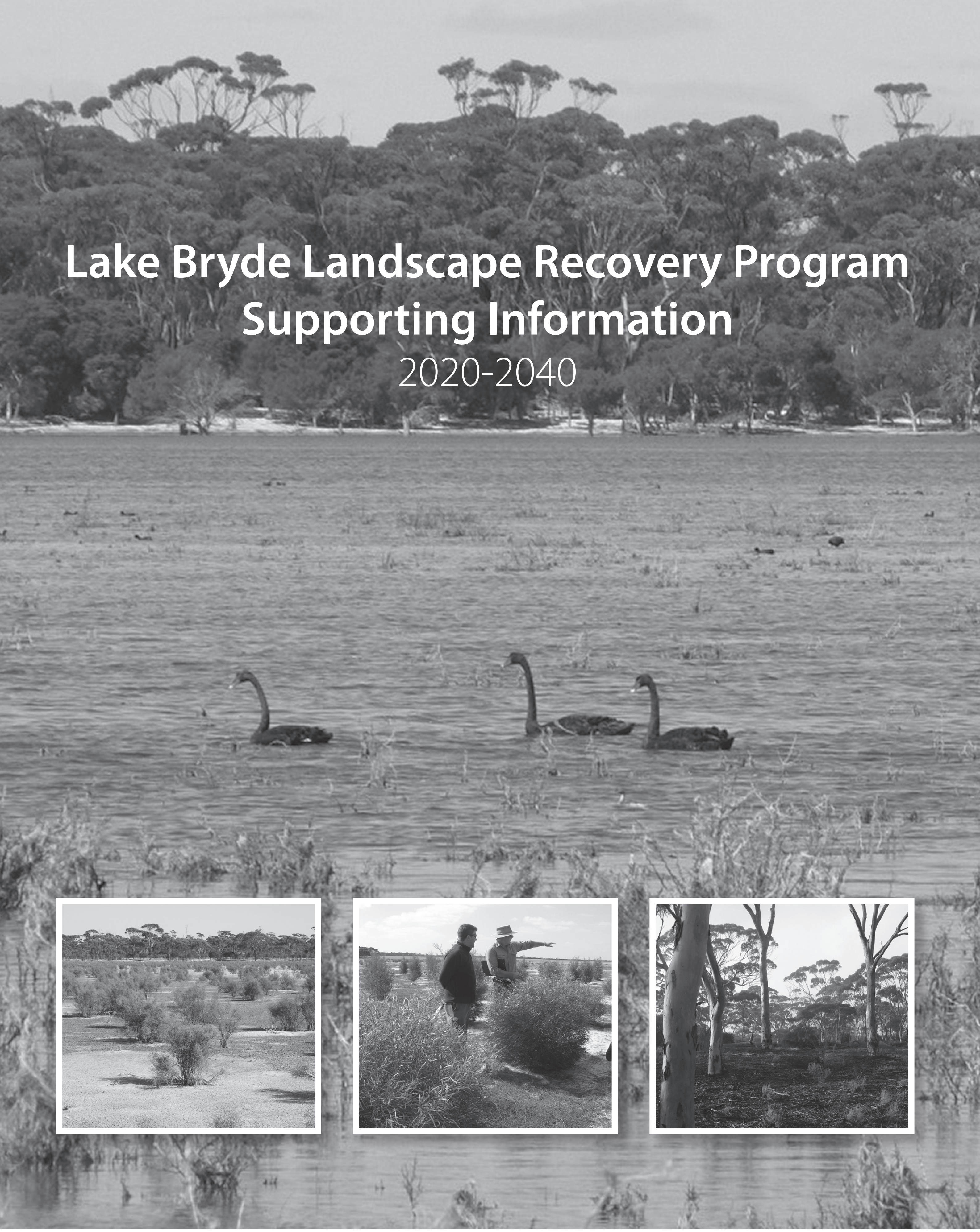

Lake Bryde Landscape Recovery Program Supporting Information

2020-2040

GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

PARKS AND WILDLIFE SERVICE

Department of **Biodiversity, Conservation and Attractions**

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GOVERNMENT OF WESTERN AUSTRALIA

Lake Bryde Landscape Recovery Program 2020–2040

Supporting Information

February 2021

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Appendix 1: **The Natural Diversity Recovery Catchment program**

1.1 Introduction

The Natural Diversity Recovery Catchment (NDRC) program was a commitment by the Government of Western Australia arising from the *Western Australian Salinity Action Plan* (Government of Western Australia, 1996). The program's objective was:

> *To develop and implement works within the South West Land Division that protect, and where practicable recover, the biological diversity of significant, natural wetlands and associated valley biological communities from the adverse effects of altered hydrology. Primary values underpinning this goal will be specified for each catchment project.*

Reviews of the state government's salinity programs have reconfirmed the importance of the NDRC program and, where appropriate, have proposed its expansion (Wallace *et al*., 2011).

The NDRC program provided one focus for government and community actions to manage the impact of salinity on native biota in the south-west agricultural region. In designated catchments, it aimed to conserve representative biological communities and their related physical diversity, together known as 'natural diversity'[1]. At the catchment scale, the focus was on selecting elements that represent the range of biological diversity threatened by salinity. Responsibility for the NDRC program resides with the Department of Biodiversity, Conservations and Attractions (DBCA).

NDRCs were one of two types of existing recovery catchments, the other being water resource recovery catchments (potable water resources) managed by the Department of Water and Environmental Regulation (DWER). There was useful cross-agency support across these two programs.

1.2 Priority setting for salinity actions

To guide resource allocation to protect high value elements threatened by salinity the WA State Salinity Council commissioned the development of the Salinity Investment Framework in 2000. This study recognised that it is crucial to have a rigorous framework for ranking salinity investments by governments given the extent and consequences of salinity and the very high cost of management.

The recommended approach to priority setting is described in two reports: *Salinity Investment Framework: Interim Report Phase I* (Department of Environment, 2003) and *Salinity Investment Framework Phase II* (Sparks *et al*., 2006). The elements evaluated were native biota, agricultural land, water resources, rural infrastructure, and social amenities.

Three NDRCs were established in 1996 under the *Western Australian Salinity Action Plan* (Wallace *et al*., 2011). These were Toolibin Lake, Lake Warden, and the Muir – Unicup Wetland Complex.

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[1] This document is concerned with the conservation of natural biological diversity rather than domesticated species and other biological diversity arising from human actions.

Table 1 Selection criteria for recovery catchments.

Criterion	Comment
Biological diversity values at risk	This is the primary criterion for selecting recovery catchments for natural diversity. Recovery catchments will contain very high nature conservation values at risk. Assessment of catchments will involve the following attributes: • how representative the catchment biota is of important native communities • presence of threatened communities and species • species and community richness • whether the catchment provides an important biological corridor (for example, connecting Lake Magenta Nature Reserve and Fitzgerald River National Park), or other significant ecological service • International or national significance of the area (for example, Ramsar Convention, Directory of Important Wetlands in Australia).
Biogeographic representation	It is desirable to have recovery catchments that represent a range of situations. For example, as many IBRA regions as practicable will be represented, consistent with other criteria.
Opportunities for research and development or demonstration sites	Research and development or demonstration sites, particularly those with state or national or international significance, might include special management techniques for: • nature conservation • farm economics • cultural change or improved social interaction • landcare.
Tenure of land at risk	While conservation lands that are the focus of recovery catchments for natural diversity should be vested with the Western Australian Conservation and Parks Commission, other land tenures may be considered for selection as recovery catchments if they are sufficiently important for nature conservation and threatened by salinity.
Representation of hazard	The greater the hazard to an important site, the greater the urgency for action. However, recovery catchments will be selected that represent a range of hazard situations including those that are threatened in the longer term by salinity but are at present in good condition.
Potential for success	In the main, catchments will be selected that are likely to lead to success. This will involve, for example, taking into consideration: • ‘Physics’ of pressure (for example, is hydrological pressure overwhelming?) • area of catchment (bigger catchments are generally more difficult to recover) • degree of threat • level of landcare community support, knowledge, and enthusiasm • potential to use prospective commercial species in revegetation • current area and distribution of remnant vegetation (the more the better).
Socio-political considerations	There will be demands from a plethora of socio-political stakeholder groups ranging from catchment groups to federal agencies and politicians. The demands from these groups will need to be taken into consideration.

Lake Bryde NDRCs was established in 1999, and Buntine-Marchagee and Drummond NDRCs in 2001. The selection of the later NDRCs was informed by the preliminary results of the Wheatbelt biological survey (Keighery *et al*., 2004).

A set of criteria has been developed for identifying recovery catchments (Table 1):

- biological values at risk from altered hydrology
- biogeographic representation
- opportunities for research and development or demonstration
- tenure of land at risk
- representation of hazard
- potential for success (note that local community support was an important element assessed in this regard)
- socio-political considerations.

An analysis using data generated by the Wheatbelt biological survey (Keighery *et al*., 2004) has been used to determine which other areas of the Wheatbelt might best complement the existing NDRCs (Walshe *et al*., 2004). This information has been combined with the results from the Salinity Investment Framework to select potential recovery catchments for the future.

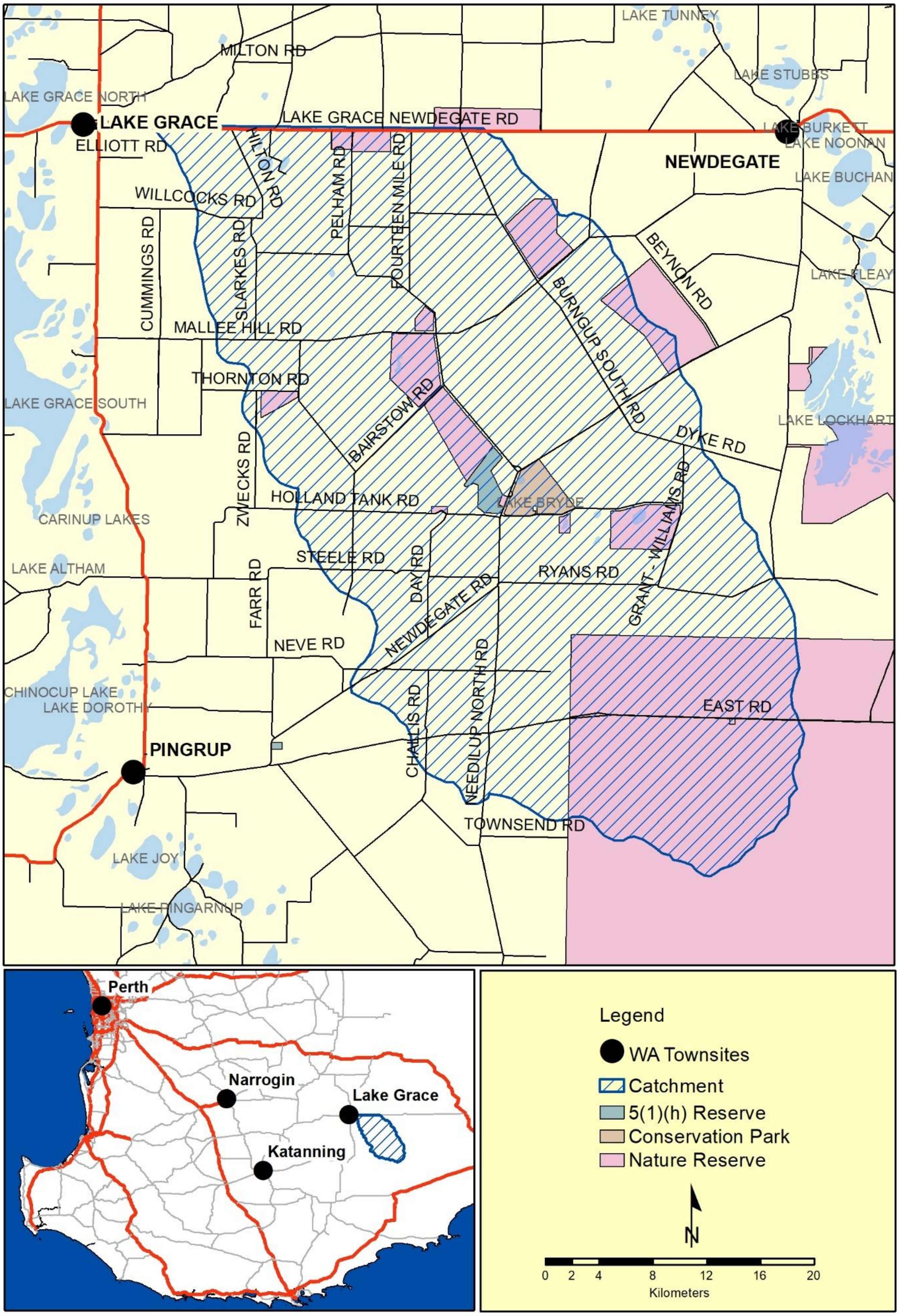

Figure 1 The location of the Lake Bryde Catchment.

Appendix 2: **Catchment background**

2.1 Catchment overview

The Lake Bryde Catchment is located about 350km south-east of Perth at the headwaters of the Lockhart Catchment of the Avon River Basin. The centre of the catchment is approximately equidistant from the towns of Lake Grace, Newdegate and Pingrup.

The catchment covers about 161,000 hectares in a largely agricultural landscape. About 34% (55,400 hectares) of its original native vegetation remains.

In terms of the Lake Bryde Catchment's relationship to key administrative regions:

- About 57% of the catchment overlaps part of the Shire of Kent
- About 43% of the catchment overlaps part of the Shire of Lake Grace
- The catchment lies entirely within the Department of Biodiversity, Conservation and Attractions (DBCA; the department) Wheatbelt Region.

2.2 Historical background

Nyoongar peoples

The Nyoongar peoples of south-west Western Australia are believed to have inhabited the region for about 40-50 000 years. The Nyoongar peoples can be subdivided into 12 dialect groups, each of which occupied a different geographical area within the south-west region (Tindale, 1974). The Lake Bryde Catchment overlies parts of the traditional lands of the Wudjari and Njakinjaki peoples. Currently the catchment is known to contain one registered aboriginal site.

Early European period

Between the establishment of the Swan River Colony in 1829 and 1911, when parts of the catchment were first settled for agriculture, the area was only visited occasionally by Europeans. An 1848 exploration party led by Government Surveyor John Septimus Roe may have traversed part of Lakeland Nature Reserve (Zweck, unpublished). In the 1870's sandalwood cutters were reported to be active in the area. The catchment was next visited in 1893, when a cart track linking Broomehill to the Coolgardie Goldfields was constructed by John Holland and three companions (Ball, 1992).

Agricultural settlement

The agricultural development of the Lake Bryde Catchment commenced in the early 20^{th} century. However, there were significant differences between the development of the northern section and the central and southern sections of the catchment.

The development of the northernmost section of the catchment benefitted from the establishment of Lake Grace township in 1911 and the arrival of the rail line in 1916 (Landgate, 2019). Land settlement near Lake Grace township was further reinforced by the opening of a school in 1913 and a hospital in 1922. This was followed by an extension of the rail line to Newdegate in 1926 and the addition of a spur line to Hyden in 1933 which made Lake Grace into a railway junction. These developments provided a solid foundation for the agricultural development of the northern section of the catchment.

Land in the central and southern catchment was first released for settlement in the 1920s (Zweck, unpublished). The lands released were limited to areas of 'first class land', which mainly comprised woodlands. As much of the catchment was mallee, these potential settlement areas were quite scattered and isolated. One such area was centred on Lake Bryde.

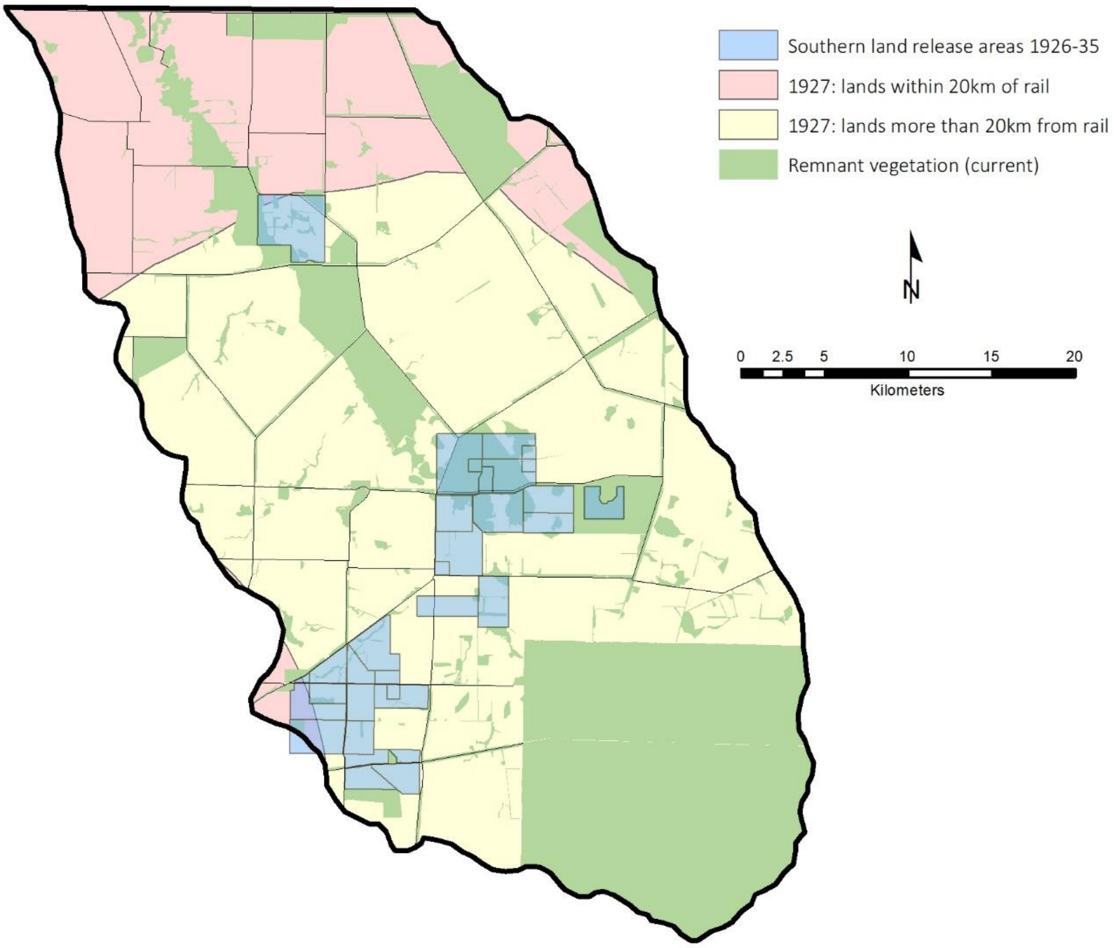

Figure 2 The catchment was affected by the 1927 government land release policy.

Only a few settlers made progress with land clearing before abandoning their farms in the early 1930s. The reasons for the failure of settlement included:

- The curtailment of further land releases in areas more than 20 km (12 miles) from a railway station.
- The resultant social and economic isolation of the settlers already in these areas.
- The cancellation of a planned rail extension into the Lake Bryde area.
- The impact of the Great Depression on the value of agricultural commodities.

Agricultural expansion recommenced following the end of World War II. Large areas in the central and southern sections of the catchment were release for agricultural development in the 1960s (Zweck, unpublished), with major releases in 1963, 1964 and 1965. This brought 100,000 hectares into occupancy and effectively exhausted the supply of uncleared lands with agricultural potential.

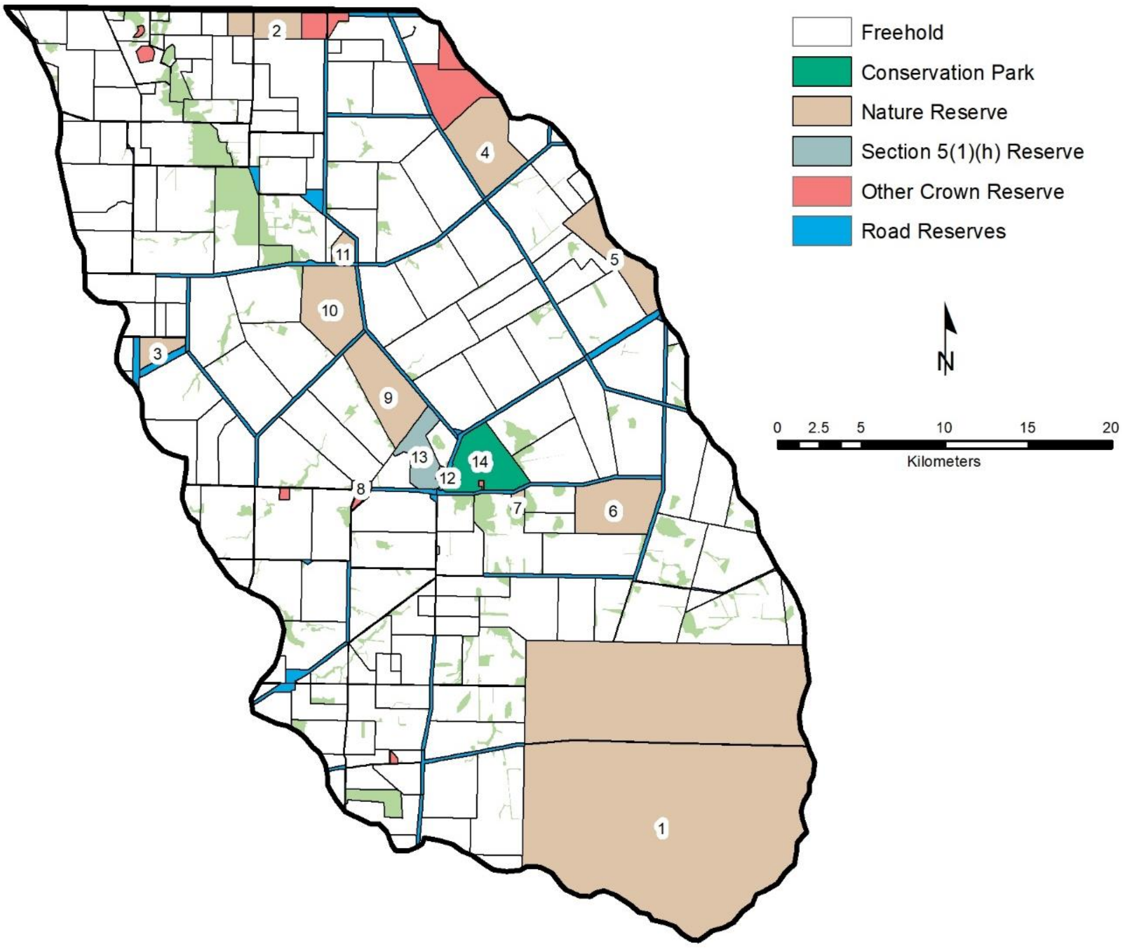

Figure 3 Current land tenure in the Lake Bryde catchment.

Table 2 Reserves managed by the department.

Id	Reserve No.	Class	Category	Name	Area (ha)
1	R 25113 (part)	A	Nature Reserve	Lake Magenta Nature Reserve	25944.6
2	R 26762	A	Nature Reserve	Heathland Nature Reserve	668.5
3	R 28173		Nature Reserve		328.0
4	R 29018 (part)	A	Nature Reserve	Silver Wattle Hill Nature Reserve	1639.5
5	R 29019 (part)	A	Nature Reserve	Breakaway Ridge Nature Reserve	1134.7
6	R 29020	A	Nature Reserve	Lake Bryde Nature Reserve	1527.8
7	R 29021	A	Nature Reserve	Lake Bryde Nature Reserve	107.0
8	R 29022	A	Nature Reserve	Holland Rocks Nature Reserve	49.6
9	R 29023	A	Nature Reserve	Lakeland Nature Reserve	1529.3
10	R 29024		Nature Reserve	Lakeland Nature Reserve	1579.1
11	R 29025	A	Nature Reserve	Lakeland Nature Reserve	206.9
12	R 29026	A	Nature Reserve	Lake Janet Nature Reserve	32.3
13	R 47384		Section 5(1)(h) Reserve		724.8
14	R 48436		Conservation Park	Lake Bryde Nature Reserve	1301.5
				Total area in Lake Bryde Catchment	**36,773.6**

The late development of the central and southern sections of the catchment had several important consequences:

- Unlike the earlier phase of agricultural development, land on the valley floor was now recognised as prone to salinity. Most potentially saline areas were not released for agricultural development. Instead, these areas were set aside as large reserves that were later managed by DBCA.
- Many of the newly created road reserves were much wider than those created in the 1920s. These road reserves, particularly those that are 200m wide and well vegetated, now provide good ecological linkages between some otherwise isolated patches of remnant vegetation.
- About 30 years had elapsed between the commencement of extensive land clearing in the southern and central sections of the catchment and the widespread appreciation of the threat salinity posed to agriculture and biodiversity. For the Lake Bryde Catchment this meant that:
    - salinity impacts were less advanced and threatened values more readily recoverable than in areas with a longer history of settlement
    - the farming community was more aware of the salinity threat and more receptive to modifying land use practices to address this issue.

2.3 Land tenure

Currently, the Lake Bryde Catchment is occupied by three land tenure categories:

Freehold lands

Farming properties, in the form of freehold lands, occupy about 116,279 hectares or 72% of the catchment. They are managed by about 60 farming enterprises, most of which are family based. The main agricultural activities undertaken are cereal and pulse cropping, and sheep and cattle production.

These lands contain about 22.5% (12,541 hectares) of the catchment's remnant vegetation much of which is associated with either the valley floor, particularly in the northern section of the catchment, or with drainage channels on the valley slopes.

DBCA-managed reserves

The catchment intersects with 14 reserves in the care, control and management of the Conservation and Parks Commission (a statutory authority). However, DBCA's Parks and Wildlife Service conducts all management operations. Most of the reserves are class A nature reserves set aside to conserve native flora and fauna, but the catchment also contains:

- a Section 5(1)(h) reserve established for the purpose of rehabilitation trials and demonstrations, hydrological management, and conservation
- a conservation park covering the Lake Bryde area, which allows for both conservation and related recreational activities, such as boating.

The combined area of these reserves within the catchment is about 36,773 hectares (24%). They contain about 65.2% of the catchment's remnant vegetation.

Other Crown lands

Road reserves occupy 5944 hectares or 3.7% of the catchment and contain about 9.2% of the catchment's remnant vegetation. Other Crown reserves, such as water reserves and the Newdegate Research Station, occupy 1925 hectares or 1.2% catchment and contain about 3.1% of the catchment's remnant vegetation.

Appendix 3: **Soils and landforms**

The Lake Bryde Catchment's gently undulating terrain is typical of the south-western interior of Western Australia (Sawkins, 2011). The terrain ranges from 290-392m elevation and has developed on the mainly granitic Archaean basement rocks of the Yilgarn Block. It can be subdivided into two broad terrain classes (Farmer et al., 2002).

3.1 Valley floors

The catchment is dissected by relatively flat valley floors that receive runoff from upslope areas. The primary valley floor trends north to north-westerly and can be up to three kilometres wide. Minor tributary valleys intersect with it from several directions.

Farmer et al. (2002) found that the primary valley floor and some of the tributary valley contain poorly defined drainage pathways. These pathways are frequently blocked by colluvial and aeolian deposits.

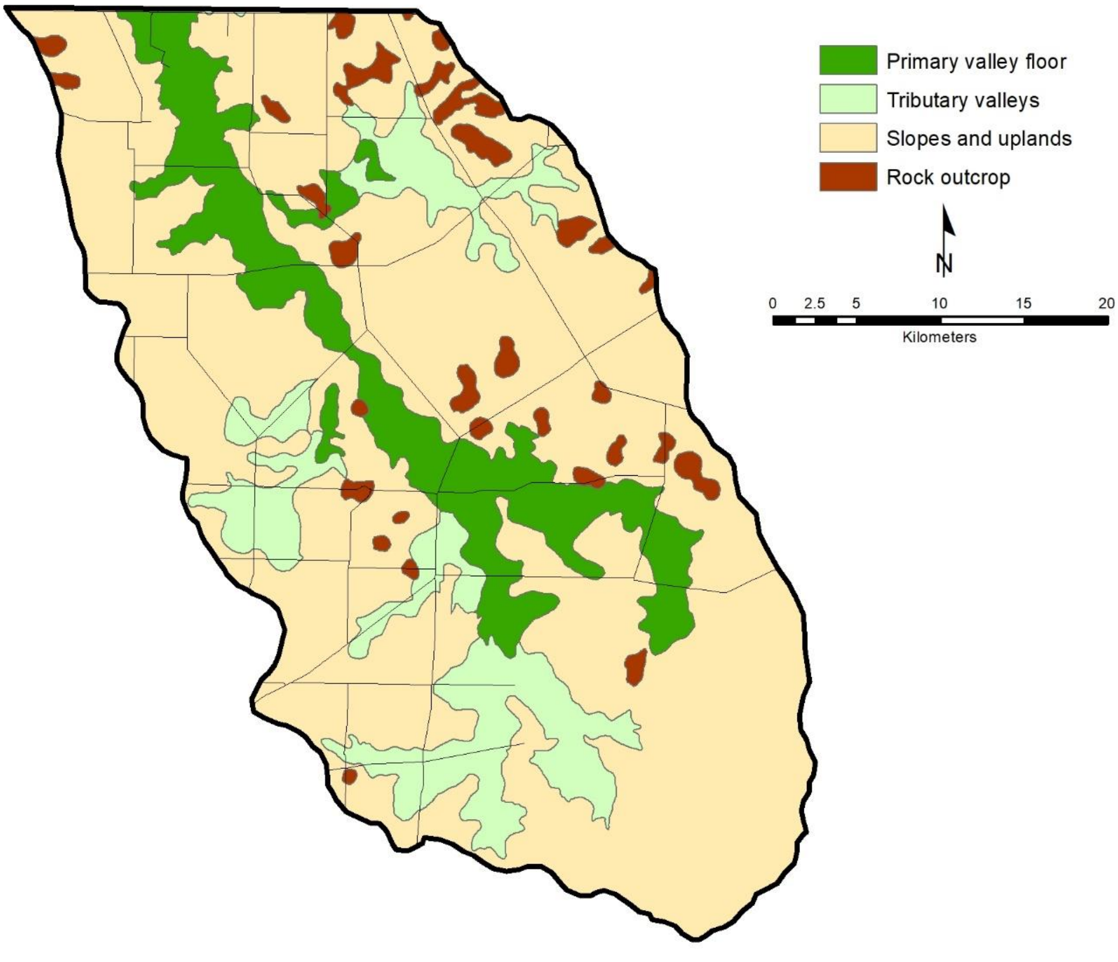

Figure 4 Terrain classes in the Lake Bryde Catchment.

The drainage pathways also link chains of ephemeral lakes. The lakes frequently lie adjacent to the drainage pathway and are connected to it by an "S" shaped inflow and outflow channel. The lakes typically have a clay base, and often have high salinity. Dunes and lunettes, which usually lie adjacent to the lakes, contain gypsiferous sand and silt. Valley flats, which occupy much of the valley floors, are comprised of duplex soils with grey clays and calcrete nodules. Areas of quaternary alluvium and colluvium are also associated with tributary valleys leading to the valley flats.

3.2 Slopes and uplands

The catchment's upper slopes are gently undulating with gradients of 3-5%. These landforms are usually covered by reworked lateritic sandplain and are incised by minor, well-defined drainage channels which become poorly defined as they approach the flat terrain of the valley floors. Their soils are predominantly shallow gravels, duplex sandy gravels, and sandy duplex soils.

The upper slopes and crests are also occupied by areas of outcropping granitic basement rock. Associated soils include stony soils, yellow/brown deep sandy duplex soils, deep sands, and red soils.

Appendix 4: **Climate and rainfall**

The Lake Bryde Catchment experiences a Mediterranean climate with warm to hot summers (December to February) and mild, wet winters (June to August). However, both temperature and rainfall statistics show changing trends which are likely to have long-term consequences for both agriculture and biodiversity conservation.

4.1 Temperature

Based on weather records at Lake Grace (BOM 10592), Newdegate (BOM 10692) and Pingrup (BOM 10627), the catchment's mean daily maximum and minimum temperatures are about 22.9°C and 9.6°C. Recent climate studies have found that, over the last 40 years, WA's average annual temperature has increased by about 1°C (Sudmeyer *et al.* 2016). In the catchment, the maximum temperature statistics for Lake Grace, Newdegate and Pingrup show the mean daily maximum temperature has increase by about 1°C, from about 22.7°C to 23.7°C, since the 1970s (Figure 5).

The average maximum temperature has increased across most months (Figure 6). However, the largest percentage increase in temperature occurs in between March and August.

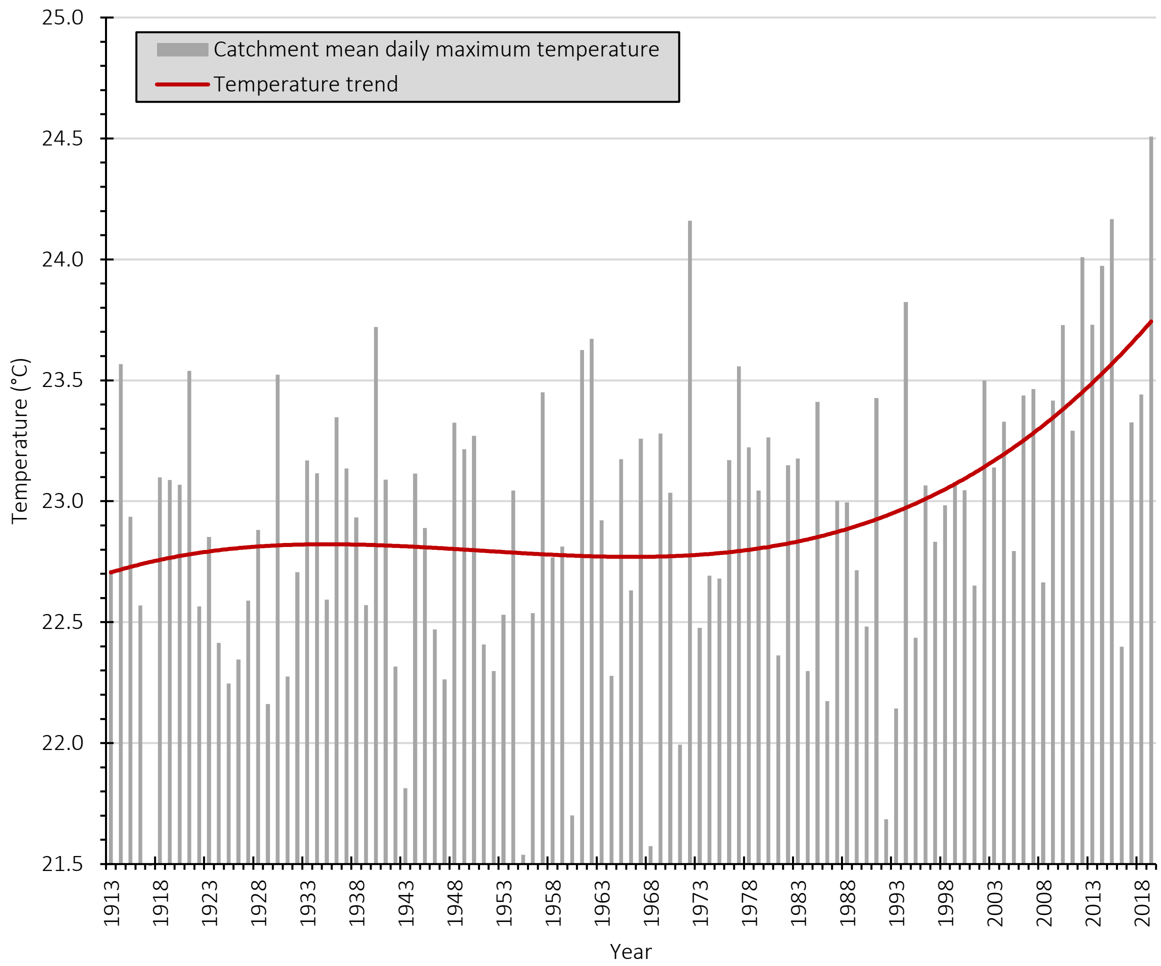

Figure 5 Annual mean daily maximum temperature and trend recorded in the catchment.

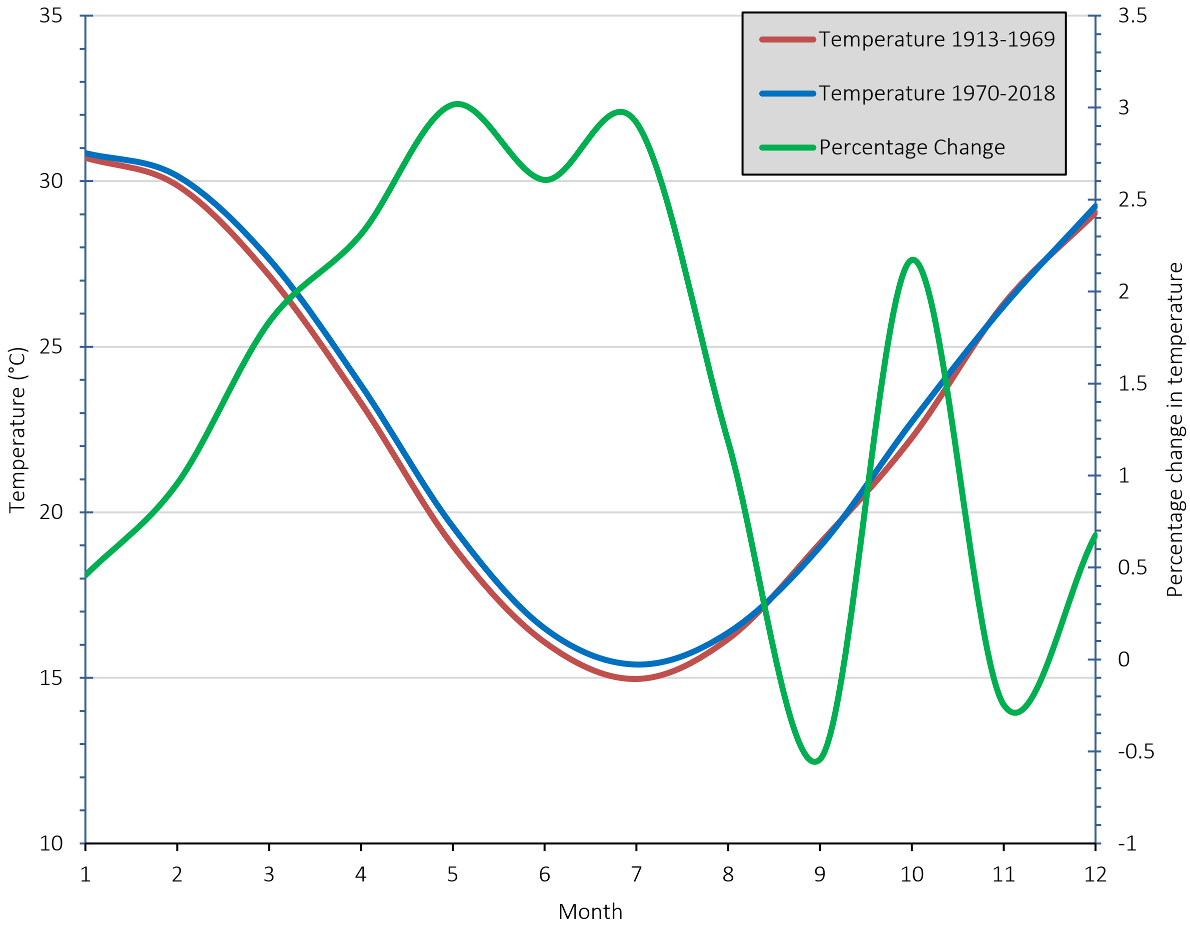

Figure 6 Changes in the monthly maximum temperature since the 1970s.

4.2 Rainfall

Based on weather records at Lake Grace (BOM 10592), Newdegate (BOM 10692) and Pingrup (BOM 10627), the catchment's average rainfall is about 359mm per year. The highest monthly rainfall generally occurs in cooler months.

Since the 1960s, annual rainfall along the west coast and the far south-west has declined by up to 20%, with much of this reduction occurring in winter and autumn (Sudmeyer *et al.* 2016). Catchment rainfall records show a modest declining trend in annual rainfall since records commenced, from 375mm in 1913 to 336mm in 2018. This represents a rainfall decline of about 10%.

However, the data indicates that the decline in rainfall is most severe in the winter months, with the June rainfall reduced by 18%. This has been partially compensated for by a moderate increase in summer rainfall (Figure 8).

While winter rainfall is dominant and can generate sufficient water flows to inundate the valley floor, summer rainfall events – such as intense thunderstorms or rain bearing depressions associated with tropical cyclones – now account for a greater proportion of runoff events causing valley floor inundation.

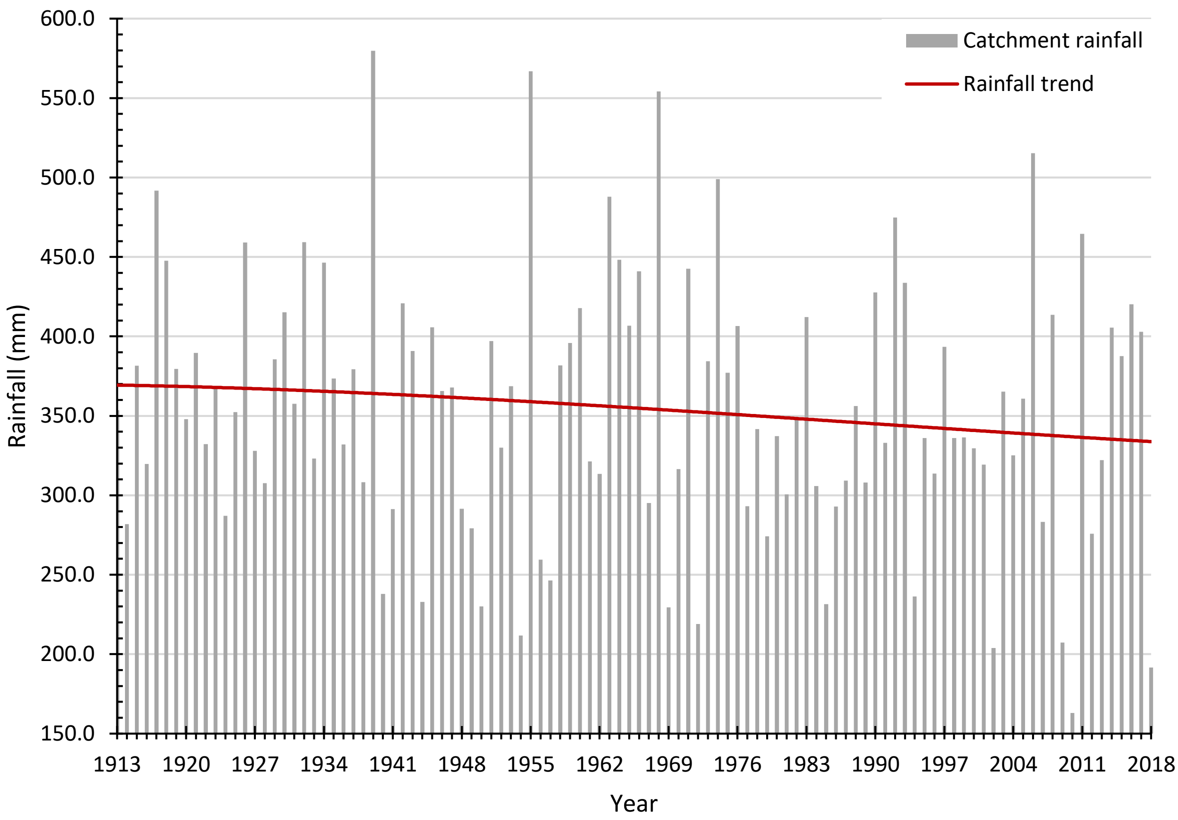

Figure 7 Annual rainfall and trend recorded in the catchment

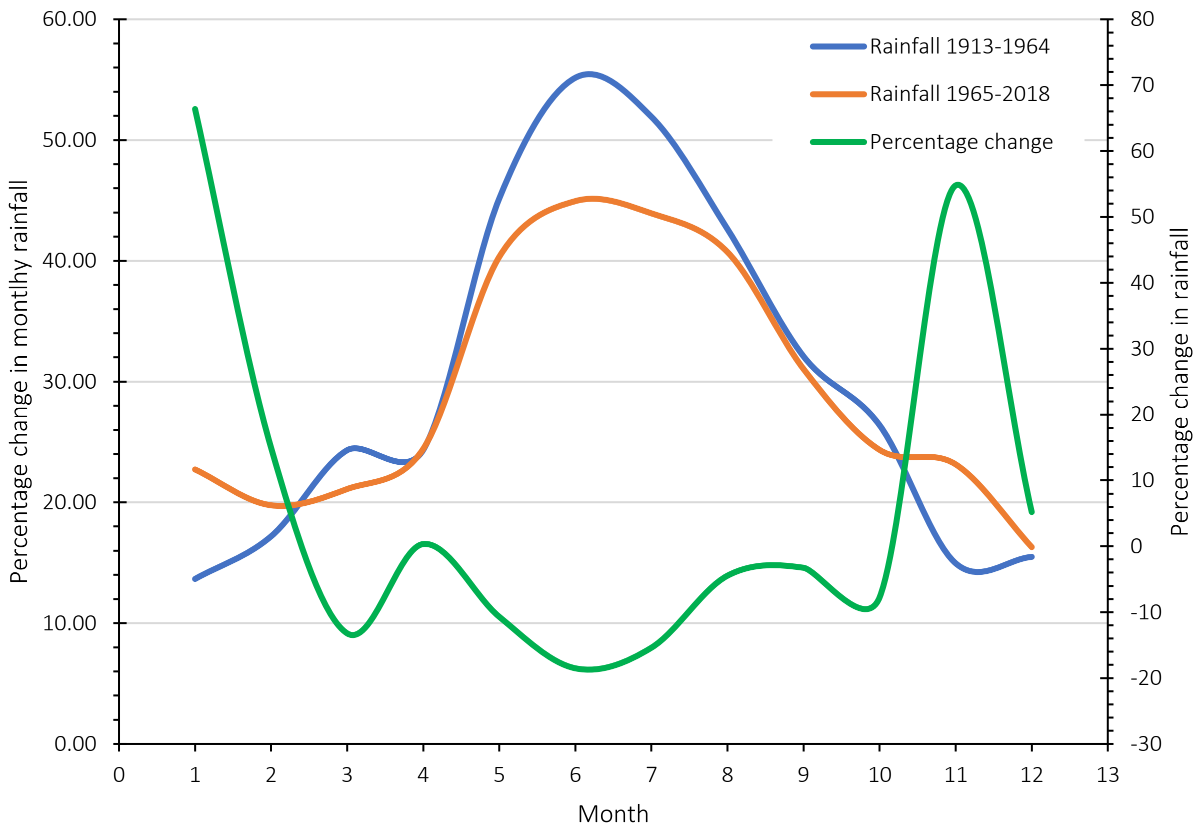

Figure 8 Changes in the monthly rainfall since the 1960s.

Appendix 5: **Surface water hydrology**

5.1 General catchment dynamics

The key biodiversity assets under threat from salinity are concentrated in the southern and central sections of the catchment. In this area surface water hydrology has been subject to several investigations (Giraudo *et al*., 1996; Overheu, 1999; Sinclair Knight Merz Pty Ltd, 2000; Farmer *et al*., 2002; Syrinx Environmental Pty Ltd, 2003; Farmer, 2006, 2015).

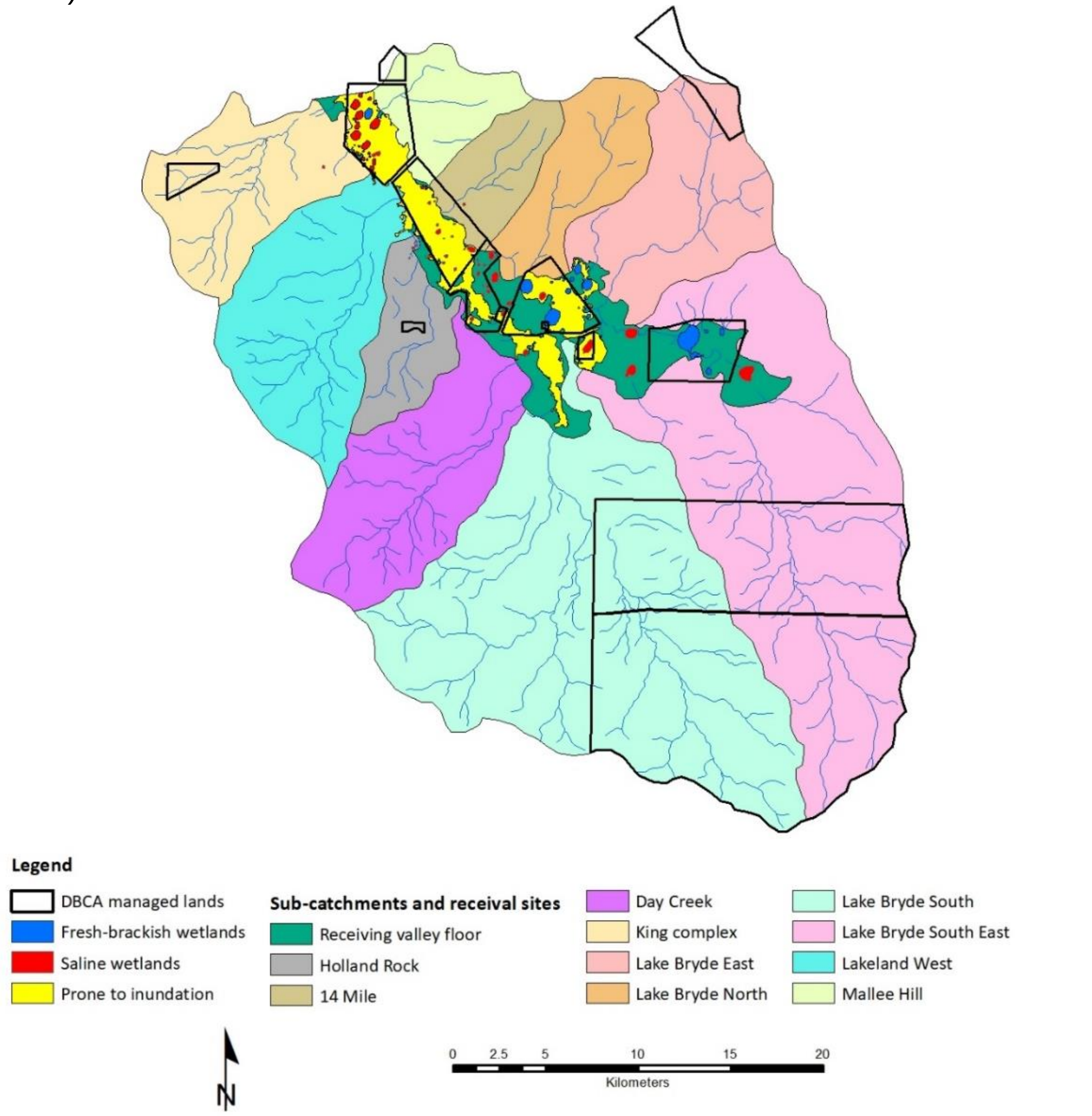

Figure 9 Surface water hydrological features of the upper Lake Bryde Catchment

Farmer *et al*. (2002) identified 10 sub-catchments and one receiving landscape (valley floor), with each of the sub-catchments delivering flows to different parts of the valley floor (Figure 9).

Farmer *et al*. (2002) found that clearing has significantly lowered runoff thresholds on the catchment's upper slopes. Consequently, the valley floor must cope with significantly higher runoff volumes and more frequent inundation than before clearing. This raised the concern that valley floor biodiversity assets may be detrimentally inundated more frequently and for much longer periods than before clearing.

5.2 Key effects of inundation

Minor inundation events

Following moderate rainfall, surface flows on the upper slopes are usually confined to minor, well-defined drainage channels (Farmer 2015). Once these flows enter the valley floor, which has a gradient of less than 2%, flows tend to have low velocity and to be relatively shallow.

Prior to the construction of the waterway, these flows were frequently blocked by natural colluvial and aeolian deposits and therefore tended to pond. Some the flows were also diverted to partially fill valley floor wetlands, which typically sit to one side of the drainage channel and are connected to it by an “S” shaped inflow and outflow channel. Due to the shallow depth wetland inundation usually lasted only a few months.

The ponding has led to the accumulation of salt in low lying parts of the valley floor. This has caused plant deaths in riparian and wetland plant communities in the area of salt accumulation. As the valley floor and wetlands dry out, the salt-impacted biological communities tended to be replaced by samphire shrublands.

Large inundation events

Large inundation events are usually triggered by heavy rainfall events associated with severe winter cold fronts, rain bearing depressions and summer thunderstorms. Under these conditions, surface water flows on the upper slopes can quickly develop into broad shallow sheet flows (Farmer, 2015) which rapidly enter the valley floor and quickly overwhelm the obstructions which hinder shallow water flows.

As a result of the greater depth of these types of events valley floor plant communities can be inundated for several months, and wetlands, which are typically deeper, can be inundated for several years. Prolonged inundation has been observed to cause widespread deaths in riparian vegetation, such as melaleuca and mallee plant communities. However, wetland plant communities appear be better adapted to inundation.

When the valley floor dries out riparian communities usually recover through seedling recruitment and resprouting, except where the communities had previously been impacted by salinity. Wetland communities also show signs of recovery, as their dominant species have evolved adaptions to inundation. However, wetland plant communities in the more heavily salt affected areas tend to be replaced by samphire.

5.3 Surface water monitoring

Surface water monitoring schedule

Regular surface water monitoring has been undertaken by several different programs:

- The South West Wetland Management Program (SWMMP) operated between 1977 and 2019. It commenced monitoring at Lake Bryde in 1979.
- Natural Resources Branch hydrologists. This departmental branch operated between 2003 and 2015. They generated considerable data which included numerous surface water (SW) observations.
- Lake Bryde Catchment personnel. The catchment management team commenced in November 1999, with the appointment of a conservation officer and later a technical officer. Many of their early observations are related only to fill events.

In 2016, new monitoring procedures were introduced which improved the regularity and quality of monitoring observations. Surface water monitoring is now undertaken four times per year. However, if wetlands are at any time observed to contain water, surface water monitoring is then undertaken on a monthly basis until the wetlands dry.

Types of surface water observations and estimations

Wetland water depth

Wetland depth is directly observed at depth boards installed near the deepest section of the wetlands with an accuracy of ±0.005m. These ‘A’ depth boards are complemented by surveyed ‘B’ boards installed on the shorelines. ‘B’ boards are only used during inundation, for safety and efficiency reasons.

Wetland volume estimation

The bathymetry of Lake Bryde and East Lake Bryde has been surveyed. It is therefore possible to convert wetland depth observations into wetland volume estimates. This derived data is used in the calculation of wetland salt load. The conversion of depth to volume is most accurate when water depth is greater than 0.20m. For this reason, salt load is not usually estimated when lake depths are less than 0.20m estimates

Wetland electrical conductivity, total dissolved solids and pH

Surface water samples are collected from near the depth boards and analysed with a conductivity-pH-temperature meter (TPS WP-81). The electrical conductivity (EC) is usually measured in millisiemans per metre (mS/m) with an accuracy of 0.5% when accurately calibrated. Acidity is measured using the pH range with an accuracy of ±0.01pH when accurately calibrated.

The EC data is later converted into total dissolved solids (TDS), which is usually expressed in terms of milligrams per litre (mg/L), using the conversion proposed by George *et al.* (1996). The derived TDS data can then be used in the estimation of salt load.

Salt load

Salt load is an estimate of the amount or mass of salt dissolved in a wetland. It is calculated by multiplying the salt concentration (TDS) by the volume estimate derived from direct, simultaneous observations. The most accurate estimates of salt load occur a few months after the lake has flooded, as soil stored salts take some time to enter the water column.

5.4 Lake Bryde fill event analyses

In this section, the seven largest fill events recorded catchment since 1979 are analysed. Salt load changes are related to rainfall, inflows and outflows, and evaporation. However, confidence in these analyses is affected by two factors:

- The reliability of the salt load estimates, which are dependent on direct observations of depth and EC. These observations in turn depend on the observer’s skills, instrument accuracy and the reliability of the monitoring procedures used.
- The exclusion from the analyses of some factors which may contribute to salt load, such as soil salinity and surface water – groundwater interactions. These factors are difficult to estimate and monitor regularly.

Consequently, while these analyses use the best data available, they will need to be reassessed at each of the recovery program's five-year reviews. Ideally, these reassessments should be based on complex hydrological monitoring and modelling.

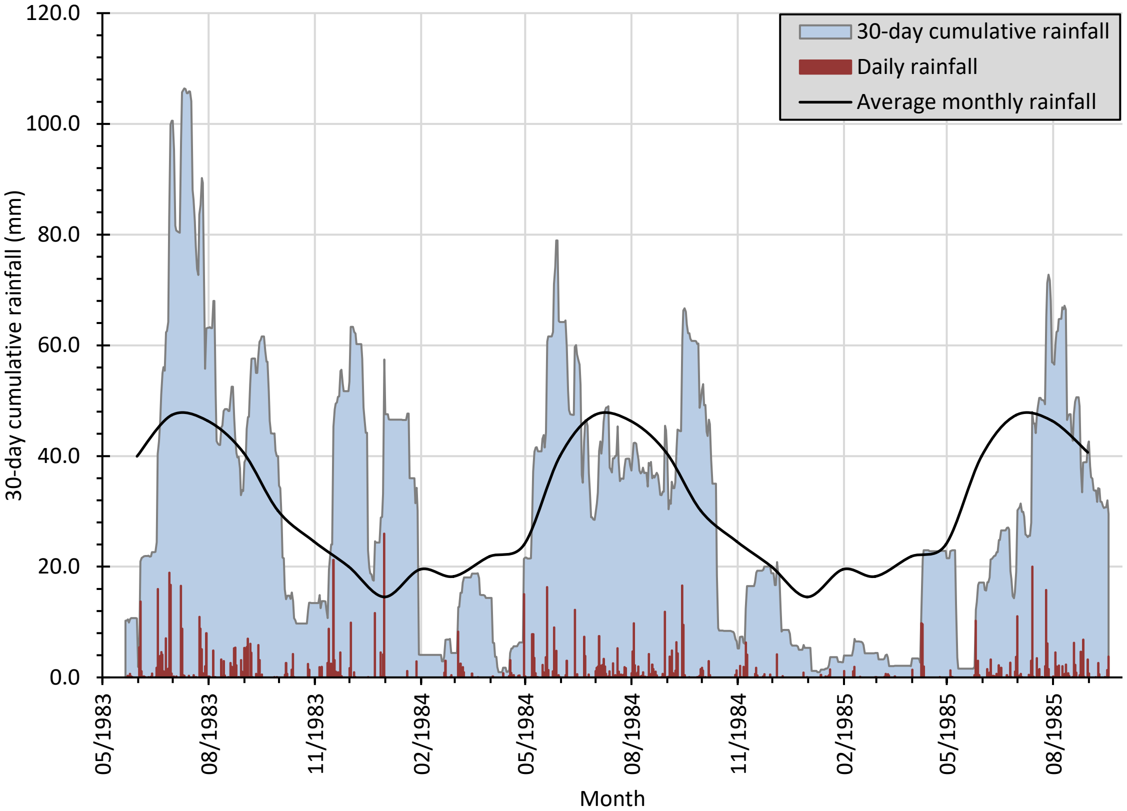

Figure 10 Rainfall relating to the 1983-85 fill event.

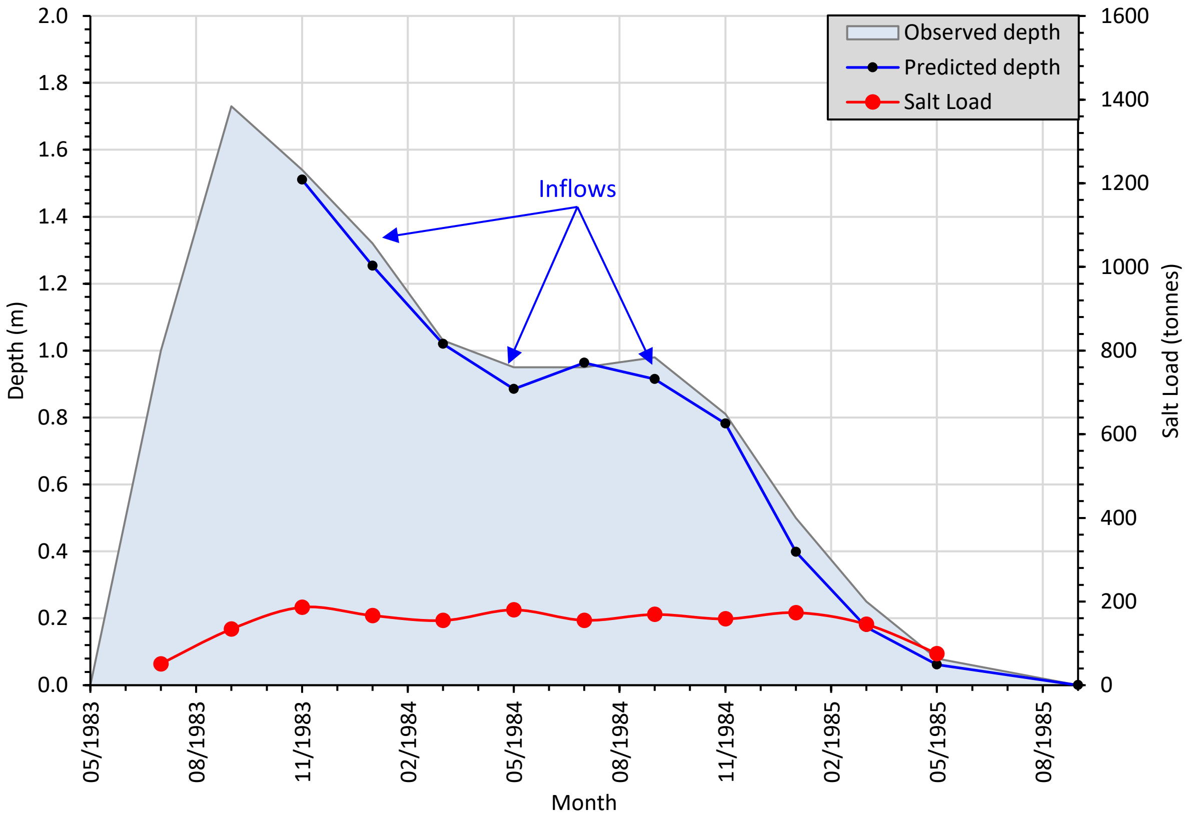

Figure 11 Lake depth and salt load data trends for the 1983-85 fill event.

1983-85 Lake Bryde fill event

This fill event was well monitored by SWWMP with observations of depth, salinity and pH being recorded every two months. However there remains some uncertainty about instrument accuracy and the procedures used.

Rainfall, lake depth and inflows (Figures 10 and 11):

- The fill event was triggered by above average monthly rainfall events in June and July 1983 (Figure 10). This rainfall raised the lake depth to about 1.0m at the time of SWWMP's first observation (15 July) and to 1.73m at the time of the second observation (16 September).
- Based on differences between the observed and predicted depth[2], there appears to have been several small inflows during the course of the fill event:
    - 30-day cumulative rainfall of 40-60mm on 30 contiguous days in November-December 1983 appears to have triggered inflows which caused a depth increase of about 0.07m.
    - 30-day cumulative rainfall of 40-70mm on 40 contiguous days in May 1984 appears to have caused inflow with the depth being 0.07m deeper than predicted.
    - 30-day cumulative of 40-60mm rainfall on 30 contiguous days in September 1985 generated small inflows increasing the depth by 0.06m.
- Between January and May 1985 there was a significant difference between observed and predicted depth which cannot be explained by recorded rainfall, either in terms of the catchment average or at any of the recording stations. It is possible that this discrepancy may relate to either inflows from an isolated (and unrecorded) thunderstorm event, or to a lower level of evaporation than has been predicated.
- The rainfall in July-August 1985, comparable to rainfall events in May and September 1984, does not appear to have generated any inflows. However, catchment rainfall in the preceding nine months was below average and the resultant dry soil conditions may have reduced runoff and inflows.
- It is most likely that the lake dried out in June 1985 (Figure 9).

Salt load (Figure 11):

- During the first 4-5 months of the fill event, salt load rose asymptotically to about 165 tonnes (Figure 11) and then stabilised at this level throughout the fill event.
- The minor inflows in this latter part of the fill event must have been fresh because there was no significant increase in salt load, as happened during later fill events.

[2] The "predicted depth" at a particular observation point is the prior depth observation plus the cumulative rainfall since the prior depth observation, less the cumulative evaporation since the prior depth observation. Discrepancies between the observed and predicted depth can infer inflows.

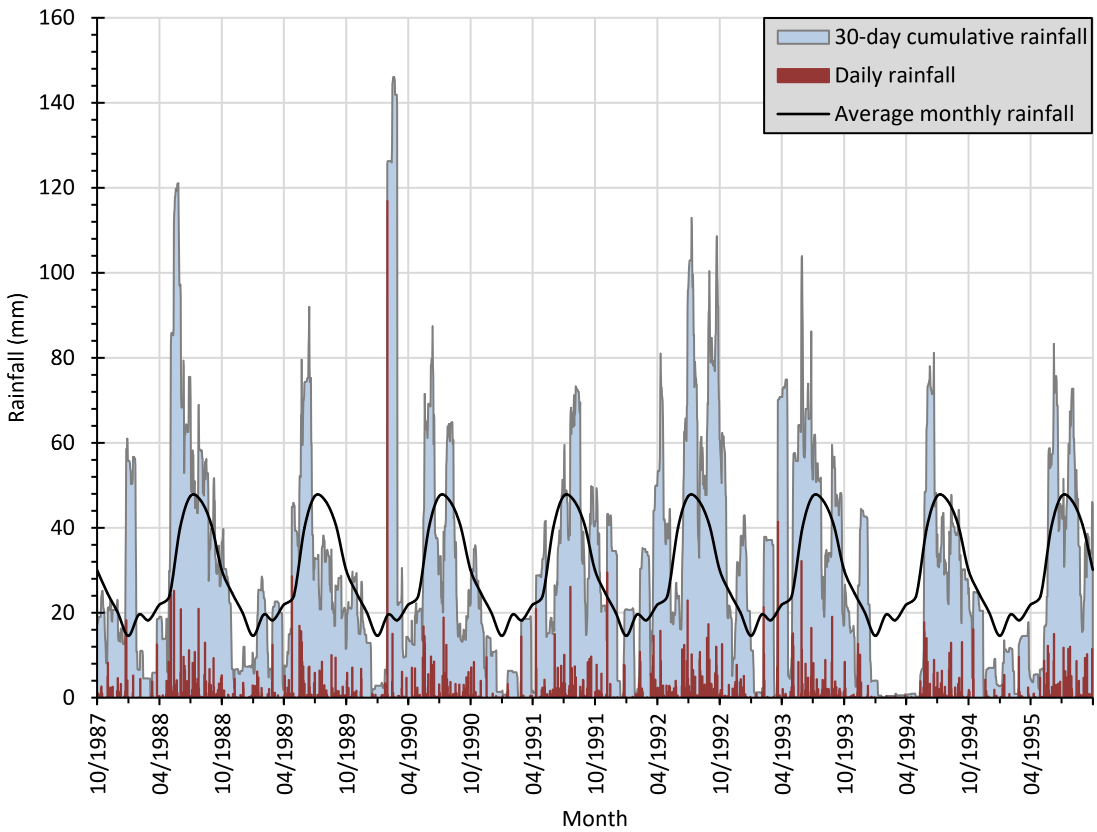

Figure 12 Rainfall relating to the 1988-95 fill event.

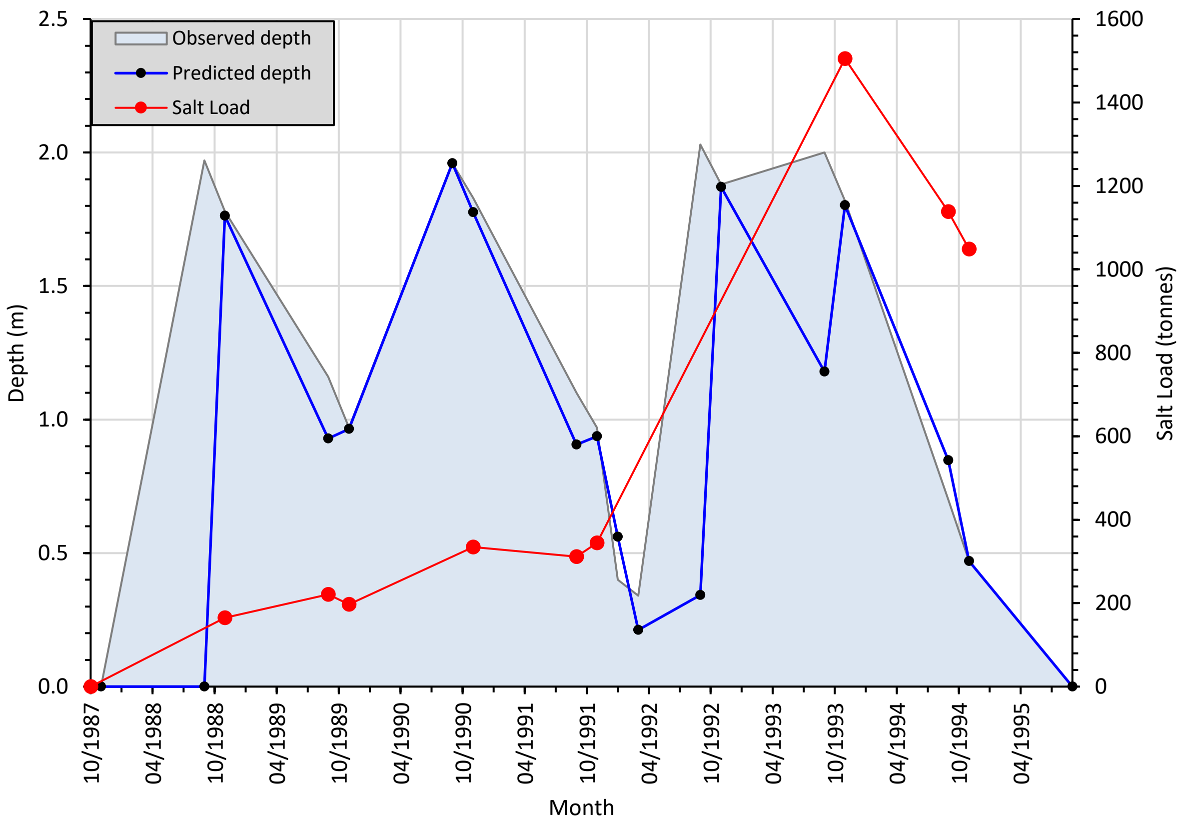

Figure 13 Lake depth and salt load data trends for the 1988-95 fill event.

1988-95 Lake Bryde fill event

During this period of inundation, SWWMP undertook surface water monitoring only twice per year, usually in September and November. Consequently, there is a lower level of detail in the data and what can be inferred from it is far more limited. Additionally, there remains some uncertainty about monitoring procedures and the instrumentation used.

<u>Rainfall, lake depth and inflows (Fgure 11 and 12):</u>

- The initial trigger for this fill event appears to have been above average monthly rainfall in May 1988, with the 30-day cumulative rainfall exceeding 100mm over a 16-day period.
- However, an unusual aspect of this fill event was that the period of inundation was extended from the usual two years of inundation to seven years by a succession of large rainfall events.
  - 116. 9mm of rainfall on 29 January 1990 from summer thunderstorms.
  - By 30-day cumulative rainfall of more than 100mm on 10 contiguous days, in July 1992.
  - By 30-day cumulative rainfall of more than 100mm on two contiguous days in September 1992.
  - By 30-day cumulative rainfall of more than 100mm on two contiguous days in May 1993.
- Other above average rainfall events may have triggered minor inflows, but these are difficult to identify, due to the very sparse observations undertaken during this fill event.

<u>Salt load (Figure 13):</u>

- The first salt load estimation on 7 November – after six months of inundation – was 165 tonnes, matching the estimate for the 1983-85 fill event.
- By November 1991, the salt load had doubled to 340 tonnes.
- The salt load then increased to about 1,100 tonnes in 1994 before the lake dried out.

The salt load estimates from 9 November 1993 of 1,505 tonnes appears to be erroneous, due to the consistently lower value of subsequent estimates and the absence of any rainfall events sufficient to have triggered outflows that would have reduced the salt load.

It is unclear from the available data whether the increase in salt load during this fill event was caused by saline surface water inflows, surface water/groundwater interactions, or a combination of the two.

However, the increase in salt load was so significant it drew the attention of the then local Land Conservation District Committee, the Department of Agriculture and the Department of Conservation and Land Management. The action of these organisations saw an increasing investment in research and recovery activities in the catchment, which ultimately led to the catchment being listed as a Natural Diversity Recovery Catchment in 1999.

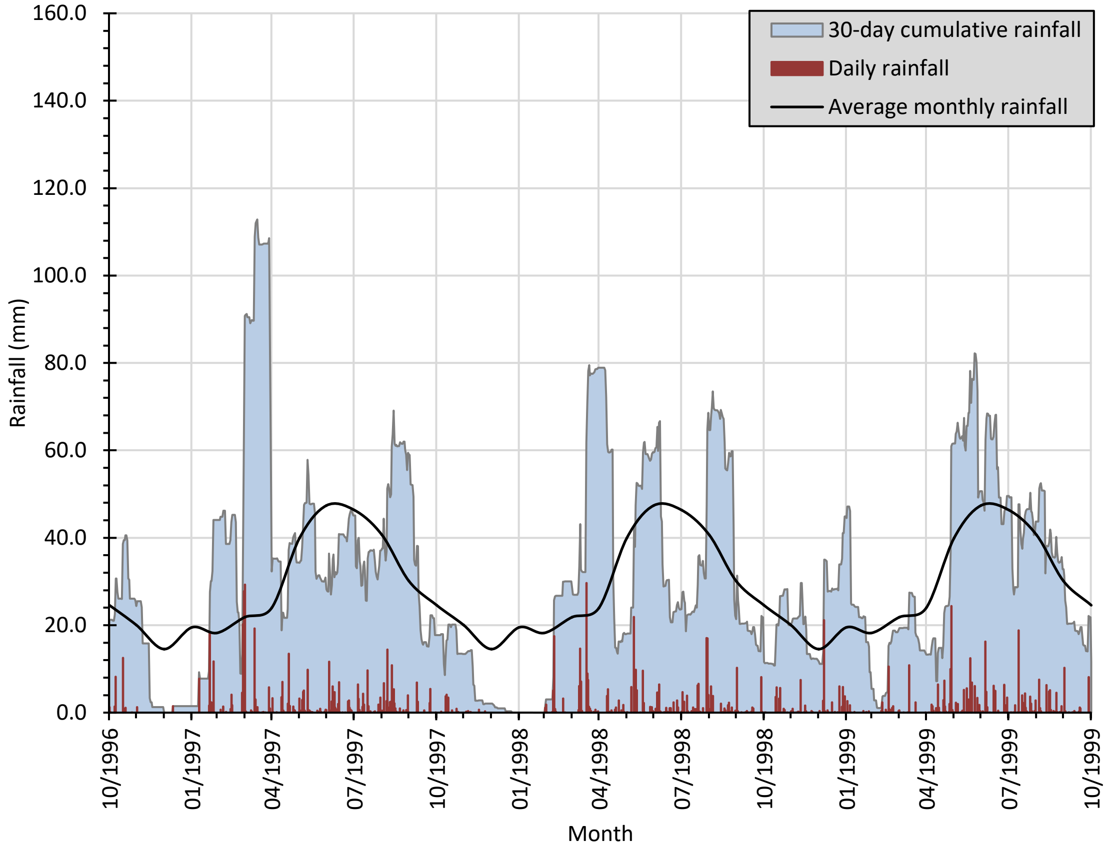

Figure 14 Rainfall relating to the 1997-98 fill event.

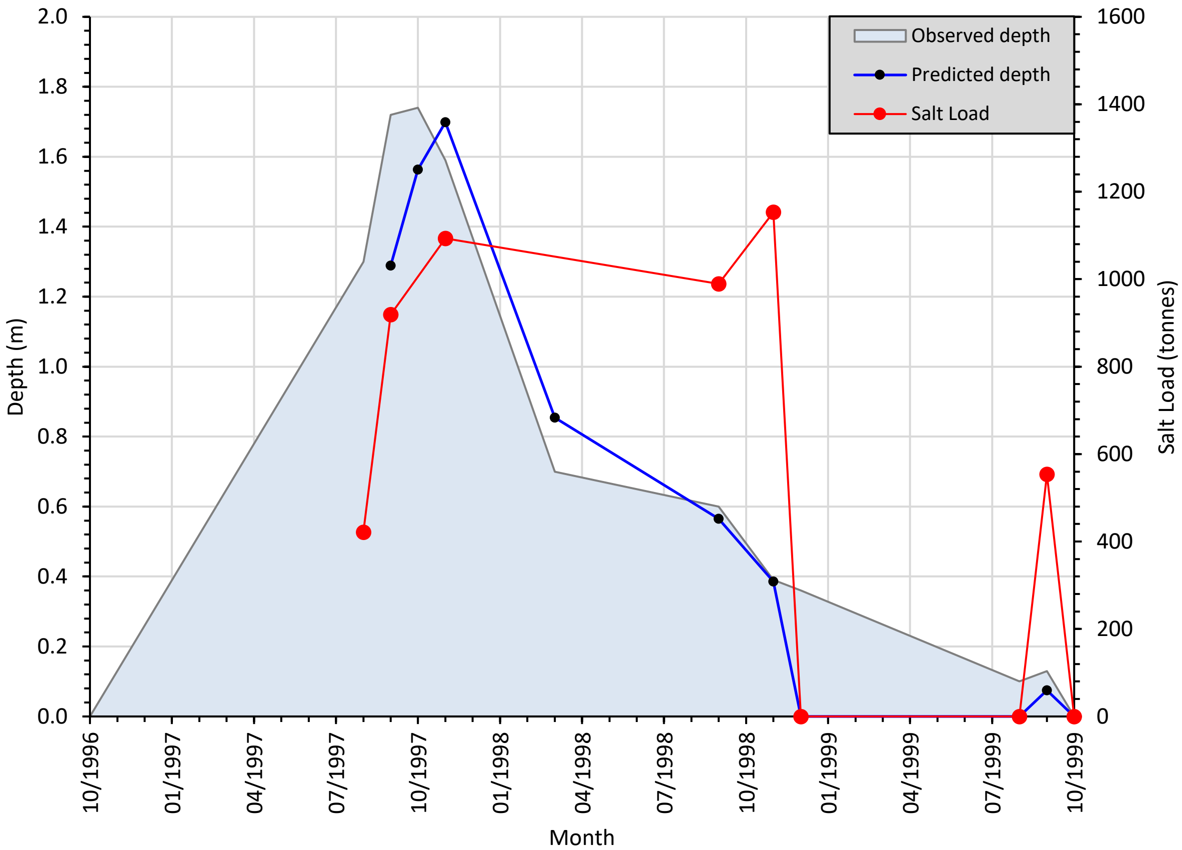

Figure 15 Lake depth and salt load data trends for the 1997-98 fill event.

1997-98 Lake Bryde fill event

This fill event was monitored by SWWMP on 11 occasions. However, the monitoring was irregular with several large gaps (6-10 months) and there is uncertainty about the type and accuracy of the instrumentation and procedures used to quantify observations. These make reconstructing the fill event somewhat problematic.

Rainfall, lake depth and inflows (Figures 14 and 15):

- The fill event was most likely triggered by above average rainfall (17 contiguous days with 30-day cumulative rainfall exceeding 100mm) in April 1997. When first observed in August, the lake level was 1.30m. Above average rainfall in September further raised the lake's level to 1.74m.
- This was followed by a period of steady depth decline until February 1998. The observed depth decline parallels predicted depth which was slightly higher. This may indicate that the actual evaporation rate was higher than the predicted rate or that the catchments experienced lower rainfall than that recorded.
- From February to August 1998 the lake depth plateaued due to above average seasonal rainfall.
- The lake may also have received a very minor seasonal inflow at this time which boosted its depth by 0.03m above prediction.
- The lake was next monitored in November 1998 and the results indicate the commencement of a declining trend in lake depth. Unfortunately, the next observation was not until August 1999, so it is unclear what actually happened. However, based on rainfall and the estimated evaporation rate it seems most likely that:
  - The lake dried out in December 1998 or January 1999, under mainly dry summer conditions.
  - The water depths observation from August and September 1999 relate to a separate and partial fill events triggered by winter runoff in May 1999.

Salt load (Figure 15):

- The lake's salt load rose asymptoticly to about 1,100 tonnes in about 6-7 months. This is slightly longer than in previous fill events.
- The maximum fill event salt load estimate is about the same as the preceding 1988-95 fill event suggesting inflows did not have a significant effect on salt load.
- The salt load estimate September 1999 relates to a separate, partial fill event and is not comparable to Lake Bryde's salt load during 'full lake' inundations.

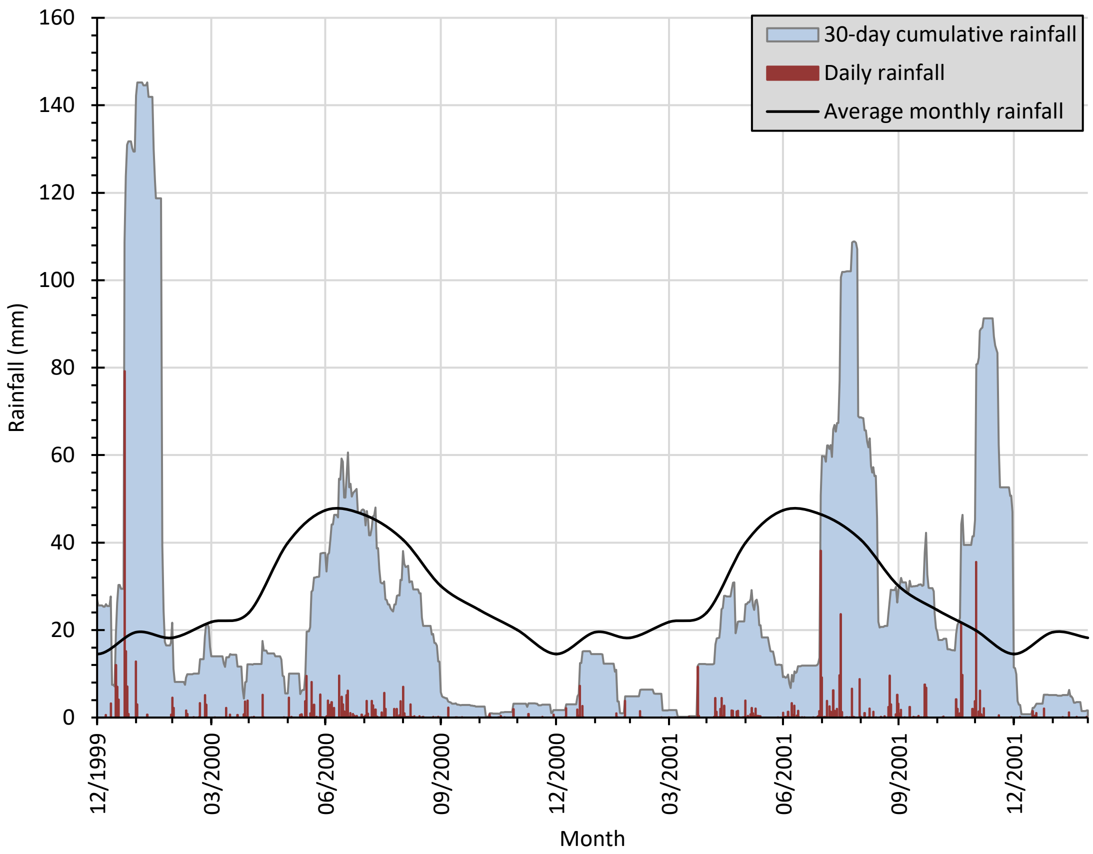

Figure 16 Rainfall relating to the 2000-01 fill event.

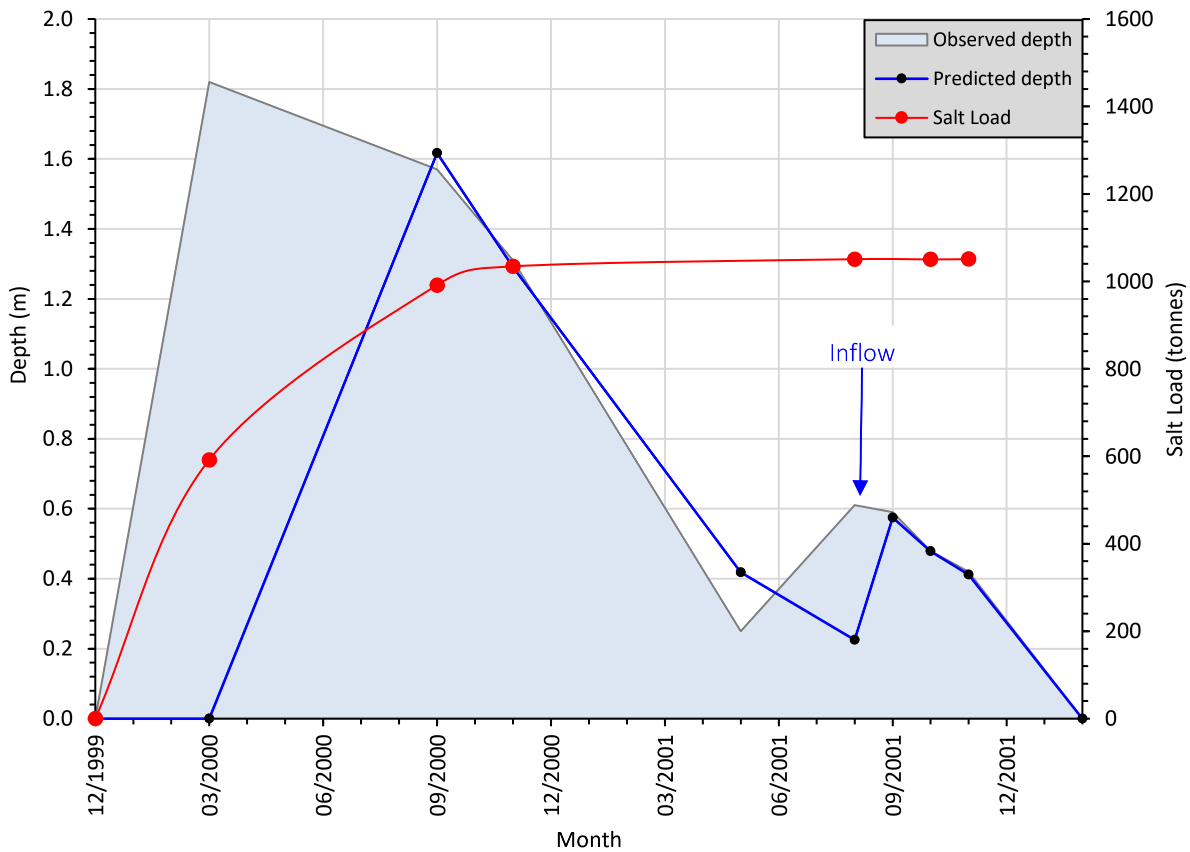

Figure 17 Lake depth and salt load data trends for the 2000-01 fill event.

2000-01 Lake Bryde fill event

This fill event was monitored by SWWMP and catchment officers on eight occasions, at irregular intervals. There remains some uncertainty about the procedures and the accuracy of the instrumentation used.

Rainfall, lake depth and inflows (Figures 16 and 17):

- The event appears to have been triggered on 22 January 2000 by a surface trough interacting with a mid-level disturbance. It delivered 79.2mm of rainfall across the catchment (104mm at Lake Grace). This in turn affected the 30-day cumulative rainfall statistic for the following 30 days, with each day exceeding 100mm cumulative rainfall.
- When first observed two months later, in March 2000, the lake level was 1.82m. However, in the two months between the rainfall event and the first monitoring the catchment received an additional rainfall of 0.05m (cumulative) and evaporation of 0.32m (cumulative). It is therefore likely that the lake's depth exceeded the level necessary for outflow during this initial period by about 0.1m.
- Winter rains and seasonally reduced evaporation led to a relatively gradual decline in lake depth until September 2000.
- Between September 2000 and August 2001, the catchment experienced below average rainfall. Perhaps as a result, Lake Bryde's depth declined at a slightly greater rate than the prediction.
- Between 25 August and 12 September 2001, the lake depth rose from 0.25 to 0.61m. The most likely cause was a period of above average rainfall which included 15 contiguous days where the preceding 30-day cumulative rainfall exceeded 100mm.
- The lake then progressively dried out, consistent with the depth prediction until 12 February 2002, when the lake was observed to be dry.
- Lake Bryde was observed to have dried out after 24 months.

Salt load (Figure 17)

- Based on the limited observation data available, it took eight months for the lake's salt load to reach its maximum of 1050 tonnes. This is, again, a month longer than was recorded for the previous fill event.
- The salt load remained stable at 1050 tonnes throughout the remainder of the fill event.
- The salt load estimate is 50-tonne lower than for the 1997-98 event. This could reflect a measurement error, or it may reflect a minor outflow event. This may have occurred at the start of the fill event, if the lake had over-filled and then outflowed, taking some of its salt load with it.

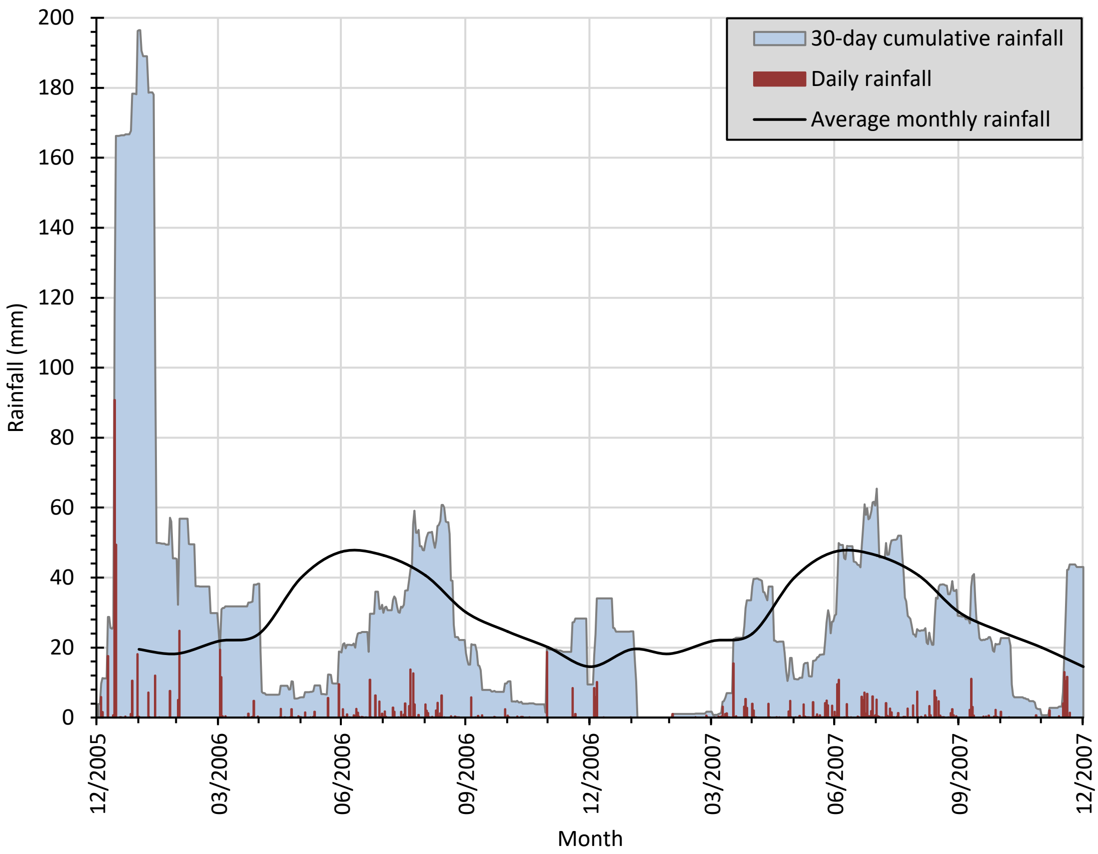

Figure 18 Rainfall relating to the 2006-08 fill event

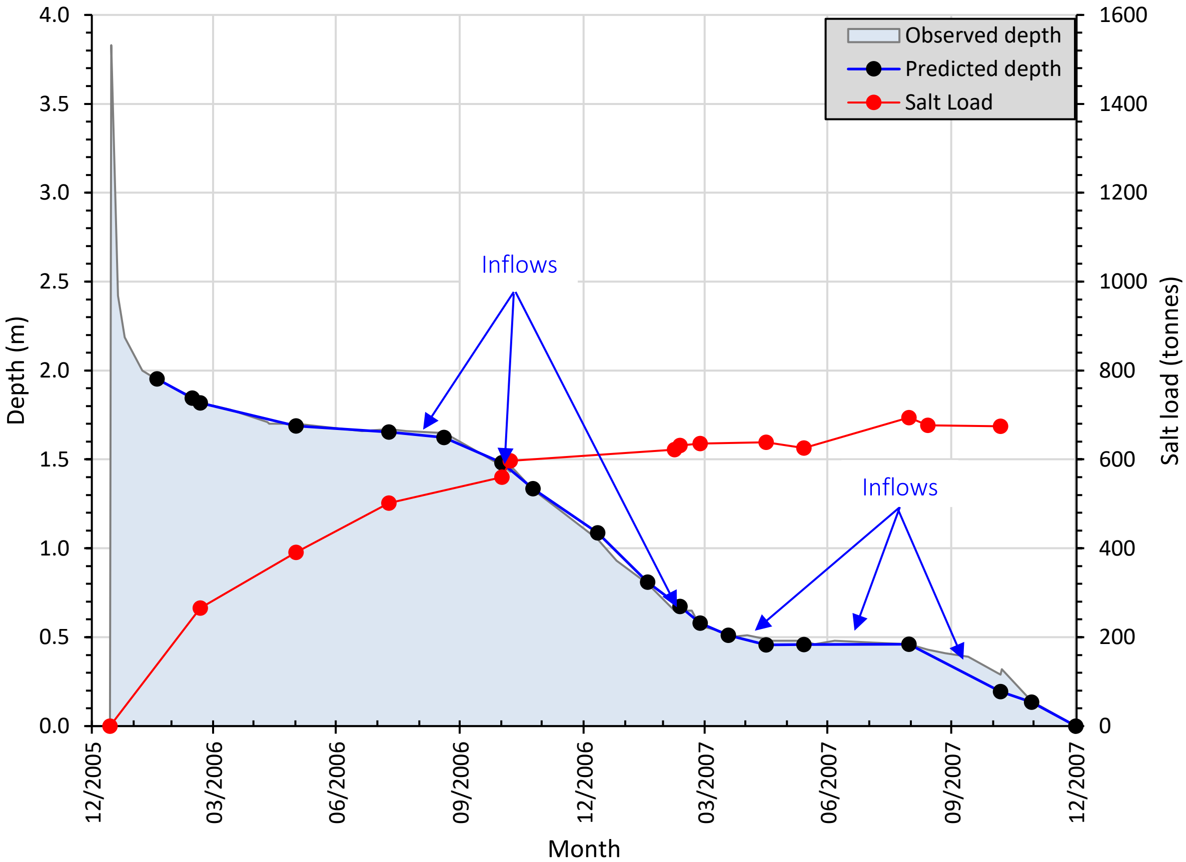

Figure 19 Lake depth and salt load data trends for the 2006-08 fill event.

2006-08 Lake Bryde fill event

The 2006-08 fill event was well monitored and documented by catchment officers and hydrologists. The instrumentation used to monitor the event appears to have been well calibrated with highly consistent observations, but the procedures used are not documented.

Rainfall, lake depth and inflows (figures 18 and 19)

- It commenced in 13 January 2006 with the arrival of a tropical low (ex-tropical cyclone Clare). This rain bearing depression deposited an average of 142.2mm of rainfall over a 48-hour period across the catchment (215.5mm at Lake Grace).
- Initially, the water level in Lake Bryde rose to 3.83m, about 1.8m higher than the lake's inlet/outlet channel (2.04m), reflecting the depth of water on the valley floor. As the waters on the valley floor gradually receded over the following three weeks, the lake steadily outflowed until the depth reached 2.04m, the height of the lake's outflow channel.
- The observed and predicted depth data indicate the lake received small inflows from February to October 2006, coinciding with periods of above average monthly rainfall. These included:
  - August-September 2006 (0.03m > prediction).
  - November 2006 (0.02m > predictions).
  - May-August 2007 (0.03m > prediction).
  - September-December 2007 (0.09m > prediction).
- In total these inflows added 0.24m to the lake's depth. While all of these inflows relate to above average rainfall events, many were only marginally above average, suggesting the heavy rainfall which triggered inflows in January 2006 also reduced subsequent runoff thresholds.

Salt load (Figure 19)

- It is thought that, during the initial phase of this fill event, a significant proportion of the Lake Bryde's salt load was dissolved into the wetland's water column. During the subsequent outflow from the lake, a proportion of the lakes salt load was then discharged.
- The salt load estimate at six months, when the salt load should have been approaching the asymptotic maximum, was about 500 tonnes. This compares favourably with the estimates of 1,100 tonnes for the 1997-98 and the 1050 tonnes of the 2000-01 fill events.
- However, as the inundation progressed the estimated salt load did not stabilise. Instead, it continued to rise in a series of incremental steps to about 680 tonnes. Many of these increases in the salt load estimate appear to coincide with the minor seasonal inflows identified earlier.
- As the final salt load estimate was 680 tonnes, the small inflows appear to have added 180 tonnes of salt to the lake.

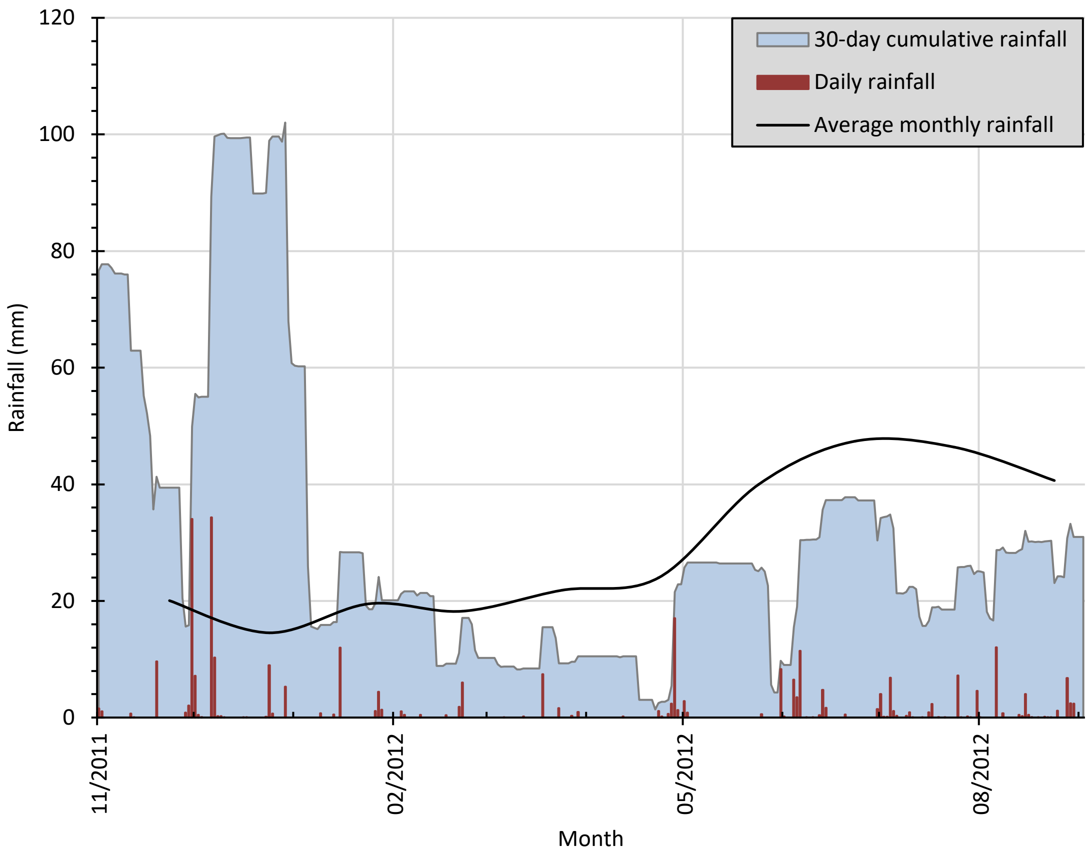

Figure 20 Rainfall relating to the 2011-12 partial fill event.

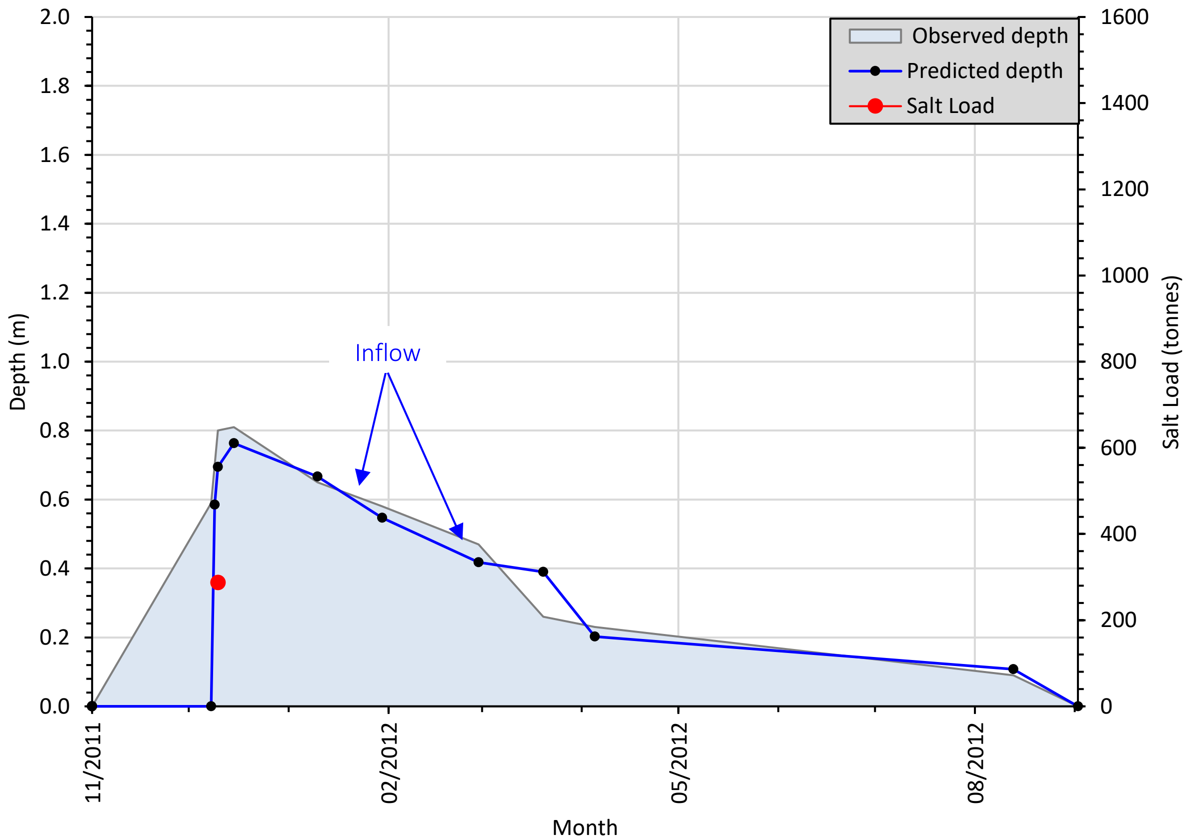

Figure 21 Lake depth and salt load data trends for the 2011-12 partial fill event.

2011-12 Lake Bryde fill event

This partial fill event appears to have been well monitored and documented by departmental staff. However there remains some uncertainty about the procedures and instrumentation used.

Rainfall, lake depth and inflows (Figures 20 and 21):

- It was triggered by a series of mid-level troughs which moved through the South West Land Division in December 2011. As a result, there were two contiguous days (16 and 17 December 2011), which had each experienced more than 100mm rainfall in the preceding 30 days.
- However, Lake Bryde only partially filled to 0.8m. Several factors may account for the reduced inflow:
  - There had been a 23-month period of significant rainfall deficiency in the catchment. Above average monthly rainfall fell in November 2011, but this may not have been sufficient to fully address drought-induced soil dryness. Therefore, a higher proportion of the December rainfall may have infiltrated into the soil, than would be the case in an average-rainfall year.
  - The rainfall occurred in summer over an extended period (31 days). Consequently, evaporation was likely to have reduced a higher proportion of rainfall available to runoff than would have occurred in winter.
  - This was the first major inflow into Lake Bryde since the completion of the waterway (Appendix 7.1). It is possible that some surface water from the Lake Bryde South sub-catchment, bypassed the lake's inlet and flowed into the waterway rather than the lake.
- Due to the limited scale of the fill event, Lake Bryde dried out after only eight months.

Salt load (Figure 21)

- Only one estimate of salt load was calculated due to the low water level.
- As a result of the shallow depth, the water body covered only a part of the lake bed where salts had been deposited by previous fill events. Consequently, a salt load estimate of 287 tonnes from this event is not comparable with any of the 'full lake' salt load estimates which preceded it and is not an accurate indicator of wetland condition.

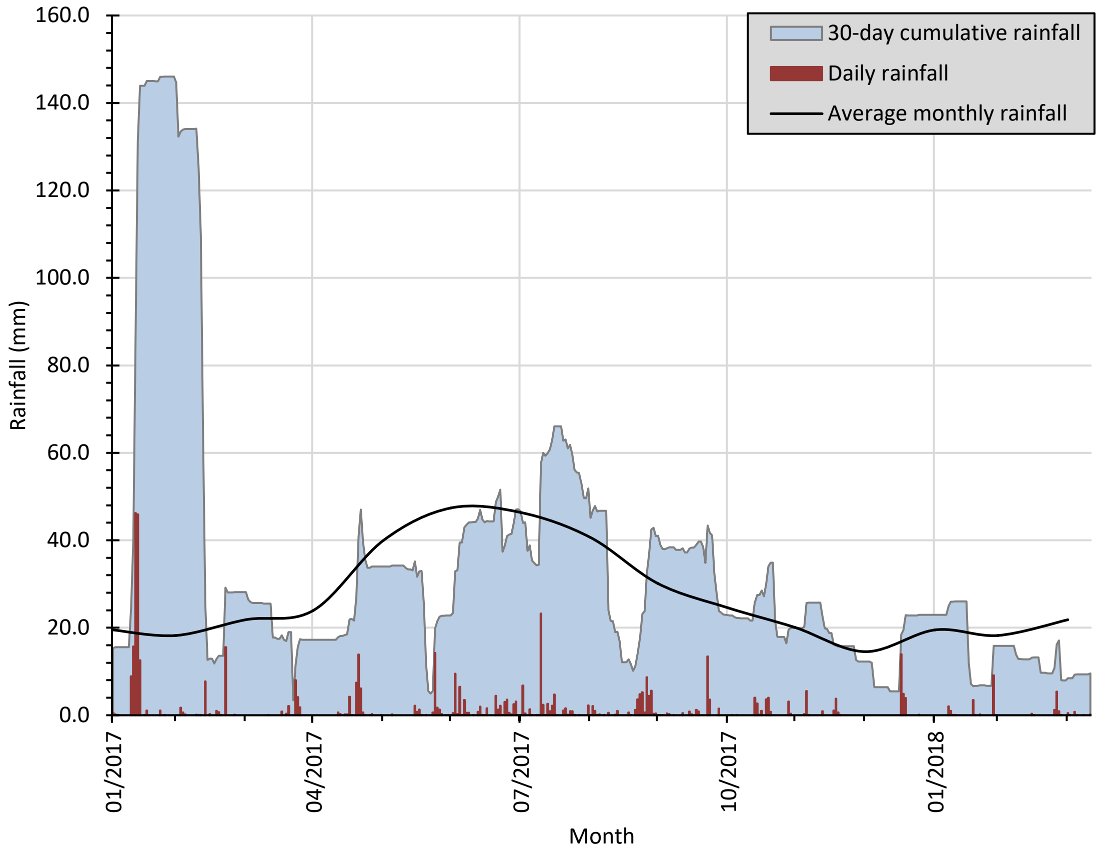

Figure 22 Rainfall relating to the the 2017-18 partial fill event.

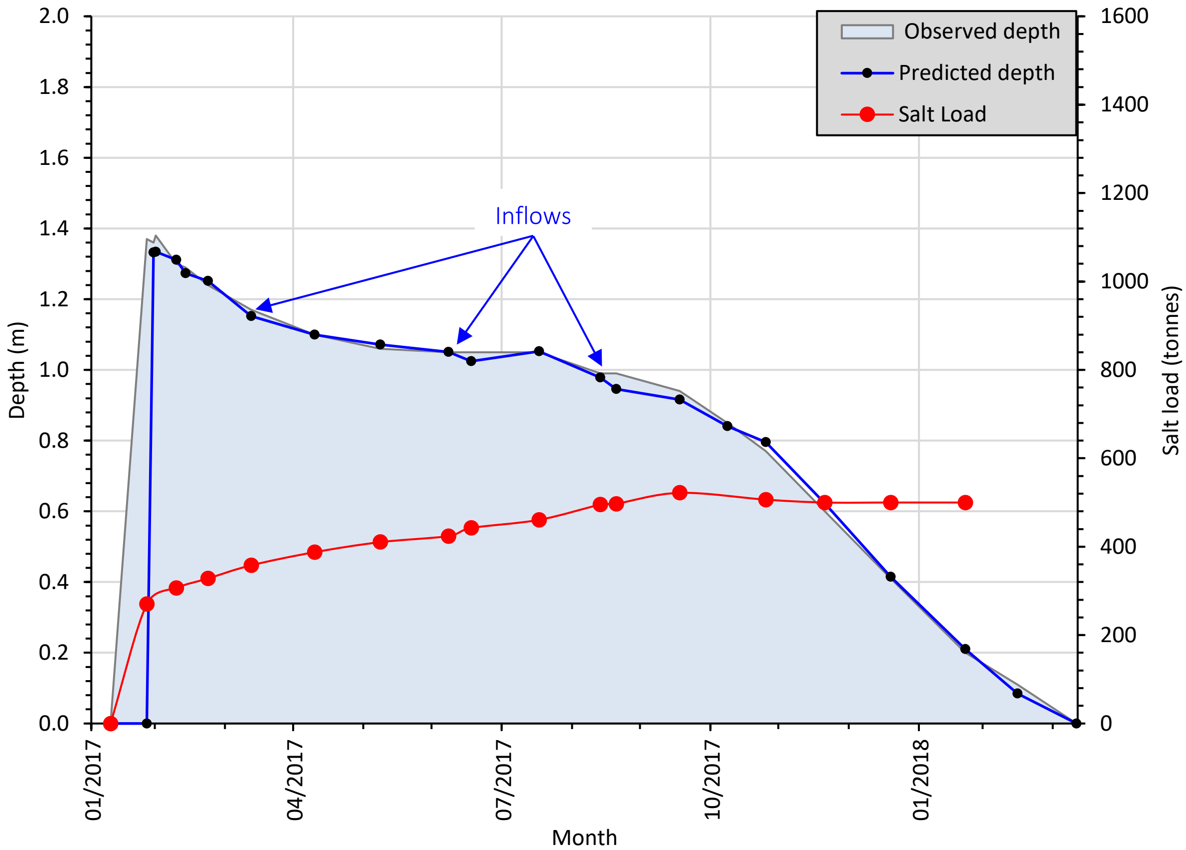

Figure 23 Lake depth and salt load data trends for the 2017-18 partial fill event.

2017-18 Lake Bryde fill event

This partial fill event was well monitored and documented by catchment officers, who followed a recently developed monitoring protocol. As a result, the instrumentation was well calibrated, and the observations appear to be accurate and consistent.

<u>Rainfall, lake depth and inflows (figures 20 and 21)</u>

- Commencing on 10 February 2017, a cloud band associated with tropical low brought widespread rainfall to the catchment over five days. As a result, 29 contiguous days each experienced more than 100mm rainfall in the preceding 30 days.
- However, Lake Bryde only partially filled to 1.37m. Several factors may account for the reduced inflow:
  - Because the rainfall event occurred in summer over an extended period, evaporation was likely to have reduced a greater proportion of rainfall available to runoff than would occur in winter.
  - Similarly, some of the runoff would also have been lost to soil infiltration due to dry soil conditions during the prevailing summer.
  - It is also possible that some surface water flow bypassed the lake's inlet and flowed into the waterway.
- There are several instances during the course of the fill event when the observed depth exceeded the predicted depth suggesting inflows into the lake:
  - April 2017 (0.02m above prediction)
  - July 2017 (0.02m above prediction)
  - September-November 2017 (up to 0.03m above prediction for several contiguous observations)
- The shallow lake depth meant Lake Bryde dried out in only 13 months.

<u>Salt load (Figure 21)</u>

- As a result of the shallow depth, the water body covered only a part of the lake bed where salts had been deposited by previous fill events. Consequently, the salt load estimates for this event are not comparable with any of the 'full lake' salt load estimates which preceded it.
- About six months into this fill event, the salt load showed signs of approaching the asymptotic maximum of about 420 tonnes.
- However, the salt load estimated thereafter continued to rise in a series of small incremental steps. These steps coincide with the periods of shallow inflow as detailed above.
- In total, these small inflows appear to have increased the lakes salt load by about 80 tonnes.

5.5 Key findings

Triggers for fill events

The seven fill events the catchment has experienced since 1979 provide an insight into the factors triggering valley floor inundation and lake filling events.

There are two cases were fill events have been triggered by more than 70mm rainfall within a 24-hour period. These all appear to be associated with major summer rainfall events:

- In January 2000, 79.2mm from a trough interacting with a mid-level depression.
- In January 2006, 90.8mm from an ex-tropical cyclone.

There were three cases where inundation was triggered when the 30-day cumulative rainfall exceeded 100mm on several contiguous days in autumn-winter. These appear to be associated with winter cold front events:

- June-July 1983, when 11 days met the criteria.
- May 1988, when 16 days met the criteria.
- April 1997, when 17 days met the criteria

There were also two cases when the 30-day cumulative rainfall exceeded 100mm on several contiguous days but resulted in only partial fill events. Both events occurred in summer months:

- In December 2011, two days met the rainfall criteria, but the lake filled to only 0.80m.
- In February 2017, 29 days met the rainfall criteria, but the lake filled to only 1.37m.

Both events occurred when conditions, such as higher evaporation rates and greater soil dryness, were likely to significantly reduce runoff. This suggests that during summer a higher cumulative rainfall may be required to achieve a complete fill of the wetland, compared with winter.

It may also be the case that some surface water flows from the Lake Bryde South sub-catchment may have bypassed the lake’s inlet and flowed into the waterway during these two events. However, it is difficult to determine the role played by the waterway, as no comparable summer fill events were observed prior to its construction.

This unresolved issue warrants further investigation (Lake Bryde Catchment Recovery Plan, Section 10, Actions 4, 15, 16 and 18) which should improve modelling of Lake Bryde’s water balance (Hydrologia 2017).

Factors contributing to salt load

The seven monitored fill events experienced since 1979, provide an insight into the factors affecting salt load within Lake Bryde.

<u>Factors contributing to salt load decrease</u>

The 2006-08 fill event provides strong evidence of a reduction in salt load. It was triggered by substantial summer rainfall (142.2mm in 48 hours) which caused a deep inundation of the valley floor. Lake Bryde recorded a depth of 3.83m which is about 1.8m higher that its inlet/outlet channel.

During this over-full phase, it has been postulated that a significant proportion of the lake's salt load dissolved in the water column. As water levels on the valley floor then receded over the first three weeks of the fill event, much of the lake's salt load was transported out of the lake by the outflowing water. This process ceased when the lake depth reached the height of its inlet/outlet channel (2.04m). This appears to have reduced the salt load from 1,050 tonnes estimated during the 2000-01 event to about 500 tonnes.

A 50-tonne reduction in salt load may also have occurred under similar circumstances during the early phase of the 2000-01 fill event.

Factors contributing to salt load increase

In the 1990s, it was thought that an increase in salt load was attributable to the initial, large inflows the lake had received from its southern sub-catchment. However, a reassessment of the available salt load data suggests a different cause, especially for the more recent fill events:

- When first monitored in the 1980s, Lake Bryde's salt load was 165 tonnes.
- During the 1988-95 fill event, it rose to 1100 tonnes. The cause of this increase was not investigated and remains uncertain.
- Salt load did not increase during the 1997-98 and 2001-01 fill events.
- While the initial phase of the 2006-08 fill event was marked by a significant reduction in salt load, as the event progressed several small increases in salt load were detected which appear to have added 180 tonnes of salt to the lake. These increases in salt load appear to have coincided with shallow inflows into the lake.
- During the 2017-18 fill event, minor inflows in the middle phase of the fill event again coincided with incremental increases in the salt load. These increases totalled about 80 tonnes.

In all the monitored fill events where there was an increase in salt load, the increase occurred not at the commencement of the fill event, but in the middle and later phases. In the most recent fill events, the salt load increase has clearly been associated with minor inflows. However, this was not the case for inflows recorded during the 1983-85, 1997-98 and 2000-01 fill events. Inflows were recorded but in each case no increase in salt load was detected.

It may therefore be the case that large rainfall events within the Lake Bryde Catchment have mobilised salts, triggering saline seepage into water courses. Runoff from subsequent rainfall events has then transported the salt into the lake.

This matter should be the focus of future investigations. If proven, consideration should be given to re-engineering the Lake Bryde inlet to divert such saline inflows away from Lake Bryde consistent with the recommended actions (Lake Bryde Catchment Recovery Plan, Section 10, Actions 4, 15, 16 and18).

Appendix 6: **Groundwater hydrology**

6.1 Groundwater monitoring sites

To determine the salinity risk from rising groundwater table, departmental staff have regularly monitored up to 193 groundwater monitoring bores, installed between 1995 and 2012. These are distributed (Figure 24) throughout the central and southern catchment (Bourke and Ferguson, 2015).

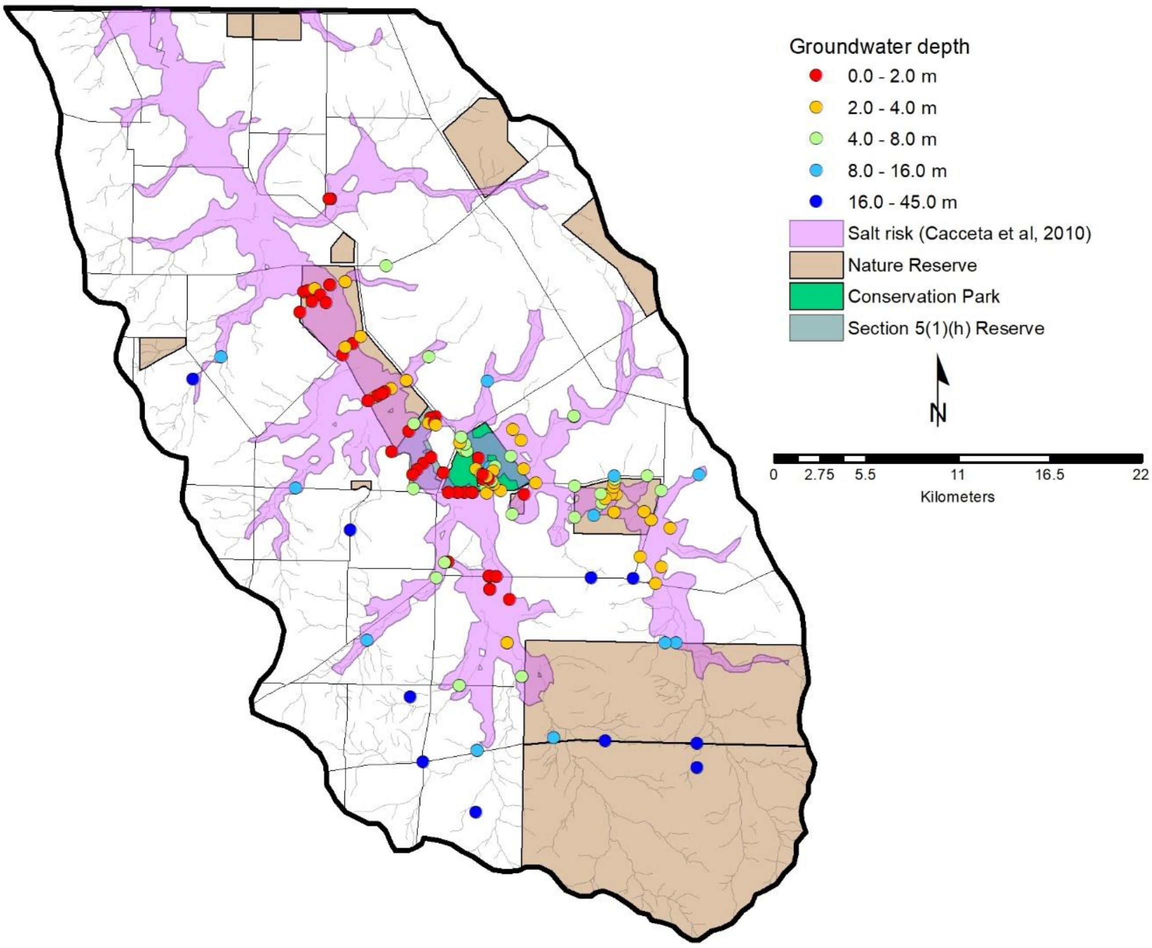

Figure 24 Groundwater depth and the salinity risk zone in the Lake Bryde Catchment.

6.2 Groundwater monitoring methods

While monitoring was originally undertaken on a monthly basis, a recent review (Rockwater, 2016) has reduced the number of bores requiring monitoring to 92, most of which are now monitored on a quarterly basis in January, April, July, and October.

Monitoring involves lowering a ‘plopper’ – a tubular metal device with an acoustic cup on its base - attached to a measuring tape down the bores. When the plopper enters the groundwater, it makes a distinctive sound which can be used to measure the depth with an accuracy of ± 0.010m.

The upper tubular section of the plopper can be used to collect groundwater samples which are then analysed with a conductivity-pH-temperature meter (TPS WP-81). The electrical conductivity (EC) is usually measured in millisiemans per metre (mS/m) with an accuracy of 0.5% when accurately calibrated. Acidity is measured using the pH range with an accuracy of ±0.01pH when accurately calibrated.

6.3 Groundwater monitoring results

Groundwater chemistry

The groundwater chemistry has been monitored sporadically since the 1990s. Most samples from valley floor bores were found to be highly saline (>35,000 mg/l) and consequently toxic to most terrestrial plants. Shallow, rising groundwater tables therefore represent a major threat to affected agricultural and biodiversity assets.

Groundwater depth and trends on the valley floor

Many valley floor bores tend to have groundwater tables of between 2.0 and 3.0m below ground level (mbgl). At this depth, the ongoing discharge of groundwater through evaporation will likely lead to the accumulation of salt in the soil profile, to the detriment of those plant species sensitive to salinity and shallow groundwater tables.

Several early studies indicated rising groundwater trends (Giraudo *et al*., 1996, Overheu, 1999, Sinclair Knight Merz Pty Ltd, 2000, Nott and Cattlin, 2006). However, Bourke and Ferguson (2015), reported that between 2000 and 2014, static or falling groundwater levels were the dominant trend within the valley floor monitoring site. They suggested that this trend may relate to a drying climate. However, climatic factors may take decades to reduce soil salinity.

Groundwater depth and trends on valley slopes

Bores sited on tributary valleys and lower hill slopes tend to have groundwater 3.0 - 8mbgl whereas those on upper slopes tend to have groundwater greater than 8mbgl. However, while groundwater levels at such sites are much deeper, a rising groundwater level trend has been observed at many of the bores (Bourke and Ferguson, 2015).

This trend is consistent with observations in other areas of the Wheatbelt (Raper *et al*., 2014), with the continued rise a consequence of vertical recharge rates exceeding horizontal discharge.

6.4 Conclusions

Caccetta *et al*. (2010) predicted the future likely extent of salt-affected land, as it relates to agricultural production in the WA Wheatbelt. The catchment's groundwater observations appear to confirm these predictions, with the only anomalous bores appearing to be on the valley floor near East Lake Bryde and on the outermost tributaries of the salinity risk zone, where bores show either a static or rising trend.

While there has been a recent downward trend observed on many of the groundwater bores on the valley floor, a considerable area within the catchment has shallow and highly saline aquifers, including:

- About 21,200 hectares of freehold land on the valley floor. This amounts to 18% of this tenure type within the catchment. Of this total 15,200 hectares is cleared agricultural land while the remainder (5990 hectares) is occupied by remnant vegetation.
- About 5196 hectares (or 14% of the catchment area) are DBCA managed conservation reserves within the catchment. The area at risk is concentrated on the primary valley floor, where about 68% of the conservation reserves are

affected. The reserves contain important biodiversity assets including all occurrences of the Bryde TEC, and a range of woodlands, mallee and melaleuca communities which are restricted to the valley floor terrain class.

- About 14% of the catchment's other Crown lands such as water reserves and road reserves.

Consequently, based on the predictions of Caccetta *et al*. (2010), a moderate to high risk of hydrological impacts applies to the valley floor soil-landscape. An assessment of long-term future risk is, however, dependant on future climate trends (Bourke and Ferguson, 2015).

Appendix 7: **Catchment recovery activities**

Many of the catchment's important biological elements are at risk from altered hydrology. Between 1999 and 2018, management activities were implemented in advance of the publication of the recovery program to counter degradation of these assets.

7.1 Surface water management

Several studies (Davis, 1996; Farmer *et al*, 2002; Giraudo, 1995; Giraudo *et al*, 1996; Sinclair Knight Mertz, 2000) identified biological elements on the valley floor which were threatened by altered hydrology. The key threats were seen to be prolonged inundation of the valley floor and rising salt loads within Lake Bryde, which were caused by the impedance of surface water flows by natural barriers and road formations.

The flat nature of the catchment's valley floor and the lack of either a defined channel, or an obvious disposal point for managed water, created a unique problem for surface water management.

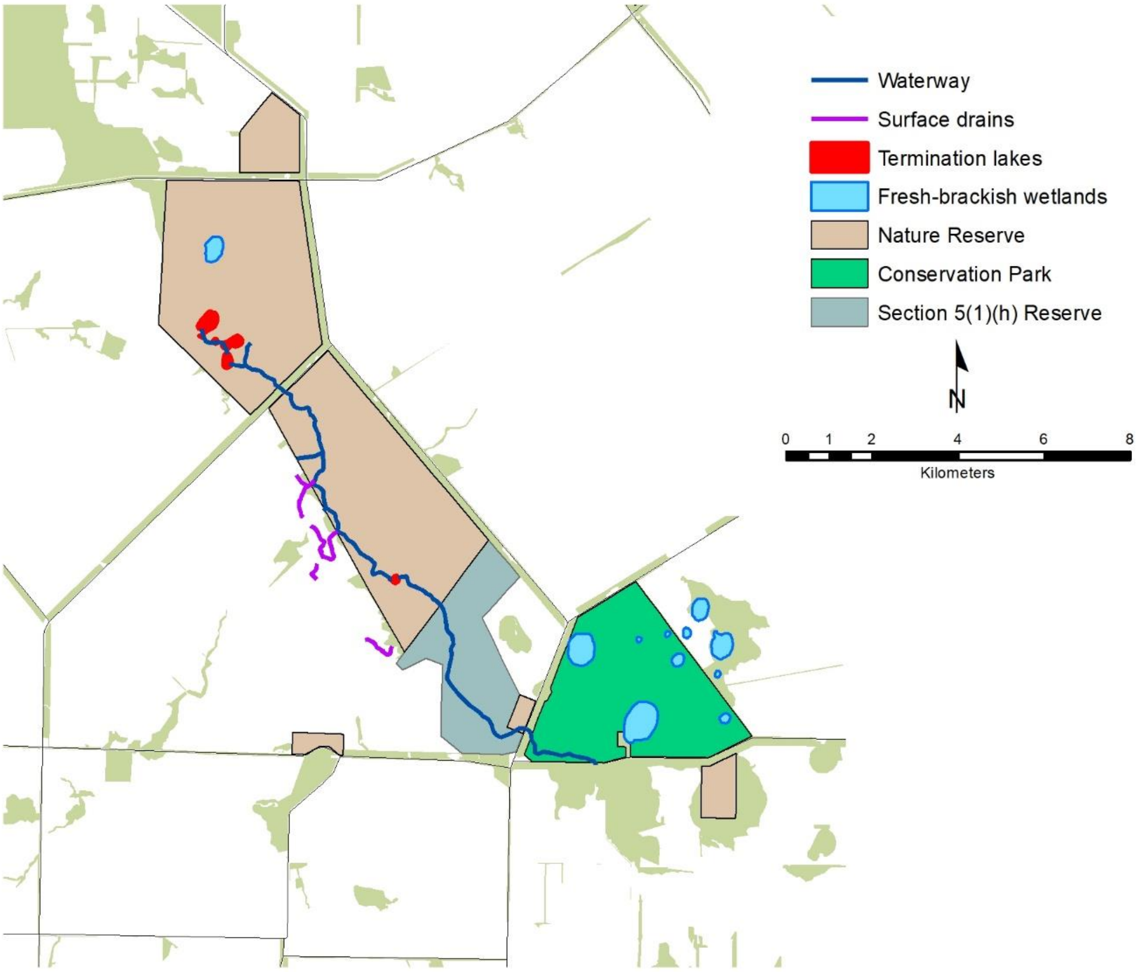

Figure 25 Surface water management infrastructure in the Lake Bryde Catchment

To address these threats, a surface water conveyance structure (waterway) 10-15m wide was designed to reduce inundation and ponding. Its construction would entail:

- Removing natural barriers to surface water flow by grading, with laser levelling technology, a waterway along the valley floor, from near the Lake Bryde inlet to a set of degraded termination lakes in the northern part of Lakeland Nature Reserve.

- Upgrading road culverts and track crossings at points where public roads and firebreaks crossed the waterway.

The waterway design was subsequently approved by both the former Conservation Commission of Western Australia and the EPA. Construction commenced in 2005 but, due to prolonged flooding of the valley floor in 2006-07, the waterway was not completed until 2009.

In 2010, surface water drains, linked to the waterway, were installed on freehold land on the western boundary of Lakeland Nature Reserve. Their purpose was to reduce the inundation of the adjoining section of the reserve, which had suffered significant hydrological impacts (Mudgway and Nicholson, 2010). Weirs were installed along the drains to reduce water velocity to prevent erosion of the drains.

Consequently, the waterway has provided a means of reducing:

- Salt accumulation on the valley floor adjacent to the Lake Bryde inlet, and
- Prolonged inundation along the valley floor and the western boundary of Lakeland Nature Reserve.

However, it has achieved these results at the cost of removing some surface water from the upstream part of the drainage system and transferring the salinity to down-stream wetlands and groundwater aquifers.

7.2 Revegetation

Many of the hydrological changes which threaten the biological elements within the Lake Bryde Catchment are related to reduced evapotranspiration following the widespread removal of perennial native vegetation. To address these problems, the department undertook a range of revegetation projects.

Freehold land

The department has undertaking 395 hectares of revegetation on freehold land. Most of this work has been undertaken on a voluntary cost-share basis, with the department meeting the cost of seedling production and the plantings operations, and the landowner covering the cost of site preparation and long-term management.

- 24 revegetation projects involved native biodiversity plantings. A total of 397,000 seedlings were used to establish 238 hectares of revegetation.
- A further 18 projects involved revegetation with potentially commercial plantings. These projects established 250,000 oil mallee seedlings on 157 hectares.

Reserves

The department has also undertaken revegetation on two reserves within the Lake Bryde Catchment.

In 2003, the department purchased a portion of a freehold property which connected the Lake Bryde Conservation Park with Lakeland Nature Reserve. The land in question contained areas of cleared and arable land and areas of remnant vegetation. It had experienced degradation due to recent inundation and salinity. However, it was immediately recognised that the property provided excellent connectivity between the existing reserves, the opportunity to demonstrate revegetation techniques to landowners and the means to address hydrological threats on the valley floor.

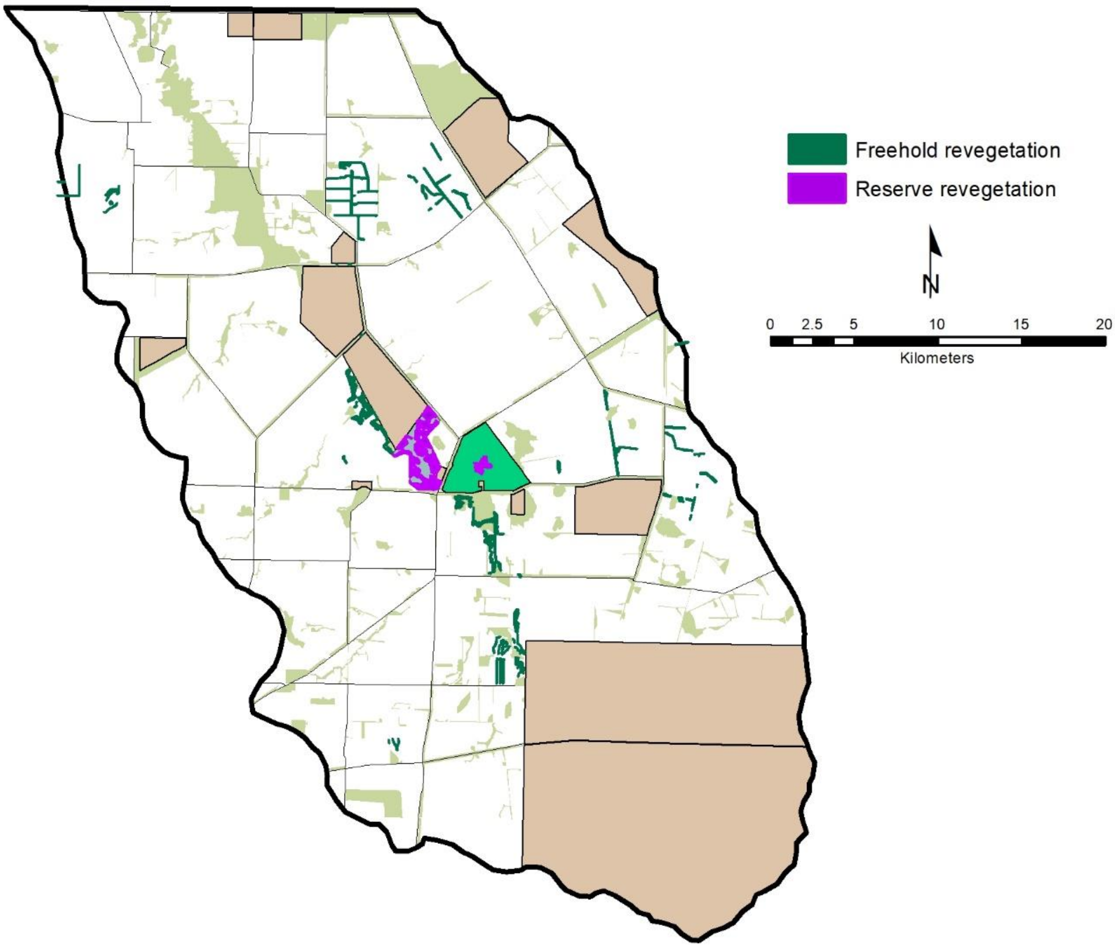

Figure 26 Revegetation projects undertaken in the Lake Bryde Catchment.

The 725 hectares property became a departmental 5(1)(h) reserve in 2004 with a purpose of rehabilitation trials and demonstrations, hydrological management, and conservation.

Since its purchase, the department has revegetated 376 hectares for a range of different purposes, including:

- Potential commercial trials, for carbon credits, biomass, and production of eucalyptus oil and broombush fencing.
- Demonstration of different ripping methods and planting densities.
- Plantings to restore biodiversity using seed collected from local species.

The second reserve to be revegetated was the Lake Bryde Conservation Park. Reserve 48436 was vested with the then Conservation Commission as a conservation park in 2006. The reserve contained two cleared areas dating from the 1920's, when these areas had been part of the failed agricultural settlement of the area.

In 2016 an assessment was made of these sites. As there had been almost no natural woodland regeneration within the clearings, it was decided to revegetate the 25 hectares site with a range of local native species to restore biodiversity and increase water utilisation. This work was completed in July 2017.

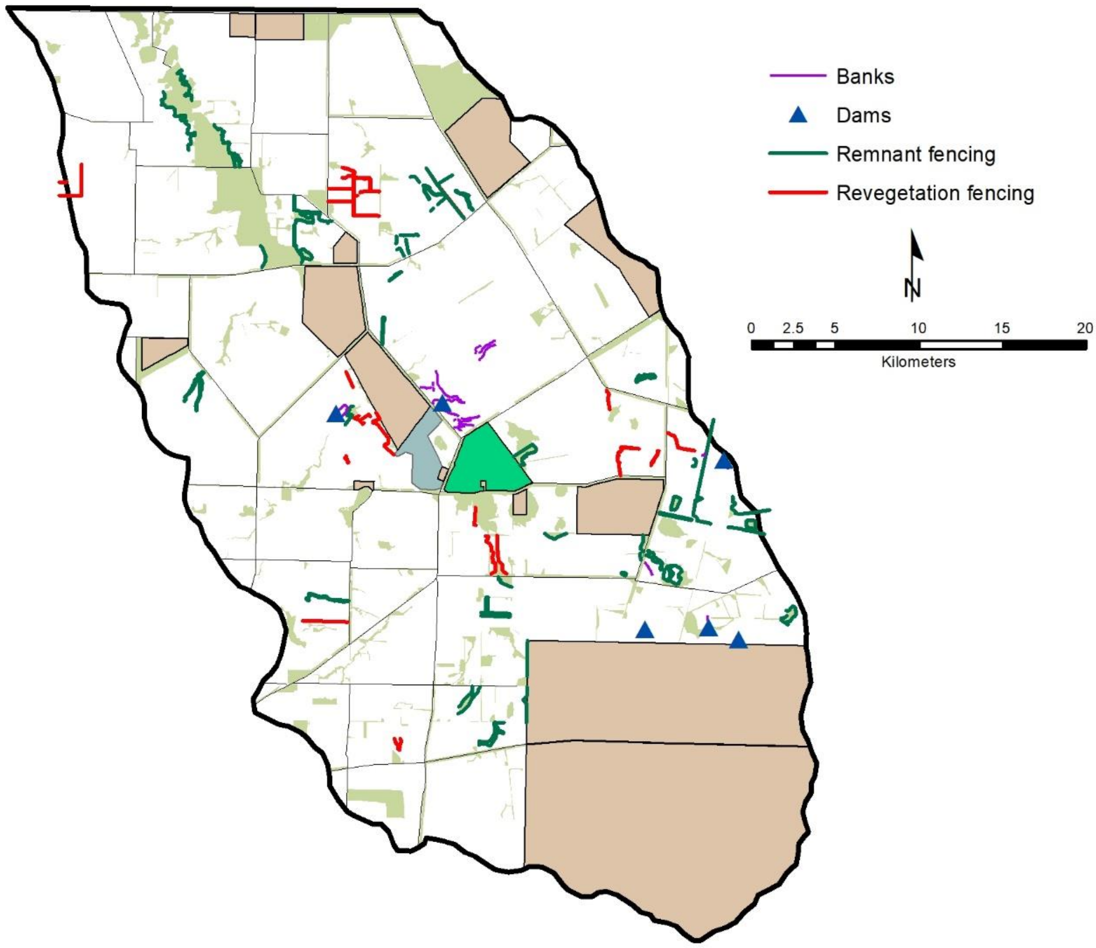

Figure 27 Cost-share fencing, dams and banks projects in the Lake Bryde Catchment.

7.3 Other Activities

The department has also undertaken a range of other activities on a cost-share basis. These activities have included:

- 51km of stock-proof fencing which was installed around revegetation sites to allow for improved water utilisation through evapotranspiration.
- 165km of stock-proof fencing which was installed around remnant bushland, to protect the vegetation from grazing and to thereby maintain or improve water utilisation through evapotranspiration.
- Surface water banks and dams which were constructed in the upper catchment to increase surface water storage and utilisation. In total, 12 dams and nearly 13.5km of banks and drains were constructed.

7.4 Landowner initiated changes to land management

Many farmers within the Lake Bryde area are progressive and there has been widespread adoption of improved tillage and other innovative farming practices. Direct advice to landholders is provided by the Department of Agriculture and Food, Lake Grace District Office. Through the South Lake Bryde Focus Catchment project (DAFWA, mid-late 1990's) and the subsequent Lake Bryde Natural Diversity Recovery Project (2000-15) many landholders have become aware of local issues and have been incorporating this awareness into the refinement of their agricultural practices and land management activities.

Appendix 8: **Recovery team and technical advisory group**

8.1 Background

The Lake Bryde Catchment (previously referred to as the Lake Bryde Natural Diversity Recovery Catchment) contains several high value public assets, together with their associated biological elements. These include regionally rare freshwater wetlands, such as Lake Bryde and East Lake Bryde, which have significant conservation and recreational values.

Most of these public assets are sited within nature reserves and a conservation park managed by DBCA. Since 1999, the department has coordinated management actions within the catchment, to protect these high-value public assets and their associated biological elements which are both threatened by changed hydrology, particularly salinity.

The current planning approach focuses on managing biological elements for their key human values and, consequently, the recovery team should represent these values. It is also important to ensure that stakeholders directly affected by management in the catchment are represented. The landscape recovery program will provide the direction for management over the next 20 years and as such, there is a clear need to establish and define roles for the team and to consider the future role of specialist advisors.

These terms of reference were developed with the aim of achieving an effective recovery team and specialist group to oversee the development and implementation of the new landscape recovery program.

8.2 Role of the Lake Bryde Catchment recovery team

The recovery team has no decision-making powers and meets as an advisory group only. The department considers advice from the team in relation to the department's statutory responsibilities and, if necessary, seeks approvals for a specific recovery action following the hierarchy described in Figure 28.

The role of the recovery team is to advise the department on the following:

- Development and review of the landscape recovery program for the Lake Bryde Catchment
- Implementation of recovery actions, particularly as representatives of a range of stakeholders
- Development of priorities for recovery action
- Dissemination of information on the progress of recovery
- Development of progress reports.
- The DBCA Regional Manager Wheatbelt Region will chair the recovery team.

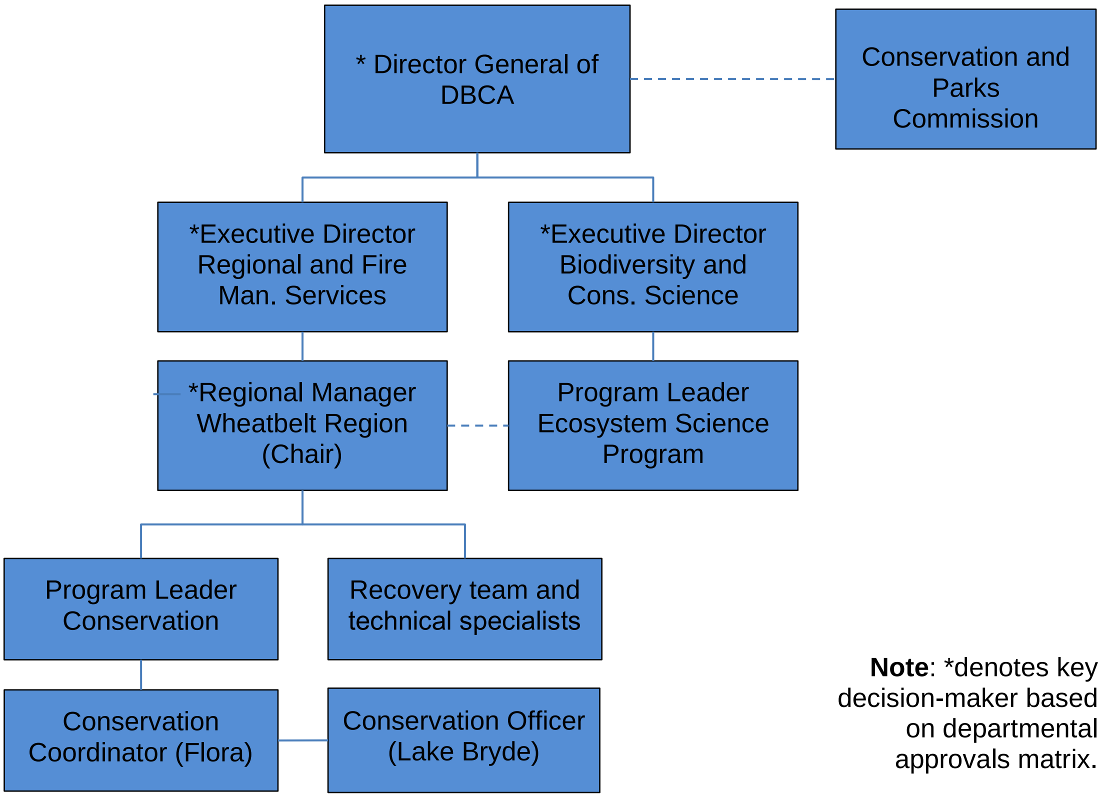

Figure 28 Management hierarchy and the reporting and decision-making framework for Lake Bryde Catchment recovery actions.

8.3 Recovery team operating procedures

The recovery team will aim to meet twice a year. However, this will depend on the need for a meeting as determined by the chairperson.

The role of the chairperson is to:

- schedule meetings, set and distribute the agenda and notify all members
- guide the meeting according to the agenda and the time available
- review, approve and distribute minutes of meetings
- invite specialists to attend meetings when necessary.

Other invited guests may attend meetings, but they are not formal members. Generally, the Conservation Officer and Operations Officer (Lake Bryde) will attend meetings and take minutes. If a member is unable to attend the meeting, they should arrange a proxy.

8.4 Membership of the recovery team

The recovery team will consist of up to 12 representatives from key stakeholder groups who represent the values derived from the biological elements within the Lake Bryde Catchment, or who represent those directly affected by management of Lake Bryde (Table 3). The Director General of the Department of Biodiversity, Conservation, and Attractions endorses all recovery team memberships.

The position or representation by the group is listed, not individual people. It is the responsibility of the person nominated as the group representative to arrange for alternative representation if they are unable to attend. To ensure equity of representation, only one individual from each stakeholder group will be nominated.

Table 3 Stakeholder representative group

Stakeholder/organisation	Sector/group	Position
Department of Biodiversity, Conservation and Attractions	Government	Regional manager
	Wetland Conservation Program	Program leader
Shire of Kent	Shire	Councillor
Shire of Lake Grace	Shire	Councillor
Local community	Landholders	Landholder
	Community and ratepayers	Community member
Wheatbelt NRM	NRM group	Regional officer
Department of Water and Environmental Regulation	Water management	Manager
Department of Primary Industries and Regional Development	Agriculture	Project manager Land and Water Assessment Program
Wagyl Kaip And Southern Noongar or Ballardong	Aboriginal custodians	Elder
Landcare District Committee	Local environment	Landcare coordinator
Birdlife Australia	Fauna	Member

8.5 Technical advisory group and technical specialist advice

Technical specialists can advise the department and the recovery team on a range of technical, research and development issues related to the Lake Bryde Catchment. Prior to 2015, these specialists were referred to as the technical advisory group (TAG). They are now called the technical specialist advice (TSA). These terms are therefore interchangeable in these supporting documents.

A list of technical and research advisors is provided below. Expert advice will be sought as issues arise. This list is not exhaustive and relevant experts, both private and government, may be called to provide advice on recovery matters.

- Hydrology – surface water and groundwater (DBCA/Department of Primary Industries and Regional Development [DPIRD], private)
- Hydro-geology (DBCA)
- Sustainable land use (DPIRD)
- Engineering (DBCA, DPIRD, private)
- Ecology (DBCA, private)
- Botanist (DBCA, private)
- Wetlands – physical and biological factors (DBCA)
- Revegetation (DBCA)
- Research/education (DBCA, universities, CSIRO)
- Climate change (DBCA, universities)
- Others as required.

Appendix 9: **Catchment values ranking procedure**

A summary of the process and results for the Lake Bryde Catchment values-ranking exercise is covered under three headings: classification of values, methods, and results and discussion.

9.1 Classification of values

The classification of values used for the Lake Bryde Catchment is provided in Table 5. The value set was based on that described by Lindenmayer and Burgman (2005) and was modified to:

1. reduce redundancy among the categories
2. minimise double counting
3. increase the clarity and simplicity of the classification for use in a practical application where there are often time limitations.

To the extent practicable, the classification reflected the ideas outlined in Wallace (2012).

9.2 Methods

Identification and involvement of stakeholders

The Government of WA is responsible for managing the biological elements subject to planning in the Lake Bryde Catchment. Thus, the statutory functions of DBCA mean that the biological elements are being managed on behalf of the Western Australian community, who are the stakeholders that need to be engaged. The department's approach was to identify groups and organisations that might reasonably be expected to represent a broad set of community views.

Table 4 Relevant stakeholder groups and their responsibilities for the Lake Bryde Catchment

Stakeholder group	Organisation (if relevant)	Invited	Attended
Landholders		Y	1
State government	Department of Parks and Wildlife (now DBCA)	Y	5
	Department of Agriculture and Food WA (now DPIRD)	Y	1
	Department of Education – local schools	Y	N
	Great Southern Development Commission	Y	1
Local government	Shire of Lake Grace	Y	2
	Shire of Kent	Y	N
Native Title Service Provider	SWALC	Y	N
Fauna conservation groups	Mallee Fowl Preservation Group	Y	1

Table 4 lists the groups invited to participate in the values exercise for Lake Bryde Catchment and identifies those who were represented. This group broadly formed the advisory group for management planning and was chaired by the then local department District Manager.

Table 5 Values from native biota – Lake Bryde Catchment

Values	Description of value and examples
Productive use	Are the values of biological diversity ones that are harvested commercially, or ones that contribute to the production of commercial goods? E.g.: • food (harvesting of kangaroos, hydrological protection from bushland) • potable water (role of native biota in sediment and nutrient stripping) • structural materials (fence posts, timber) • energy (firewood) • wild harvest of cut flowers and other plant products.
Consumptive use	Are the values of biological diversity harvested for domestic use and used without passing through a market? May include any of those above, e.g. farmers using trees from their properties for firewood or fence posts.
Recreation	The importance of biological diversity for leisure activities is well known. Includes passive recreation (e.g. birdwatching, nature photography) and more active recreation which may require significant construction works (e.g. extensive walk trails). Research links recreation in natural environments to both physical and mental health. There are strong links between recreation and amenity (aesthetic) values.
Health (physical environment)	Those values from biological diversity that contribute to the quality of our chemical and physical environment: • shade and shelter from remnant vegetation around yards and houses • biological diversity as indicators (i.e. 'the canary in the coal mine') • dust reduction through retained vegetation, with a positive effect on human health.
Health (protection from other organisms)	Biological diversity helps to maintain our health by protecting us from other organisms. Includes: • medicines (e.g. eucalyptus oil) • biological diversity as a form of disease suppression (epidemic prevention, e.g. by maintaining low populations amongst disease-carrying organisms).
Aesthetics	Scenic and other aesthetic values of natural landscapes, beauty of wildflowers and birds. Includes 'sense of place' values, although this could be incorporated into the next category.
Philosophical/spiritual contentment	All humans operate within either an explicit or implicit set of philosophical beliefs that: • establish and explain the role of humans in the world/universe, including birth and death • provide guidance for how we should live our lives and interact with other people, other organisms, and the inanimate world. Biological diversity is often an important part of our spiritual/philosophical and moral framework. Intrinsic values are incorporated here given that they are a statement of beliefs.

Values	Description of value and examples
Knowledge and heritage	Natural biological diversity is widely used for scientific and educational purposes. E.g. maintaining a set of representative, undisturbed soils and their related biota is essential if we wish to understand the changes brought about by various uses. Other examples include the widespread use of bushland to research natural processes, and as an educational resource by schools.
Future options	The conservation of biological diversity provides for a range of future opportunities in any of the above categories. Most obvious is the germplasm resource in native plants. Thus, opportunity values are those values listed elsewhere in this table that are not currently realised. They will include maintaining the opportunity for: • discovery of currently unknown values in our native biota • currently known values to be used at some time in the future • future generations to make their own decisions concerning biological diversity values.

Elicitation

The department undertook the values elicitation and ranking in August 2013. Prior to the elicitation, it was emphasised to the workshop participants that the outputs were advisory, and that ultimately the nature reserves had to be managed consistent with the relevant State government legislation. The elicitation was then conducted using the following steps.

1. The department offered definitions of the term ‘value’ and these were discussed with the workshop participants. The definition used for the exercise was that values are benefits for human well-being where this encompasses survival, reproduction, and other key human needs. The facilitator then presented the proposed list of values which the participants discussed.
2. The group described the biological elements of the native biota at risk from altered hydrology in the Lake Bryde Catchment as:
   - several important vegetation communities including those dominated by species such as salmon gum (*Eucalyptus salmonophloia*), *Melaleuca* species, and *Duma* shrubland.
   - priority and rare flora.
   - threatened fauna (other than waterbirds).
   - waterbirds.
   - aquatic invertebrates associated with Lake Bryde.
   - other flora and fauna.
3. The workshop participants and the facilitator discussed the values that may arise from the biological elements and ensured that the group was comfortable with the values classification.
4. The workshop participants formed into groups of three and discussed amongst themselves the values that may arise from the biological elements. The participants then reformed as a single group and discussed the outputs of their deliberations. This ensured that all participants had a comprehensive and shared set of views concerning the values that might arise from the biological elements.

5. Workshop members individually and anonymously ranked values from their stakeholder group perspective and from their personal perspective. It was expected that the rankings for the two approaches would differ, thus providing support for the notion that the stakeholders could put aside their personal feelings to represent their stakeholder group.

The facilitator then collated the results, which were presented to the workshop group for discussion and finalisation. The group did not express any concerns with the results. The top three ranked values were identified as the priority values for the recovery planning process. During the group discussion of the results the facilitators documented more detail about why values were important.

9.3 Results and discussion

Figure 29 shows that increasing scores on the y-axis reflect increasing agreement amongst stakeholders and increasing scores on the x-axis showing increasing level of importance ascribed to the value.

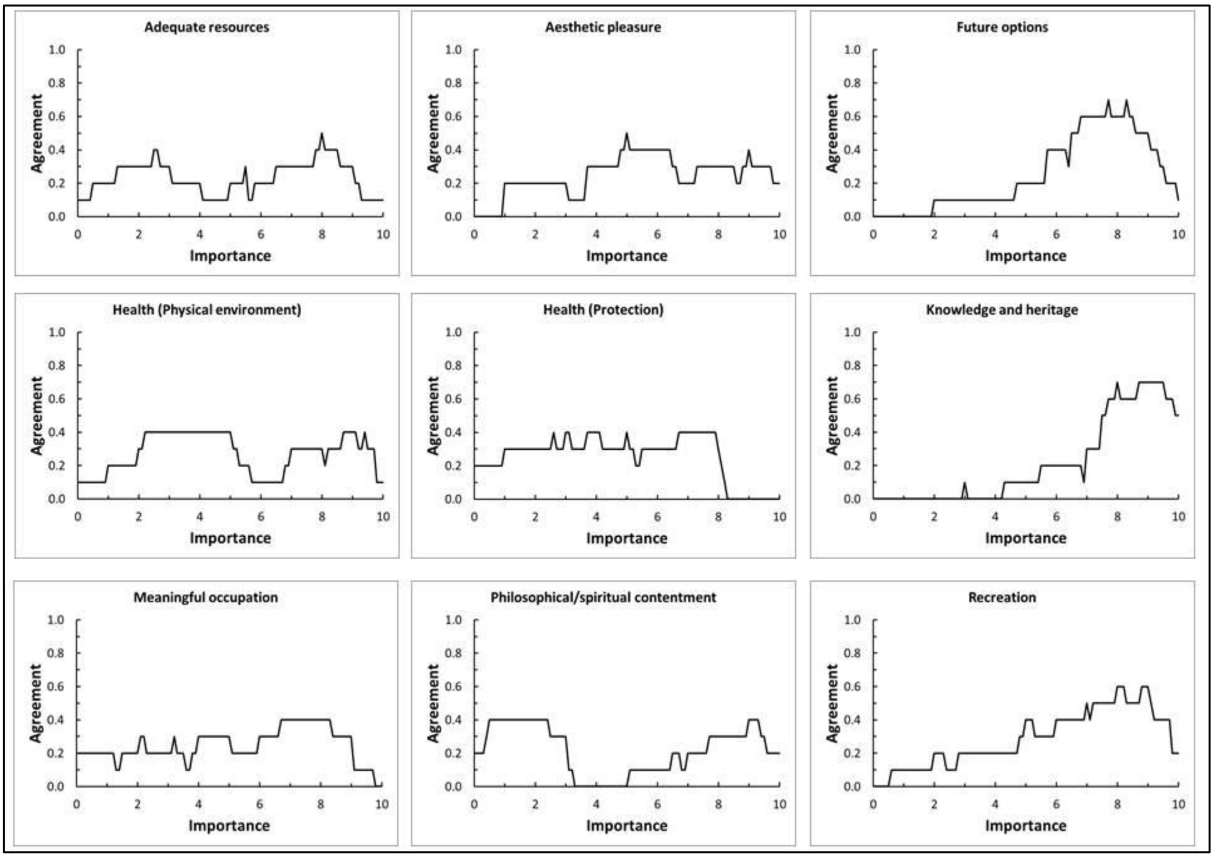

Figure 29 The aggregated importance estimates for each human value. Narrower spread across the x-axis and greater peaks along the y-axis equates to greater agreement. From Wallace 2014.

Three trend types are apparent from this analysis

- For the Knowledge and Heritage, Future Options, and Recreation values there is general agreement amongst stakeholders that these values are important.
- For the Health (physical-chemical environment); Adequate Resources; and Philosophical-spiritual Contentment values, stakeholders separate into two groups (i.e., form a bimodal distribution) one group considering these values to be important, and the second group seeing them as unimportant.

- For the remaining three values there is little agreement amongst stakeholders, and the scores are widely spread.

The information in Figure 29 provides valuable insights into the level of agreement amongst stakeholders concerning the importance of individual values. For example, selecting a value with a bimodal distribution as a priority would, unless carefully managed, create serious divisions within the stakeholder group.

Based on the premise that the priority values guiding the planning process should be those for which stakeholders agree on their high importance, the values of Knowledge and Heritage, Future Options and Recreation are the most important. With stakeholder consent, these three values were taken into the planning process as the priorities driving goal formation and priority setting amongst the biological elements.

Appendix 10: **Biological elements**

10.1 Fauna elements

Between 1996 and the present, the Lake Bryde Catchment was subject to a series of fauna surveys (Burbidge *et al*., 2004; Cale *et al*., 2004; Cale, 2006; Cale, 2013; Halse *et al*., 2004; Pinder *et al*., 2004) covering aquatic invertebrates, waterbirds and terrestrial vertebrate fauna. This was further supported by the publication of fauna observations collated by Birds Australia, the Western Australian Museum and DBCA (including its predecessor agencies) (2007 - 20).

Table 6 Mammal species recorded or likely to be found in the Lake Bryde Catchment.

Native mammal species	Common name	Conservation status
Antechinus flavipes	Mardo	
Cercartetus concinnus	Western pygmy-possum	
Chalinolobus morio	Chocolate wattled bat	
Dasyurus geoffroii	Chuditch	T - VU
Vespadelus finlaysoni	Finlayson's cave bat	
Hydromys chrysogaster	Water-rat	P4
Isoodon obesulus fusciventer	Southern brown bandicoot	P5
Macropus eugenii derbianus	Tammar wallaby	P5
Macropus fulignosus	Western grey kangaroo	
Macropus irma	Western brush wallaby	P4
Macropus robustus	Euro, common wallaroo	
Mormopterus planiceps	Southern freetail bat	
Myrmecobius fasciatus	Numbat	
Ningaui yvonnae	Southern ningaui	
Notomys mitchellii	Mitchell's hopping mouse	
Nyctophilus gouldii	Gould's long-eared bat	
Nyctophilus geoffroyi	Lesser long-eared bat	
Nyctophilus major	Central long-eared bat	P4
Phascogale calura	Red-tailed phascogale	T -EN
Pseudomys albocinereus	Ash-grey mouse	
Pseudomys occidentalis	Western mouse	P4
Pseudomys shortridgei	Heath mouse	T - VU
Rattus fuscipes	Bush rat	
Scotorepens balstoni	Inland broad-nosed bat	
Sminthopsis crassicaudata	Fat-tailed dunnart	
Sminthopsis gilberti	Gilbert's dunnart	
Sminthopsis granulipes	White-tailed dunnart	
Sminthopsis griseoventer	Grey-bellied dunnart	
Tachyglossus aculeatus	Echidna	
Tadarida australis	White-striped freetail-bat	
Tarsipes rostratus	Honey possum	
Trichosurus vulpecula	Brushtail possum	
Chalinolobus gouldii	Gould's wattled bat	
Vespadelus regulus	Southern forest bat	

Table 7 Waterbird species recorded or likely to be found in the Lake Bryde Catchment.

Native waterbird species	Common name	Conservation status
Anas castanea	Chestnut teal	
Anas gracilis	Grey teal	
Anas rhynchotis	Australasian shoveler	
Anas superciliosus	Pacific black duck	
Anhinga melanogaster	Darter	
Ardea novaehollandiae	White-faced heron	
Aythya australis	Hardhead	
Biziura lobata	Musk duck	
Botaurus poiciloptilus	Australasian bittern	T - EN
Calidris acuminata	Sharp-tailed sandpiper	IA
Charadrius melanops	Black-fronted dotterel	
Chenonetta jubata	Maned duck, Wood duck	
Cygnus atratus	Black swan	
Egretta alba	Great egret	
Erythrogonys cinctus	Red-kneed dotterel	
Fulica atra	Eurasian coot	
Gallinula tenebrosa	Dusky moorhen	
Gallinula ventralis	Black-tailed native hen	
Himantopus himantopus	Black-winged stilt	
Larus novaehollandiae	Silver gull	
Malacorhynchus membranaceus	Pink-eared duck	
Megalurus gramineus	Little Grassbird	
Oxyura australis	Blue-billed duck	P4
Phalacrocorax carbo	Great cormorant	
Phalacrocorax melanoleucos	Little pied cormorant	
Platalea flaviceps	Yellow-billed spoonbill	
Poliocephalus poliocephalus	Hoary-headed grebe	
Stictonetta naevosa	Freckled duck	
Tachybaptus novaehollandiae	Australasian grebe	
Tadorna tadornoides	Australian shelduck, mountain duck	
Charadrius rubricollis	Hooded plover	P4
Threskiornis aethiopica	Sacred ibis	
Threskiornis molucca	Australian white ibis	
Threskiornis spinicollis	Straw-necked ibis	
Tringa nebularia	Common greenshank	
Vanellus tricolor	Banded lapwing	

Table 8 Terrestrial bird species recorded or likely to be found in the Lake Bryde Catchment.

Native terrestrial bird species	Common name	Conservation status
Acanthiza apicalis	Inland thornbill	
Acanthiza chrysorrhoa	Yellow-rumped thornbill	
Acanthiza ewingii	Brown thornbill	
Acanthiza pusilla	Brown thornbill	
Acanthiza uropygialis	Chestnut-rumped thornbill	
Acanthogenys rufogularis	Spiny-cheeked honeyeater	
Accipiter cirrhoceophalus	Collared sparrowhawk	
Accipiter fasciatus	Brown goshawk	
Aegotheles cristatus	Owlet nightjar	
Anthochaera carunculata	Red wattlebird	
Anthochaera chrysoptera	Little wattlebird	
Anthus novaeseelandiae	Richard's pipit	
Aquila audax	Wedge-tailed eagle	
Ardeotis australis	Australian bustard	P4
Artamus cinereus	Black-faced wood-swallow	
Artamus cyanopterus	Dusky wood-swallow	
Barnardius (Platycercus) zonarius	Twenty-eight	
Burhinus magnirostris	Bush thick-knee	
Cacatua roseicapilla	Galah	
Calyptorhynchus baudinii	Baudin's Black cockatoo	T – EN
Calyptorhynchus latirostris	Carnaby's black cockatoo	T - EN
Caprimulgus guttatus	Spotted nightjar	
Cecropis nigricans	Tree martin	
Cinclorhamphus cruralis	Brown songlark	
Climacteris rufa	Rufous tree-creeper	
Colluricincla harmonica	Grey shrike-thrush	
Coracina novaehollandiae	Black-faced cuckoo-shrike	
Corvus bennetti	Little crow	
Corvus coronoides	Australian raven	
Coturnix australis	Brown quail	
Coturnix pectoralis	Stubble quail	
Cracticus nigrogularis	Pied butcherbird	
Cracticus torquatus	Grey butcherbird	
Crysococcyx basalis	Horsfield's bronze cuckoo	
Crysococcyx lucidus	Shining bronze cuckoo	
Crysococcyx osculans	Black-eared cuckoo	
Cuculus pallidus	Pallid cuckoo	
Cuculus pyrrhophanus	Fan-tailed cuckoo	
Daphnoenositta chrysoptera	Varied sittella	
Dicauem hirundinaceum	Mistletoe bird	
Dromaius novaehollandiae	Emu	
Drymodes brunneopygia	Southern scrub-robin	
Elanus notatus	Black-shouldered kite	

Native terrestrial bird species	Common name	Conservation status
Elanus scriptus	Letter-winged kite	P4
Eopsaltria griseogularis	Western yellow robin	
Ephthianura albifrons	White-fronted chat	
Ephthianura tricolor	Crimson chat	
Falco berigora	Brown falcon, brown hawk	
Falco cenchroides	Australian kestrel, nankeen kestrel	
Falco hypoleucos	Grey falcon	T - VU
Falco peregrinus	Peregrine falcon	S
Gerygone fusca	Western gerygone	
Gerygone levigaster	Warbler	
Glossopsitta porphyrocephala	Purple-crowned lorikeet	
Grallina cyanoleuca	Australian magpie-lark	
Gymnorhina tibicen race dorsalis	Western magpie	
Haliastur sphenurus	Whistling kite, whistling eagle	
Hamirostra melanosternon	Black-breasted kite	
Heiraaetus morphnoides	Little eagle	
Hirundo neoxena	Welcome swallow	
Hylacola cauta whitlocki	Shy heathwren	P4
Leipoa ocellata	Malleefowl	T - VU
Lichenostomus cratitius	Purple-gaped honeyeater	
Lichenostomus leucotis	White-eared honeyeater	
Lichenostomus ornatus	Yellow-plumed honeyeater	
Lichenostomus virescens	Singing honeyeater	
Lichmera indistincta	Brown honeyeater	
Lophoictinia isura	Square-tailed kite	
Malurus lambertii	Variegated fairy-wren	
Malurus pulcherrimus	Blue-breasted fairy-wren	
Malurus splendens	Splendid fairy-wren	
Manorina flavigula	Yellow-throated miner	
Melanodryas cucullata	Hooded robin	
Melithreptus brevirostris	Brown-headed honeyeater	
Melopsittacus undulatus	Budgerigah	
Merops ornatus	Rainbow bee-eater	IA
Microeca leucophaea	Jacky winter	
Myiagra inquieta	Restless flycatcher	
Neophema elegans	Elegant parrot	
Ninox connivens connivens	Barking owl (southwest pop)	P2
Ninox novaeseelandiae	Southern boobook	
Ocyphaps lophotes	Crested pigeon	
Oreoica gutturalis gutteralis	Crested bellbird	P4
Pachycephala pectoralis	Golden whistler	
Pachycephala rufiventris	Rufous whistler	
Pardalotus punctatus	Spotted pardalote	
Pardalotus striatus	Striated pardalote	
Petroica goodenovii	Red-capped robin	
Phaps calcoptera	Common bronzewing	
Phaps elegans	Brush bronzewing	

Native terrestrial bird species	Common name	Conservation status
Phylidonyris melanops	Tawny-crowned honeyeater	
Phylidonyris nigra	White-cheeked honeyeater	
Platycerus icterotis icterotis	Western rosella	
Podargu strigoides	Tawny frogmouth	
Polytelis anthopeplus	Regent parrot, smoker	
Pomatostomus superciliosus	White-browed babbler	
Psephotus varius	Mulga parrot	
Psophodes nigularis oberon	Western Whipbird (sthn WA subsp)	P4
Purpureicephalus spurius	Red-capped parrot	
Rhipidura fulignosa	Grey fantail	
Rhipidura leucophrys	Willie wagtail	
Calamanthus campestris montanellus	Rufous fieldwren	P4
Sericornis brunneus	Red-throat	
Sericornis frontalis	White-browed scrubwren	
Sericornis fuliginosus	Calamanthus	
Smicrornis brevirostris	Weebill	
Stipiturus malachurus	Southern emu-wren	
Strepera versicolor	Grey currawong	
Zosterops lateralis	Silvereye	

Table 9 Reptile species recorded or likely to be found in the Lake Bryde Catchment.

Native reptile species	Common name	Conservation status
Acanthophis antarcticus	Common death adder	
Aprasia pulchella	Western granite worm lizard	
Aprasia repens	South-west sandplain worm lizard	
Chelodina colliei	Oblong turtle	
Crenadactylus ocellatus ocellatus	Clawless gecko	
Cryptoblepharus plagiocephalus	Common western sun skink	
Ctenophorus cristatus	Bicycle dragon	
Ctenophorus maculatus	Spotted military dragon	
Ctenophorus ornatus	Ornate crevice dragon	
Ctenophorus salinarum	Salt pan dragon	
Ctenotus catenifer	Chain-striped south-west ctenotus	
Ctenotus gemmula	Jewelled ctenotus	
Ctenotus impar		
Ctenotus inornatus		
Ctenotus labillardieri	South-west red-legged ctenotus	
Ctenotus schomburgkii	Barred wedge-snout ctenotus	
Delma australis		
Delma fraseri	Fraser’s legless lizard	
Diplodactylus granariensis	Wheatbelt stone gecko, wood gecko	
Diplodactylus maini	Main’s ground gecko	
Crenadactylus ocellatus		
Diplodactylus polyophthalmus	Speckled stone gecko	
Diplodactylus spinigerus	Western spiny-tailed gecko	
Diplodactylus vittatus		

Native reptile species	**Common name**	**Conservation status**
Elapognathus coronatus	Crowned snake	
Echiopsis curta	Bardick	
Egernia kingii	King’s skink	
Egernia napoleonis	South-western crevice egernia	
Liopholis multiscutata bos	Bull skink	
Egernia richardi	Bight crevice egernia	
Gehyra variegata	Variegated dtella	
Hemiergis initialis	Southern five-toed earless skink	
Hemiergis peronii	Lowland's earless skink	
Acritoscincus trilineatus		
Lerista distinguenda	South-western four-toed lerista	
Lialis burtonis	Burton's snake lizard	
Menetia greyii	Common dwarf skink	
Moloch horridus	Thorny devil	
Morelia spilota imbricata	South-western carpet python	S
Morethia butleri	Woodland morethia	
Morethia obscura	Southern pale-flecked morethia	
Notechis scutatus	Tiger snake	
Hesperoedura reticulata	Reticulated velvet gecko	
Christinus marmoratus marmoratus	Marbled gecko	
Pogona minor	Western bearded dragon	
Pseudechis australis	Common mulga snake	
Pseudonaja affinis	Dugite	
Pseudonaja nuchalis	Gwardar	
Pseudonaja modesta	Ringed brown snake	
Pygopus lepidopodus	Common scalyfoot	
Ramphotyphlops australis	Southern blindsnake	
Ramphotyphlops bituberculatus	Prong-snouted blindsnake	
Rhinoplocephalus gouldii	Gould's snake	
Parasuta nigriceps	Black backed snake	
Eremiascincus richardsonii	Broad-banded sand swimmer	
Parasuta gouldii	Gould’s hooded snake	
Tiliqua occipitalis	Western bluetongue	
Tiliqua rugosa rugosa	Bobtail, shingle-back	
Ctenophorus adelaidensis	Western heath dragon	
Underwoodisaurus milii	Southern barking gecko	
Varanus gouldii	Gould’s monitor	
Varanus rosenbergi	Southern heath monitor	
Varanus tristis	Racehorse monitor	

Table 10 Amphibian species recorded or likely to be found in the Lake Bryde Catchment.

Native amphibian species	Common name	Conservation status
Heleioporus albopunctatus	Western spotted frog	
Heleioporus barycragus	Hooting frog	
Heleioporus eyrei	Moaning frog	
Limnodynastes dorsalis	Western banjo frog	
Litoria adelaidensis	Southern slender tree frog	
Litoria cyclorhyncha	Spotted-thighed frog	
Litoria moorei	Western green tree frog	
Myobatrachus gouldii	Turtle frog	
Neobatrachus albipes	Trilling frog	
Neobatrachus kunapalari	Kunapalari frog	
Neobatrachus pelobatoides	Humming frog	
Neobatrachus sutor	Shoemaker frog	
Pseudophryne guentheri	Crawling toadlet	
Crinia pseudinsignifera	Bleating froglet	

Table 11 Wetland invertebrates collected from Lake Bryde.

Phyllum – Class – Order	Family – Genus – Species
Worms	
Platyhelminthes (Flat worms)	*Turbellaria*
Nematoda (Round worms)	*Nematoda*
Rotifera (Wheel animals)	*Hexarthra mira*
	Brachionus quadridentatus
	Trichocerca rattus carinata
Oligocheata (Earthworms)	*Ainudrilus nharna*
	Dero digitata
	Enchytraeidae
Crustaceans	
Conchostraca (Clam shrimp)	*Caenestheria* sp. nov. A (nr lutraria)
	Caenestheriella sp.
Cladocera (Water fleas)	*Alona diaphana*
	Alona diaphana vermiculata
	Alona rigidicaudis s.l.
	Alona longinqua
	Alona sp. nov. A (Bryde)
	Leydigia cf. ciliata
	Monospilus diporus
	Monospilus elongatus
	Plurispina cf. chauliodis
	Pleuroxus cf. foveatus
	Daphnia carinata
	Daphnia cephalata
	Daphniopsis queenslandensis
	Daphniopsis sp.
	Simocephalus exspinosus
	Simocephalus victoriensis
	Macrothrix breviseta
	Neothrix cf. armata
Ostracoda (Ostracods, seed shrimp)	*Limnocythere mowbrayensis*
	Ilyocypris australiensis
	Bennelongia australis
	Candonocypris novaezelandiae
	Cypretta baylyi
	Heterocypris vatia
	Mytilocypris ambiguosa
	Mytilocypris tasmanica chapmani
	Reticypris clava
	Ilyodromus ellipticus
	Cypericercus sp. 442
	Sarscypridopsis aculeata
Copepoda (Copepods)	*Boeckella triarticulata*
	Calamoecia ampulla
	Metacyclops sp. 462
	Australocyclops australis
	Eucyclops australiensis
	Apocyclops dengizicus
	Mesochra nr flava

Phyllum – Class – Order	Family – Genus – Species
Amphipoda (Amphipods)	*Austrochiltonia subtenuis subtenuis*
INSECTS	
Coleoptera (Beetles)	*Allodessus bistrigatus*
	Antiporus gilberti
	Sternopriscus sp.
	Necterosoma penicillatus
	Berosus discolor
	Berosus munitipennis
	Berosus sp.
	Enochrus eyrensis
	Hydrophilidae
	Heteroceridae
	Curculionidae
Diptera (Flies)	*Tipulidae group C*
	Aedes camptorhynchus
	Culicoides sp.
	Stratiomyidae
	Ephydridae
	Muscidae
	Procladius paludicola
	Procladius villosimanus
	Ablabesmyia notabilis
	Paramerina levidensis
	Paralimnophyes sp. 1 (pullulus)
	Cricotopus albitarsus
	Orthocladiinae sp. A
	Tanytarsus sp. A (nr. K10)
	Chironomus occidentalis
	Chironomus tepperi
	Chironomus sp.
	Chironomus aff. Alternans
	Dicrotendipes pseudoconjunctus
	Cryptochironomus griseidorsum
	Cladopelma curtivalva
	Parachironomus sp. 1
Hemiptera (Backswimmers, water boatmen)	*Agraptocorixa parvipunctata*
	Micronecta gracilis
	Anisops occipitalis
	Anisops sp.
Odonata (Dragonflies and damselflies)	*Austrolestes annulosus*
	Hemianax papuensis
	Hemicordulia tau
Trichoptera (Caddisflies)	*Oecetis sp.*
	Leptoceridae

10.2 Fungi and terrestrial invertebrates

There have been no systematic surveys of fungi or terrestrial invertebrates in the Lake Bryde Catchment. Species richness and rarity have been estimated by experts for the purpose of this plan.

10.3 Vegetation elements

Mallee shrubland

Mallee shrubland is the largest vegetation type in the catchment, and one of the most diverse in species.

Salmon gum woodland

There is a number of Salmon gum (*Eucalyptus salmonophloia*) woodlands in the catchment that are more numerous than in the Wheatbelt generally. This woodland can be interspersed with *Eucalyptus kondininensis* woodland and supports a wide variety of understorey and mid storey species.

Yate Swamp

Yate swamps are relatively rare in the south–west land division and there are two occurrences in LBNR. There is a single species of Yate, *Eucalyptus occidentalis* in the lake beds and they are regularly in combination with *Melaleuca strobophylla.*

Other woodlands

The Other Woodland element is spread across all nature reserves along the valley floor and includes numerous species.

Melaleuca shrubland

Melaleuca shrubland is dominated by species of *Melaleuca*. This element has been poorly represented in past vegetation surveys.

Duma horrida shrubland

This element includes the only known occurrences of the critically endangered Threatened Ecological Community, 'Unwooded freshwater wetlands of the southern Wheatbelt of Western Australia, dominated by *Duma horrida* subsp. *abdita* and *Tecticornia verrucosa* across the lake floor'. Within the landscape recovery program, it may also be referred to as the *Bryde* TEC.

Samphire

Samphires are abundant across a number of lake beds in the LBRC and also in adjacent low-lying areas particularly those which have been impacted by salinity. This community is characterised by species of *Tecticornia*.

10.4 Flora elements

Data on the flora elements has been sourced from a range of reports and databases (Department of Parks and Wildlife, 2007 - ; Ecoscape (Australia) Pty Ltd, 2001, 2004; Gibson *et al*., 2004; Hamilton-Brown and Blyth, 2001; Mattiske Consulting Pty Ltd, 1999, 2001, 2006; Phillimore *et al*., 2003; Phillips, 2011; Rick, 2017, 2018, 2019; Viv Read and Associates, 2002).

Table 12 Plant species recorded in the Lake Bryde Recovery Catchment.

Native flora species	Common name	Duma shrublands	Mallee shrublands	Melaleuca shrublands	Other woodlands	Salmon gum	Samphire shrublands	Yate swamps	Conservation status
Acacia ? squamata			x						
Acacia acanthoclada					x				
Acacia acuminata	Jam				x				
Acacia acutata					x	x			
Acacia brachyclada					x				
Acacia chamaeleon					x				
Acacia eremophila					x				
Acacia erinacea					x	x			
Acacia hemiteles					x	x			
Acacia lasiocarpa	Panjang				x				
Acacia leptospermoides					x	x			
Acacia microbotrya	Manna wattle					x			
Acacia multispicata			x						
Acacia mutabilis subsp. *stipulifera*			x		x	x	x		P3
Acacia pulchella	Prickly Moses		x						
Acacia saligna	Orange wattle				x				
Acacia viscifolia			x						
Actinobole uliginosum	Flannel cudweed				x	x			
Allocasuarina microstachya			x						
Allocasuarina pinaster	Compass bush			x					
Alyxia buxifolia	Dysentery bush				x	x			
Amphipogon amphipogonoides			x						
Amphipogon turbinatus			x						
Andersonia sprengelioides			x						
Angianthus pygmaeus	Pygmy Angianthus						x		
Angianthus tomentosus	Camel-grass					x		x	
Argentipallium niveum			x						
Astartea ? ambiguus			x		x				
Astroloma compactum			x		x				
Astroloma epacridis					x	x			
Astroloma microphyllum			x						
Atriplex exilifolia					x				
Atriplex paludosa	Marsh saltbush				x	x	x		

Native flora species	Common name	Duma shrublands	Mallee shrublands	Melaleuca shrublands	Other woodlands	Salmon Gm woodlands	Samphireu shrublands	Yate swamps	Conservation status
Atriplex semibaccata		x							
Atriplex vesicaria	Bladder saltbush			x	x	x			
Austrostipa drummondii	Cottony speargrass				x	x			
Austrostipa elegantissima					x	x			
Austrostipa juncifolia				x	x				
Austrostipa puberula					x	x			
Austrostipa pycnostachya			x		x	x			
Austrostipa semibarbata					x	x			
Austrostipa trichophylla					x				
Baeckea aff *preissiana*			x						
Baeckea crispiflora			x						
Baeckea preissiana			x						
Banksia cirsioides			x						
Banksia epimicta			x						P2
Banksia media	Southern plains Banksia		x						
Banksia prionotes	Acorn Banksia		x						
Banksia pteridifolia	Tangled honeypot		x						
Banksia rufa			x						
Banksia violacea	Violet Banksia		x						
Banksia xylothemelia			x						P3
Beaufortia schaueri	Pink bottlebrush					x			
Bentleya spinescens					x				P4
Beyeria brevifolia			x		x				
Billardiera fusiformis	Australian bluebell		x						
Billardiera lehmanniana	Kurup		x		x	x			
Blennospora drummondii					x	x			
Boronia inornata	Desert Boronia				x				
Bossiaea halophila				x					
Brachyscome ? iberidifolia					x	x			
Brachyscome lineariloba				x					
Calectasia grandiflora	Blue tinsel lily		x						
Calectasia pignattiana			x						T (VU)
Callitris roei	Roe's cypress pine				x				
Calytrix leschenaultii			x		x	x			
Carpobrotus sp.		x			x	x		x	

Native flora species	Common name	Duma shrublands	Mallee shrublands	Melaleuca shrublands	Other woodlands	Salmon gum woodlands	Samphire shrublands	Yate swamps	Conservation status
Centipeda cunninghamii	Common sneezewood					x			
Centrolepis aristata					x				
Chamaexeros macranthera			x						
Chamaexeros serra	Little fringe-leaf		x						
Chamelaucium ciliatum				x	x				
Chorizandra sp.					x				
Chorizema aciculare	Needle-leaved Chorizema		x						
Coleanthera coelophylla					x				P1
Comesperma integerrimum					x	x			
Comesperma scoparium					x				
Conostephium roei			x		x				
Conostylis petrophiloides			x						
Coopernookia strophiolata					x				
Crassula colorata	Dense stonecrop				x	x		x	
Cryptandra minutifolia			x						
Cryptandra myriantha			x						
Cryptandra nutans			x						
Dampiera lavandulacea			x		x				
Dampiera orchardii					x	x			P2
Darwinia inconspicua					x				
Darwinia vestita					x				
Daucus glochidiatus	Australian carrot				x	x			
Daviesia decurrens	Prickly bitter-pea		x		x				
Daviesia dilatata			x						
Daviesia gracilis			x						
Daviesia incrassata			x						
Daviesia lancifolia			x						
Daviesia mollis			x		x				
Daviesia scoparia			x						
Daviesia uncinata			x						P3
Desmocladus asper			x		x	x			
Desmocladus flexuosus					x				
Desmocladus myriocladus					x				
Desmocladus parthenicus			x						

Native flora species	Common name	Duma shrublands	Mallee shrublands	Melaleuca shrublands	Other woodlands	Salmon gum woodlands	Samphire shrublands	Yate swamps	Conservation status
Dianella brevicaulis					x	x			
Dianella revoluta	Blueberry lily				x				
Dicrastylis corymbosa					x				
Disphyma crassifolium	Round-leaved pigface	x		x	x	x			
Dodonaea amblyophylla			x		x	x			
Dodonaea bursariifolia			x		x				
Dodonaea caespitosa			x		x	x			
Dodonaea ceratocarpa								x	
Dodonaea divaricata			x						
Dodonaea pinifolia			x		x				
Duma horrida subsp. *abdita*		x				x	x		T (EN)
Enchylaena tomentosa	Barrier saltbush			x	x	x			
Eremaea pauciflora			x		x				
Eremophila decipiens	Slender fuchsia				x	x			
Eremophila subfloccosa subsp. *lanata*					x				
Erymophyllum ramosum					x				
Eucalyptus alipes			x		x				
Eucalyptus annulata	Open-fruited Mallee		x						
Eucalyptus calycogona	Gooseberry Mallee				x	x			
Eucalyptus celastroides						x			
Eucalyptus depauperata					x				
Eucalyptus extensa				x					
Eucalyptus flocktoniae	Merrit				x			x	
Eucalyptus horistes			x		x				
Eucalyptus incrassata	Lerp Mallee		x						
Eucalyptus kondininensis	Kondinin blackbutt			x	x	x			
Eucalyptus loxophleba	Lake Grace gum			x	x	x			
Eucalyptus mimica subsp. *continens*					x	x			P1
Eucalyptus mimica subsp. *mimica*					x	x			P3
Eucalyptus myriadena						x			
Eucalyptus occidentalis	Flat-topped Yate		x		x	x		x	
Eucalyptus perangusta			x		x	x			
Eucalyptus phaenophylla			x						

Native flora species	Common name	Duma shrublands	Mallee shrublands	Melaleuca shrublands	Other woodlands	Salmon gum woodlands	Samphire shrublands	Yate swamps	Conservation status
Eucalyptus phenax			x		x	x			
Eucalyptus salmonophloia	Salmon gum				x	x		x	
Eucalyptus salubris	Gimlet					x			
Eucalyptus scyphocalyx	Goblet Mallee				x				
Eucalyptus spathulata	Swamp Mallet			x					
Eucalyptus sporadica			x		x				
Eucalyptus suggrandis				x					
Eucalyptus tenera					x				
Eucalyptus urna						x			
Euchiton sphaericus					x	x		x	
Exocarpos aphyllus	Leafless Ballart				x	x			
Exocarpos sparteus	Broom Ballart				x	x			
Frankenia pauciflora	Seaheath				x	x	x		
Gahnia ancistrophylla	Hooked-leaf saw sedge				x				
Gahnia lanigera					x				
Gahnia sp. L (K.R. Newbey 7888)			x		x				
Gahnia trifida	Coast saw-sedge					x			
Gastrolobium cruciatum			x						P3
Gastrolobium punctatum			x						
Gastrolobium reticulatum			x		x				
Gnephosis multiflora					x				P3
Gnephosis tenuissima					x				
Grevillea acuaria			x						
Grevillea disjuncta			x						
Grevillea dolichopoda			x						
Grevillea huegelii					x	x			
Grevillea newbeyi			x			x			P3
Grevillea oligantha			x		x				
Grevillea prostrata	Pallarup Grevillea		x		x				P4
Grevillea teretifolia	Round leaf Grevillea		x						
Haegiela tatei					x	x			P4
Hakea adnata					x			x	
Hakea brachyptera	Short-winged Hakea		x						P3
Hakea circumalata			x		x				
Hakea commutata			x						
Hakea corymbosa	Cauliflower Hakea		x		x	x			

Native flora species	Common name	Duma shrublands	Mallee shrublands	Melaleuca shrublands	Other woodlands	Salmon gum woodlands	Samphire shrublands	Yate swamps	Conservation status
Hakea cygna	Swan fruit Hakea		x						
Hakea erecta			x						
Hakea incrassata	Marble Hakea		x						
Hakea lasiocarpha			x		x	x			P3
Hakea laurina	Pincushion Hakea				x				
Hakea linearis					x				
Hakea lissocarpha	Honey bush		x			x			
Hakea nitida	Frog Hakea				x				
Hakea obliqua	Needles and corks		x			x			
Hakea preissii	Needle tree				x	x			
Hakea scoparia					x				
Hakea trifurcata	Two-leaf Hakea		x						
Harperia lateriflora			x						
Helichrysum leucopsideum					x				
Hibbertia commutata			x						
Hibbertia exasperata			x		x				
Hibbertia gracilipes			x						
Hypolaena caespitosa			x						
Hypolaena fastigiata			x		x				
Isopogon axillaris			x						
Isopogon buxifolius			x						
Isopogon teretifolius	Nodding coneflower		x						
Jacksonia nematoclada			x						
Jacksonia racemosa			x		x				
Juncus radula						x			
Lasiopetalum rosmarinifolium			x		x				
Lawrencia diffusa		x							
Lawrencia squamata				x	x	x			
Laxmannia paleacea			x						
Lechenaultia brevifolia			x						
Lepidium rotundum	Veined peppercress					x			
Lepidobolus chaetocephalus	Bristle-headed chaff rush		x						
Lepidobolus preissianus subsp. *preissianus*					x				
Lepidosperma brunonianum			x		x	x			

Native flora species	**Common name**	Duma shrublands	Mallee shrublands	Melaleuca shrublands	Other woodlands	Salmon gum woodlands	Samphire shrublands	Yate swamps	Conservation status
Lepidosperma carphoides	Black rapier sedge		x						
Lepidosperma gracile	Slender sword sedge		x						
Lepidosperma pruinosum			x		x				
Lepidosperma sanguinolentum			x		x				
Lepidosperma tenue					x				
Lepidosperma viscidum	Sticky sword sedge				x			x	
Leptomeria empetriformis						x			
Leptomeria preissiana			x						
Leptospermum erubescens	Roadside tea tree		x		x	x			
Leptospermum inelegans			x						
Leucopogon concinnus			x						
Leucopogon conostephioides			x						
Leucopogon dielsianus			x						
Leucopogon sp. Kau Rock (M.A. Burgman 1126)					x				
Leucopogon tamminensis			x						
Lobelia rarifolia					x				
Lomandra effusa	Scented matrush				x	x			
Lomandra micrantha	Small-flower matrush				x	x			
Lomandra mucronata					x				
Loxocarya cinerea			x		x				
Lycium australe	Australian boxthorn			x					
Lyginia imberbis			x						
Lysinema ciliatum	Curry flower		x						
Melaleuca ? torquata			x						
Melaleuca acuminata			x		x	x		x	
Melaleuca adnata			x		x	x			
Melaleuca brophyi			x	x	x				
Melaleuca carrii			x		x	x			
Melaleuca cuticularis	Saltwater paperbark				x				
Melaleuca depauperata			x		x				
Melaleuca glaberrima					x				
Melaleuca halmaturorum		x	x				x		
Melaleuca hamulosa					x				
Melaleuca haplantha			x						
Melaleuca lateralis			x			x			

Native flora species	Common name	Duma shrublands	Mallee shrublands	Melaleuca shrublands	Other woodlands	Salmon gum woodlands	Samphire shrublands	Yate swamps	Conservation status
Melaleuca lateriflora	Gorada		x	x	x	x	x	x	
Melaleuca laxiflora			x		x				
Melaleuca marginata					x				
Melaleuca pauperiflora	Boree			x	x	x			
Melaleuca platycalyx			x						
Melaleuca sculponeata				x					P3
Melaleuca sheathiana						x			
Melaleuca societatis			x						
Melaleuca strobophylla		x	x			x		x	
Melaleuca subtrigona			x		x				
Melaleuca thyoides					x	x			
Melaleuca tuberculata			x						
Melaleuca uncinata			x	x	x	x		x	
Mesomelaena preissii			x						
Mesomelaena pseudostygia			x						
Microcybe multiflora					x				
Neurachne alopecuroidea	Foxtail mulga grass		x		x	x		x	
Olearia dampieri			x	x	x	x		x	
Olearia muelleri	Goldfields daisy				x	x			
Olearia muricata	Rough-leaved daisy bush				x				
Olearia ramosissima	Much-branched daisy bush		x		x				
Olearia sp. Kennedy Range						x			
Ozothamnus lepidophyllus					x				
Persoonia striata			x						
Petrophile brevifolia			x						
Petrophile ericifolia			x						
Petrophile longifolia	Long leaved cone bush		x						
Petrophile rigida			x						
Petrophile seminuda			x						
Petrophile squamata			x						
Phebalium microphyllum			x						
Phebalium tuberculosum			x						
Pimelea argentea	Silvery-leaved Pimelea				x	x		x	
Pimelea lehmanniana			x		x				

Native flora species	Common name	Duma shrublands	Mallee shrublands	Melaleuca shrublands	Other woodlands	Salmon gum woodlands	Samphire shrublands	Yate swamps	Conservation status
Pithocarpa pulchella			x						
Pittosporum angustifolium	Weeping Pittosporum					x		x	
Platysace maxwellii			x		x				
Platysace trachymenioides			x						
Podolepis capillaris	Wiry Podolepis		x	x	x	x			
Podolepis lessonii					x				
Podotheca angustifolia	Sticky longheads				x	x			
Pogonolepis stricta					x	x			
Pterochaeta paniculata					x				
Ptilotus holosericeus					x	x			
Puccinellia stricta		x							
Rhagodia crassifolia								x	
Rhagodia drummondii					x				
Rhagodia preissii			x		x	x		x	
Rinzia affinis			x						P4
Roycea pycnophylloides					x				T (VU)
Rytidosperma caespitosa					x	x			
Santalum acuminatum	Quandong		x		x	x			
Sarcocornia blackiana					x				
Scaevola spinescens	Currant bush				x	x			
Schoenus clandestinus			x						
Schoenus pleiostemoneus			x						
Schoenus sp. A1 Boorabin (K. Wilson 2581)			x						
Schoenus subflavus	Yellow bog-rush		x						
Sclerolaena diacantha	Grey copperburr				x	x			
Senecio sp.					x	x			
Senna artemisioides						x			
Senna charlesiana					x	x			
Spyridium mucronatum					x				
Stackhousia muricata					x	x			
Stylidium repens	Matted triggerplant		x		x	x			
Synaphea boyaginensis			x						P2
Synaphea sp. Jilakin Flat Rock Rd			x						
Synaphea spinulosa			x						

Native flora species	**Common name**	Duma shrublands	Mallee shrublands	Melaleuca shrublands	Other woodlands	Salmon gum woodlands	Samphire shrublands	Yate swamps	Conservation status
Tecticornia doleiformis		x			x	x	x		
Tecticornia indica					x		x		
Tecticornia lepidosperma					x		x		
Tecticornia pergranulata	Blackseed samphire	x	x	x	x	x	x		
Tecticornia syncarpa		x		x	x	x	x		
Tecticornia verrucosa		x					x		
Templetonia sulcata	Centipede bush		x	x	x	x			
Tetraria capillaris	Hair sedge				x	x			
Thelymitra sp.					x	x			
Threlkeldia diffusa	Coast bonefruit				x	x	x		
Thysanotus patersonii	Twining fringe lily		x		x	x			
Trachymene cyanopetala					x				
Triglochin mucronata		x							
Verticordia acerosa			x						
Verticordia chrysantha			x						
Verticordia densiflora	Compacted featherflower					x			
Verticordia endlicheriana			x			x			
Verticordia grandiflora	Claw featherflower		x						
Verticordia integra			x						P4
Verticordia plumosa	Plumed featherflower				x				
Verticordia roei	Roe's featherflower		x						
Verticordia tumida			x						
Vittadinia cuneata					x	x			
Vittadinia gracilis	Fuzzweed				x				
Waitzia acuminata	Orange immortelle			x	x				
Westringia rigida	Stiff Westringia		x		x				
Wilsonia humilis	Silky Wilsonia	x			x		x		
Wilsonia rotundifolia		x			x				

Appendix 11: **Conservation codes for flora, fauna, ecological communities**

11.1 Conservation codes for Western Australian flora and fauna

Threatened, Extinct and Specially Protected fauna or flora[3] are species[4] which have been adequately searched for and are deemed to be, in the wild, threatened, extinct or in need of special protection, and have been gazetted as such.

The Wildlife Conservation (Specially Protected Fauna) Notice 2018 and the Wildlife Conservation (Rare Flora) Notice 2018 have been transitioned under regulations 170, 171 and 172 of the Biodiversity Conservation Regulations 2018 to be the lists of Threatened, Extinct and Specially Protected species under Part 2 of the *Biodiversity Conservation Act 2016*.

Categories of Threatened, Extinct and Specially Protected fauna and flora:

T: Threatened species

Listed by order of the Minister for the Environment as Threatened in the category of critically endangered, endangered, or vulnerable under section 19(1), or is a rediscovered species to be regarded as threatened species under section 26(2) of the *Biodiversity Conservation Act 2016* (BC Act).

Threatened fauna is that subset of 'Specially Protected Fauna' listed under schedules 1 to 3 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for Threatened Fauna.

Threatened flora is that subset of 'Rare Flora' listed under schedules 1 to 3 of the Wildlife Conservation (Rare Flora) Notice 2018 for Threatened Flora.

The assessment of the conservation status of these species is based on their national extent and ranked according to their level of threat using IUCN Red List categories and criteria as detailed below.

CR: Critically endangered species

Threatened species considered to be 'facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with criteria set out in the ministerial guidelines'.

Listed as critically endangered under section 19(1)(a) of the BC Act in accordance with the criteria set out in section 20 and the ministerial guidelines. Published under schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for critically endangered fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for critically endangered flora.

EN: Endangered species

Threatened species considered to be 'facing a very high risk of extinction in the wild in the near future, as determined in accordance with criteria set out in the ministerial guidelines'.

[3] The definition of flora includes algae, fungi, and lichens

[4] Species includes all taxa (plural of taxon - a classificatory group of any taxonomic rank, e.g. a family, genus, species or any infraspecific category i.e. subspecies or variety, or a distinct population)

Listed as endangered under section 19(1)(b) of the BC Act in accordance with the criteria set out in section 21 and the ministerial guidelines. Published under schedule 2 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for endangered fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for endangered flora.

VU: Vulnerable species

Threatened species considered to be ‘facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with criteria set out in the ministerial guidelines’.

Listed as vulnerable under section 19(1)(c) of the BC Act in accordance with the criteria set out in section 22 and the ministerial guidelines. Published under schedule 3 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for vulnerable fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for vulnerable flora.

Extinct species

Listed by order of the Minister as extinct under section 23(1) of the BC Act as extinct or extinct in the wild.

EX: Extinct species

Species where “there is no reasonable doubt that the last member of the species has died”, and listing is otherwise in accordance with the ministerial guidelines (section 24 of the BC Act). Published as presumed extinct under schedule 4 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for extinct fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for extinct flora.

EW: Extinct in the wild species

Species that ‘is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; and it has not been recorded in its known habitat or expected habitat, at appropriate seasons, anywhere in its past range, despite surveys over a time frame appropriate to its life cycle and form’, and listing is otherwise in accordance with the ministerial guidelines (section 25 of the BC Act). Currently there are no threatened fauna or threatened flora species listed as extinct in the wild. If listing of a species as extinct in the wild occurs, then a schedule will be added to the applicable notice.

Specially protected species

Listed by order of the Minister for the Environment as specially protected under section 13(1) of the BC Act. Meeting one or more of the following categories: species of special conservation interest; migratory species; cetaceans; species subject to international agreement; or species otherwise in need of special protection.

Species that are listed as threatened species (critically endangered, endangered, or vulnerable) or extinct species under the BC Act cannot also be listed as Specially Protected species.

MI: Migratory species

Fauna that periodically or occasionally visit Australia or an external Territory or the exclusive economic zone; or the species is subject of an international agreement that relates to the protection of migratory species and that binds the Commonwealth; and listing is otherwise in accordance with the ministerial guidelines (section 15 of the BC Act).

Includes birds that are subject to an agreement between the government of Australia and the governments of Japan (JAMBA), China (CAMBA) and The Republic of Korea (ROKAMBA), and fauna subject to the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), an environmental treaty under the United Nations Environment Program. Migratory species listed under the BC Act are a subset of the migratory animals, that are known to visit WA, protected under the international agreements or treaties, excluding species that are listed as Threatened species.

Published as migratory birds protected under an international agreement under schedule 5 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018.

CD: Species of special conservation interest (conservation dependent fauna)

Fauna of special conservation need being species dependent on ongoing conservation intervention to prevent it becoming eligible for listing as threatened, and listing is otherwise in accordance with the ministerial guidelines (section 14 of the BC Act).

Published as conservation dependent fauna under schedule 6 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018.

OS: Other specially protected species

Fauna otherwise in need of special protection to ensure their conservation, and listing is otherwise in accordance with the ministerial guidelines (section 18 of the BC Act).

Published as other specially protected fauna under schedule 7 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018.

Priority species

Possibly threatened species that do not meet survey criteria, or are otherwise data deficient, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as threatened fauna or flora.

Species that are adequately known, are rare but not threatened, or meet criteria for near threatened, or that have been recently removed from the threatened species or other specially protected fauna lists for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring.

Assessment of Priority codes is based on the WA distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations.

P1: Priority 1: Poorly known species

Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.

P2: Priority 2: Poorly known species

Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.

P3: Priority 3: Poorly known species

Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species need further survey.

P4: Priority 4: Rare, Near Threatened and other species in need of monitoring

(a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection but could be if present circumstances change. These species are usually represented on conservation lands.

(b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for vulnerable but are not listed as Conservation Dependent.

(c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

11.2 Conservation codes for Western Australian ecological communities

Threatened Ecological Communities

A threatened ecological community (TEC) is an ecological community[5] which is found to fit into one of the following categories: 'presumed totally destroyed', 'critically endangered', 'endangered' or 'vulnerable'.

PD: Presumed Totally Destroyed

An ecological community that has been adequately searched for but for which no representative occurrences have been located. The community has been found to be totally destroyed or so extensively modified throughout its range that no occurrence of it is likely to recover its species composition and/or structure in the foreseeable future.

An ecological community will be listed as presumed totally destroyed if there are no recent records of the community being extant and either of the following applies:

a) Records within the last 50 years have not been confirmed despite thorough searches of known or likely habitats, or
b) All occurrences[6] recorded within the last 50 years have since been destroyed.

CR: Critically Endangered

An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or that was originally of limited distribution and is facing severe modification or destruction throughout its range in the immediate future, or is already severely degraded throughout its range but capable of being substantially restored or rehabilitated.

An ecological community will be listed as Critically Endangered when it has been adequately surveyed and is found to be facing an extremely high risk of total destruction in the immediate future. This will be determined on the basis of the best available information, by it meeting any one or more of the following criteria:

a) The estimated geographic range, and/or total area occupied, and/or number of discrete occurrences since European settlement have been reduced by at least 90% and either or both of the following apply:
    i) geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is imminent (within about 10 years);

[5] Ecological community: a naturally occurring biological assemblage that occurs in a particular type of habitat. Note: The scale at which ecological communities are defined will often depend on the level of detail in the information source, therefore no particular scale is specified.

[6] Occurrence: a discrete example of an ecological community, separated from other examples of the same community by more than 20m of a different ecological community, an artificial surface or a totally destroyed community. By ensuring that every discrete occurrence is recognised and recorded future changes in status can be readily monitored.

ii) modification throughout its range is continuing such that in the immediate future (within about 10 years) the community is unlikely to be capable of being substantially rehabilitated.

b) Current distribution is limited, and one or more of the following apply:

i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the immediate future (within about 10 years);

ii) there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes;

iii) there may be many occurrences, but total area is very small and each occurrence is small and/or isolated and extremely vulnerable to known threatening processes.

c) The ecological community exists only as highly modified occurrences that may be capable of being rehabilitated if such work begins in the immediate future (within about 10 years).

EN: Endangered

An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or was originally of limited distribution and is in danger of significant modification throughout its range or severe modification or destruction over most of its range in the near future.

An ecological community will be listed as Endangered when it has been adequately surveyed and is not Critically Endangered but is facing a very high risk of total destruction in the near future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria:

a) The geographic range, and/or total area occupied, and/or number of discrete occurrences have been reduced by at least 70% since European settlement and either or both of the following apply:

i) the estimated geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is likely in the short-term future (within about 20 years)

ii) modification throughout its range is continuing such that in the short-term future (within about 20 years) the community is unlikely to be capable of being substantially restored or rehabilitated.

b) Current distribution is limited, and one or more of the following apply:

i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the short-term future (within about 20 years)

ii) there are few occurrences, each of which is small and/or isolated and all or most occurrences are very vulnerable to known threatening processes

iii) there may be many occurrences, but total area is small and all or most occurrences are small and/or isolated and very vulnerable to known threatening processes.

c) The ecological community exists only as very modified occurrences that may be capable of being substantially restored or rehabilitated if such work begins in the short-term future (within about 20 years).

VU: Vulnerable

An ecological community that has been adequately surveyed and is found to be declining and/or has declined in distribution and/or condition and whose ultimate security has not yet been assured and/or a community that is still widespread but is believed likely to move into a category of higher threat in the near future if threatening processes continue or begin operating throughout its range.

An ecological community will be listed as Vulnerable when it has been adequately surveyed and is not Critically Endangered or Endangered but is facing a high risk of total destruction or significant modification in the medium (within about 50 years) to long-term future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria

a) The ecological community exists largely as modified occurrences that are likely to be capable of being substantially restored or rehabilitated.

b) The ecological community may already be modified and would be vulnerable to threatening processes, is restricted in area and/or range, and/or is only found at a few locations.

c) The ecological community may be still widespread but is believed likely to move into a category of higher threat in the medium to long-term future because of existing or impending threatening processes.

11.3 Priority ecological communities

Possible threatened ecological communities that do not meet survey criteria or that are not adequately defined are added to the Priority Ecological Community List under priorities 1, 2 and 3. Ecological communities that are adequately known and are rare, but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list, are placed in Priority 4. Conservation Dependent ecological communities are placed in Priority 5.

P1: Priority One: Poorly known ecological communities

Ecological communities that are known from very few occurrences with a very restricted distribution (generally ≤5 occurrences or a total area of ≤ 100ha). Occurrences are believed to be under threat either due to limited extent or being on lands under immediate threat (e.g. within agricultural or pastoral lands, urban areas, active mineral leases) or for which current threats exist. May include communities with occurrences on protected lands. Communities may be included if they are comparatively well-known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under immediate threat from known threatening processes across their range.

P2: Priority Two: Poorly known ecological communities

Communities that are known from few occurrences with a restricted distribution (generally ≤10 occurrences or a total area of ≤200ha). At least some occurrences are not believed to be under immediate threat (within about 10 years) of destruction or degradation. Communities may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under threat from known threatening processes.

P3: Priority Three: Poorly known ecological communities

(i) Communities that are known from several to many occurrences, a significant number or area of which are not under threat of habitat destruction or degradation, or

(ii) Communities known from a few widespread occurrences, which are either large or with significant remaining areas of habitat in which other occurrences may occur, much of it not under imminent threat (within about 10 years), or

(iii) Communities made up of large, and/or widespread occurrences, that may or may not be represented in the reserve system, but are under threat of modification across much of their range from processes such as grazing by domestic and/or feral stock, inappropriate fire regimes, clearing, hydrological change etc.

Communities may be included if they are comparatively well known from several localities but do not meet adequacy of survey requirements and/or are not well defined, and known threatening processes exist that could affect them.

P4: Priority Four: Ecological communities that are adequately known, rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list.

These communities require regular monitoring.

(i) Rare. Ecological communities known from few occurrences that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection but could be if present circumstances change. These communities are usually represented on conservation lands.

(ii) Near Threatened. Ecological communities that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for a higher threat category.

(iii) Ecological communities that have been removed from the list of threatened communities during the past five years.

P5: Priority Five: Conservation Dependent ecological communities

Ecological communities that are not threatened but are subject to a specific conservation program, the cessation of which would result in the community becoming threatened within five years.

Appendix 12: **Other catchment attributes**

The catchment also contains other attributes which are of considerable human value. These include the agricultural value of the landscape, water supply sites and places for water-based recreational activities, all of which are also threatened by salinity.

While threats to these attributes are not specifically addressed by recovery actions, an assumption of the planning approach is that, by successfully managing the highest priority biological elements, we will also deliver benefits to other elements such as those listed below.

12.1 Agriculture

Agriculture is the main economic activity occurring within the catchment. In the Shires of Kent and Lake Grace, agricultural businesses make up 62% of all local businesses. A further 17% of local businesses appear to be involved in agriculture support services such as transport, construction, and wholesale trades. Agriculture is therefore the most important enterprise and employer in the catchment.

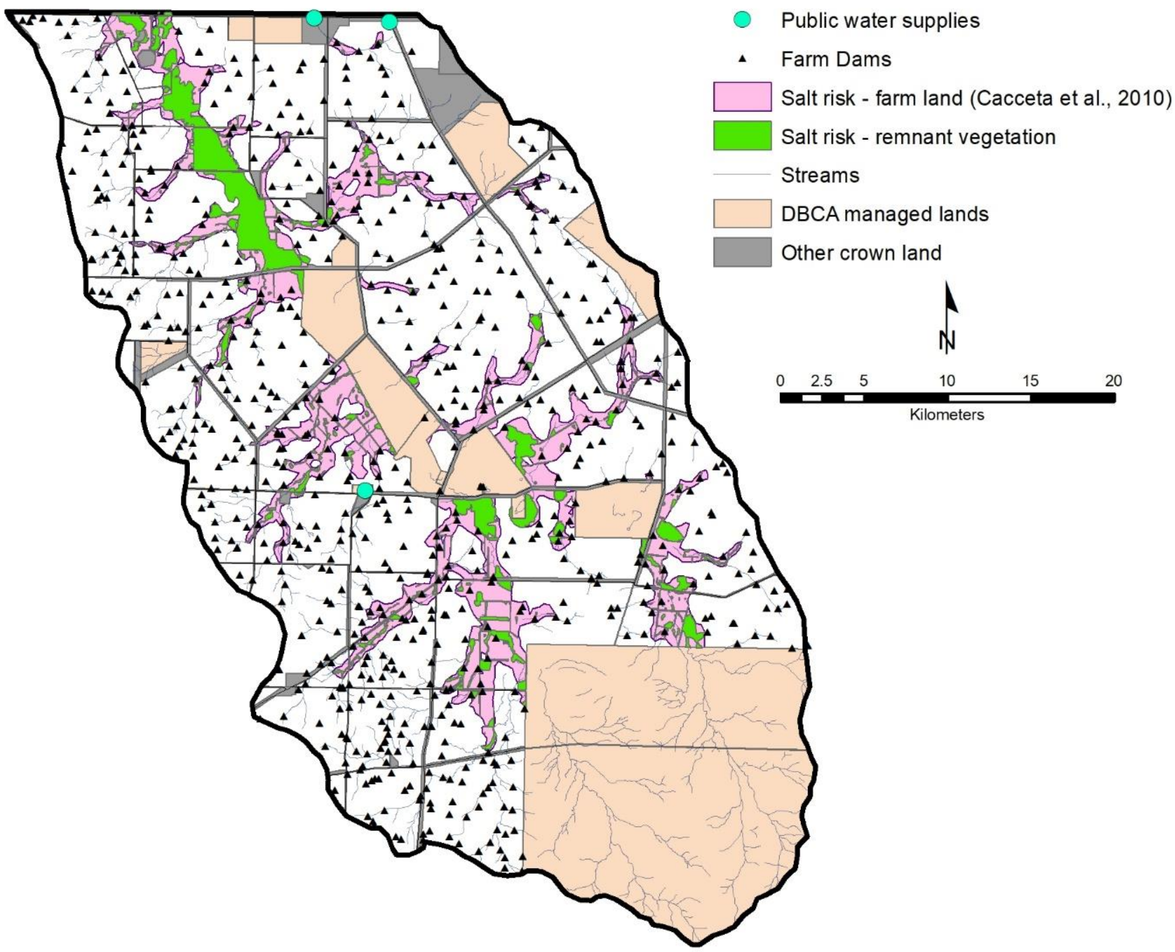

Figure 30 Farm water supply infrastructure in the Lake Bryde Catchment.

The predicted risk of salinisation due to shallow groundwater tables (Caccetta *et al*., 2010) implicates about 21,200 hectares or 18% of the catchment's freehold land sited on the valley floor. About 15,200 hectares of this total is cleared agricultural land and the remainder is either remnant vegetation, revegetation, rock outcrops or wetlands.

12.2 Water supply

Fresh water for human consumption, stock and agricultural purposes has always been limited within the catchment. Currently there are only three public water sources in the catchment:

- A concrete tank at Hollands Rock.
- A dam on Reserve 17648, adjacent to the Lake Grace-Newdegate Road.
- A standpipe and tank in the extreme north of Burngup South Road.

Dams constructed on the shoreline of Lake Bryde to aid the settlement of the southern catchment during the 1960s and 1970s are no longer used for water supply purposes, because the lake is usually dry when water is most needed – during times of drought.

Consequently, most farms must use dams sited on natural drainage lines, and tanks filled from the roofs of farm buildings to meet their water supply needs.

About 22% of these farm dams are sited in or in very close proximity to the salt risk zone (Caccetta *et al*., 2010).

12.3 Recreation

Lake Bryde is one of only a few freshwater wetlands remaining in the Wheatbelt which, when filled, are large and deep enough to accommodate powered craft and water skiing. It is therefore a popular local recreation site during significant fill events as it is widely utilised by the local community for recreational activities such as water-skiing and swimming.

Nature appreciation and picnicking are also locally important recreational activities.

Appendix 13: **Prioritising biological elements**

13.1 The approach

Given the constraints (e.g. funding, staff availability, etc.) that characterise most environmental programs (Hobbs and Kristjanson, 2003), management necessarily focuses, at least in part, on the highest priority biological elements. Prioritisation should favour the subset of biological elements that are the most valuable — in terms of the priority human values.

An assumption of this approach is that, by successfully managing the highest priority biological elements (a subset of the overall native biota), we will deliver a greater proportion of the key human values than if available funds were, for example, equally distributed across all elements.

Properties and their importance to the management of biological elements

Even though 15 biological elements have been identified as important, we can further rate these elements in terms of their value to supplement the prioritisation process. A critical part of this 'element valuation' analysis and to understanding the planning approach in general, is the identification of important properties of the biological elements.

Properties are the physical states (e.g. richness, rarity, size) of elements arising from the structure and composition of the element under consideration (based on Vbra and Elderedge, 1984). One can think of properties as attributes that can be used to describe an element, akin to the relationship between an adjective (property) and a noun (element) in sentence structure. We are most concerned with the properties that affect the element's value.

Because properties can affect element value (e.g. Lindemann-Matthies *et al*., 2010, Montgomery, 2002), it is the properties themselves that are controlled with on-ground management activities. Depending on the risk analysis, only a subset of the properties may need to be managed. Given the importance of properties to the planning process, we provide a simplistic and hypothetical example to further explain the concept.

The grain protein content [a property] of a wheat crop [a non-natural biological element] influences its resource value [a value]. A landholder may attempt to manage the processes that influence the grain protein content of the crop to maximise its resource value.

Although any biological element will have many properties (such as richness or intactness) that characterise it, only a subset will appreciably influence its value; like the grain protein content example, natural resource managers should focus their management on properties (such as species richness and intactness) that influence the important values. It is therefore critical to understand the relationships between properties and values.

13.2 Property modelling

Because the catchment's biological elements share properties (i.e. all the biological elements have a species richness and a size), their relative expected value can be estimated and compared by quantifying and combining shared property information. To do this the relationships between each property and each value (e.g., greater property score = greater value or vice versa) must be quantified.

The department, working with researchers from the School of Computer Science and Horizon Digital Economy Institute at the University of Nottingham, UK[7], has developed a new modelling approach that uses element properties to rate biological elements on their value (Property-values analysis; Pourabdollah *et al*. (2014)). This method applies Fuzzy Logic mathematical modelling of the relationships between the properties and the values. The identification of important properties and the derivation of their relationships with the key values are described by Smith *et al*. (2015).

From Smith *et al*. (2015), six properties were identified as important in terms of element value (for the three priority values) by the Technical Advisory Group and the Stakeholder Representative Group: Size, Total native species richness, Rarity, Loss of species, Visibility and Charisma. The property definitions are provided in Table 13.

As outlined in Smith *et al*. (2015), the Technical Advisory Group quantified the relationships between each property and each priority value (Figure 31). Increasing darkness of shading indicates increasing agreement and certainty among the experts in terms of the expected relationship between the property and the value. By way of explanation, there was very strong agreement and certainty that loss was negatively related to Recreation value, but considerable uncertainty and difference in opinions with respect to the relationship between Future options and Rarity.

These relationships were then used in the Fuzzy Logic System of Pourabdollah *et al*. (2014) to generate unit-less relative estimates (centroids) of the overall value or utility (an index generated from the three priority values) of each biological element (Figure 32). In Figure 32, the uncertainty surrounding each centroid estimate is captured by a kurtosis score which is one way to quantify the variability and shape of the fuzzy set used to generate the utility expectations.

To assess the model outputs, analogous estimates to the model utility scores were elicited directly from stakeholder representatives for comparison (Figure 16). A detailed explanation of the methods and analysis is provided in Smith *et al*. (2015).

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[7] As part of the UK EPSRC funded research project "Towards Data-Driven Environmental Policy Design", EP/K012479/1, led by Dr C. Wagner

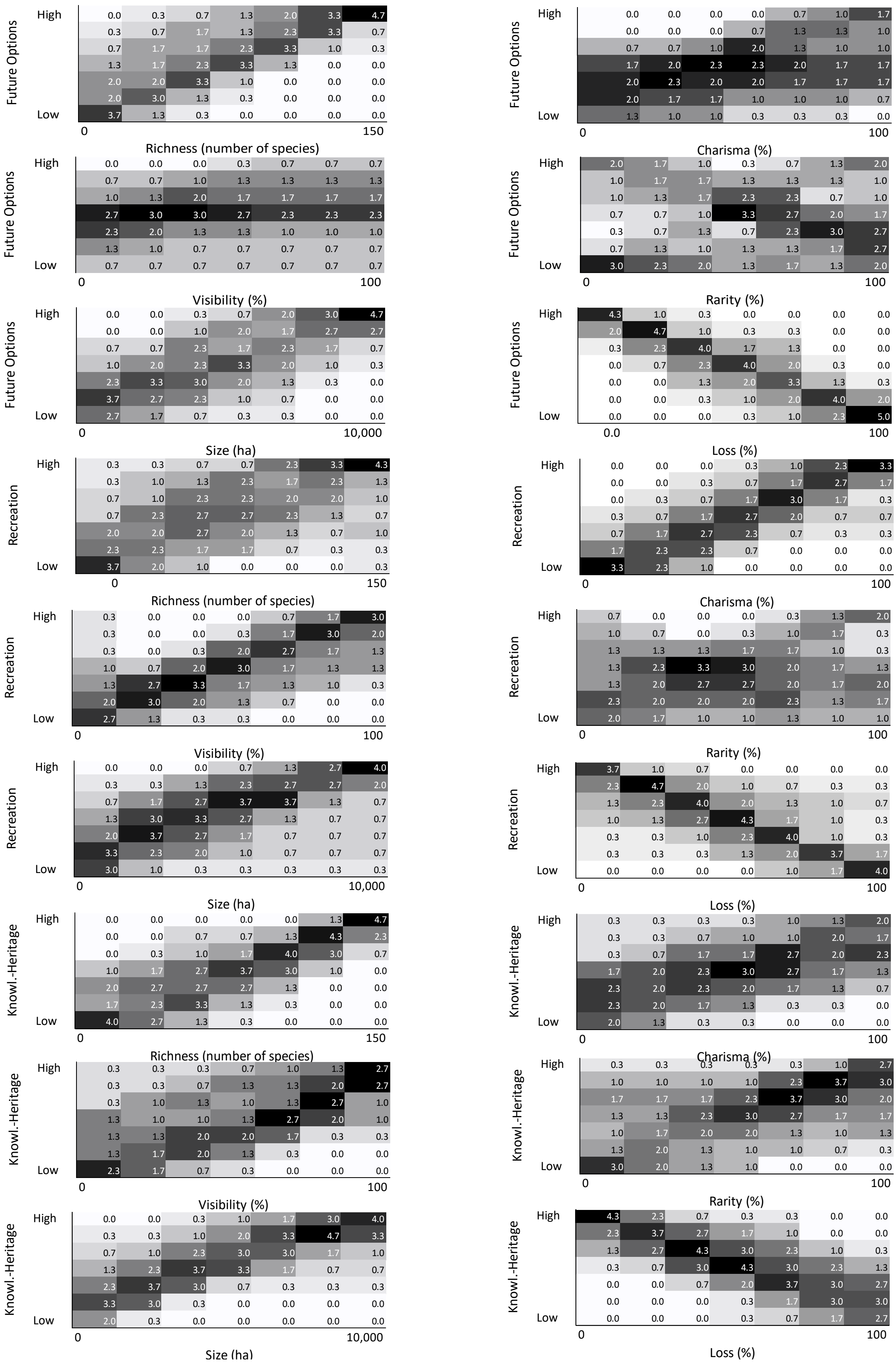


Figure 31 Aggregated expert opinion on the relationship between each key property and each priority value.

Table 13 The element properties identified as important in terms of the Knowledge-Heritage, Recreation and Future options values.

Property	**Definition**
Rarity (in the south-west land division)	The 'unusualness' of the collection of species that characterise the element within the context of the south west land division of Western Australia. Thus, we may consider the rareness of elements at the level of species and sub-species (e.g., Declared Rare Flora, Endangered Fauna); or at the level of an assemblage or community (e.g., Threatened Ecological Community). The maximum rarity of an element is 100% - for example, where there is only one representative of the element persisting or where the element has the rarest species when compared to the other elements. The minimum rarity of an element is 0%. Note that in the case of some elements, it is the particular collection of species that is considered unusual or rare even though some of the species that constitute element may be quite common. In some instances, for example, a collection of waterbirds may constitute very common species, but it is unusual to have that particular gathering of species together in one place and so the element would be rare. In contrast, the collection of frog species in the area may include all common species and may not be a particularly unusual gathering of species and so would be of low rarity.
Size	The total area of occupancy of the species that characterise the element. At some level, occupancy will relate to habitat avoidance. For example, species will typically occupy areas where they feed, reproduce, etc. They may generally try to avoid many areas (e.g., roads, open paddocks, etc.), but may have to traverse such areas to utilise preferred habitats. Birds, for example, may fly between different important habitats, via less preferred areas. Similarly, frogs may rely on habitats in and around water bodies, but on occasion move between habitats. Again, in this example, the areas of occupancy would be the critical habitats and not include the areas the frog moves over to get to an important habitat. In the context of the Lake Bryde Catchment, we therefore think of the important habitats as constituting the area of preferred/required occupancy, but not the areas that are traversed as a means to reaching preferred/required habitat. Obviously, there will be considerable uncertainty around size (and the other properties) which will be incorporated into the modelling.
Species composition (total species richness)	The total number of native species that occur within the element.
Loss of species	Conceptually, loss is equivalent to, or a subset of, the notion of biological integrity which is defined by Callicott *et al*. (1999) as "native species populations in their historic variety and numbers naturally interacting in naturally structured biotic communities" and includes ecosystem processes. For the Lake Bryde NDRC, loss was thought of in terms of the loss of native species from an element.
Visibility	Essentially optical visibility can be thought of as a compound property and relates to the ease with which we can see the species that constitute a particular element. So, a particularly visible element may mostly include large (size of individuals) sedentary species. Alternatively, less visible elements may include species that are shy, cryptic (mostly hidden from sight – even if they are large), very small, etc. Should be considered as being viewed at optimum time of day for the component species (e.g., birds may be best seen early in the morning, possums at night, etc).
Charisma	Elements are charismatic when they stimulate strong emotional attraction amongst humans. This attraction may stem from a number of sources, including that an element may be invested with significant symbolic meaning (e.g., national flora and fauna emblems), be 'cute' (e.g., koalas), widely admired for a particular characteristic such as beauty or strength (e.g., birds of paradise, lions), or be otherwise very famous or very popular. Such elements generally have a high public profile or are widely known. This is also really a compound property, but it seems to be an important general discriminator for the stakeholder representatives.

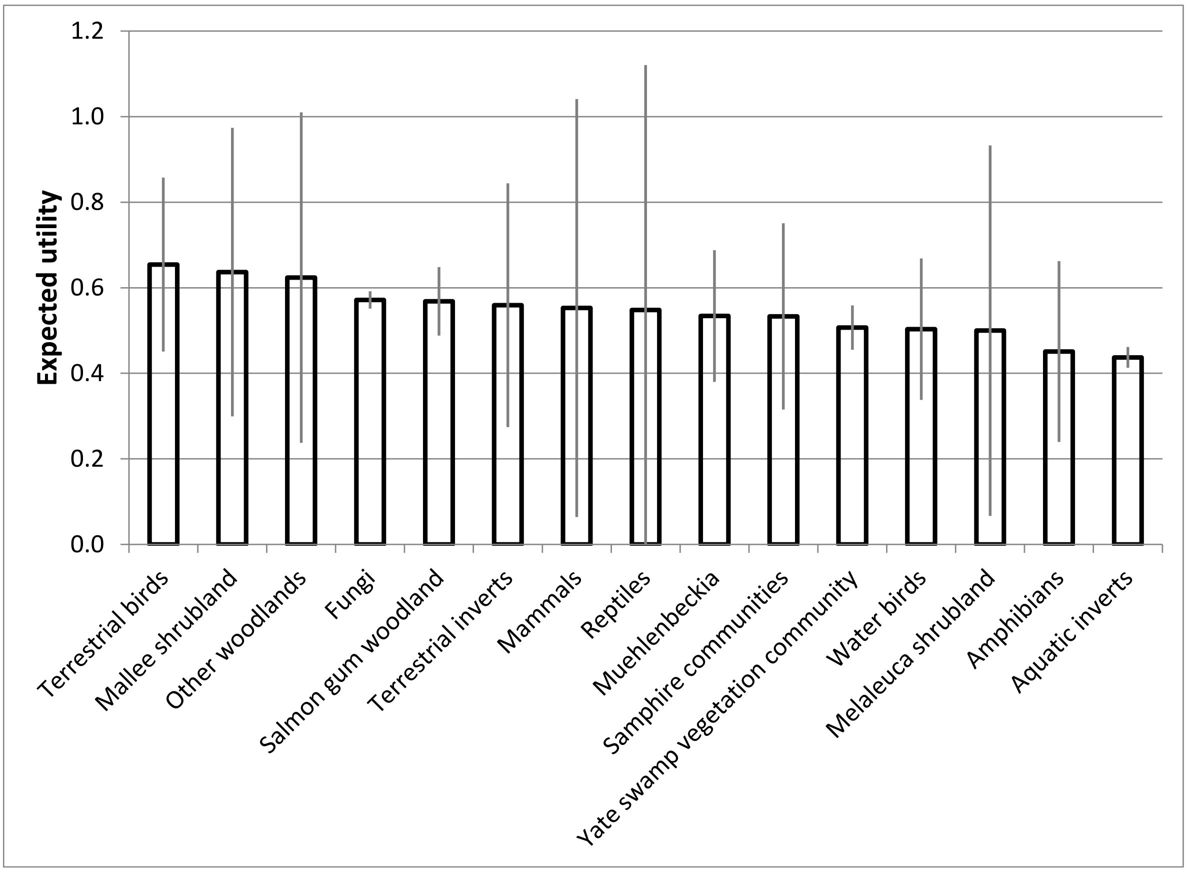


Figure 32 Estimated overall utility (overall value) for Lake Bryde elements in terms of the three priority human values as estimated by the Fuzzy Logic System. Bar height is determined by the centroid utility estimate and grey lines indicate kurtosis — a measure of the variability and shape of the fuzzy set used to generate the utility expectations.

13.3 Priority biological elements

It is important to note that all the elements are of value to people. Indeed, the expected utilities were not massively different from each other (Figure 32) especially when we consider the levels of uncertainty. However, elements will vary in why, how and to what extent we value them and so it is important for managers to understand these differences.

The stakeholder representative rating of the overall value of each biological element in relation to the model estimate is provided in Figure 5 of the landscape recovery program. In general, the two estimates were in good agreement, with the greatest level of disagreement occurring between the rating of the mammals and the waterbirds (the model rated these two elements lower than the stakeholder representatives).

Smith *et al*. (2015) discuss some of the possible reason behind these differences which included the possibility that the model is missing some important properties, the importance of properties like charisma have been underrated or there are some differences in the way stakeholders and experts view the relationships between particular properties and the value of the biological elements.

Appendix 14: **Management action**

To estimate the probability of success for each management option, a technical expert group was convened to provide their opinions in a formal workshop setting. The workshop was held in the department's Narrogin District Office on 12 May 2015. Seven experts attended: a Regional Ecologist, District Nature Conservation Program Leader, Nature Conservation Officer, Recovery Catchment Officer, Senior Hydrologist, Principal Research Scientist and District Manager.

14.1 Method

The experts were presented an introductory talk to re-familiarise them with relevant aspects of the previous planning steps — the catchment goal, the biological elements, the outcomes of the risk analysis and the associated management target — and the important concepts for the proceeding workshop. These concepts included the elicitation question and a description of the elicitation approach with several examples to function as basic training. The various concepts were discussed in an attempt to bring all experts to a similar level of understanding and agreement with respect to the workshop and its purpose. The experts also worked through the key threatening processes and identified the available and practicable management options (Table 14).

For each of the 31 management options, each expert created an ellipse on a scale to capture their estimate of its likelihood of success and their level of uncertainty. The ellipse approach is described in detail in Wallace *et al*. (2016), Smith *et al*. (2015) and Smith *et al*. (2016). For each of the management options each expert asked themselves the question:

> *What is the probability that [management option] will be successful (i.e. no loss of species in the effected elements) over the management period (20 years) given all practicable management actions and unlimited resources?*

The ellipses created by each expert for each management option were aggregated (Figure 33) and from this 'Fuzzy Set" a Centroid and Actual Average Deviation statistic was calculated (Figure 15). These statistics provide an estimate of the probability of success and the associated uncertainty around that estimate, respectively. Note, two of the experts felt that they could not adequately conduct the elicitation approach.

A similar method was then used to estimate the cost (and associated uncertainty) of each management option that included a single threatening process (and the 'walk' away option; options 1 to 6). For each of the management options each expert asked themselves the question:

> *What is the cost of the [management option] over the management period (20 years) given all practicable management actions and unlimited resources?*

The ellipses created by each expert for the cost of each management option were aggregated (Figure 34) and from this 'Fuzzy Set" a Centroid and Actual Average Deviation statistic was calculated (Table 16). These statistics were used to estimate the likely cost of each management option in addition to the associated uncertainty around that estimate.

Table 14 Management options for the key threatening processes. A tick indicates which processes are targeted in the option**.**

Management option	Climate	Fire	Hydrology	Surrounding land use	Problem species
1	✓				
2		✓			
3			✓		
4				✓	
5					✓
6					
7	✓			✓	
8	✓	✓			
9		✓		✓	
10		✓			✓
11	✓		✓		
12		✓	✓		
13			✓	✓	
14			✓		✓
15	✓				✓
16				✓	✓
17	✓	✓		✓	
18	✓	✓			✓
19		✓		✓	✓
20	✓		✓	✓	
21	✓	✓	✓		
22		✓	✓	✓	
23		✓	✓		✓
24	✓		✓		✓
25			✓	✓	✓
26	✓			✓	✓
27	✓	✓		✓	✓
28	✓	✓	✓		✓
29		✓	✓	✓	✓
30	✓		✓	✓	✓
31	✓	✓	✓	✓	✓

14.2 Results

The aggregated Fuzzy Sets for each management option and each cost estimate are provided in Figures 33 and 34 and the associated statistics in Tables 15 and 16.

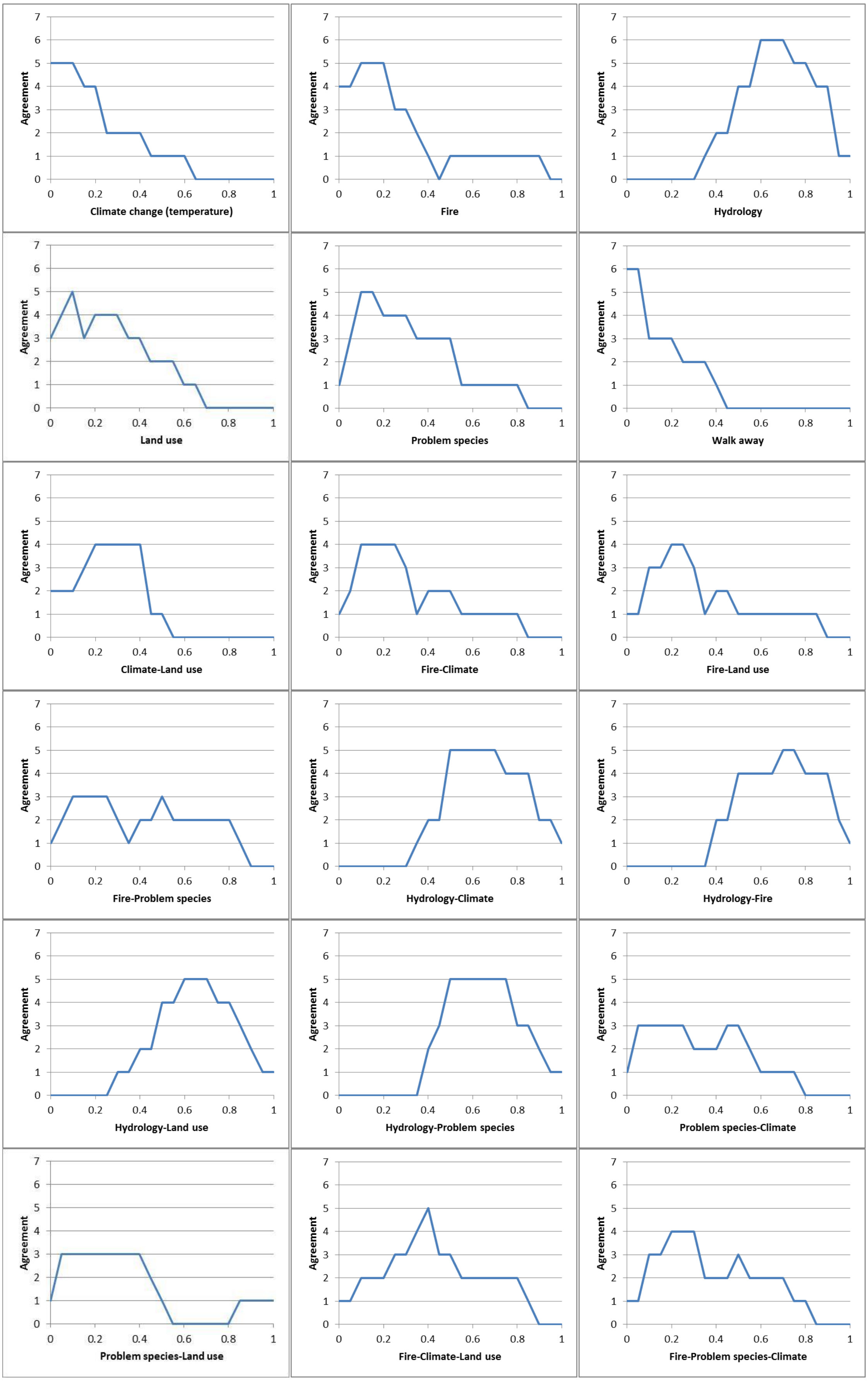
From these results it can be seen that, in general, there was very high agreement among the experts (high peaks in the graphs) and for the management options, the inclusion of hydrology increased the probability of success. For many of the options that did not include hydrology (e.g., Problem Species-Climate-Landuse; option 26) there was less agreement (low peak) and typically a lower probability of success (lower centroid estimate).

In general, there was considerable uncertainty surrounding each estimate of benefit, highlighting the possibility, that any option may be more or less effective (in terms of not losing species and cost) than expected. However, the inclusion of hydrology in any management option, despite its high cost, significantly increases the expected effectiveness of a management option (Figure 18).

The most effective management options were:

1. Manage all options hydrology/fire/problem species/climate/land use,
2. Manage hydrology/fire/problem species/climate or
3. Hydrology/fire/problem species.

The analysis also found that walking away from the management area was the least effective option.


Agreement
0
1
2
3
4
5
6
7
0
0.2
0.4
0.6
0.8
1
Climate change (temperature)
Fire
Hydrology
Land use
Problem species
Walk away
Climate-Land use
Fire-Climate
Fire-Land use
Fire-Problem species
Hydrology-Climate
Hydrology-Fire
Hydrology-Land use
Hydrology-Problem species
Problem species-Climate
Problem species-Land use
Fire-Climate-Land use
Fire-Problem species-Climate

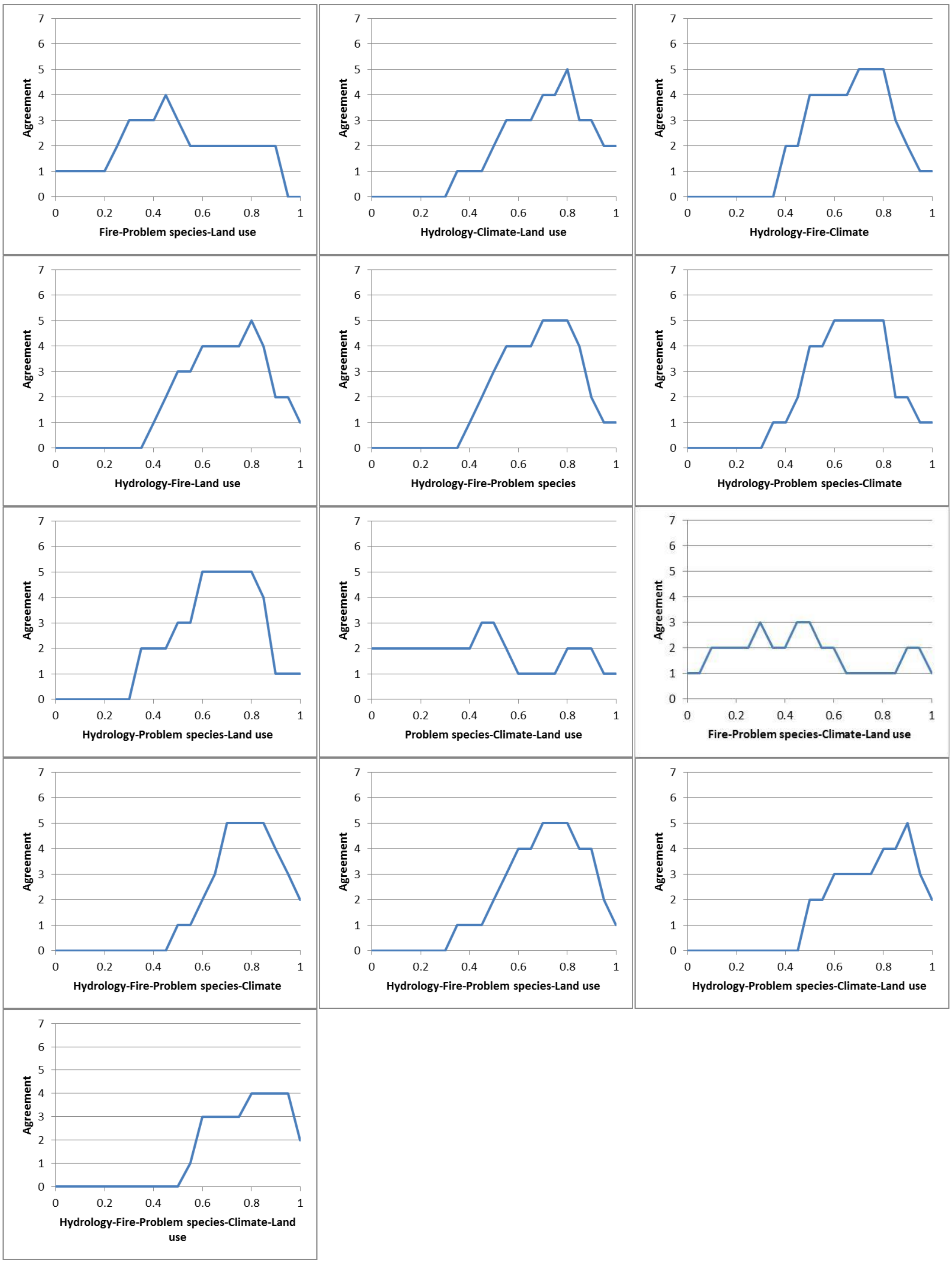


Figure 33 Aggregation graphs for each management option (in order from 1 to 31). Note, x-axis is the probability of success and y-axis indicates the level of agreement amongst the different experts.

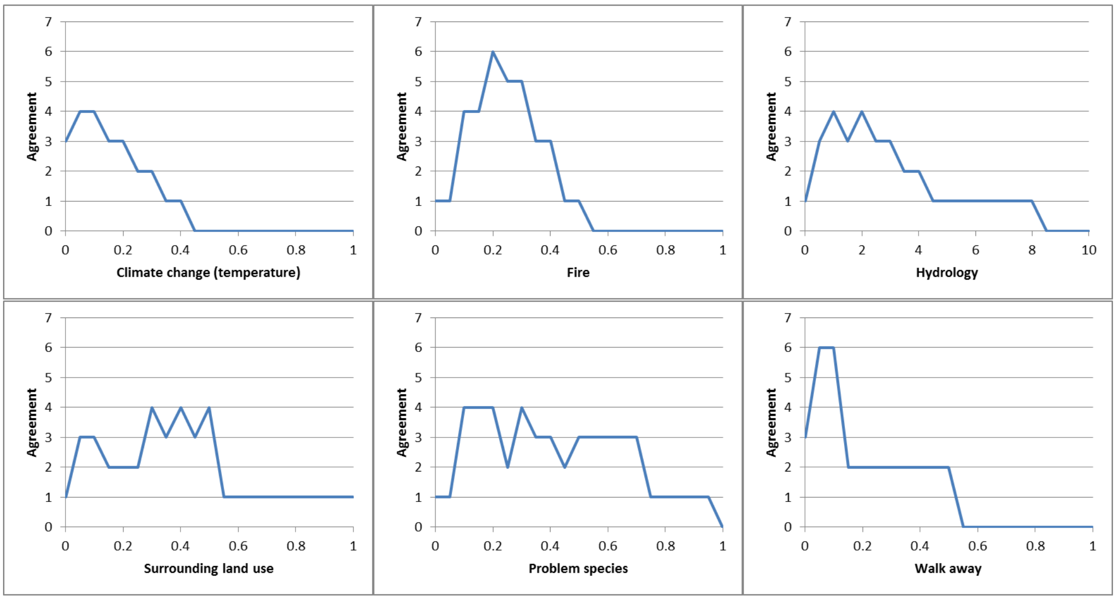


Figure 34 Aggregation graphs for the cost of each individual management option. Note, x-axis is the expected cost in 10s of millions of dollars and y-axis indicates the level of agreement amongst the different experts.

Table 15 Centroid and actual average deviation (AAD) estimates for each management option.

Management option	Description	Centroid	AAD
1	Climate change	0.196	0.135
2	Fire	0.280	0.200
3	Hydrology	0.679	0.127
4	Land use	0.260	0.148
5	Problem species	0.308	0.164
6	Walk away	0.138	0.104
7	Climate/Land use	0.248	0.108
8	Fire/Climate	0.311	0.174
9	Fire/Land use	0.342	0.188
10	Fire/Problem species	0.403	0.216
11	Hydrology/Climate	0.667	0.133
12	Hydrology/Fire	0.694	0.133
13	Hydrology/Land use	0.655	0.132
14	Hydrology/Problem species	0.658	0.124
15	Problem species/Climate	0.324	0.175
16	Problem species/Land use	0.328	0.193
17	Fire/Climate/Land use	0.424	0.178
18	Fire/Problem species/Climate	0.365	0.181
19	Fire/Problem species/Land use	0.488	0.196
20	Hydrology/Climate/Land use	0.718	0.136
21	Hydrology/Fire/Climate	0.677	0.126
22	Hydrology/Fire/Land use	0.701	0.127
23	Hydrology/Fire/Problem species	0.693	0.120
24	Hydrology/Problem species/Climate	0.670	0.123
25	Hydrology/Problem species/Land use	0.666	0.130
26	Problem species/Climate/Land use	0.455	0.243
27	Fire/Problem species/Climate/Land use	0.472	0.229
28	Hydrology/Fire/Problem species/Climate	0.782	0.102
29	Hydrology/Fire/Problem species/Land use	0.714	0.126
30	Hydrology/Problem species/Climate/Land use	0.769	0.124
31	Hydrology/Fire/Problem species/Climate/Land use	0.795	0.109

Table 16 Centroid and actual average deviation (AAD) estimates for the cost (in 10s of millions of dollars) of each management option over 20 years.

Management option	Description	Centroid	AAD
1	Climate change	0.15	0.09
2	Fire	0.24	0.09
3	Hydrology	3.02	1.75
4	Land use	0.40	0.17
5	Problem species	0.42	0.21
6	Walk away	0.20	0.14

Appendix 15: **Introduced fauna and flora**

Table 17 Naturalised plant species recorded in the Lake Bryde Catchment since 1999

Family	Species name	Common name
Aizoaceae	*Carpobrotus edulis*	Hottentot fig
	Mesembryanthemum nodiflorum	Slender iceplant
Apiaceae	*Cyclospermum leptophyllum*	
Asteraceae	*Carduus tenuiflorus*	Sheep thistle
	Arctotheca calendula	Cape weed
	Cotula bipinnata	Ferny Cotula
	Hypochaeris glabra	Smooth catsear
	Sonchus asper	Rough sowthistle
	Sonchus oleraceus	Common sowthistle
	Ursinia anthemoides	Ursinia
Brassicaceae	*Hornungia procumbens*	
Caryophyllaceae	*Spergularia diandra*	Lesser sand spurry
	Spergularia rubra	Sand spurry
Fabaceae	*Trifolium arvense*	Hare's foot clover
	Trifolium subterraneum	Subterranean clover
	Trifolium tomentosum	Woolly clover
Gentianaceae	*Centaurium erythraea*	Common centaury
Plantaginaceae	*Plantago coronopus subsp. commutata*	
Poaceae	*Aira caryophyllea*	Silvery hairgrass
	Avellinia michelii	
	Bromus diandrus	Great brome
	Bromus rubens	Red brome
	Hainardia cylindrica	Common barbgrass
	Hordeum glaucum	Northern barley grass
	Lolium perenne	Perrenial ryegrass
	Lolium rigidum	Wimmera ryegrass
	Parapholis incurva	Coast barbgrass
	Pentameris airoides	False hairgrass
	Rostraria cristata	
	Vulpia bromoides	Squirrel tail fescue
	Vulpia muralis	
	Vulpia myuros	
Primulaceae	*Lysimachia arvensis*	Pimpernel

Sources: Ecoscape (Australia) Pty Ltd (2001, 2004); Mattiske Consulting Pty Ltd (1999, 2001, 2005 and 2006); Phillips (2011); Rick, (2017, 2018 and 2019); and departmental Catchment Officers' reports.

Table 18 Naturalised fauna recorded in the Lake Bryde Catchment since 1999.

Family	**Species name**	**Common name**
Crustaceans		
Parastacidae	*Cherax destructor*	Yabbie
Mammals		
Canidae	*Canis familiaris*	Dog (feral)
	Vulpes vulpes	Red fox
Felidae	*Felis catus*	Cat (feral)
Leporidae	*Oryctolagus cuniculus*	Rabbit
Muridae	*Mus musculus*	House mouse
Suidae	*Sus scrofa*	Pig (feral)
Birds		
Columbidae	*Streptopelia senegalensis*	Laughing turtle-dove
Halcyonidae	*Dacelo novaeguineae*	Laughing kookaburra

Sources: Burbidge *et al*., 2004, Cale *et al*., 2004, Cale, 2006, Cale, 2013, Halse *et al*., 2004, Pinder *et al*., 2004; Department of Parks and Wildlife, 2007 - 20; and unpublished departmental Catchment Officers' reports.

Appendix 16: **Flora fire regenerative characteristics**

Data on the fire regenerative characteristics of the flora elements are from two sources:

- Barrett *et al*. (2009), Shedley (2007) and Carley and Brooks (2013) classified the fire regenerative characteristics of some species found in the Avon Wheatbelt Bioregion of Western Australia using the following fire response codes:

Code	Fire response
OS	obligate seeders, canopy seed storage
SS	obligate seeders, soil-stored seed bank
RS bs	basal resprouters
RS ep	epicormic resprouters
RS/SC or RS/SS	facultative resprouters (able to resprout and germinate after fire)

- Gosper *et al*. (2012) and Harvey *et al*., (2017) similarly classified the fire regenerative characteristics of some species found in the Mallee bioregion of Western Australia using the following plant functional type codes:

Code	Plant functional type
NStree	non-resprouting (N) serotinous (S) trees
NSshrub	non-resprouting (N) serotinous (S) shrubs
RSshrub	resprouting (R) serotinous (S) shrubs
NNshrub	non-resprouting (N) non-serotinous (N) shrubs
RNshrub	resprouting (R) non-serotinous (N) shrubs
NNlow	non-resprouting (N) non-serotinous (N) sedges and perennial herbs
RNlow	resprouting (R) non-serotinous (N) sedges and perennial herbs
Ephem	ephemerals
Geo	geophytes

In both sources, where there was some level of uncertainty about the attribution, the authors applied a '?' to the code.

Table 19 Known fire regenerative responses of plant species recorded in the Lake Bryde Recovery Catchment**.**

Native flora species	Fire response	Plant Functional Type	Duma shrublands	Mallee shrublands	Melaleuca shrblnds	Other woodlands	Salmon gum wdlnds	Samphire shrblnds	Yate swamps
Acacia ? squamata				x					
Acacia acanthoclada	SS?	NNshrub				x			
Acacia acuminata	RS bs/SS					x			
Acacia acutata						x	x		
Acacia brachyclada						x			
Acacia chamaeleon						x			
Acacia eremophila						x			

Native flora species	Fire response	Plant Functional Type	Duma shrublands	Mallee shrublands	Melaleuca shrblnds	Other woodlands	Salmon gum wdlnds	Samphire shrblnds	Yate swamps
Acacia erinacea	*SS?*	*NNshrub*				*x*	*x*		
Acacia hemiteles						x	x		
Acacia lasiocarpa	SS?	NNshrub				x			
Acacia leptospermoides						x	x		
Acacia microbotrya	SS						x		
Acacia multispicata	SS			x					
Acacia mutabilis	SS	NNshrub		x		x	x	x	
Acacia pulchella	SS	NNshrub		x					
Acacia saligna						x			
Acacia viscifolia				x					
Actinobole uliginosum						x	x		
Allocasuarina microstachya	RS bs	RSshrub		x					
Allocasuarina pinaster					x				
Alyxia buxifolia						x	x		
Amphipogon amphipogonoides				x					
Amphipogon turbinatus		RNlow		x					
Andersonia sprengelioides	SS	NNshrub		x					
Angianthus pygmaeus								x	
Angianthus tomentosus							x		x
Argentipallium niveum				x					
Astartea ? ambiguus				x		x			
Astroloma compactum				x		x			
Astroloma epacridis		RNshrub				x	x		
Astroloma microphyllum				x					
Atriplex exilifolia						x			
Atriplex paludosa						x	x	x	
Atriplex semibaccata			x						
Atriplex vesicaria					x	x	x		
Austrostipa drummondii						x	x		
Austrostipa elegantissima		RNlow				x	x		
Austrostipa juncifolia					x	x			
Austrostipa puberula						x	x		
Austrostipa pycnostachya				x		x	x		
Austrostipa semibarbata						x	x		
Austrostipa trichophylla		Ephem				x			
Baeckea aff. *preissiana*		RNshrub?		x					
Baeckea crispiflora				x					
Baeckea preissiana		RNshrub		x					

Native flora species	Fire response	Plant Functional Type	Duma shrublands	Mallee shrublands	Melaleuca shrblnds	Other woodlands	Salmon gum wdlnds	Samphire shrblnds	Yate swamps
Banksia cirsioides	OS			x					
Banksia epimicta				x					
Banksia media	OS	NStree		x					
Banksia prionotes	OS			x					
Banksia pteridifolia	RS bs	RSshrub		x					
Banksia rufa	RS bs	NSshrub		x					
Banksia violacea	OS	NSshrub		x					
Banksia xylothemelia	RS bs	RSshrub		x					
Beaufortia schaueri	OS	NSshrub					x		
Bentleya spinescens						x			
Beyeria brevifolia				x		x			
Billardiera fusiformis				x					
Billardiera lehmanniana				x		x	x		
Blennospora drummondii						x	x		
Boronia inornata		NNshrub				x			
Bossiaea halophila					x				
Brachyscome ? iberidifolia						x	x		
Brachyscome lineariloba					x				
Calectasia grandiflora				x					
Calectasia pignattiana		NNshrub		x					
Callitris roei	OS	NStree				x			
Calytrix leschenaultii		NNshrub		x		x	x		
Carpobrotus sp.			x			x	x		x
Centipeda cunninghamii							x		
Centrolepis aristata						x			
Chamaexeros macranthera				x					
Chamaexeros serra		RNlow		x					
Chamelaucium ciliatum					x	x			
Chorizandra sp.						x			
Chorizema aciculare		NNshrub		x					
Coleanthera coelophylla						x			
Comesperma integerrimum						x	x		
Comesperma scoparium		RNshrub				x			
Conostephium roei				x		x			
Conostylis petrophiloides				x					
Coopernookia strophiolata						x			
Crassula colorata						x	x		x

Native flora species	Fire response	Plant Functional Type	Duma shrublands	Mallee shrublands	Melaleuca shrblnds	Other woodlands	Salmon gum wdlnds	Samphire shrblnds	Yate swamps
Cryptandra minutifolia				x					
Cryptandra myriantha				x					
Cryptandra nutans				x					
Dampiera lavandulacea		RNshrub		x		x			
Dampiera orchardii						x	x		
Darwinia inconspicua						x			
Darwinia vestita		NNshrub				x			
Daucus glochidiatus						x	x		
Daviesia decurrens				x		x			
Daviesia dilatata				x					
Daviesia gracilis				x					
Daviesia incrassata	SS	NNshrub		x					
Daviesia lancifolia	RS bs	RNlow		x					
Daviesia mollis				x		x			
Daviesia scoparia				x					
Daviesia uncinata		NNshrub		x					
Desmocladus asper				x		x	x		
Desmocladus flexuosus						x			
Desmocladus myriocladus						x			
Desmocladus parthenicus		NNlow		x					
Dianella brevicaulis						x	x		
Dianella revoluta						x			
Dicrastylis corymbosa						x			
Disphyma crassifolium			x		x	x	x		
Dodonaea amblyophylla				x		x	x		
Dodonaea bursariifolia		RNshrub		x		x			
Dodonaea caespitosa				x		x	x		
Dodonaea ceratocarpa	RS bs								x
Dodonaea divaricata				x					
Dodonaea pinifolia	RS bs			x		x			
Duma horrida subsp. *abdita*			x				x	x	
Enchylaena tomentosa					x	x	x		
Eremaea pauciflora	SS	RSshrub		x		x			
Eremophila decipiens						x	x		
Eremophila subfloccosa subsp. *lanata*						x			
Erymophyllum ramosum						x			

Native flora species	Fire response	Plant Functional Type	Duma shrublands	Mallee shrublands	Melaleuca shrblnds	Other woodlands	Salmon gum wdlnds	Samphire shrblnds	Yate swamps
Eucalyptus alipes	OS			x		x			
Eucalyptus annulata	RS bs			x					
Eucalyptus calycogona						x	x		
Eucalyptus celastroides							x		
Eucalyptus depauperata		RStree				x			
Eucalyptus extensa	OS				x				
Eucalyptus flocktoniae	RS bs	RStree				x			x
Eucalyptus horistes				x		x			
Eucalyptus incrassata		RStree		x					
Eucalyptus kondininensis	RS bs/OS				x	x	x		
Eucalyptus loxophleba	RS bs/OS				x	x	x		
Eucalyptus mimica subsp. *continens*						x	x		
Eucalyptus mimica subsp. *mimica*						x	x		
Eucalyptus myriadena							x		
Eucalyptus occidentalis	OS/RS ep			x		x	x		x
Eucalyptus perangusta		RStree		x		x	x		
Eucalyptus phaenophylla		RStree		x					
Eucalyptus phenax	RS ep	RStree		x		x	x		
Eucalyptus salmonophloia	OS/RS ep					x	x		x
Eucalyptus salubris	OS/RS ep?						x		
Eucalyptus scyphocalyx		RStree				x			
Eucalyptus spathulata	RS bs/OS				x				
Eucalyptus sporadica		RStree		x		x			
Eucalyptus suggrandis		RStree			x				
Eucalyptus tenera	RS bs	RStree				x			
Eucalyptus urna	OS						x		
Euchiton sphaericus						x	x		x
Exocarpos aphyllus		NNshrub				x	x		
Exocarpos sparteus		NNtree				x	x		
Frankenia pauciflora						x	x	x	
Gahnia ancistrophylla						x			

Native flora species	Fire response	Plant Functional Type	Duma shrublands	Mallee shrublands	Melaleuca shrblnds	Other woodlands	Salmon gum wdlnds	Samphire shrblnds	Yate swamps
Gahnia lanigera						x			
Gahnia sp. L (K.R. Newbey 7888)	RS?			x		x			
Gahnia trifida							x		
Gastrolobium cruciatum				x					
Gastrolobium punctatum				x					
Gastrolobium reticulatum				x		x			
Gnephosis multiflora						x			
Gnephosis tenuissima						x			
Grevillea acuaria				x					
Grevillea disjuncta				x					
Grevillea dolichopoda	SS	NNshrub		x					
Grevillea huegelii		RNshrub				x	x		
Grevillea newbeyi		RNshrub		x			x		
Grevillea oligantha	RS bs/SS	NNshrub		x		x			
Grevillea prostrata				x		x			
Grevillea teretifolia				x					
Haegiela tatei	SS					x	x		
Hakea adnata	OS?					x			x
Hakea brachyptera				x					
Hakea circumalata				x		x			
Hakea commutata	OS	NSshrub		x					
Hakea corymbosa	OS	NSshrub		x		x	x		
Hakea cygna	OS	NSshrub		x					
Hakea erecta		NSshrub		x					
Hakea incrassata	RS bs	RSshrub		x					
Hakea lasiocarpha	OS			x		x	x		
Hakea laurina	OS	NStree				x			
Hakea linearis	RS					x			
Hakea lissocarpha	RS	RSshrub		x			x		
Hakea nitida	RS	RSshrub				x			
Hakea obliqua	OS			x			x		
Hakea preissii	OS					x	x		
Hakea scoparia	OS					x			
Hakea trifurcata	OS	NStree		x					
Harperia lateriflora				x					
Helichrysum leucopsideum						x			

Native flora species	Fire response	Plant Functional Type	Duma shrublands	Mallee shrublands	Melaleuca shrblnds	Other woodlands	Salmon gum wdlnds	Samphire shrblnds	Yate swamps
Hibbertia commutata				x					
Hibbertia exasperata		RNshrub		x		x			
Hibbertia gracilipes		RNlow		x					
Hypolaena caespitosa				x					
Hypolaena fastigiata				x		x			
Isopogon axillaris	RS bs			x					
Isopogon buxifolius	OS			x					
Isopogon teretifolius	RS bs	NSshrub		x					
Jacksonia nematoclada				x					
Jacksonia racemosa		NNlow		x		x			
Juncus radula							x		
Lasiopetalum rosmarinifolium				x		x			
Lawrencia diffusa			x						
Lawrencia squamata					x	x	x		
Laxmannia paleacea				x					
Lechenaultia brevifolia				x					
Lepidium rotundum							x		
Lepidobolus chaetocephalus		RNlow		x					
Lepidobolus preissianus		RNlow				x			
Lepidosperma brunonianum		RNlow		x		x	x		
Lepidosperma carphoides		RNlow		x					
Lepidosperma gracile				x					
Lepidosperma pruinosum				x		x			
Lepidosperma sanguinolentum				x		x			
Lepidosperma tenue		RNlow				x			
Lepidosperma viscidum						x			x
Leptomeria empetriformis							x		
Leptomeria preissiana				x					
Leptospermum erubescens	RS bs	RSshrub		x		x	x		
Leptospermum inelegans		RNtree		x					
Leucopogon concinnus				x					
Leucopogon conostephioides	SS	NNshrub		x					
Leucopogon dielsianus		NNshrub		x					
Leucopogon sp. Kau Rock (M.A. Burgman 1126)						x			
Leucopogon tamminensis		NNshrub		x					
Lobelia rarifolia		Ephem				x			

Native flora species	Fire response	Plant Functional Type	Duma shrublands	Mallee shrublands	Melaleuca shrblnds	Other woodlands	Salmon gum wdlnds	Samphire shrblnds	Yate swamps
Lomandra effusa		RNlow				x	x		
Lomandra micrantha		RNlow				x	x		
Lomandra mucronata		RNlow				x			
Loxocarya cinerea				x		x			
Lycium australe					x				
Lyginia imberbis				x					
Lysinema ciliatum	SS			x					
Melaleuca ? torquata				x					
Melaleuca acuminata	RS bs, OS	NSshrub		x		x	x		x
Melaleuca adnata				x		x	x		
Melaleuca brophyi				x	x	x			
Melaleuca *carrii*		NSshrub		x		x	x		
Melaleuca cuticularis	RS ep					x			
Melaleuca depauperata				x		x			
Melaleuca glaberrima	OS					x			
Melaleuca halmaturorum			x	x				x	
Melaleuca hamulosa	RS bs					x			
Melaleuca haplantha	OS?			x					
Melaleuca lateralis				x			x		
Melaleuca lateriflora	RS bs/OS	RSshrub		x	x	x	x	x	x
Melaleuca laxiflora		RSshrub		x		x			
Melaleuca marginata						x			
Melaleuca pauperiflora	OS				x	x	x		
Melaleuca platycalyx		RSshrub		x					
Melaleuca sculponeata		NSshrub			x				
Melaleuca sheathiana	OS						x		
Melaleuca societatis	OS			x					
Melaleuca strobophylla			x	x			x		x
Melaleuca subtrigona	RS bs	RSshrub		x		x			
Melaleuca thyoides	RS bs					x	x		
Melaleuca tuberculata		NSshrub		x					
Melaleuca uncinata	RS bs	RSshrub		x	x	x	x		x
Mesomelaena preissii		RNlow		x					
Mesomelaena pseudostygia				x					
Microcybe multiflora						x			
Neurachne alopecuroidea		RNlow		x		x	x		x

Native flora species	Fire response	Plant Functional Type	Duma shrublands	Mallee shrublands	*Melaleuca* shrblnds	Other woodlands	Salmon gum wdlnds	Samphire shrblnds	Yate swamps
Olearia dampieri				x	x	x	x		X
Olearia muelleri						x	x		
Olearia muricata		NNshrub				x			
Olearia ramosissima		NNlow		x		x			
Olearia sp. Kennedy Range							x		
Ozothamnus lepidophyllus						x			
Persoonia striata	RS bs/SS	RNshrub		x					
Petrophile brevifolia		NSshrub		x					
Petrophile ericifolia	OS			x					
Petrophile longifolia	OS			x					
Petrophile rigida	RS bs			x					
Petrophile seminuda	RS bs/OS	RSshrub		x					
Petrophile squamata	OS	NSshrub		x					
Phebalium microphyllum		NNshrub		x					
Phebalium tuberculosum		NNshrub		x					
Pimelea argentea						x	x		x
Pimelea lehmanniana				x		x			
Pithocarpa pulchella				x					
Pittosporum angustifolium							x		x
Platysace maxwellii		RNlow		x		x			
Platysace trachymenioides				x					
Podolepis capillaris				x	x	x	x		
Podolepis lessonii						x			
Podotheca angustifolia						x	x		
Pogonolepis stricta						x	x		
Pterochaeta paniculata						x			
Ptilotus holosericeus						x	x		
Puccinellia stricta			x						
Rhagodia crassifolia									x
Rhagodia drummondii						x			
Rhagodia preissii				x		x	x		x
Rinzia affinis				x					
Roycea pycnophylloides						x			
Rytidosperma caespitosa						x	x		
Santalum acuminatum	SS	NNtree		x		x	x		
Sarcocornia blackiana						x			

Native flora species	Fire response	Plant Functional Type	Duma shrublands	Mallee shrublands	Melaleuca shrblnds	Other woodlands	Salmon gum wdlnds	Samphire shrblnds	Yate swamps
Scaevola spinescens						x	x		
Schoenus clandestinus				x					
Schoenus pleiostemoneus		RNlow		x					
Schoenus sp. A1 Boorabin (K. Wilson 2581)		RNlow		x					
Schoenus subflavus		RNlow		x					
Sclerolaena diacantha						x	x		
Senecio sp.						x	x		
Senna artemisioides							x		
Senna charlesiana						x	x		
Spyridium mucronatum		NNshrub				x			
Stackhousia muricata						x	x		
Stylidium repens		NNlow		x		x	x		
Synaphea boyaginensis				x					
Synaphea sp. Jilakin Flat Rock Rd				x					
Synaphea spinulosa		RNshrub		x					
Tecticornia doleiformis			x			x	x	x	
Tecticornia indica						x		x	
Tecticornia lepidosperma						x		x	
Tecticornia pergranulata			x	x	x	x	x	x	
Tecticornia syncarpa			x		x	x	x	x	
Tecticornia verrucosa			x					x	
Templetonia sulcata	SS	RNshrub		x	x	x	x		
Tetraria capillaris						x	x		
Thelymitra sp.						x	x		
Threlkeldia diffusa						x	x	x	
Thysanotus patersonii		RNlow, Geo		x		x	x		
Trachymene cyanopetala						x			
Triglochin mucronata			x						
Verticordia acerosa		NNshrub		x					
Verticordia chrysantha		NNshrub		x					
Verticordia densiflora		RNshrub					x		
Verticordia endlicheriana	RS bs/SS			x			x		
Verticordia grandiflora		NNshrub		x					
Verticordia integra	SS	NNshrub		x					

Native flora species	Fire response	Plant Functional Type	Duma shrublands	Mallee shrublands	Melaleuca shrblnds	Other woodlands	Salmon gum wdlnds	Samphire shrblnds	Yate swamps
Verticordia plumosa	SS	NNshrub				x			
Verticordia roei		NNshrub		x					
Verticordia tumida		RNshrub		x					
Vittadinia cuneata						x	x		
Vittadinia gracilis						x			
Waitzia acuminata					x	x			
Westringia rigida				x		x			
Wilsonia humilis			x			x		x	
Wilsonia rotundifolia			x			x			

Appendix 17: **Hydrological data**

17.1 Lake Bryde hydrological data

Depth and volume data

Since 1979, Lake Bryde has experienced seven fill events that have exceeded 0.6m depth caused by heavy rainfall events associated with severe thunderstorms, rain bearing depressions or decaying tropical cyclones.

The longest period of inundation, of seven years (1988-95), involved a succession of overlapping inflow events. However, most of these early fill events were only monitored twice per year, so their exact dynamics, compared with more recent and intensive monitoring, are poorly known.

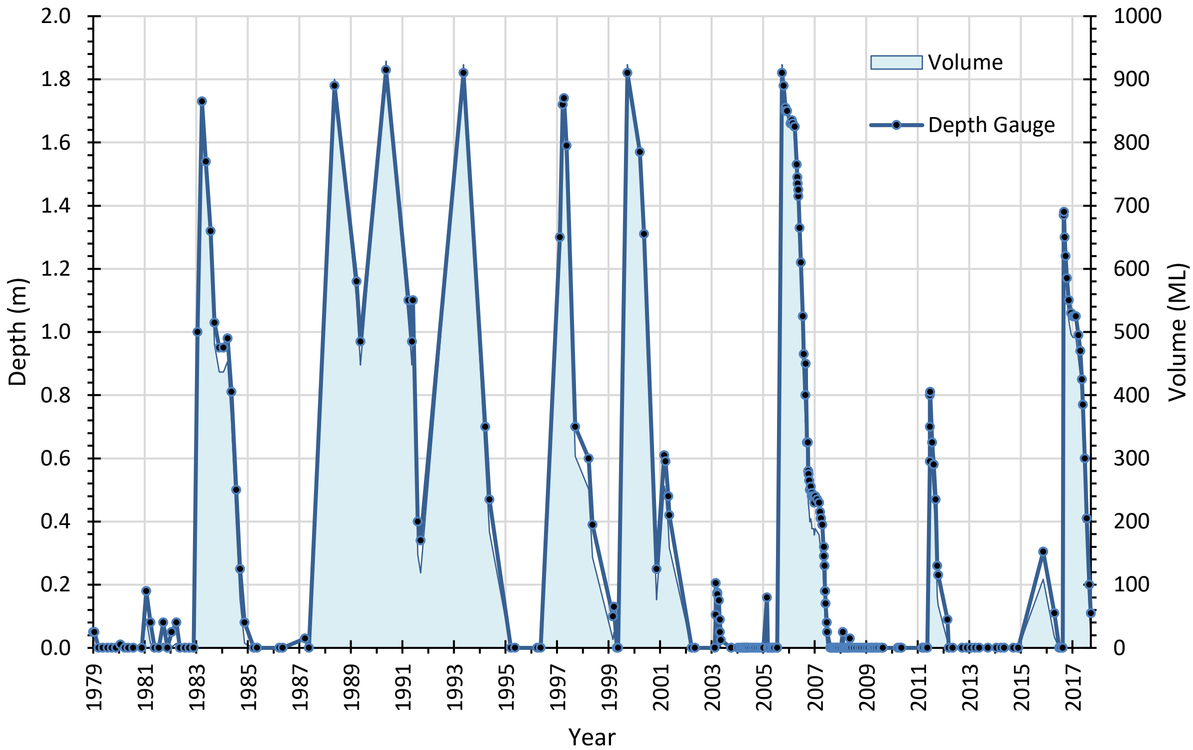


Figure 35 The Lake Bryde fill events.

Wetland acidity (pH)

The acidity of the surface water tends to move from weakly alkaline (pH 7.7) when the lake is full (i.e. when depth is ≥1.83 m), to moderately alkaline (pH 8.5-9.25) when evaporation has reduced the surface water to a depth of 0.0-0.5 m.

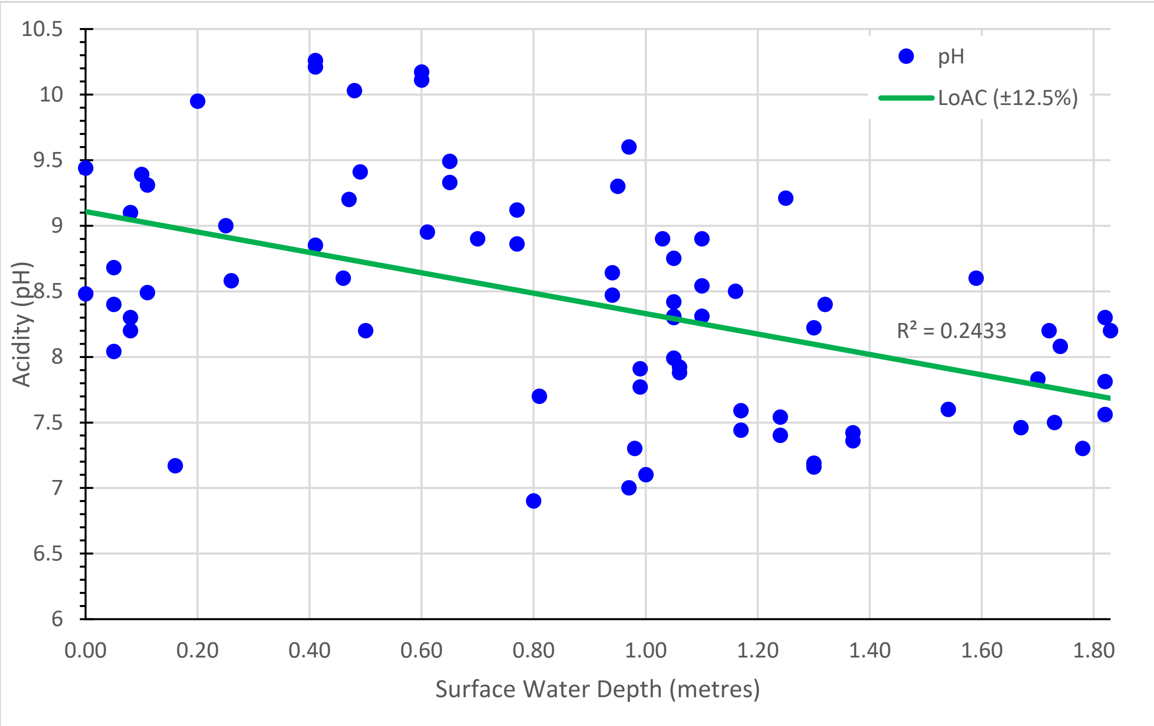


Figure 36 Lake Bryde acidity (pH).

Salt load

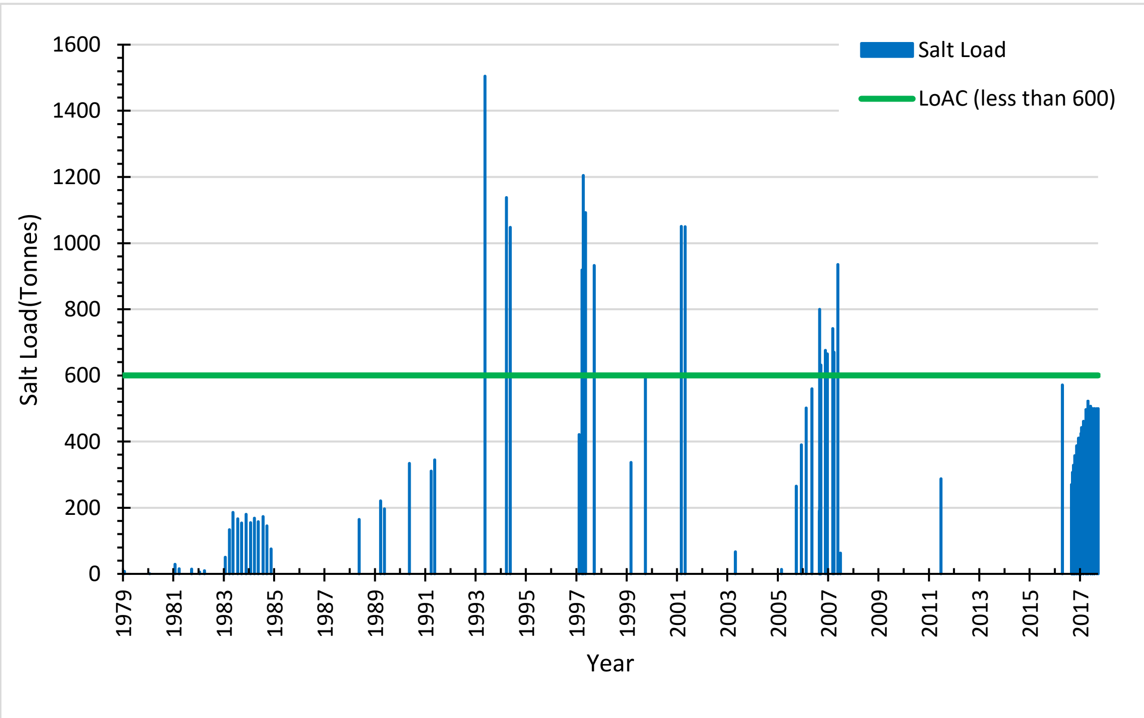


Figure 37 Lake Bryde's salt load trends.

In the first 10 years of monitoring, the Lake Bryde salt load remained stable at about 165 tonnes. However, in the earlier 1990's the salt load rose dramatically to a maximum of 1500 tonnes.

However, since 1997 there has been a steady reduction in salt load with each successive fill event. The salt load reduction can be explained by outflows, particularly during the 2006-08 fill event.

Groundwater trends

Five groundwater observation bores were installed on the Lake Bryde lake bed between 2003 and 2009. Monitoring commenced in 2003 with monthly monitoring the norm until 2017 when monitoring was reduced to quarterly. During fill events it is not possible to monitor groundwater, as surface water usually infiltrates the bores giving false indications of the depth of groundwater.

Between 2003 and 2006, groundwater depth was quite shallow (avg 1.02 mbgl). This was followed by a two-year long fill event which meant depth observations were not possible. However, as a result of the drought conditions in 2010-11, the average groundwater depth dropped to 2.33 m. After a fill event in 2011, the average depth rose to about 1.65 mbgl. After the most recent fill event in 2017, the most recent monitoring indicates an average depth of about 1.89 mbgl.

The data suggests that evapotranspiration will take two to three years to reduce the groundwater table to pre-fill event levels.

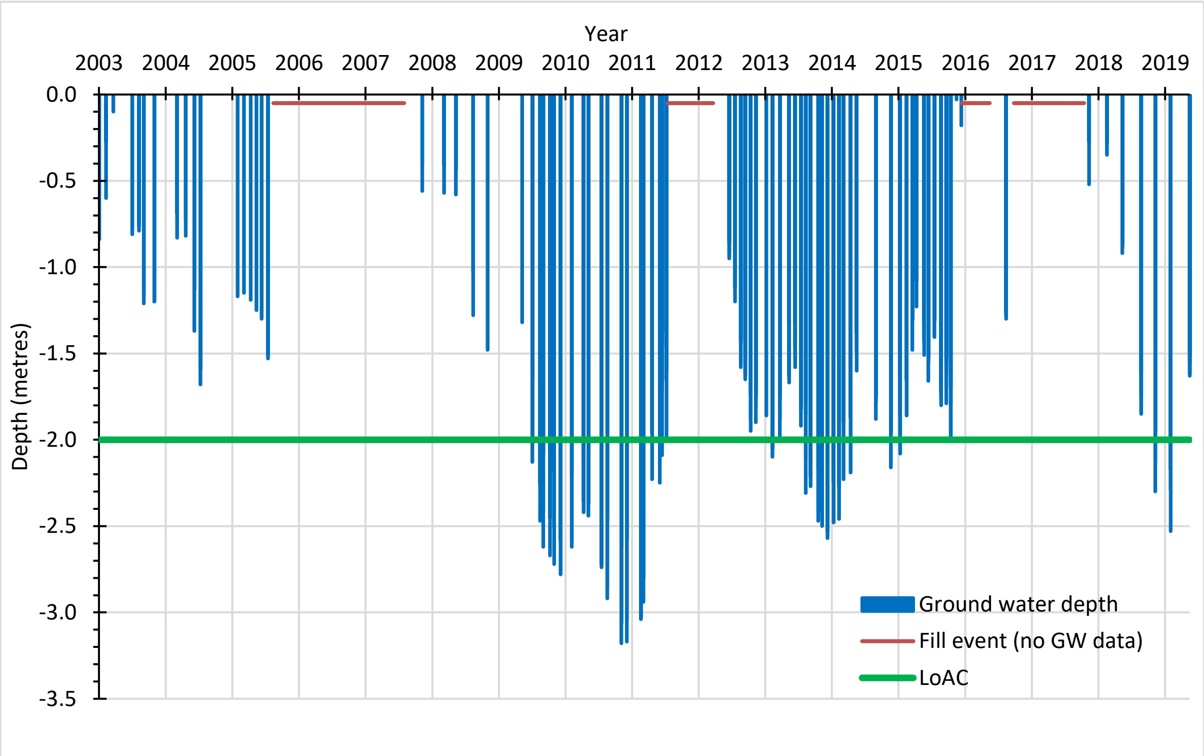


Figure 38 Groundwater trends beneath Lake Bryde.

17.2 East Lake Bryde hydrological data

Depth and volume data

Surface water monitoring of East Lake Bryde started in 1979 but was discontinued in 1985 because, in contrast to Lake Bryde, the lake rarely held water. Due to the different topography and soils of its catchment, the wetland rarely contained significant surface water. As an example, in September 1983 Lake Bryde filled to 1.73m depth compared with only 0.08m observed at East Lake Bryde.

Regular monitoring resumed in 2000. The only significant fill event observed in the wetland occurred between January 2006 and July 2008.

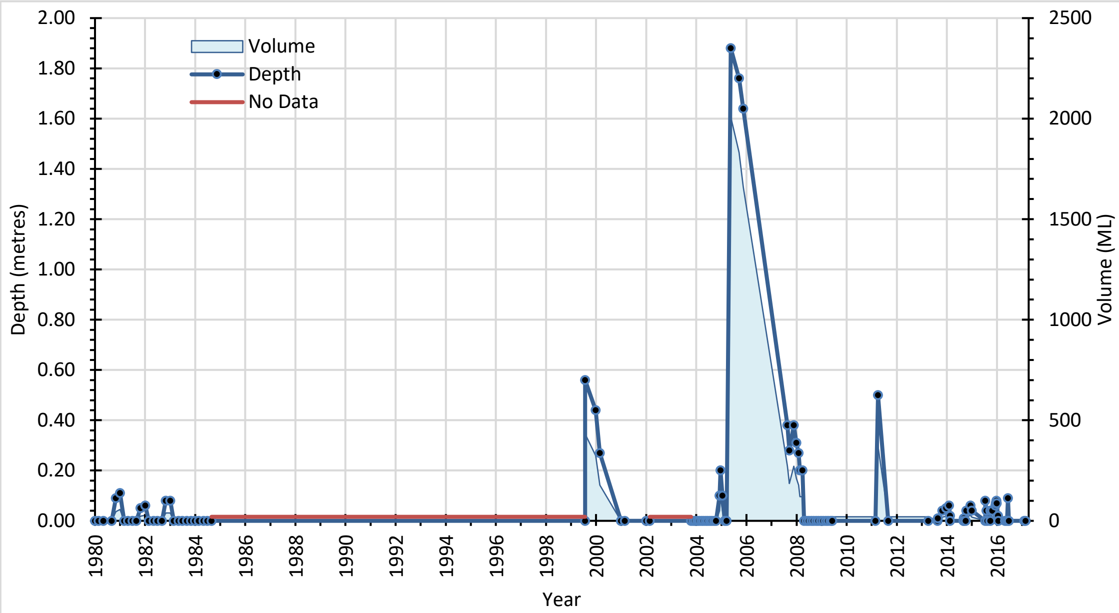


Figure 39 East Lake Bryde recorded fill events (compare with Figure 21).

Wetland acidity (pH)

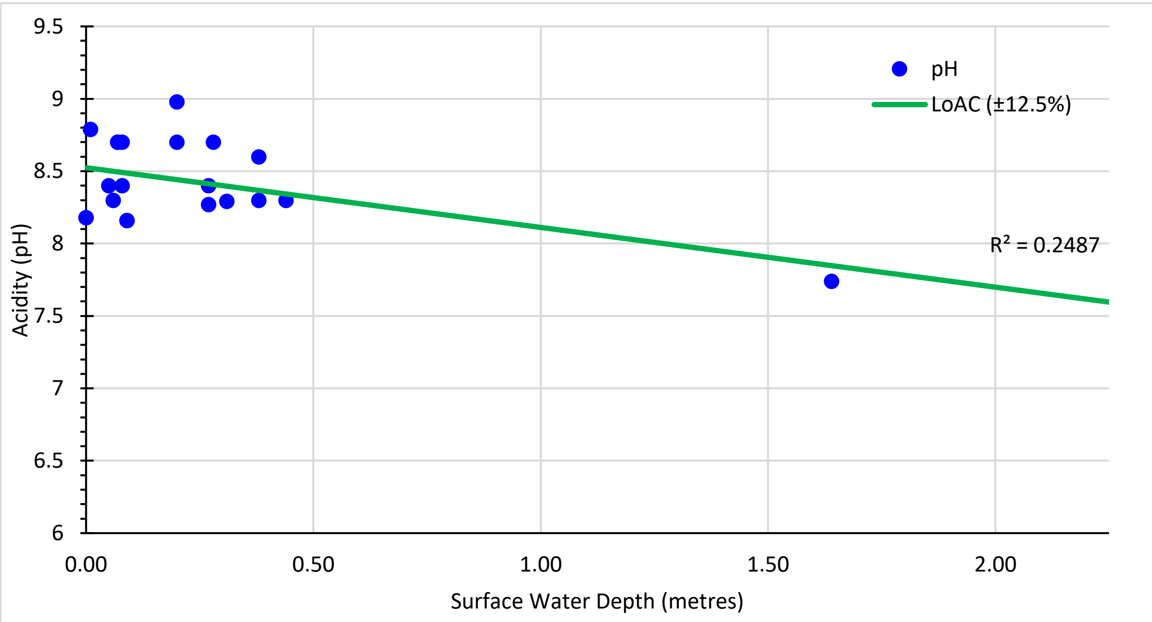


Figure 40 East Lake Bryde acidity (pH).

East Lake Bryde tends to be weakly alkaline (pH 7.7) when the lake depth is about 2.0m), to moderately alkaline (pH 8-9) when water depth is 0.0-0.5 m.

Salt load

East Lake Bryde usually only receives very shallow inflows so not all the soil-stored salt has time to enter into solution before the lake dries. Consequently, salt load estimates during these shallow fill events are not accurate indications of the true salt load.

The only substantial and fully monitored fill event (2006-08) produced a set of highly variable estimates of salt load, ranging from 225 to 513 tonnes. The average of these estimates was 399 tonnes (median: 310.00 tonnes).

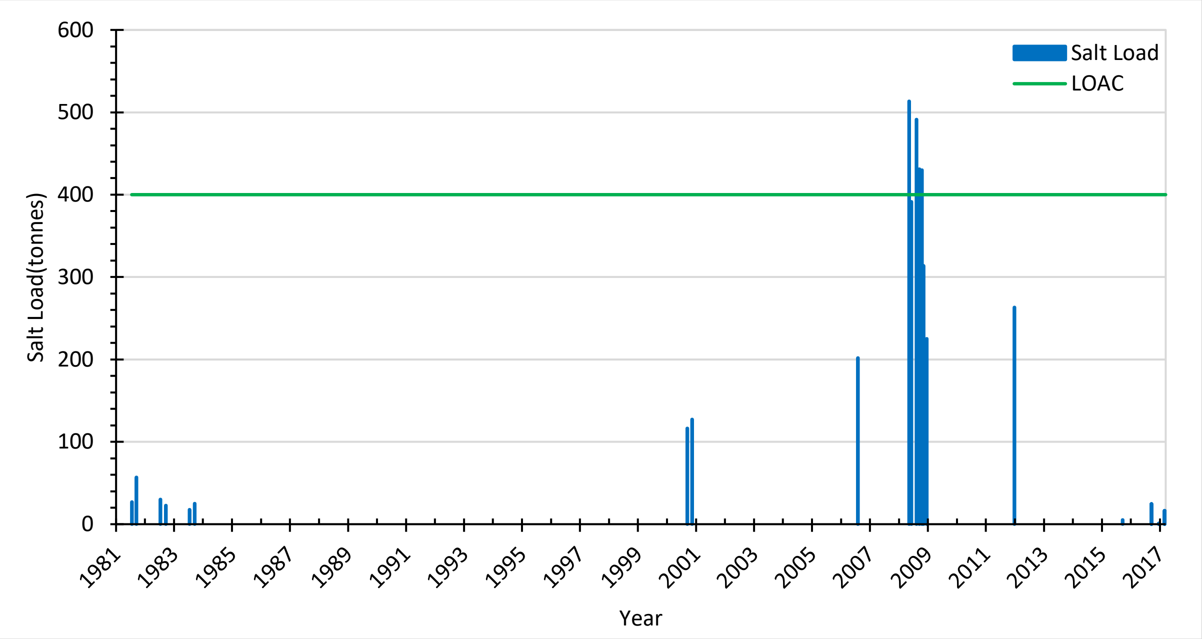


Figure 41 East Lake Bryde's salt load trends.

Groundwater trends

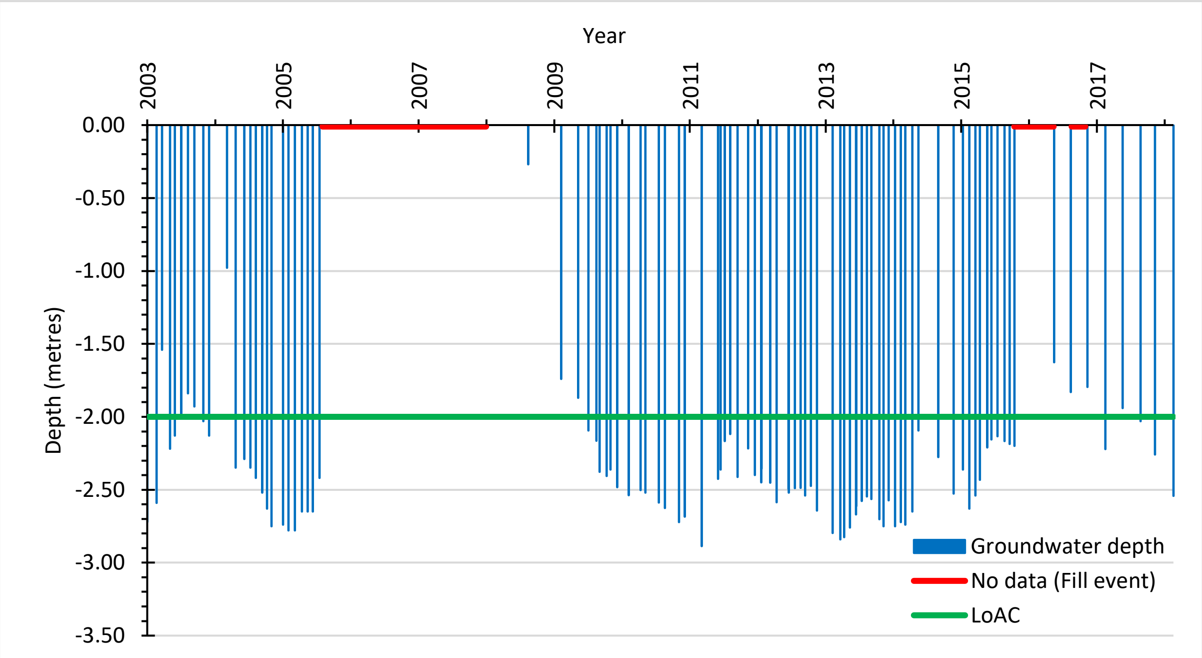


Figure 42 Groundwater trends beneath East Lake Bryde.

Five groundwater observation bores were installed on East Lake Bryde between 2003 and 2009. Monthly monitoring commenced in 2003 until 2017 and thereafter quarterly.

The monitoring indicates that the groundwater level is in excess of 2m depth.

As with Lake Bryde, groundwater trends suggest a strong link between fill events and groundwater depth, with evapotranspiration conditions taking three to four years to reduce groundwater depth to its pre-fill event level.

17.3 Yate Swamp hydrological data

Yate Swamp is located within the Lake Bryde Conservation Park (Reserve 48436) about 500m south of the intersection of Fourteen Mile and Newdegate roads.

The wetland represents a significant challenge for surface water monitoring. The chief difficulty is caused by the cracking and swelling clays which occur throughout the wetland, which produce numerous gilgai. When inundated the wetland's surface waters are highly turbid, making foot navigation to the surface water monitoring site extremely problematic.

Depth and volume data

Yate Swamp surface water depth monitoring started in July 2005 and has been done on three occasions. The wetland has had regular shallow (0.00-0.50m) fill events that result from direct rainfall such as in July and August 2005 and in February 2017.

The deepest inundation observation was recoded in March 2006, when the depth was 1.16m. This followed a significant rainfall event in January 2006 which caused significant inundation at other wetlands (see Figure 35 and 39).

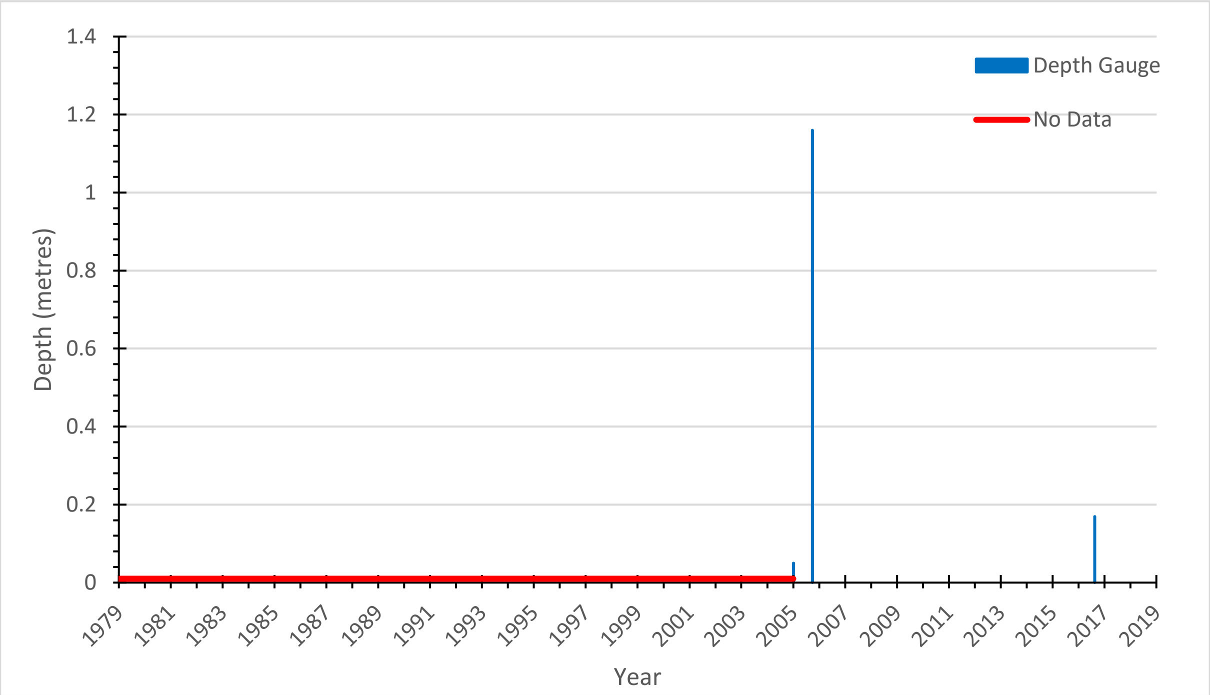


Figure 43 Yate Swamp recorded fill events.

Yate Swamp groundwater trends

Five groundwater observation bores were installed on Yate Swamp between 2003 and 2009. Monitoring started in 2003 with monthly observations until 2017 and thereafter quarterly.

The monitoring indicates the groundwater level is in excess of 2m depth.

As with Lake Bryde, groundwater trends suggest a strong link between fill events and groundwater depth, with groundwater depth taking three to four years to reduce to pre-fill event level.

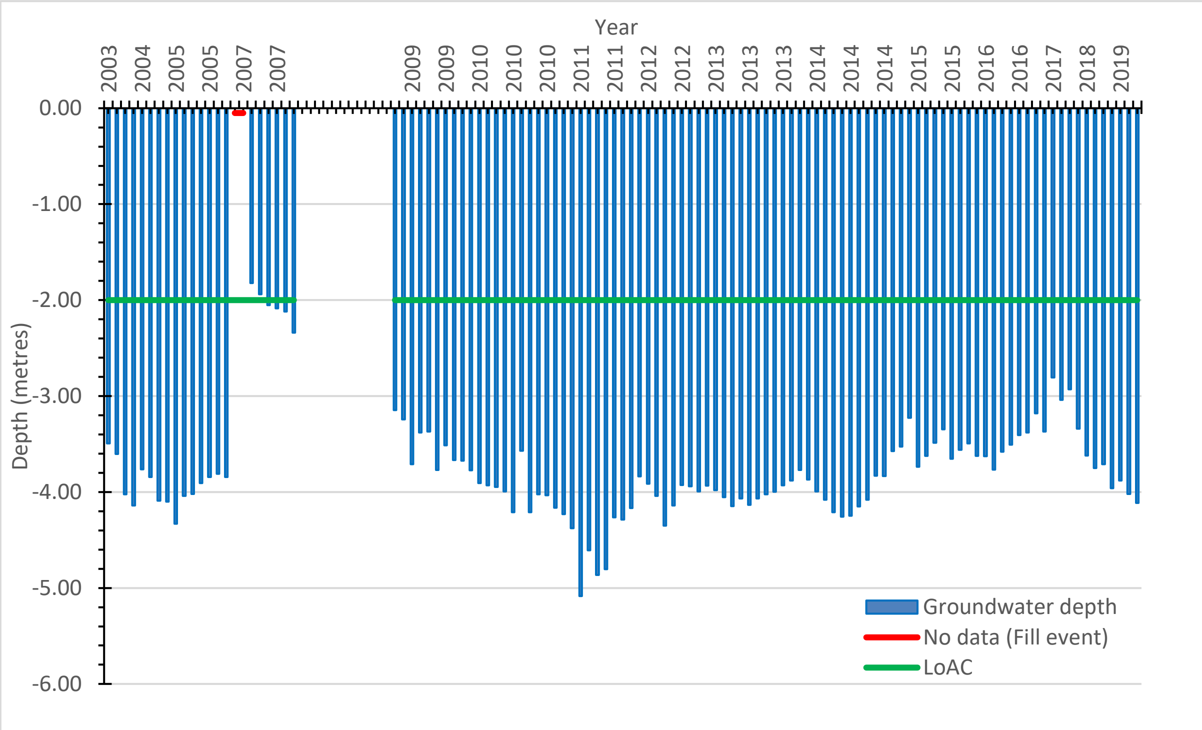


Figure 44 Yate Swamp lake bed groundwater trends.

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