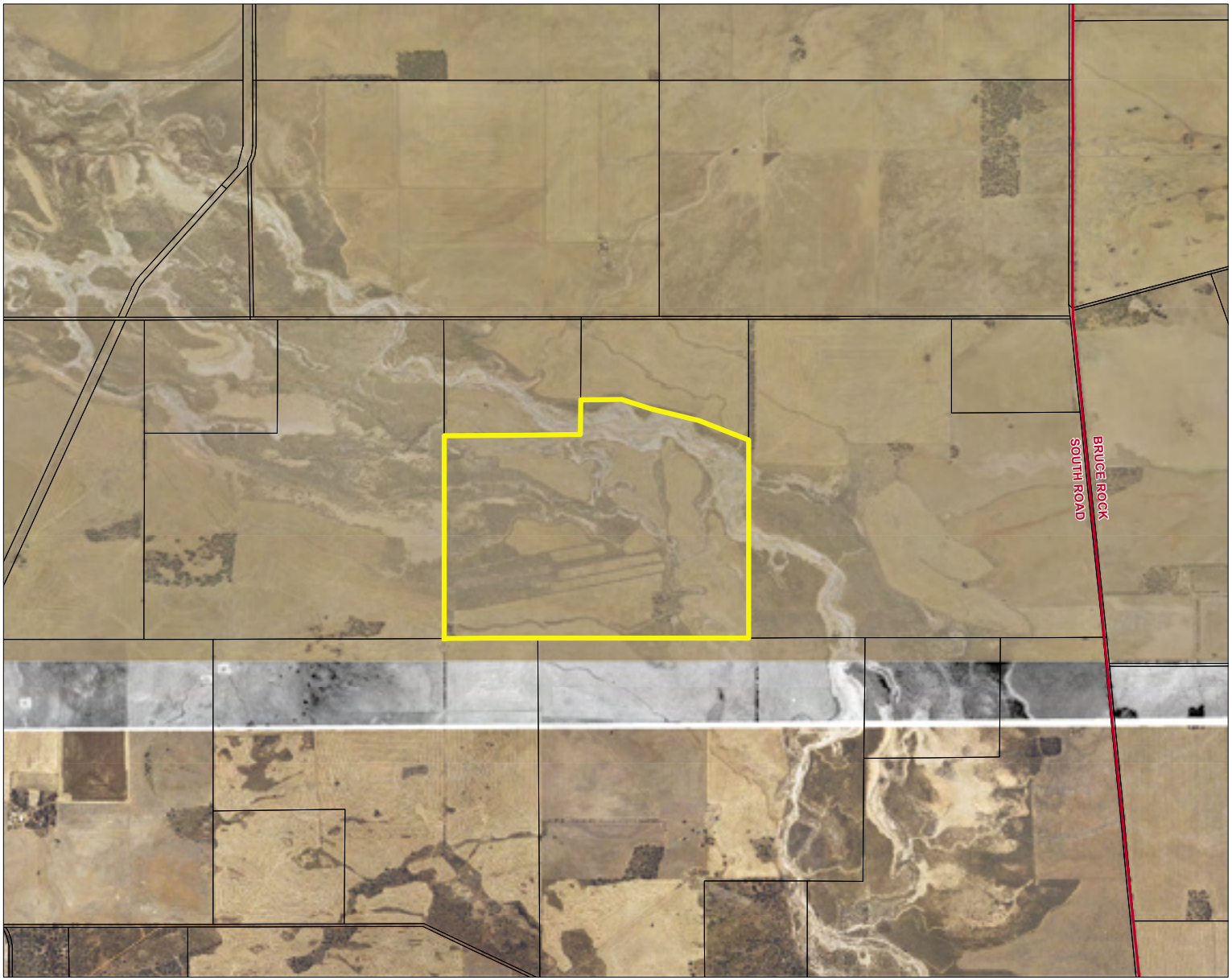
Department of Water
Government of Western Australia

This map is a product of the Department of Water (Measurement and Water Information Branch) and was completed in April 2008.

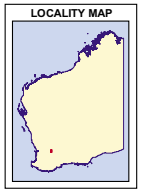
This map was produced with the intent that it be used for the Lower Lockhart River mapping project at the scale of 1:35 000.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Map 12
Survey site
LLR10 Muntz's



LOCALITY MAP



LEGEND

- Survey site boundaries
- Cadastral land parcels
- Road centrelines

Kellerberrin-Southern Cross 1999 aerial imagery

Bruce Rock-Muntadgin 2001 aerial imagery

Narembeen 2005 aerial imagery

N

0 1

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requested by: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_series\B4148\0002_LowerLockhart\mxd\Map12_LLR10_A4.mxd
Date: April 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:

Cadastral land parcels - Landgate - June 2007
Road centrelines - Landgate - June 2004
Aerial imagery - Landgate - 1999, 2001 and 2005

Department of Water
Government of Western Australia

This map is a product of the Department of Water (Measurement & Water Information Branch) and was completed in April 2008.

This map was produced with the intent that it be used for the Lower Lockhart River mapping project at the scale of 1:35 000.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Photo 32 *Broad eroded main flow channel with Bruce Rock-Corrigin Road culverts*

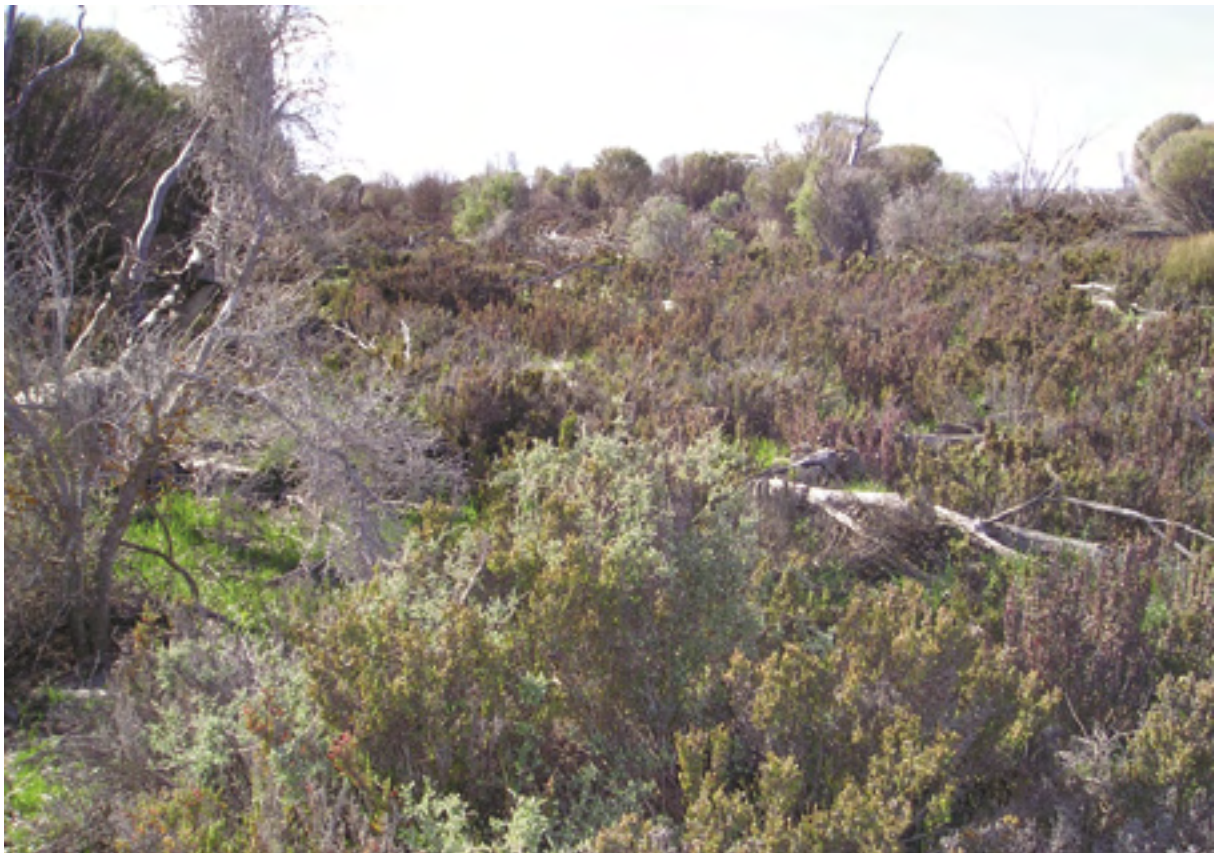


Photo 33 *Degraded patch of remnant vegetation on sand dune*

Photo 34 *Eroded valley floor*

Photo 35 *Impact of water and wind erosion on fragile soils*

by salinity is now being colonised by samphire.

Tributary J influences the site from the north. This tributary extends adjacent to and beyond the town of Bruce Rock. There are minor tributaries south of the site.

There is one significant area of remnant vegetation 4.5 km south of the site.

Condition assessment

The vegetation condition assessment for this site is shown in Table 16.

Table 16 LLR09 — Crook's vegetation condition assessment

Vegetation condition	Percentage of site
Pristine	0
Excellent	0
Very good	0
Good	0
Degraded	10
Completely degraded	90

The entire site is significantly degraded from its natural condition. Samphire now dominates areas that were previously woodland or melaleuca vegetation. Large areas are affected by water or wind erosion (photos 34 and 35) and are a source of sedimentation downstream. The site is prone to further degradation due to salinity.

Management considerations

This site needs to be stabilised. The condition of the soil is relatively fragile and there is potential for downstream sedimentation. The site will need a considerable period without further disturbance to recover. Even low grazing pressure on this fragile site will inhibit site recovery.

The condition of fencing on the eastern, western and southern boundaries is poor.

4.1.10 LLR10 — Muntz's

Central site coordinates

E 608137, N 6460694

Site description

This approximately 270 ha privately owned site extends across the valley floor which is relatively narrow (less than 2 km). The site is located where the lower Lockhart River changes direction from north to north-west (Map 12).

Streamflow is contained within a single well-defined drainage channel with several broad alternative floodways. The site is otherwise characterised by a relatively featureless floodplain with no lakes or indentations of the drainage system providing flood retention.

Tributary K flows from the north to this site. While there is a defined streamflow channel for this tributary, it has a broad valley floor linked to Tributary J and is prone to salinity.

Natural vegetation has been cleared from most of the site. Cleared land has been cropped and has continuing grazing use. There is now no woodland vegetation. The few isolated salmon gum (*Eucalyptus salmonophloia*) and gimlet (*Eucalytptus salubris*) trees indicate the former extent of the vegetation. These are now senescent. Bluebush (*Maireana brevifolia*) has recolonised most of the valley floor.

Yilgerin Nature Reserve is located 2.5 km south from this site.

Condition assessment

The vegetation condition assessment for this site is shown below.

Table 17 LLR10 — Muntz's vegetation condition assessment

Vegetation condition	Percentage of site
Revegetation	5
Pristine	0
Excellent	0
Very good	0
Good	0
Degraded	0
Completely degraded	95

Almost all of the valley floor at this site is degraded due to clearing for agriculture. Rising water tables and salinity have affected the broader floodplain areas. This land was previously cropped but is now regenerating with halophytic (salt-tolerant) shrubs (Photo 36).

While not all of the site is prone to water erosion, the broad stream channel is severely eroded (Photo 37). Remaining stumps of previous vegetation root systems indicate the extent of erosion (Photo 38). Fragile 'morrel' soils on the steep slopes north of the stream channel are continuing to erode (Photo 39).

Management considerations

There are signs of significant management effort to tackle salinity at this site. Areas have been revegetated with tree belts and some with saltbush (*Atriplex spp.*) for

Photo 36 *Bluebush regeneration on broad areas of floodplain*

Photo 37 *Broad eroding stream channel*

Photo 38 *Remaining root system stumps indicate the extent of erosion*

Photo 39 *Fragile 'morrel' soils north of the stream channel*

fodder shrubs. Most of these works are now of limited benefit to site recovery due to their degraded condition.

While some areas of regeneration can withstand low grazing pressure, the eroding soils of the stream channel and fringing landform should be protected from grazing. Additional fencing is required to protect the river environment from grazing.

4.1.11 LLR11 — Wandjagill Nature Reserve

Central site coordinates

E 608990, N 6451533

Site description

The Wandjagill Nature Reserve site is an area of some 760 ha extending for approximately 5 km north of the Old Beverley Road (Map 13). The width of the valley floor reduces from approximately 5 km at the upstream end to approximately 1.5 km at the downstream end (Foss Road). The stream channel gradient has a fall of 1.89 m over the length of the site (0.038 per cent). This very low gradient is characteristic of the lower Lockhart River.

Although there is a defined meandering main flow channel, there is significant additional indentation of the drainage system. All drainage channels are broad, bare and scalded. Two saline lakes occur in the north-east of the reserve. These are not well connected with the surface drainage system.

A saline lake on private land occurs as a part of the valley floor system on the western side.

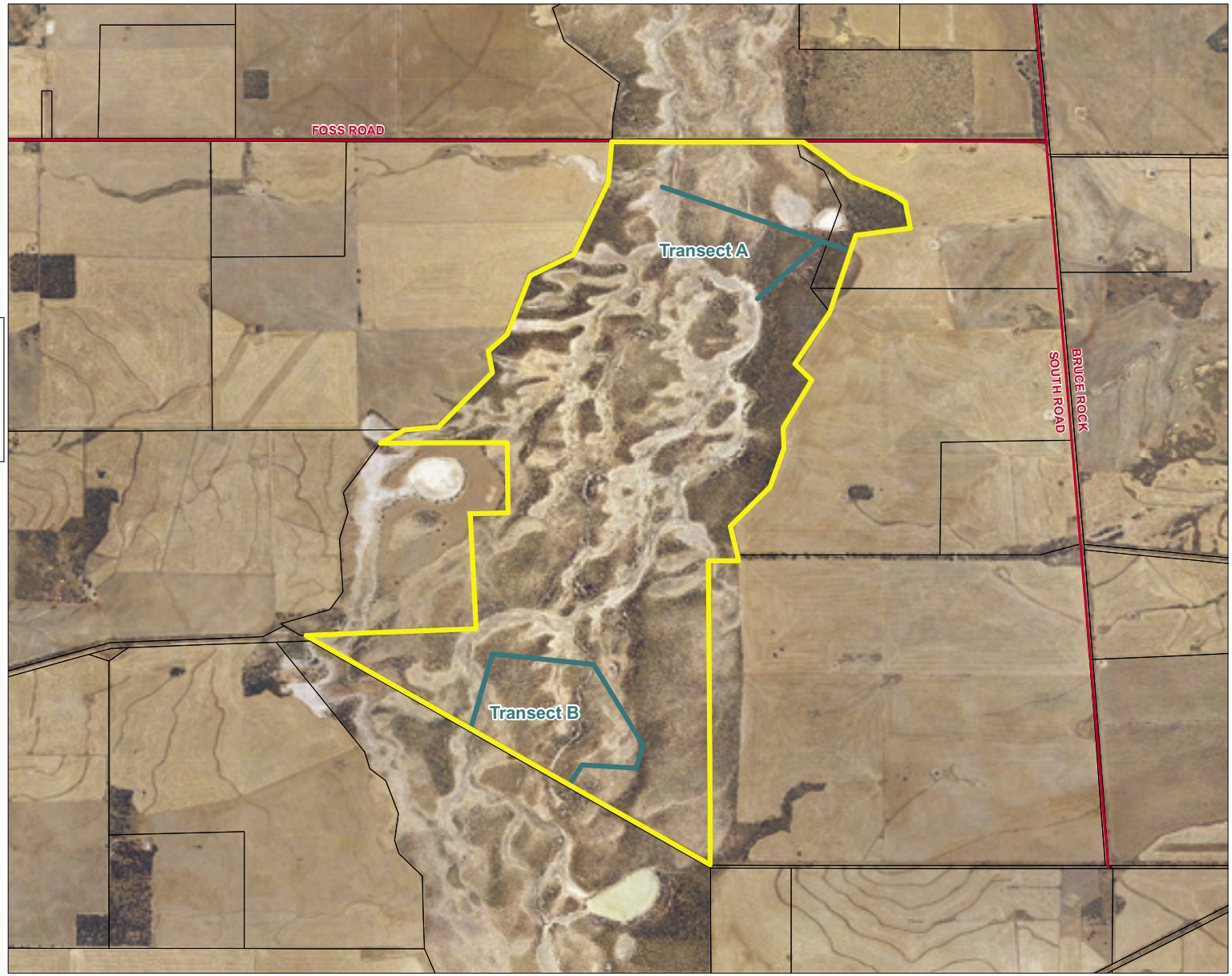
Tributary L influences the site from the west. There are also smaller localised tributaries to the south-west and east of the site. The confluence of Wakeman Creek is approximately 4 km upstream of the Old Beverley Road.

A large proportion of the site is characterised by large, well-connected patches of remnant vegetation.

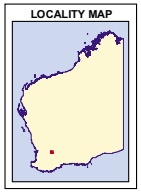
In the northern section of the reserve, woodland vegetation occurs on relatively well elevated dunes (approximately 1.5 m above the valley floor). The white-leaved mallee (*Eucalyptus albida* – Photo 40) and *Eucalyptus myriadena* are dominant species. The Kondinin blackbutt (*E. kondininensis*) occurs on the margin of lakes or the drainage system. Melaleuca vegetation is dominant in the lower drainage systems.

The Seagroatt Nature Reserve is 4 km south of the site and the Yilgerin Nature Reserve is 4 km to the north. There are substantial areas of natural vegetation 6.5 km to the north-west at Ardath.

Map 13 Survey site LLR11 Wandjagill Nature Reserve



LOCALITY MAP



LEGEND

- Survey site boundaries
- Cadastral land parcels
- Transects
- Road centrelines

Narembeen 2005 aerial imagery

N

0 1

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50

Project Information
Requested by: Kate Gole
Map Author: Aidan Belouardi
Task ID: 6897
Filename: \\Pentecost\gis_projects\gisprojects\Project\B_series\B4148\0002_LowerLockhart\mxd\Map13_LLR11_A4.mxd
Date: April 2008

SOURCES

DoW acknowledges the following datasets and their custodians in the production of this map:

Cadastral land parcels - Landgate - June 2007
Road centrelines - Landgate - June 2004
Aerial imagery - Landgate - 2005

Department of Water
Government of Western Australia

This map is a product of the Department of Water (Measurement & Water Information Branch) and was completed in April 2008.

This map was produced with the intent that it be used for the Lower Lockhart River mapping project at the scale of 1:35 000.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Photo 40 E. Albida *woodland vegetation on elevated dunes*

Photo 41 *Degraded fringing vegetation of the broad valley floor*

Photo 42 *Ongoing impact of rising water tables and salinity on fringing vegetation*

Photo 43 *Degraded margin of the main drainage channel*

Photo 44 *Salinity effects on vegetation and signage within the reserve*

Photo 45 *Restriction of samphire community colonisation by a road*

Condition assessment

The vegetation condition assessment for this site is shown below.

Table 18 LLR11 — Wandjagill Nature Reserve vegetation condition assessment

Vegetation condition	Percentage of site
Pristine	0
Excellent	5
Very good	10
Good	10
Degraded	25
Completely degraded	50

The condition of the reserve was assessed at two locations. The first was by an east-west walking transect located approximately 0.5 km south of Foss Road that traversed lake margins, elevated dunes and the broad scalded main channel. Woodland that occurs on the elevated dunes is in healthy condition and has moderately diverse vegetation communities. In contrast, the melaleuca-dominant vegetation of the lakes and valley floor is substantially affected by rising groundwater and salinity. This is an extensive and ongoing process (photos 41 and 42).

The second assessment was by a north-south walking transect extending approximately 1 km upstream from the Old Beverley Road and including the broad valley floor of the drainage channel. Woodland vegetation is dominated by melaleuca species. Dune formation is generally subdued and almost all vegetation is severely affected by rising groundwater and salinity with approximately 90 per cent of the vegetation in this area scored as completely degraded and the remaining 10 per cent as degraded. The processes are extensive and ongoing (photo 44).

Salt-affected vegetation is being colonised by samphire (*Halosarcia spp*.) in the valley floor. It is interesting to note that the Old Beverley Road is restricting colonisation (photo 45).

Management considerations

Wandjagill Nature Reserve is an extensive area that has substantial and ongoing impacts from the rising watertable and salinity. These are regional groundwater processes and would be difficult and costly to control at a scale that would recover the site. Any actions that will add to these processes of site degradation should be avoided.

Other reserve management activities, including maintaining stock-proof boundary fencing and weed control, should be applied to this reserve.

5 Overall assessment of the study area

The survey of the lower Lockhart River was done by assessing 11 sample sites. The site locations are spaced at relatively even intervals over the 86 km river length. Five sites are on privately owned land, five are public reserves and one is unallocated Crown land. Sites LLR09 and LLR10 are on private landholdings that have previously been cleared for agriculture.

This section provides an overall assessment of the lower Lockhart River system, based on the detailed observations made at the 11 sampling sites.

5.1 Landscape and valley floor description

The catchment of the lower Lockhart River system is typical of the zone of ancient drainage landscapes of the Avon River basin. Landscape relief is subdued with occasional bedrock exposures higher than 300 m AHD. On the catchment divide these sometimes exceed 350 m AHD in elevation. The width of the catchment increases from approximately 20 km, near the confluence with the Yilgarn River, to 40 km midway and well over 100 km upstream (where the catchment divide expands to include the Wakeman Creek catchment). Further upstream, the Camm River and Pingrup River are significant tributaries with extensive catchment areas.

The valley floor varies in width from 0.5 km (Site LLR02) to over 3 km. The width, shape, coarse meander pattern and orientation of the valley floor are substantially determined by geological formation and ancient drainage processes.

The gradient of the valley floor decreases by 23 metres over the 86 km length of the study area (average gradient of 0.027 per cent). Figure 2 shows that there is some variation in valley floor gradient. There is a relatively steep section between about 70 to 75 km upstream from the start of the study area. This is where the river changes direction from northerly to north-westerly. The two most eroded sites (LLR09 and LLR10) are located near this relatively steep section. Increased streamflow velocity due to the higher gradient may be a partial cause of the high erosion at these sites.

The valley floor of the lower Lockhart River is characterised by three landscape units which are described in Section 2.5. The *Baandee* unit includes the drainage channel, lakes and interfluvial dunes. The *Merredin* unit contains the alluvial and colluvial soils of the floodplain. The *Belka* unit is the occasional occurrence of deep leaching sand lenses (as occurs at sites LLR02 and LLR07). While not commonly occurring in the valley floor, these sand lenses are of relatively high conservation value because they discharge relatively fresh water to the river system and, where they are uncleared, are areas of high biological diversity.

The *Baandee* unit varies considerably in the study area. Where the valley floor narrows (for instance at site LLR02) the unit is dominated by stream channels with

no lakes and a small number of isolated interfluvial dunes. Where the valley floor broadens, the elements of this unit become more complex. Sites LLR01, LLR04 and LLR07 are characterised by a high level of drainage pattern indentation so that the interfluvial dunes are relatively small and separated. These sites are capable of retaining large quantities of water during high flows. The indented drainage pattern may occupy more than 70 per cent of the valley floor (for example at site LLR04).

Lakes are dominant in some sections of the study area (sites LLR03, LLR05 and LLR06). These provide flood retention capacity if empty at the times of high streamflow. Where lakes characterise the valley floor, the interfluvial dunes are greater in area and are well interconnected.

The interfluvial dunes vary in elevation. Some rise more than 2 m above the valley floor (for example at site LLR05) while others are of low relief (for example at the southern end of site LLR11). Dune height is significant in relation to salinity risk. Woodland vegetation on the more elevated dunes is in better condition and is less threatened than that of the lower dunes.

Tributaries are broad and of low gradient near their confluence with the lower Lockhart River. Fifteen major tributaries were identified (Map 2). There are many smaller, localised tributaries that also influence the valley floor. Groundwater processes may have greater influence on the condition of the lower Lockhart River than surface water processes. Changes in catchment hydrology that have occurred since clearing native vegetation for agriculture are causing local and regional groundwater aquifers to rise. The impact of groundwater rise and associated salinity is greatest in the valley floor and at the confluence of ancient drainage systems. Paleo-drainage channels are likely to occur below most of the major tributaries.

Appendix 5 provides landscape and valley floor information for each of the survey sites.

5.2 Vegetation description and condition

The Beard vegetation associations identified at each survey sites are shown in Table A.5.2 in Appendix 5. Much of the groundcover is provided by shrubs. These are predominantly halophytes (samphire, saltbush and bluebush). Woodland tree cover varies considerably from none (site LLR09) to a high level (most of site LLR01). Rushes or sedges were identified at six of the sites. There is a high proportion of bare ground at all sites, with some up to, or exceeding, 70 per cent.

The descriptions and conservation status of Beard vegetation associations for the study area are given in Table 5. Two vegetation associations were identified as depleted (vegetation association 141 occurring at four sites and vegetation association 951 occurring at seven sites) and one was identified as vulnerable (vegetation association 1053 occurring at two sites) (Department of Natural Resources and Environment 2002.

The dominant native vegetation species identified at each site during the survey are listed in Table A.5.4 in Appendix 5. This list is derived from one site visit with a reconnaissance scale survey based on selected walking transects at each site. It is not a comprehensive botanical listing for the lower Lockhart River but does provide indicative information about the occurrence of vegetation species.

The most commonly occurring species are samphire (*Halosarcia species*), Australian boxthorn (*Lycium australe*), saltbush (*Atriplex* species) and pigface (*Carpobrotus* species). Two species are listed by the Department of Environment and Conservation as declared rare flora at site LLR01.

The condition of natural vegetation is shown for each survey site in Table A.5.6 in Appendix 5. Two sites (LLR06 and LLR07) have small areas considered to be in near pristine condition. These areas have retained natural vegetation community structure and composition. The areas are not obviously affected by rising groundwater or salinity and introduced weeds were not observed. Other sites have up to 20 per cent considered to be in excellent condition (sites LLR05, LLR07 and LLR08). Five sites have 30 per cent or more that is in very good, excellent or near pristine condition.

Disturbance factors recorded for each of the survey sites are shown in Table A.5.7 in Appendix 5. The most significant for all sites is the impact of salinity and waterlogging or other changes in groundwater processes. Other than the previous clearing of natural vegetation for agriculture at two sites, the impact of salinity is overwhelmingly the most significant disturbance factor in the lower Lockhart River study area. Erosion is significant at two sites (LLR09 and LLR10). Rubbish deposition at several sites is unsightly but is not considered to be a major disturbance factor. The potential for pathogenic plant disease at one site (LLR07) does exist.

Some sites are substantially degraded by rising groundwater, salinity and a change in the hydroperiod of lakes. This occurs more extensively at the upstream sites. Survey sites LLR09, LLR10 and LLR11 have 50 per cent or more considered as being completely degraded. Two of these sites have more than 90 per cent identified as completely degraded. The fourth site (LLR11) has recent and ongoing processes of degradation and the proportion that is completely degraded is expected to increase. Two of the degraded sites (LLR09 and LLR10) have been extensively cleared for agricultural use and have large areas of soil erosion.

Woodland vegetation on low (less than 1.0 m above the valley floor) interfluvial dunes is threatened by rising groundwater and salinity. Where the dunes are higher (more than 1.5 m above the valley floor), the woodland vegetation condition is considered to be healthy and not at risk. The white-leaved mallee (*Eucalyptus albida*) and *Eucalyptus mydriadema* are generally not threatened where they occur on dunes. Tree species adjacent to lakes or fringing drainage channels are affected by, or at risk from, rising groundwater and salinity. Kondinin blackbutt (*Eucalyptus kondininensis*) and salmon gum (*Eucalyptus salmonophloea*) are significantly threatened where they occur. The two sites with the greatest threat to woodland vegetation condition are LLR08 and LLR11.

The most significant effect of rising groundwater and salinity is on melaleuca-dominant vegetation. *M. scalena*[2] and *M. lateriflora* are commonly occurring species that have been extensively affected. All sites have areas with melaleuca stumps or stags. These vegetation types grew on the fringes of drainage lines and lakes, and occasionally were dominant within lakes. Most of this is now dead and is being replaced by samphire.

5.3 Introduced weeds

The recorded occurrence of introduced weeds at each survey site is listed in Table A.5.8 in Appendix 5. Other than for the site with highest agricultural use (LLR10), the range and abundance of weeds is relatively low. Most are annual agricultural weeds that have invaded from adjacent farms. The weed burden that exists is not considered to be a threat to existing vegetation or a major cause of low regeneration of natural vegetation.

It is significant to note that neither bridal creeper (*Asparagus asparagoides*) nor sharp rush (*Juncus acutus*) is established in the lower Lockhart River.

5.4 Native and exotic fauna

Bird species were recorded at each of the sites during the field survey. The list for each site is provided in Appendix 5, Table 29. The results of the bird surveys vary due to many factors including time of day and wind conditions, so the records based on a single visit to each site do not provide a comprehensive assessment of the avifauna. The number of species recorded from the site visits, with approximately equal time being spent at each site, does provide a relative index of the habitat quality at the site. Three sites have more than 10 species recorded (LLR03, LLR04 and LLR06). The three most degraded sites had the least species recorded.

Sites with higher vegetation structural diversity and species diversity provide higher quality habitat for native fauna. The identified threatening processes (especially high water tables and associated salinity) are reducing these desirable characteristics of habitat diversity. This is broadly indicated by the observations of bird species at each site during this assessment.

Other terrestrial vertebrates at survey sites were the western grey kangaroo (*Macropus fuliginosis*) recorded at eight sites and echidna (*Tachyglossus aculeatus*) whose diggings were recorded at two sites. Introduced pest species recorded were rabbits, foxes and feral cats.

[2] This species was originally identified as *Melaleuca uncinata*, a commonly occurring paperbark in the Avon River basin. A taxonomic review of the broombush complex (Craven et al., 2004) has identified 11 species from the original *M. uncinata*. The species recorded in the field are attributed as the revised *M. scalena*.

5.5 Water quality and aquatic biota

The conductivity, acidity and temperature of water were taken from one or more locations for each survey site (with the exception of LLR08 that had no surface water at the time of the survey). The samples were taken from streamflow where this occurred. The recorded information is shown in Appendix 5, Table 30. Only sites LLR02 and LLR03 had streamflow which was measured near the Kwolyn Hill gauging station. Other than for site LLR06, the salinity of surface water at all sites exceeds that of seawater (approximately 35 000 mg/L). Some of the samples are from lakes that have increased salt concentration due to evaporation. The salinity of surface water is generally higher than that of annual average streamflow (average salinity measured at the Kwolyn Hill gauging station is 33 900 mg/L). Most surface water present at the time of the survey was considered to be predominately from groundwater discharge.

The pH of samples ranged from 3.98 (slightly acidic) to 6.7 (neutral). Previous snapshot sampling undertaken by the Department of Water shows that the pH of the river was neutral (range 6.1 to 7.7) during 2006. The pH of water samples will vary considerably between sites and over time. The pH of streamflow measured at the Kwolyn Hill gauging station ranges from 3.2 (acidic) to 8.7 (alkaline) as shown in Appendix 4.

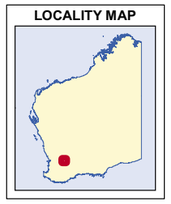
Observations of aquatic biota during site surveys were recorded, including:

Daphnia species	Water fleas
Oligochaeta	Aquatic worm
Malacostraca	Aquatic shrimp

A fibrous filamentous macrophyte occurred extensively in one wetland at site LLR05 (Shackleton Lakes).

Saline wetlands have a distinctive aquatic flora and fauna (Davis 2004). While the species richness of these ecosystems is less than for freshwater wetlands, and is reduced by increasing salinity, they do remain as productive systems (Strehlow et al, 2005).

Map 14A
Salinity risk for the lower Lockhart River: Caroline Gap to Shackleton Lakes



LEGEND

Road network
- Main road
- Local road
- Track

River network
- Major watercourse
- Minor watercourse

Boundaries
- Lockhart River catchment
- Nature reserve

Salinity risk
- Areas at risk of becoming saline
- Recent saline areas (1995-1998)
- Older saline areas (1989-1991)
- Year 2000 bush mask
- Landsat TM band 5 background
- Water

Other
- Town
- Stream gauging site
- Spot height

N

0 1 2 3 4 5 6

Kilometres

Datum and Projection Information

Vertical Datum: Australian Height Datum (AHD)
Horizontal Datum: Geocentric Datum of Australia (GDA 94)
Projection: Unprojected

Project Information

Requested by: Kate Gole
Map Author: Tom Lee\Aidan Belouardi
Task ID: 6897
Filepath: \\Pentecost\gis_projects\gisprojects\Project\B_series\B4148\0002\mxd\Map14A_CarolineGap_ShackeltonLk.mxd
Date: June 2008

SOURCES

The Department of Water acknowledges the following datasets and their custodians in the production of this map:

Towns – Landgate – August 2004
Road centrelines – Landgate – May 2004
Hydrography, heirachy – DoW – April 2005
Hydrography, linear – DoW – February 2004
Hydrographic catchments – DoW – March 2005
Local government Authorities – Landgate – July 2004
LM_salinitymap_00_25m_ll.ecw – Landgate – 2000

Department of Water
Government of Western Australia

This map is a product of the Department of Water Spatial Analysis Section and was completed in June 2008.

This map was produced with the intent that it be used at the scale of 1:100 000 when printed at A3.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Map 14B
Salinity risk for the lower Lockhart River: Shackleton Lakes to Old Beverley Rd

LEGEND

Road network
- Main road
- Local road
- Track

River network
- Major watercourse
- Minor watercourse

Boundaries
- Lockhart River catchment
- Nature reserve
- Local government authority

Salinity risk
- Areas at risk of becoming saline
- Recent saline areas (1995-1998)
- Older saline areas (1989-1991)
- Year 2000 bush mask
- Landsat TM band 5 background
- Water

Other
- Town
- Spot height

N

0 1 2 3 4

Kilometres

Datum and Projection Information

Vertical Datum: Australian Height Datum (AHD)
Horizontal Datum: Geocentric Datum of Australia (GDA 94)
Projection: Unprojected

Project Information

Requested by: Kate Gole
Map Author: Tom Lee\Aidan Belouardi
Task ID: 6897
Filepath: \\Pentecost\gis_projects\gisprojects\Project\B_series\B4148\0002\mxd\Map14B_Lockwood_OldBeverlyrd.mxd
Date: June 2008

SOURCES

The Department of Water acknowledges the following datasets and their custodians in the production of this map:

Towns – Landgate – August 2004
Road centrelines – Landgate – May 2004
Hydrography, heirachy – DoW – April 2005
Hydrography, linear – DoW – February 2004
Hydrographic catchments – DoW – March 2005
Local government authorities – Landgate – July 2004
LM_salinitymap_00_25m_ll.ecw – Landgate – 2000

Department of Water
Government of Western Australia

This map is a product of the Department of Water Spatial Analysis Section and was completed in June 2008.

This map was produced with the intent that it be used at the scale of 1:115 000 when printed at A3.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

6 Conclusions

6.1 Waterway condition

The lower Lockhart River is a broad, subdued drainage system that is characteristic of the zone of ancient drainage. While adjacent landscapes have been extensively cleared of natural vegetation, the valley floor has substantial areas not disturbed by clearing.

The channel of the lower Lockhart River is poorly defined, discontinuous and frequently alters in form. Where a distinct channel does occur (for example at sites LLR02 and LLR10), it is broad and shallow. More commonly, the main stream channel meanders through complex systems of salt lakes and drainage indentations. In some locations, such as LLR01 and LLR04, the drainage pattern is highly scalloped and occupies more than 50 per cent of the area of the valley floor. The channel at site LLR05 (Shackleton Lakes) is absorbed in a series of well-defined interconnected lakes. This also occurs but through less defined lakes at site LLR06 (Mokami Nature Reserve).

Two sites have a high level of channel erosion (LLR09 and LLR10). Both of these sites have previously been extensively cleared for agriculture, have been grazed and occur in a location where the stream channel gradient is higher than the average for the study area. Channel erosion is in the form of surface soil dispersal and streamflow sediment mobilisation, causing the channel to broaden. Exposed root systems within the channel of the two eroded sites indicate that channel depth has increased by 20 to 30 cm. There was no evidence of gully-head erosion within the channel.

There was also no evidence of significant sedimentation (such as sand slugs) within the channels or salt lakes of the survey sites. However, channel erosion is continuing to occur, therefore sediment must be being deposited further downstream. Major flood events mobilise unconsolidated sediments within the valley floor. The relatively recent flood in January 2000 probably transported sediment downstream and is the reason for little being observed during this survey.

The floodplain of the lower Lockhart River is not clearly defined by river terracing or change in slope of adjacent landscapes. Floodwaters are probably largely contained within the drainage and natural retention capacity of the valley floor. Where they do occur, floodplain soils (the *Merredin* soil landscape unit) have been extensively cleared for agriculture (for example, site LLR10) and are at high risk from rising groundwater, waterlogging and salinity. Maps 14A and 14B shows the salinity risk to the broad valley floor and tributaries. These areas are derived from the Land Monitor Project based on calibrated digital elevation models and Landsat imagery. Areas affected by salinity are shown in orange and red and those at risk of being affected by salinity in purple.

6.2 Riparian vegetation condition

The distribution of natural vegetation within the valley floor is determined substantially by riverine landform. The salt-scalded drainage lines, which in places occupy more than 50 per cent of the valley floor area, are generally bare. Samphire has colonised some, but not all, drainage beds. Melaleuca-dominated vegetation communities were established in some of the areas that are now bare.

The vegetation fringing lakes and drainage lines has altered significantly due to rising groundwater and salinity. *Melaleuca* species were commonly in dense stands on the margins of water bodies. Almost universally, only their stags now remain. The processes of ecological transition to samphire-dominant fringing vegetation communities are continuing. Melaleucas are regenerating on two lakes recorded during the survey (in sites LLR05 and LLR11) probably in response to fresh water inundation following the January 2000 flood. This regeneration is not expected to continue nor the existing seedlings to survive once root systems reach the saline groundwater. The processes of transition to halophytic fringing vegetation are considered to be irreversible.

Natural vegetation occurring on low profile dunes is substantially affected or further threatened by rising groundwater and salinity. The vegetation communities most at risk are those dominated by *Melaleuca scalena* and *Melaleuca lateriflora*. In some locations, these have been completely replaced by samphire and other halophytes leaving only stags of the former vegetation communities. These processes are continuing to occur extensively, especially within Wandjagill Nature Reserve (site LLR11).

Woodland communities on higher profile dunes are significantly less threatened. Many are in healthy condition, have relatively high species diversity and the threats of salinity and weed invasion are generally low. Small areas of sandplain vegetation that occur within the valley floor area also generally healthy and have high species diversity.

The size of healthy woodland patches varies considerably. At some survey sites (such as LLR01) there are areas of woodland that are small and isolated although in good condition. There are larger healthy patches in Kwolyin Nature Reserve (site LLR03) and Shackleton Lakes reserve (site LLR05). There are also large patches of woodland vegetation on private land (site LLR08), although this is considered to be at significant risk to rising groundwater and salinity.

There are five public reserves for nature conservation and one for recreation that occur in the valley floor within the study area. These are not subject to grazing pressures. Other areas of privately-owned land, such as the valley floor of site LLR01, also have high conservation value. The adjacent landscape however is substantially fragmented by clearing for agriculture and there are very few significant public reserves or areas of private remnant vegetation that adjoin the lower Lockhart River valley floor. Those that do occur are:

- Glenluce Nature Reserve in the Yilgarn River valley floor
- private remnant vegetation on a rocky outcrop west of the Shackleton Lakes (site LLR05)
- Crown Reserve 38522 adjacent to Yarding Nature Reserve (site LLR07)
- Yilgerin Nature Reserve south of site LLR10
- private remnant vegetation north-west of Wandjagill Nature Reserve.

The highly fragmented distribution of the remaining natural vegetation is shown in maps 14A and 14B. The maps also show that there is very little connection between valley floor vegetation and remnants higher in the landscape. There is however significant connection between the high value conservation areas that remain in the valley floor.

The importance of the lower Lockhart River waterway for conservation value connection requires higher recognition. Public and private land should be managed in a consistent way to sustain or enhance the value of riparian zone connection.

6.3 Threatening processes

Salinity associated with rising groundwater processes is overwhelmingly the most significant threatening process occurring within the valley floor of the lower Lockhart River system. Substantial areas are currently affected and the potential for further degradation is substantial.

The average annual salinity measured at Kwolyn Hill gauging station is over 30 000 mg/L. The Lockhart River is the most saline river system measured in Western Australia (Department of Environment 2005).

Increasing salinity is known to reduce the species diversity and productivity of wetlands (Strehlow et al. 2005). The substantial increase in stream salinity has undoubtedly affected the ecological functions in the lower Lockhart River floodplain.

The potential for salinity to seriously reduce biodiversity values in the Wheatbelt of Western Australia is well recognised from systematic biological surveys (Keighery et al. 2004). From these surveys, an estimated 450 species are considered to be at risk of extinction. Most of these occur within valley floors.

Clearing the floodplain, and in some situations most of the valley floor vegetation, has caused significant loss of biodiveristy. There is unlikely to be any further clearing of natural vegetation within the valley floor. Natural regeneration of cleared areas is occurring with halophytes as the primary colonisers.

Grazing pressure needs to be reduced to encourage the regeneration of native species.

Erosion is occurring in some sections of the main flow channels, forming wider

stream beds. While this is a source of off-site sedimentation, it is not a significant threat to hydrological and ecological values of the waterway.

Invasive weeds were recorded at all survey sites, although not at levels sufficient to significantly affect the regenerative capacity of the river system.

In one location (within site LLR07), there is evidence of vegetative dieback, probably due to a soil-borne pathogen. The risk may be extended by vehicle movement through the affected area.

7 Recommendations

The following recommendations have been based on the results of the survey. Recommendations have been made for additional monitoring and for river management actions.

7.1 Ongoing monitoring

The assessment of the lower Lockhart River was undertaken at 11 representative sites with reconnaissance-scale survey methods. Although this provides sufficient information to make a general assessment of resource condition, it is not detailed enough to develop plans for managing specific taxonomic groups. There is not a lot known about the aquatic biota of streams, lakes and permanent discharge sites.

Although some baseline information is available from the systematic biological surveys carried out by the Department of Environment and Conservation (previously the Department of Conservation and Land Management) in 2004, there is a requirement for further surveys and ongoing monitoring of aquatic fauna in wetlands of the lower Lockhart River.

Recommendation 1

Undertake a detailed survey of aquatic biota in representative lakes or other wetlands of the lower Lockhart River over a period of two to three years to develop an understanding of seasonal variation.

Recommendation 2

Carry out long-term monitoring of aquatic biota at the representative wetland sites at intervals of five years.

Recommendation 3

Arrange long-term monitoring of the photo points at intervals of five years. Twelve photo points were established during the assessment of the lower Lockhart River (see Appendix 7). These will provide a basis for long-term visual monitoring of changes in vegetation type and condition.

7.2 Management actions

The processes of salinisation, erosion and sedimentation occurring within the lower Lockhart River are difficult to manage at specific locations within the valley floor. Catchment-scale management, including sustainable agricultural practices, road maintenance and reserves management, will be needed to effectively address these issues in the longer term.

There is a need for guidelines for catchment scale management of tributaries to improve the resource condition of the river environment. The primary focus needs to be on surface water management to minimise the impact of high flow events on the river environment.

Recommendation 4

Prepare guidelines for surface water management to reduce the key threatening processes of salinisation, erosion and sedimentation, that will be suitable for adoption by landowners and other land managers.

Recommendation 5

Voluntary management agreements for ongoing grazing management are recommended, including ensuring that there is adequate fencing and reducing stocking rates. The less the grazing pressure, the better the regeneration of natural vegetation. Valley floor ecosystems that are well vegetated and effectively regenerating are better able to reduce erosion, stabilise sediments and minimise groundwater rise.

Recommendation 6

Initiate a local community engagement program for the lower Lockhart River. This should aim to increase community understanding of the threats to the river system and the social values associated with the river, and hence increase the acceptance and adoption of on-site and off-site actions that improve the river environment.

There is already some local interest in the Lockhart River, but this is ad hoc and could be significantly increased by a formal program.

Appendix 1 Survey site information

Table A.1.1 Site names, landholders, site areas and coordinates

Site no.	Site name	Landholder	Approximate site area*	Site coordinates**
LLR01	Cole's	Alan and Eva Cole	822 ha	565959, 6480540
LLR02	UCL	Unallocated Crown land	96 ha	572132, 6475505
LLR03	Kwolyin Nature Reserve	CR30969 – DEC	341 ha	574556, 6473537
LLR04	Venemore's	John Venemore	341 ha	579486, 6470248
LLR05	CR22131	Shire of Bruce Rock	370 ha	583688, 6465569
LLR06	Mokami Nature Reserve	DEC	475 ha	588412, 6464531
LLR07	Yarding Nature Reserve	CR27108 – DEC	231 ha	593114, 6467532
LLR08	Strange's	Karen Strange	469 ha	598936, 6465294
LLR09	Crook's	Stephen Crook	359 ha	604755, 6462936
LLR10	Muntz's	Jack Muntz	270 ha	608137, 6460694
LLR11	Wandjagill Nature Reserve	CR25884 – DEC	760 ha	608990, 6451533

** Sourced from cadastral information held in GIS*

***Obtained using GIS. Coordinates are given for the approximate centre of the site in eastings and northings in GDA 94 datum and are in Map zone 50*

Appendix 2 Climate information — Narembeen and Kellerberrin

Table A.2.1 Climate information

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual average	Years of data	Start year
010612 Narembeen															
Mean maximum temperature (°C)	33.8	33.0	30.1	25.7	20.8	17.4	16.6	17.5	20.4	24.9	28.2	31.9	25.0	37	1965
Mean minimum temperature (°C)	16.4	16.6	14.7	12.0	8.2	6.4	5.4	5.2	6.2	8.8	12.0	14.4	10.5	36	1965
Mean rainfall (mm)	15.9	18.4	20.3	23.0	40.3	53.4	49.6	41.8	25.4	18.6	15.2	11.7	334.4	80	1927
Highest rainfall (mm)	171.7	116.9	140.1	106.3	141.0	154.9	134.5	112.0	71.4	88.3	75.7	69.1	589.4	80	1927
Year of highest rainfall	2000	1970	1971	1974	1974	1968	1958	1992	1996	1932	1956	1951	1974	–	1927
Lowest rainfall (mm)	0.0	0.0	0.0	0.0	0.0	7.9	11.1	1.6	2.5	0.0	0.0	0.0	174.4	80	1927
Year of lowest rainfall	2005	1998	2007	1982	1990	2001	1937	1956	1939	2000	1994	1997	1972	–	1927
Mean number of days of rain	2.1	2.3	3.2	5.0	7.7	10.9	11.9	10.7	7.3	5.1	3.5	2.5	72.2	77	1927
Mean number of days of rain >= 1 mm	1.7	1.8	2.3	3.4	5.9	8.4	8.6	7.6	5.3	3.8	2.5	1.9	53.2	80	1927
Mean number of days of rain >= 10 mm	0.5	0.5	0.6	0.6	1.2	1.5	1.3	1.0	0.5	0.4	0.4	0.3	8.8	80	1927
Mean number of days of rain >= 25 mm	0.1	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.0	0.1	0.0	0.1	0.1	80	1927
010073 Kellerberrin															
Mean maximum temperature (°C)	33.9	33.3	30.2	25.6	20.7	17.5	16.4	17.5	20.7	24.6	28.8	32.1	25.1	94	1910
Mean minimum temperature (°C)	16.8	16.9	15.2	11.8	8.4	6.8	5.7	5.5	6.4	8.7	12.3	15.0	10.8	95	1910
Mean rainfall (mm)	12.8	14.4	20.8	21.6	42.6	55.0	51.9	41.4	26.0	17.7	11.6	12.8	328.5	115	1892
Highest rainfall (mm)	100.4	126.8	152.2	109.5	119.1	162.7	122.5	121.4	76.1	76.9	85.6	77.4	661.3	115	1892
Year of highest rainfall	1990	1955	1927	1966	1974	1968	1958	1992	1973	1932	1983	1995	1963	–	1892
Lowest rainfall (mm)	0.0	0.0	0.0	0.0	0.0	4.5	9.9	2.5	2.1	0.3	0.0	0.0	167.9	115	1892
Year of lowest rainfall	2005	1999	2007	1982	1948	2001	2005	1956	1914	1946	1961	1997	1994	–	1892
Mean number of days of rain	2.0	2.3	3.3	4.7	8.4	11.7	12.9	11	8.0	5.5	3.2	2.4	75.4	101	1892
Mean number of days of rain >= 1 mm	1.4	1.4	2.0	2.9	5.4	7.6	8.1	6.9	4.7	3.4	2.0	1.5	47.3	101	1894
Mean number of days of rain >= 10 mm	0.4	0.4	0.6	0.6	1.2	1.3	1.1	0.9	0.4	0.3	0.2	0.3	7.7	101	1894
Mean number of days of rain >= 25 mm	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.1	101	1894

Source: Bureau of meteorology, 2008. Data is from record start to 2007

Appendix 3 Spot heights for the lower Lockhart River floodplain

Table A.3.1 Bed profile

Distance (km)	Easting	Northing	Elevation (m AHD)	Comment
0	561687	6480080	228	Glenluce Rd
2	563537	6479761	228	
4	565253	6480102	229	
6	567116	6479944	230	
8	568759	6480416	230	
10	570579	6479466	230	Kwolyin West Rd
12	571018	6477763	232	
14	571833	6476307	231	
16	572586	6474821	233	
18	574028	6473624	233	
20	575521	6472514	235	
22	577190	6471725	234	
24	577742	6470270	234	
26	578733	6469134	235	
28	580203	6468434	236	
30	581295	6467473	235	Erikin West Rd – between points 30 and 32
32	582399	6466518	236	
34	583940	6465480	236	
36	584400	6463674	236	
38	585958	6463192	235	
40	587409	6463429	237	Erikin South Rd
42	588676	6464019	235	
44	590256	6464664	236	
46	591040	6465654	237	
48	591878	6467112	238	Ardath-Yarding Rd – between points 48 and 50
50	593351	6468300	238	
52	594986	6468021	239	
54	596165	6467102	239	Yard-Yarding Rd – between points 54 and 56
56	597428	6467251	238	
58	598654	6466052	238	Eujinyn South Rd – between points 58 and 60
60	600038	6465658	240	
62	600538	6464473	240	
64	602107	6463900	240	Bruce Rock – Corrigin Rd between points 64 and 66
66	603802	6463458	241	
68	605547	6463015	242	

Distance (km)	**Easting**	**Northing**	**Elevation** (m AHD)	**Comment**
70	608035	6460879	244	
72	608730	6459325	247	
74	609301	6457853	248	
76	609949	6456498	248	
78	609769	6454931	249	
80	609267	6453501	250	Foss Rd
82	609548	6451753	250	
84	608945	6450206	251	
86	608162	6449365	251	Old Beverley Rd

Appendix 4 Water quality summary for Kwolyn Hill gauging station

Table A.4.1 Water quality summary for Kwolyn Hill gauging station

Water quality parameter	Unit	Minimum	Maximum	Average	Number of samples
Ag (tot)	mg/L	0.001	0.001	0.001	1
Ag (unfilt undig)	mg/L	0.001	0.001	0.001	1
Al (sol)	mg/L	21.000	56.000	38.500	2
Al (tot)	mg/L	0.200	56.000	18.833	3
Al (unfilt undig)	mg/L	22.000	22.000	22.000	1
Alkalinity (CO3–CO3)	mg/L	0.000	2.000	0.375	16
Alkalinity (CO3–CaCO3)	mg/L	1.000	1.000	1.000	2
Alkalinity (HCO3–CaCO3)	mg/L	1.000	22.000	11.500	2
Alkalinity (HCO3–HCO3)	mg/L	0.000	66.000	31.750	16
Alkalinity (tot) (CaCO3)	mg/L	0.000	192.000	29.195	22
As (tot)	mg/L	0.005	0.005	0.005	1
As (unfilt undig)	mg/L	0.005	0.005	0.005	1
B (tot)	mg/L	4.700	4.700	4.700	1
B (unfilt undig)	mg/L	1.600	1.600	1.600	1
Ba (tot)	mg/L	0.120	0.120	0.120	1
Ba (unfilt undig)	mg/L	0.093	0.093	0.093	1
Br (sol)	mg/L	140.000	140.000	140.000	1
Br (unfilt undig)	mg/L	89.000	89.000	89.000	1
C (sol org) {DOC}	mg/L	5.450	15.000	10.218	5
Ca (sol)	mg/L	23.000	1 700.0	598.619	21
Ca (tot)	mg/L	1 800.000	1 800.0	1 800.0	1
Ca (unfilt undig)	mg/L	1 100.0	1 100.0	1 100.000	1
Cd (sol)	mg/L	0.000	0.000	0.000	2
Cd (tot)	mg/L	0.002	0.002	0.002	1
Cl (sol)	mg/L	780.000	130 000.0	25 100.8	54
Colour (TCU)	TCU	3.000	100.000	31.000	8
Colour (hazen)	Hu	17.000	45.000	29.400	5
Colour (true)	Hu	5.000	310.000	13.763	190
Conductivity comp 25 °C (lab)	µS/m	190 000.0	13 000 000.0	6 792 857.1	7
Conductivity uncomp (in situ)	µS/m	117 600.0	13 700 000.0	5 746 773.0	37
Conductivity uncomp (lab)	µS/m	160 000.0	18 700 000.0	4 829 357.0	232
Cr (tot)	mg/L	0.007	0.007	0.007	1
Cr (unfilt undig)	mg/L	0.016	0.016	0.016	1
Cs (unfilt undig)	mg/L	0.003	0.003	0.003	1
Cu (tot)	mg/L	0.005	0.005	0.005	1

Water quality parameter	Unit	Minimum	Maximum	Average	Number of samples
Cu (unfilt undig)	mg/L	0.043	0.043	0.043	1
Discharge rate	m3/s	0.213	0.213	0.213	1
F (sol)	mg/L	0.800	1.400	1.100	2
Fe (sol)	mg/L	0.800	1.600	1.200	2
Fe (tot)	mg/L	0.035	2.300	0.603	14
Fe (unfilt undig)	mg/L	0.800	0.800	0.800	1
Hardness (tot) (CaCO3) {Ca+Mg}	mg/L	1 145.837	41 030.0	8 150.020	21
Hg (tot)	mg/L	0.000	0.000	0.000	1
Hg (unfilt undig)	mg/L	0.001	0.001	0.001	1
K (sol)	mg/L	12.000	420.000	207.333	3
K (tot)	mg/L	28.000	655.000	135.794	18
Mg (sol)	mg/L	49.000	9 060.0	1 789.0	21
Mn (sol)	mg/L	2.600	5.900	4.250	2
Mn (tot)	mg/L	0.010	5.900	1.072	14
Mn (unfilt undig)	mg/L	3.000	3.000	3.000	1
Mo (tot)	mg/L	0.005	0.005	0.005	1
Mo (unfilt undig)	mg/L	0.001	0.001	0.001	1
N (sum sol org) {DON}	mg/L	0.210	2.600	1.753	4
N (sum sol ox) {Nox–N, TON}	mg/L	0.030	1.000	0.327	16
N (tot kjel) {TKN}	mg/L	0.207	4.100	2.229	13
N (tot) {TN, pTN}	mg/L	0.240	4.500	2.556	31
NH3–N/NH4–N (sol)	mg/L	0.330	2.800	1.419	7
NO2–N (sol)	mg/L	0.005	0.010	0.008	2
NO3 (sol)	mg/L	1.000	11.000	2.000	16
NO3–N (sol)	mg/L	3.000	3.000	3.000	1
Na (sol)	mg/L	430.000	67 500.0	13 785.2	21
Ni (sol)	mg/L	0.056	0.056	0.056	1
Ni (tot)	mg/L	0.064	0.064	0.064	1
Ni (unfilt undig)	mg/L	0.081	0.081	0.081	1
O – DO	mg/L	4.350	9.700	7.987	4
O – DO %	%	47.200	96.300	82.456	9
O – DO (in situ)	mg/L	3.170	12.200	7.825	16
P (tot) {TP, pTP}	mg/L	0.005	0.823	0.089	32
PO4-P (sol react) {SRP, FRP}	mg/L	0.012	0.050	0.023	9
Pb (sol)	mg/L	0.091	0.091	0.091	1
Pb (tot)	mg/L	0.270	0.270	0.270	1
Pb (unfilt undig)	mg/L	0.085	0.085	0.085	1
S2- (sol)	mg/L	474.000	579.0	526.500	2
SO4 (sol)	mg/L	89.000	5 200.0	2 929.7	3
SO4 (tot)	mg/L	391.000	7 140.0	2 364.3	16
Sample depth (SLE)	m	10.250	10.250	10.250	1

Water quality parameter	Unit	Minimum	Maximum	Average	Number of samples
Se (tot)	mg/L	0.005	0.005	0.005	1
SiO2 (sol react)	mg/L	1.000	77.000	11.758	19
SiO2–Si (sol react)	mg/L	3.300	52.000	27.650	2
Suspended solids (EDI)	mg/L	30.760	30.760	30.760	1
Suspended solids (gulp)	mg/L	10.100	10.100	10.100	1
Suspended solids <63µ (gulp)	mg/L	19.439	350.000	115.820	4
TD salts (sum of ions)	mg/L	6 415.0	215 920.0	44 621.3	16
TD solids (calc @180 °C by cond)	mg/L	16 442.0	81 714.0	53 398.6	3
TD solids (evap @180 °C)	mg/L	68 000.0	101 000.0	84 500.0	2
TSS	mg/L	5.000	410.000	42.500	18
Th (unfilt undig)	mg/L	0.001	0.001	0.001	1
Turbidity	NTU	0.300	330.000	19.197	189
Turbidity (JCU)	JTU	25.000	25.000	25.000	3
U (tot)	mg/L	0.016	0.016	0.016	1
U (unfilt undig)	mg/L	0.021	0.021	0.021	1
V (tot)	mg/L	0.005	0.005	0.005	1
V (unfilt undig)	mg/L	5.000	5.000	5.000	1
Water level (SLE)	m	9.854	11.460	10.303	196
Water temperature (in situ)	°C	3.900	34.400	15.866	205
Water temperature (test)	°C	16.000	30.300	24.142	232
Zn (sol)	mg/L	0.058	0.058	0.058	1
Zn (tot)	mg/L	0.120	0.120	0.120	1
Zn (unfilt undig)	mg/L	0.066	0.066	0.066	1
pH		3.200	8.700	5.895	144
pH (in situ)		4.500	8.600	6.715	13

Appendix 5 Detailed survey site information

Table A.5.1 Survey site landscape and valley floor information

	LLR01	LLR02	LLR03	LLR04	LLR05	LLR06	LLR07	LLR08	LLR09	LLR10	LLR11
Landscape position											
Valley floor	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Valley slope		✓	✓								
Uplands											
Rocky outcrop											
Valley floor features											
Natural features											
Salt lakes (playas)	✓		✓	✓	✓	✓	✓	✓	✓		✓
Permanent water		✓	✓		✓						✓
Seasonally wet	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Braided channel	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Discontinuous									✓ (now well defined)		✓
Continuous	✓	✓	✓	✓	✓	✓	✓	✓		✓ (with alternative floodways)	✓
Lunettes (dunes)	✓	✓	✓	✓	✓	✓	✓	✓			✓
Tributary	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Constructed features											
Drain								✓	✓		✓
Dam											
Other	fences	road crossing	road crossing, gauging station		track	road crossing, water pipe, communications cable			road		

Table A.5.2 Vegetation associations and canopy cover at survey sites

Site code	Beard vegetation association numbers		Canopy cover %							
			Trees	Mallee	Shrubs	Grasses	Herbs	Rushes and sedges	Litter	Bare ground
LLR01	141, 951, 1023, 1053	Transect A[1]	2–10		70–100		2–10			30–70
		Transect B	20–30		<2		2–10			30–70
		Transect C	30–70		20–30		2–10			70–100
LLR02	8, 125, 141, 631		2–10			<2				20–30
LLR03	125, 141, 951	Reserve[2]	30–70		30–70	20–30	2–10		2–10	20–30
		Valley floor	2–10	2–10	2–10		20–30			30–70
LLR04	125, 951			2–10	30–70		2–10	<1		30–70
LLR05	125, 141, 951		2–10	2–10	20–30	<2	30–70	<2	2–10	30–70
LLR06	125, 951, 1023		20–30	2–10	30–70	2–10	20–30	<2	2–10	20–30
LLR07	125, 951		2–10	2–10	30–70	2–10	20–30	2–10	2–10	20–30
LLR08	125, 951, 1023		2–10	2–10	30–70	<2	20–30	<2	2–10	20–30
LLR09	125, 1053				2–10	<2	70–100		<2	20–30
LLR10	125, 1053		<2		30–70	70–100			<2	20–30
LLR11	125, 951, 1023		2–10	2–10	30–70	<2	30–70	<2	2–10	20–30

[1]*Three survey transects were undertaken at survey site LLR01.*

[2]*Two surveys were undertaken for survey site LLR03, one in the reserve adjacent to the valley floor and one within the valley floor.*

Table A.5.3 Descriptions of the Beard vegetation associations

Beard vegetation association	Description
8	Medium woodland, salmon gum and gimlet
125	Bare areas, salt lakes
141	Medium woodland, York gum, salmon gum and gimlet
356	Succulent steppe with open woodland, eucalypt over saltbush
631	Succulent steppe with woodland and thicket, York gum over *Melaleuca thyoides* and samphire
694	Shrublands, scrub-heath on yellow sandplain banksia-xylomelum association in the Geraldton Sandplain and Avon Wheatbelt Region
951	Succulent steppe with sparse woodland and thicket, York gum and Kondinin blackbutt over tea-tree thicket and samphire
955	Mosaic: shrublands; Scrublands, scrub-heath (SE Avon)/ shrublands: *Allocasuarina campestris* thicket
1049	Medium woodland, wandoo, York gum, salmon gum, morrel and gimlet
1053	Shrublands, *Melaleuca uncinata* thicket with scattered York gum

Table A.5.4 Natural vegetation species at survey sites

Scientific name	Common name	LLR01	LLR02	LLR03	LLR04	LLR05	LLR06	LLR07	LLR08	LLR09	LLR10	LLR11
Acacia acuminata	Jam	✓	✓	✓	✓	✓	✓					
Acacia sp.								✓				
Acacia sp.			✓		✓		✓	✓	✓	✓		✓
Acacia ineolate subsp. ineolate								✓				
Amyema miquelii	Stalked mistletoe							✓				
Atriplex hymenotheca	Saltbush species	✓	✓	✓			✓			✓		
Atriplex paludosa				✓						✓		
Atriplex undulata	Wavy-leaf saltbush		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Austrostipa elegantissima	Feather speargrass		✓			✓	✓	✓				✓
Banksia prionotes	Acorn banksia							✓				
Caladenia flava	Cowslip orchid		✓			✓						
Callitris sp.	Cypress pine							✓				
Calytrix sp.	Starflower			✓	✓	✓		✓				
Casuarina obesa	Swamp sheoak				✓							
Carpobrotus sp.	Pigface	✓	✓	✓	✓	✓	✓	✓	✓			✓
Clematis sp.	Toothache bush							✓				
Dianella revoluta	Blueberry lily	✓		✓	✓	✓		✓	✓			
Dicksonia sp.												
Disphyma crassifolium	Rounded-leaf pigface			✓			✓					✓
Diuris longifolia	Donkey orchid			✓			✓					
Drosera sp.	Sundew											
Enchylaena tomentosa	Ruby saltbush	✓	✓	✓	✓	✓	✓			✓		✓
Eragrotis dielsii	Mallee lovegrass	✓	✓	✓	✓	✓	✓		✓	✓		✓
Eremophila sp.	Eremophila			✓		✓	✓	✓	✓			

Scientific name	Common name	LLR01	LLR02	LLR03	LLR04	LLR05	LLR06	LLR07	LLR08	LLR09	LLR10	LLR11
Eucalyptus albida	White-leaved mallee				✓	✓		✓				✓
Eucalyptus kondininensis	Kondinin blackbutt	✓		✓	✓	✓	✓		✓			✓
Eucalyptus longicornis	Red morrel		✓	✓	✓		✓		✓			✓
Eucalyptus loxophloeba l	York gum	✓	✓	✓	✓	✓				✓	✓	
Eucalyptus myriadema		✓										✓
Eucalyptus salmonophloia	Salmon gum	✓		✓			✓	✓	✓			✓
Eucalyptus salubris	Gimlet			✓			✓		✓	✓	✓	✓
Eucalyptus sargentii	Salt river gum	✓					✓					
Frankenia paucifolia	Sea heath	✓	✓	✓	✓	✓	✓					✓
Grevillea pritzelii	Black toothbrush					✓	✓	✓				
Hakea pressii	Needlebush	✓	✓	✓	✓	✓	✓	✓	✓			
Hakea recurva	Hakea standback		✓	✓								
Hakea sp.	Hakea		✓	✓	✓				✓			✓
Halosarcia doleiformis	Samphire	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Helichrysum sp.	Everlasting			✓			✓					✓
Hibbertia sp.								✓				
Jacksonia furcellata (?)	Grey stinkwood					✓		✓				
Lepidosperma costale						✓						
Lepidosperma spp. (?)								✓				✓
Lambertia spp. (?)						✓						
Lomandra effusa	Scented matrush		✓		✓		✓	✓	✓	✓		✓
Lycium australe	Australian boxthorn	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Maireana brevifolia	Small leaf bluebush		✓						✓	✓	✓	
Melaleuca lateriflora	Gorada			✓		✓	✓	✓	✓	✓		✓
Melaleuca thyoides	Salt-buster myrtle		✓					✓				
Melaleuca thymoides			✓		✓							

Scientific name	Common name	LLR01	LLR02	LLR03	LLR04	LLR05	LLR06	LLR07	LLR08	LLR09	LLR10	LLR11
Melaleuca scalena	Broom bush	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Melaleuca spp.												
Pittosporum angustifolium	Native willow	✓							✓			
Ptilotus sp.	Mulla mulla											
Rhagodia drummondii	Lake fringe rhagodia	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Santalum acuminatum	Quandong		✓	✓		✓	✓	✓	✓			✓
Scholtzia involucrata	Spiked scholtzia		✓	✓	✓	✓		✓	✓	✓		✓
Templetonia sp.						✓						
Thryptomene sp.								✓				
Thysanotus multiflorus	Fringed lily											✓
Xylomelum angustifolium	Sandplain woody pear							✓				
Unidentified species		1	1	1	2	5	5	1	2	0	0	0

Table A.5.6 Natural vegetation condition at survey sites

Condition	Percentage of site										
	LLR01	LLR02	LLR03	LLR04	LLR05	LLR06	LLR07	LLR08	LLR09	LLR10	LLR11
Revegetation										5	
Pristine						20	10				
Excellent			10	2	20	5	20	20			5
Very good	30	10		8	15	5	10	20			10
Good	40	80	20	80	65	65	10	20			10
Degraded	30	10	70	10		5	50	40	10		25
Completely degraded									90	95	50

Table A.5.7 Disturbance factors affecting natural vegetation

Disturbance factor	LLR01	LLR02	LLR03	LLR04	LLR05	LLR06	LLR07	LLR08	LLR09	LLR10	LLR11
Salinity	H	H	H	H	H	H	H	H	H	H	H
Waterlogging	M	M	M	M	M	M	M	M	H	H	M
Ponding from road crossing	L	L	L			L	L				L
Drainage					M			L	L	M	L
Clearing					L				H	H	
Fire risk	L	L	L	L	L	L	L	L	M	L	M
Weed invasion	L	L	L	L	L	L	L	L	L	H	L
Stock access	M			L				M	L	H	L
Vehicle access	L	L	L	L	M	L	M	L			L
Rubbish		H	L	L	M	M			L		L
Plant disease							M				
Erosion	L	L	L	L	L	L	L	L	H	H	L
Service corridors		L	L	L		L	L	L			
Feral animals		L	L	L	L	L			L	L	L
Recreation			L		M						
Point source discharge											

A blank cell indicates that the disturbance factor was not present at that site.

Table A.5.8 Weeds at survey sites

Scientific name	Common name	LLR01	LLR02	LLR03	LLR04	LLR05	LLR06	LLR07	LLR08	LLR09	LLR10	LLR11
Alopecurus sp.	Foxtail grass			✓								
Arctotheca calendula	Capeweed	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Avena fatua	Wild oats			✓	✓	✓	✓	✓		✓	✓	
Carthamus lanatus	Thistle									✓		
Cotula sp.	Waterbuttons	✓	✓	✓	✓	✓	✓		✓		✓	
Hordeum leporinum	Barley grass				✓	✓	✓				✓	✓
Hypochaeris radicata	Flatweed	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Lolium perenne	Rye										✓	
Lupinus cosentinii	Blue lupin			✓								
Medicago sp.	Medic										✓	
Oxalis pes-caprae	Soursob	✓		✓		✓						
Raphanus raphanistrum	Wild radish			✓		✓	✓					
Romulea rosea	Guildford grass								✓			
Bromus sp.	Brome grass	✓										
Solanum nigrum	Blackberry nightshade		✓									

Table A.5.9 Bird species at survey sites

Scientific name	Common name	LLR01	LLR02	LLR03	LLR04	LLR05	LLR06	LLR07	LLR08	LLR09	LLR10	LLR11
Acanthiza apicalis	Inland thornbill	✓		✓	✓	✓	✓	✓	✓	✓		✓
Anthus australis	Australian pipit			✓						✓	✓	
Barnardius zonarius	Western ringneck	✓	✓	✓		✓	✓		✓		✓	✓
Cacatua roseicapilla	Galah	✓	✓	✓		✓						
Cacomantis flabelliformis	Fan-tailed cuckoo			✓								
Chrysococcyx basalis	Horsfield's bronze cuckoo			✓						✓		
Colluricincla harmonica	Grey shrike-thrush			✓			✓					
Corvus coronoides	Australian raven	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Cracticus nigrogularis	Pied butcherbird			✓				✓	✓		✓	
Cuculus pallidus	Pallid cuckoo			✓					✓			
Epthianura albifrons	White-fronted chat		✓	✓	✓						✓	
Falco cenchroides	Nankeen kestrel	✓								✓		
Gymnorhina tibicen	Australian magpie			✓								
Hirundo ariel	Fairy martin		✓			✓						
Hirundo neoxena	Welcome swallow		✓	✓			✓	✓				
Lichmera indistincta	Brown honeyeater							✓				
Lichenostomus virescens	Singing honeyeater				✓						✓	
Malurus splendens	Splendid fairy wren		✓	✓						✓	✓	
Manorina flavigula	Yellow-throated miner						✓					
Melithreptus brevirostris	Brown-headed honeyeater											✓
Neophema elegans	Elegant parrot	✓		✓	✓							
Ocyphaps lophotes	Australian pigeon			✓	✓	✓	✓	✓	✓			
Pachycephala rufirentris	Rufous whistler						✓					

Scientific name	Common name	LLR01	LLR02	LLR03	LLR04	LLR05	LLR06	LLR07	LLR08	LLR09	LLR10	LLR11
Pardalotus striatus	Striated pardalote			✓								
Petroica goodenovii	Red-capped robin			✓					✓			
Petroica phoenicae	Scarlet robin			✓								
Phaps elegans	Common bronzewing			✓	✓		✓		✓			
Pomatostomus superciliosus	White-browed babbler			✓	✓		✓					
Psephotus varius	Mulga parrot				✓							✓
Rhipidura leucophrys	Willie wagtail				✓			✓	✓			
Smicrornis brevirostris	Weebill					✓	✓	✓				✓
Tadorna tadornoides	Australian shelduck	✓		✓								
Number of species		7	7	22	10	7	11	8	9	6	6	6

Table A.5.10 Water quality information at survey sites

Site number	Number of samples	pH	Salinity mg/L TDS	Temperature °C	Location
LLR01	1	6.2	43 400	18.3	Transect A
LLR02	2	5.6	62 260	15.8	Near culvert downstream from gauging station.
LLR03	2	5.6	62 260	15.8	Same sample used for LLR02 taken near gauging station
LLR04	1	5.8	57 150	17.9	Shackleton Road
LLR05	1	5.4	114 750	19.4	Eastern lake
LLR06	1	5.4	24 600	17.8	South-west corner near road
LLR07	1	6.7	71 300	18.8	North-west lake
LLR08	No water present				
LLR09	1	4.0	34 250	17.7	Eastern boundary
LLR10	1	4.0	55 500	13.2	Eastern boundary
LLR11	1	4.5	78 150	21.8	North-east lake

Appendix 6 Lower Lockhart River survey site form

General details

Recorder's name: …… Survey date: ……...

Site number: …… Site name……

Landholder: …… Contact number: ……..

Property address: ……...

Site position in landscape

❒ Valley floor
❒ Valley slope
❒ Uplands
❒ Rocky outcrop

Floodplain features

Natural features:

- ❒ Salt lakes (playas)
  - ❒ Permanent water
  - ❒ Seasonally wet
- ❒ Braided channel
  - ❒ Discontinuous
  - ❒ Continuous
- ❒ Lunettes (dunes)
- ❒ Tributary

Constructed features:

- ❒ Drain
- ❒ Dam
- ❒ Other……

Vegetation description (from Keighery, 1994)

Beard vegetation association

Number	Description
141	Medium woodland; York gum and wandoo
951	Succulent steppe with sparse woodland and thicket; York gum and Kondinin blackbutt over tea-tree thicket and samphire
954	Shrublands; thicket, jam and *Allocasuarina huegeliana*
959	Succulent steppe with sparse woodland thicket; yorrell and Kondinin blackbutt over teatree and samphire
1023	Medium woodland; York gum, wandoo and salmon gum

Vegetation structure and cover (both native and weed species)

Vegetation layer	Canopy cover class*	Dominant species**
Trees		
Mallees		
Shrubs		
Grasses		
Herbs		
Rushes and sedges		
Litter		
Bare ground		
Rock outcrop		

*Canopy cover class (where canopy cover refers to the total area under an imaginary line bounding the extremities off all plants in each layer):

Very open 2-10% Sparse 20-30% Open 30-70% Closed 70-100%

**More than 3 dominant species described as mixed

Native species list

Record number of species if all species cannot be identified by name

Regeneration ❒ Yes ❒ No Species: ……

Weed species list

Record number of species if all species cannot be identified by name

Vegetation condition (from Keighery, 1994)

Condition	Description	% of site
Pristine	No obvious signs of disturbance	
Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species	
Very good	Vegetation structure altered, obvious signs of disturbance	
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate	
Degraded	Basic vegetation structure severely impacted by disturbance. Regeneration to good condition requires intensive management	
Completely degraded	Vegetation structure no longer intact and the area is without/almost without native species	

Disturbance factors affecting vegetation condition score

Disturbance factor	Threat level		
	High	Medium	Low
Salinity			
Waterlogging			
Ponding from road crossing			
Drainage			
Clearing			
Fire risk			
Weed invasion			
Stock access			
Vehicle access			
Rubbish			
Plant disease			
Erosion			
Service corridors			
Feral animals			
Recreation			
Point source discharge			
Other			

Linkages to protected remnant vegetation (from aerial photography)

Site name	Area (ha)	Approximate distance and direction from site

Aquatic vegetation (if water is present)

Is the aquatic environment dominated by:

❒ Macrophytes ❒ Phytoplankton ❒ Benthic microbial mats

Water depth and quality observations

Any data or observations on variation in water depth? Evidence – debris, water marks, salt deposits etc.

Any data or observations on water quality? (i.e. discoloured water, debris, algal blooms).

Disturbance factors impacting on in-stream functions

Disturbance factor	Threat level		
	High	Medium	Low
Salinity			
Change in hydroperiod			
Drainage			
Clearing of fringing veg			
Sediment			
Rubbish			
Point source discharge			
Recreation			
Other			

Water quality data (channels, wetlands, drains, tributaries)

Sample number	pH	Conductivity (mS/cm)	Temperature (ºC)	Location

Evidence of management

Tick the appropriate boxes:

- ❒ Revegetation
- ❒ Fencing (also need to complete fencing section below)
- ❒ Drainage
- ❒ Fire break control
- ❒ Prescribed burning
- ❒ Weed control
- ❒ Surface water management
- ❒ Other: ……

Ideas for management

Tick the appropriate boxes:

- ❒ Prescribed burning
- ❒ Firebreak control
- ❒ Fencing
- ❒ Erosion control
- ❒ Saltland grazing
- ❒ Agroforestry
- ❒ Remnant vegetation management
- ❒ Weed control
- ❒ Drainage
- ❒ Sediment management
- ❒ Surface water management
- ❒ Road crossing
- ❒ Other……..……

Fauna list

Photos (veg associations, landscape units, floodplain features etc)

Number	Description

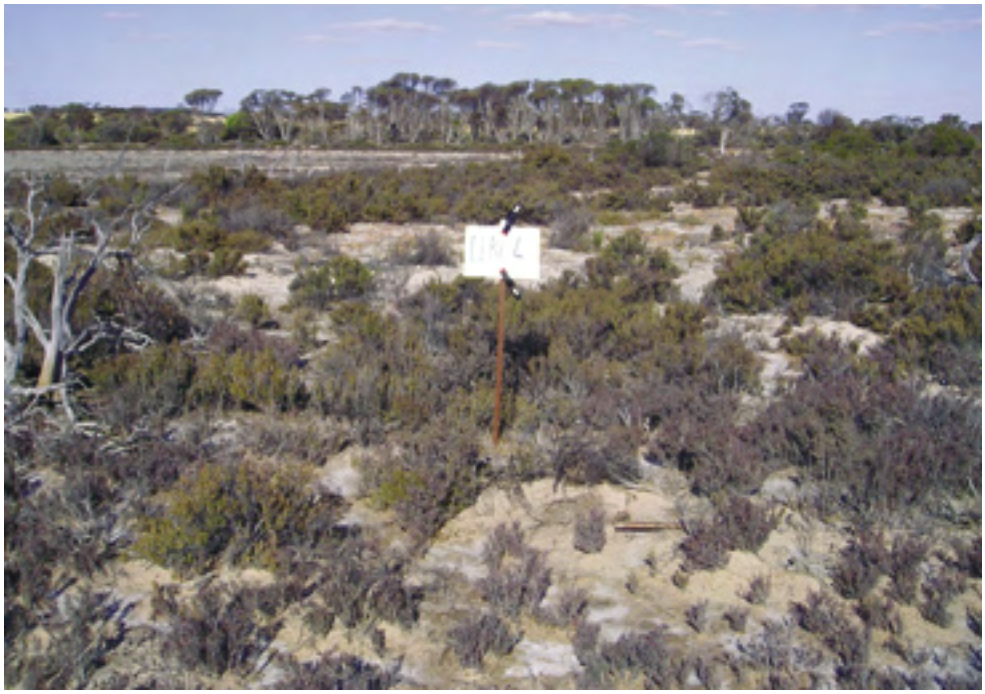
Appendix 7 Photo point reference site information

Site Reference: *LLR02*
Easting: *573216*
Northing: *6474010*
Photo location: *10 m S (1800)*

Public Road: *Kwolyin South Road*
Dominant* melaleuca *species: *M. lateriflora, M. uncinata*
Photo date: *1 December 2007*

Site Reference: *LLR03*
Easting: *573216*
Northing: *6473959*
Photo location: *3 m W (2750)*

Public Road: *Kwolyin South Road*
Dominant* melaleuca *species: *M. lateriflora*
Photo date: *1 December 2007*

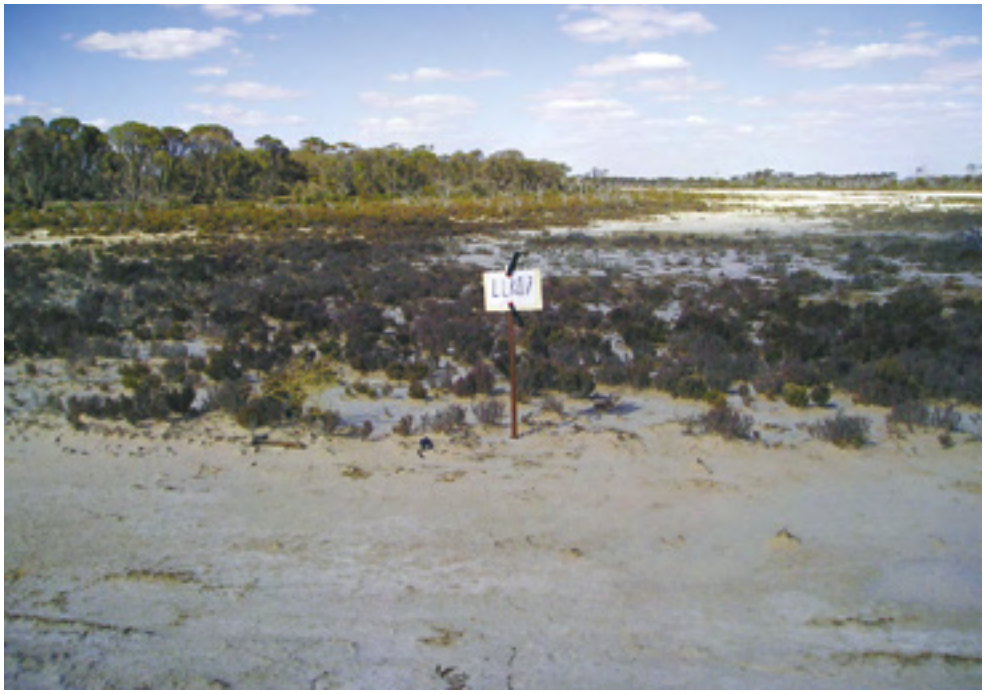


Site Reference: *LLR04*
Easting: *578463*
Northing: *6470965*
Photo location: *10 m WSW (2500)*
Public Road: *Kellerberrin-Shackleton Road*
Dominant* melaleuca *species: *M. lateriflora, M. thymoides*
Photo date: *1 December 2007*

Site Reference: *LLR05*
Easting: *582326*
Northing: *6466796*
Photo location: *10 m NW (2350)*
Public Road: *Erikin West Road*
Dominant* melaleuca *species: *M. lateriflora*
Photo date: *1 December 2007*

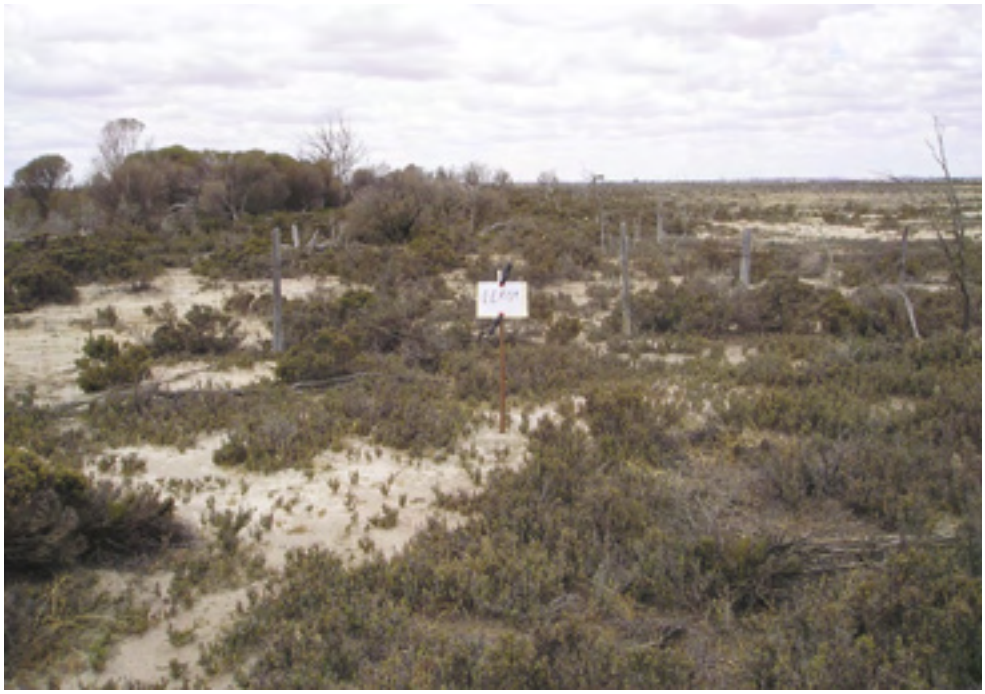
Site Reference: *LLR05*
Easting: *582326*
Northing: *6466796*
Photo location: *10 m W (2700)*
Public Road: *Erikin West Road*
Dominant* melaleuca *species: *M. lateriflora*
Photo date: *1 December 2007*

Site Reference: *LLR06*
Easting: *587333*
Northing: *6463997*
Photo location: *10 m SW (2400)*
Public Road: *Erikin South Road*
Dominant* melaleuca *species: *M. lateriflora, M. uncinata*
Photo date: *1 December 2007*



Site Reference: *LLR07*
Easting: *592684*
Northing: *6467233*
Photo location: *10 m SW (2200)*
Public Road: *Ardath-Yarding Road*
Dominant* melaleuca *species: *M. lateriflora, M. uncinata*
Photo date: *1 December 2007*

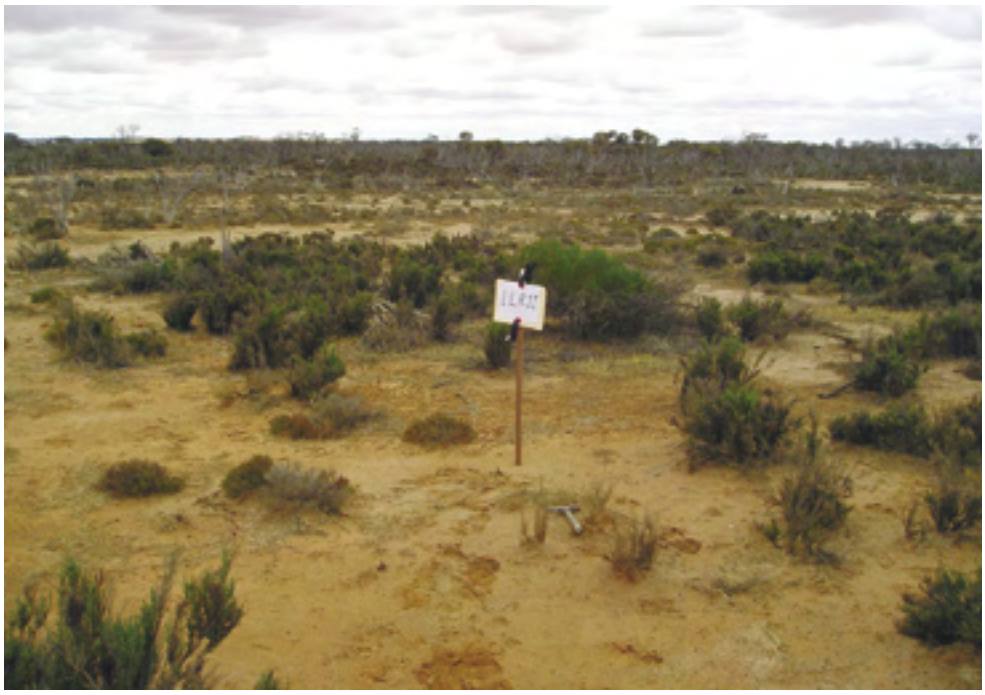
Site Reference: *LLR08*
Easting: *599764*
Northing: *6465242*
Photo location: *5 m SE (400)*
Public Road: *Eujinyn Road*
Dominant* melaleuca *species: *M. lateriflora*
Photo date: *1 December 2007*



Site Reference: *LLR09*
Easting: *603558*
Northing: *6463636*
Photo location: *10 m WNW (2900)*
Public Road: *Bruce Rock – Corrigin Road*
Dominant* melaleuca *species: *M. lateriflora*
Photo date: *1 December 2007*

Site Reference: *LLR11 (north)*
Easting: *609278*
Northing: *6453509*
Photo location: *12 m NE (300)*
Public Road: *Foss Road*
Dominant* melaleuca *species: *M. uncinata*
Photo date: *1 December 2007*

Site Reference: *LLR11 (south)*
Easting: *479872*
Northing: *6436187*
Photo location: *10 m SW (2250)*
Public Road: *Old Beverley Road*
Dominant* melaleuca *species: *M. lateriflora*
Photo date: *1 December 2007*



Site Reference: *LLR11 (south)*
Easting: *479872*
Northing: *6436187*
Photo location: *10 m S (1800)*
Public Road: *Old Beverley Road*
Dominant* melaleuca *species: *M. lateriflora*
Photo date: *1 December 2007*

As photo monitoring points were only established for sites with public road access, photos are not available for sites LLR01 and LLR10.

Shortened forms

ACC	Avon Catchment Council
AHD	Australian height datum
ANDA	Avon Natural Diversity Alliance
DEC	Department of Environment and Conservation
GAWA	Greening Australia Western Australia
IBRA	Interim biogeographic regionalisation of Australia
NRM	Natural resource management
UCL	Unallocated Crown land
WWF	WWF-Australia

Glossary

acid, acidic	See pH
alkaline	See pH
alluvial	Transported by water flow processes, for example ‘alluvial plain’.
alluvium	Sediment deposited by flowing water.
aquifer	A layer of rock or soil capable of receiving, storing and transmitting quantities of water.
catchment	The area of land which intercepts rainfall and contributes the collected water to a common point through surface and groundwater.
colluvial	Erosion process that transports soil downs slope. Colluvium (soil deposited on lower slopes) commonly mixes with alluvium (soils deposited by flood processes) to form the often complex distribution of floodplain soils.
confluence	Flowing together or intermingling, for example where a tributary joins the main river channel.
deflation	Lowering of the land floor surface (e.g. in the valley floor) due to soil loss. This may be caused by water or wind erosion.
discharge	Volumetric outflow rate of water, typically measured in cubic metres per second. Applies to both groundwater and surface water.
discharge area or zone	Area where groundwater discharges to the surface.
duplex soils	Also called texture contrast soils. Soil with an abrupt change in texture between the surface and the clay subsoil, for example sand over clay.
ecosystem	A biological community of interacting organisms and their physical environment.
floodplain	A broad, flat, low-lying area of land within the valley floor that is inundated during a 100-year flood. Includes the flood fringe and floodway.

flood – 100 year	The 100-year flood has a statistical probability of occurring, on average, once every 100 years. The 100-year flood level is the contour to which this flood will rise.
flood fringe	The area of the floodplain, outside of the floodway, that is affected by flooding.
floodway	The river channel and portion of the floodplain which forms the main flow path for flood waters once the main channel has overflowed.
geomorphology	The study of the origin, characteristics and development of landforms.
gigalitre (GL)	1 000 000 000 litres or 1 million cubic metres or 1 million kilolitres (kL).
groundwater	Water which occupies the pores and crevices of rock or soil.
halophyte	Plant growing naturally in saline soils.
hydrology	The study of water, it's properties, distribution and utilisation, on and below the earth's surface.
hydroperiod	The frequency and duration of inundation or saturation of a waterway.
interfluve	The area of land between streamflow channels.
kilolitres (kL)	1000 litres or one cubic metre.
kilotonne (kt)	1 000 000 kilograms or 1000 tonnes.
laterite	A highly-weathered soil that is rich in oxides of iron and aluminium. Formed by deep in-situ weathering under tropical and subtropical conditions.
lateritic	Containing, or characterised by, laterite.
lunette	Wind-blown deposits of sand and/or gypsum that form on the edge of salt lakes.
natural resource management	The ecologically sustainable management of the land, water, air and biodiversity resources for the benefit of existing and future generations.
nutrient load	The amount of nutrient (usually nitrogen and/or phosphorus) reaching a waterway over a given time period from its catchment area.

paleo-drainage channels	Ancient river channels
ph	The concentration of hydrogen ions in solution that indicates the acidity or alkalinity in water. A pH value of 7 is neutral, above 7 is alkaline and below 7 is acidic.
recharge	Volumetric inflow rate of water to an aquifer, typically measured in cubic metres per second.
recharge area or zone	An area through which water percolates to replenish (recharge) an aquifer. Unconfined aquifers are recharged through rainfall. Confined aquifers are recharged in specific areas where water leaks from overlying aquifers, or where the aquifer rises to meet the surface.
remnant vegetation	An area of vegetation remaining after a major disturbance, such as land clearing.
riparian zone	The riparian zone includes the floodplain and adjacent verge. The width of the riparian zone varies greatly, from 10s of metres to kilometres, depending on the type of waterway and its catchment.
riparian vegetation	Vegetation growing within the riparian zone.
river basin	The area drained by a waterway and its tributaries (see catchment).
runoff	Water that flows over the soil surface when rainfall is greater than the infiltration capacity of the soil. Flow in waterways results from rainfall runoff.
salinity	A measure of the total soluble (dissolved) salts in water. Commonly measured in terms of total dissolved salts (TDS) in milligrams per litre (mg/L), or electrical conductivity, in millisiemens per metre (ms/m) or millisiemens per centimetre (ms/cm). Water resources are classified as fresh, marginal, brackish or saline on the basis of salinity.
salinisation	An increase in the concentration of soluble salts in soil or water.
sediment load	The amount of sediment reaching a waterway over a given time period from its catchment area. Also refers to the amount of sediment being transported by a waterway.
senescent	The biological processes of a living organism approaching an advanced age.

surface water	Water flowing or held in waterways.
tributary	A waterway that flows into a larger waterway.
verge	Upland area adjacent to the floodplain.
water quality	The physical, chemical and biological measures of water.
waterlogging	Excess water close to the soil surface.
watertable	Saturated level of unconfined groundwater. Wetlands in low-lying areas may be surface expressions of groundwater.
waterway	Surface water bodies, including streams, rivers, lakes, wetlands, estuaries, coastal lagoons and inlets. Can be seasonally or permanently inundated.

References

Australian Bureau of Meteorology 2008, *Western Australian climate averages*, Australian Bureau of Meteorology, Canberra, viewed September 2008,<www.bom.gov.au/weather/wa>.

Avon Catchment Council 2005a, *The Avon NRM strategy: the regional natural resource management strategy for the Avon River basin*, Avon Catchment Council, Northam.

Avon Catchment Council 2005b, *Avon investment plan 2005–2006*, Avon Catchment Council, Northam.

Ballardong NRM Working Group 2006, *Ballardong Noongar Budjar: Healthy Country – Healthy People*, supporting document to the Avon NRM strategy, Avon Catchment Council, Northam.

Beard, J S 1990, *Plant life of Western Australia*, Kangaroo Press, Kenthurst.

Commander, P, Schoknecht, N, Verboom, B and Caccetta, P 2001, 'The geology, physiography and soils of Wheatbelt valleys', *Dealing with salinity in Wheatbelt valleys: processes, prospects and practical options*, Viv Read & Associates (ed.), pp. 1–39, State Salinity Council, Perth and Avon Working Group, Northam.

Craven, LA, Lepschi, BJ, Broadhurst, L and Byrne, M 2004, 'Taxonomic revision of the broombush complex in Western Australia *(Myrtaceae, Melaleuca uncinata s.l.)*', Australian Systematic Botany, vol. 17 no. 3, pp. 255-271.

Davis, J 2004, 'Valleys of salt, channels of water, pools of life – environmental aspects of salinity engineering', *Proceedings of the 1st national salinity engineering conference*, Dogramaci S and Waterhouse A (eds), Institute of Engineers, Canberra.

Department of Environment 2005, *Stream salinity status and trends in south-west Western Australia*, Salinity and land use impacts series, report no. 38, Department of Environment, Perth.

Department of Indigenous Affairs 2008 *Aboriginal heritage sites register*, Department of Indigenous Affairs, Perth, viewed September 2008, <www.dia.wa.gov.au/Heritage>.

Department of Natural Resources and Environment 2002, *Biodiversity action planning: action planning for native biodiversity at multiple scales; catchment bioregional, landscape, local*, Department of Natural Resources and Environment, Victoria.

Department of Water 2007, *A method to assess waterway condition in the zone of ancient drainage,* Water resource management series, unpublished report, Department of Water, Perth.

Department of Water 2008a, *Riparian condition of the Salt River: waterway assessment in the zone of ancient drainage*, Water resource management series, report no. 46, Department of Water, Perth.

Department of Water 2008b, *Riparian condition of the Yilgarn River, Caroline Gap to Hines Hill: waterway assessment in the zone of ancient drainage*, Water resource management series, report no. 49, Department of Water, Perth.

Environment Australia 2000, *Revision of the Interim Biogeographic Regionalisation of Australia (IBRA) and development of version 5*., Environment Australia, Canberra.

Ewers, JK 1959, *Bruce Rock: the story of a district*, Bruce Rock District Road Board.

Hopkins, AJM, Beeston, GR and Harvey, JM 2001, *A database on the vegetation of Western Australia*, stage 1, Department of Conservation and Land Management, Perth.

Keighery, B 1994, *Bushland plant survey: a guide to plant community survey for the community*, Wildflower Society of WA (Inc.), Perth.

Keighery, GJ, Halse, SA, Harvey, MS and McKenzie, NL 2004, *A biodiversity survey of the Western Australian agricultural zone*, Records of the Western Australian Museum, Supplement No. 67, Western Australian Museum, Perth.

Lantzke, N 1992, *Soils of the Northam advisory district: the zone of ancient drainage*, Bulletin no. 4244, Department of Agriculture Western Australia, Perth.

Lantzke, N and Fulton, I 1992, *Land resources of the Northam region*, Land resource series no. 11, Department of Agriculture Western Australian, Perth.

Leoni, P and Murphy-White, S 2006, *Lockhart catchment appraisal 2005*, Resource management technical report 310, Department of Agriculture and Food, Perth.

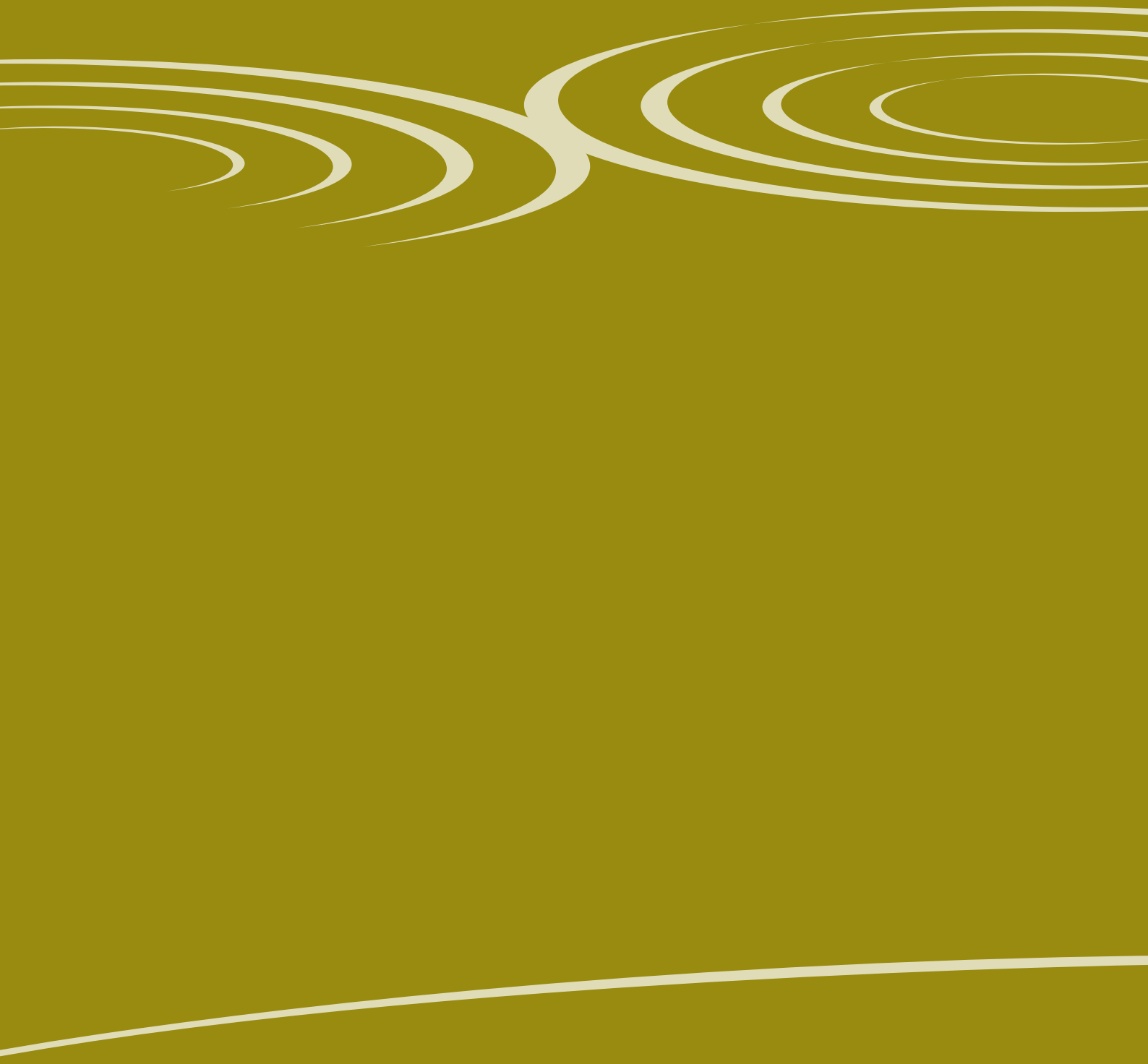
Sattler, P and Creighton, C 2002, *Australian terrestrial biodiversity assessment*, National Land and Water Resources Audit, Canberra.

Shepherd, DP, Beeston, GR and Hopkins, AJM 2002, *Native vegetation in Western Australia: extent, type and status*, Resource management technical report no. 249, Department of Agriculture, Perth.

Strehlow, K, Davis, J, Sim, L, Chambers, J, Halse, S, Hamilton, D, Horwitz, P, McComb, A and Froend, R 2005, 'Temporal changes between ecological regimes in a range of primary and secondary salinised wetlands', *Hydrobiologia*, vol. 552, pp. 17–31.

Water and Rivers Commission 2000, *Avon River flooding – January 2000*, Surface water hydrology report series, unpublished report, Water and Rivers Commission, Perth.

Weaving, SJ 1995, *Native vegetation handbook for the Shire of Bruce Rock*, Agriculture Western Australia, Perth.



www.water.wa.gov.au

ISSN 1326-6934
ISBN 978-1-921468-97-1