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

Assessment of ecological health and environmental water provisions in the Logue Brook

February to May 2011

Looking after all our water needs

Water *Science*
technical series

Report no. WST 43
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Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone +61 8 6364 7600
Facsimile +61 8 6364 7601
National Relay Service 13 36 77

www.water.wa.gov.au

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For more information about this report, contact
Gillian White, Water Science Branch, Department of Water.

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Summary

In late 2010, the environmental water provisions (flows provided to maintain environmental health) of a number of river systems in south-west Western Australia were temporarily reduced in response to reduced rainfall, with the winter of 2010 being the driest on record. The dry winter followed a prolonged period of drying climatic conditions and an associated reduction in water availability (IOCI 2005).

For the Logue Brook, the environmental water release was reduced by 50% for the months of December 2010 to March 2011, from 200 ML/month specified in the water resource management operating strategy (DoW 2009a) to 100 ML/month. This study's objective was to assess whether the release of 100 ML/month was sufficient to maintain ecosystem health downstream from the dam during the study period.

Ecosystem health was assessed in two pools within the Logue Brook system between February and May 2011, using fish and crayfish community structure, water quality parameters and habitat availability as indicators. Pool environments were selected for investigation as they represent likely refugia for biota during times of low flow and drought.

Based on the results of this study, the release of 100 ML/month appeared to be sufficient to maintain the health of the Logue Brook's aquatic ecosystem in the short term. However, the results highlight a number of areas of concern for the long-term resilience of the riverine ecosystem in the lowland. The degraded habitat (lack of intact riparian vegetation, deeply incised banks and accumulation of silt) is likely to affect the capacity of the ecosystem to withstand subsequent pressures such as reductions in flow. In addition, there is some uncertainty about the sustainability of some of the fish and crayfish populations (primarily the Swan River goby, freshwater cobbler and smooth marron, and to a lesser extent, the western pygmy perch and nightfish) (Latin names of aquatic fauna are provided in the Species List at the end of this report).

Given these concerns it would be imprudent to suggest that releases could be reduced to 100 ML/month in the summer months; as such, it is recommended that the environmental water provision releases remain as specified in the water resource management operating strategy (DoW 2009a). If, in future, a temporary reduction from the releases specified in the operating strategy is required, it is recommended that ecosystem health monitoring is undertaken and that adaptive management arrangements are put in place to respond if ecosystem health declines (e.g. increasing the release volume).

1 Introduction

This study has assessed whether the temporary reduction of the environmental water provision (EWP) for the Logue Brook (downstream from Logue Brook Dam), between December 2010 and March 2011, provided sufficient flows to maintain the health of the riverine ecosystem.

1.1 Rationale

Water is released from dams in Western Australia for a range of purposes including maintaining the ecological health of waterways and associated ecosystem services (refer Section 2.4). The volume of the EWP is specified in the water resource management operating strategy (WRMOS) for each dam, in most cases based on the recommendations of an ecological water requirement (EWR) study[1].

In late 2010 the EWPs of a number of river systems in south-west Western Australia (SWWA) were temporarily reduced in response to reduced rainfall, with the winter of 2010 being the driest on record (since comparable records began in 1900) (BoM 2010). The dry winter followed a prolonged period of drying climatic conditions and associated reduction in water availability: since the mid 1970s SWWA has experienced a decline in annual rainfall of approximately 10% (1976–2003 compared with 1925–75), corresponding with a reduction in streamflow of around 50% in the same period (IOCI 2005).

For the Logue Brook, the EWP was reduced by 50% for the months of December 2010 to March 2011, from 200 ML/month specified in the WRMOS (DoW 2009a) to 100 ML/month. The purpose of this study was to assess the health of the aquatic ecosystem under the reduced flow conditions and to determine whether the temporary reduction in the EWP had a detrimental impact on the riverine environment.

Given that climate modelling predicts that water availability is likely to decline in the future (e.g. CSIRO (2009) predicts the mean annual runoff in the Harvey region will be reduced by between 7 and 40% in 2030), the resilience of the aquatic ecosystem to withstand reductions in the EWP in the future has also been considered.

1.2 Objective

The objective of the study was to assess whether the release of 100 ML/month of water from Logue Brook Dam between December 2010 and March 2011 – 50% of the EWP specified in WRMOS (DoW 2009a) – was sufficient to maintain ecosystem health downstream from the dam during the study period.

[1] The Logue Brook's EWP was based on an EWR study conducted for Drakes Brook, with scaling applied to ensure the EWP was appropriate to the size of the Logue Brook catchment (Ian Loh, pers. comm. 2011).

2 Background

2.1 Study area

The Logue Brook is located in SWWA, approximately 100 km south of Perth (Figure 1 inset). It is a tributary of the Harvey River and forms part of the Peel-Harvey estuary catchment. The brook originates on the Darling Plateau and flows into Lake Brockman, the reservoir formed by Logue Brook Dam. From the dam outlet the brook flows north-west down the Darling Scarp and across the Swan Coastal Plain to the confluence with the Harvey River (Figure 1).

The catchment of the Logue Brook, including its tributaries, is 134 km^2. According to data collated in 2000 for the National Land and Water Resources Audit (Department of Agriculture and Food, Land use in Western Australia v2 dataset), approximately half of the catchment is classified as ‘conservation and natural environments’ (incorporating state forest and remnant native vegetation cover) and just under a third is used for dairy farming. A further 16% of the catchment is classified as ‘dryland agriculture and plantation’, while approximately 4% is used for mining, 1% for water storage and treatment and 0.3% for residential (Figure 1).

2.2 Management of the Logue Brook water resource

Logue Brook Dam was built in 1963 and has a storage capacity of 24.3 GL. Water stored in the reservoir is supplied to the Harvey Irrigation District, which is managed by Harvey Water (the trading name for the South West Irrigation Management Cooperative Ltd). Releases of water from the reservoir are controlled by the Water Corporation in accordance with the WRMOS developed by the Department of Water (DoW 2009a).

There are no current licences to abstract surface water from the Logue Brook between Logue Brook Dam and the confluence with the Harvey River (DoW Water Resource Licensing database).

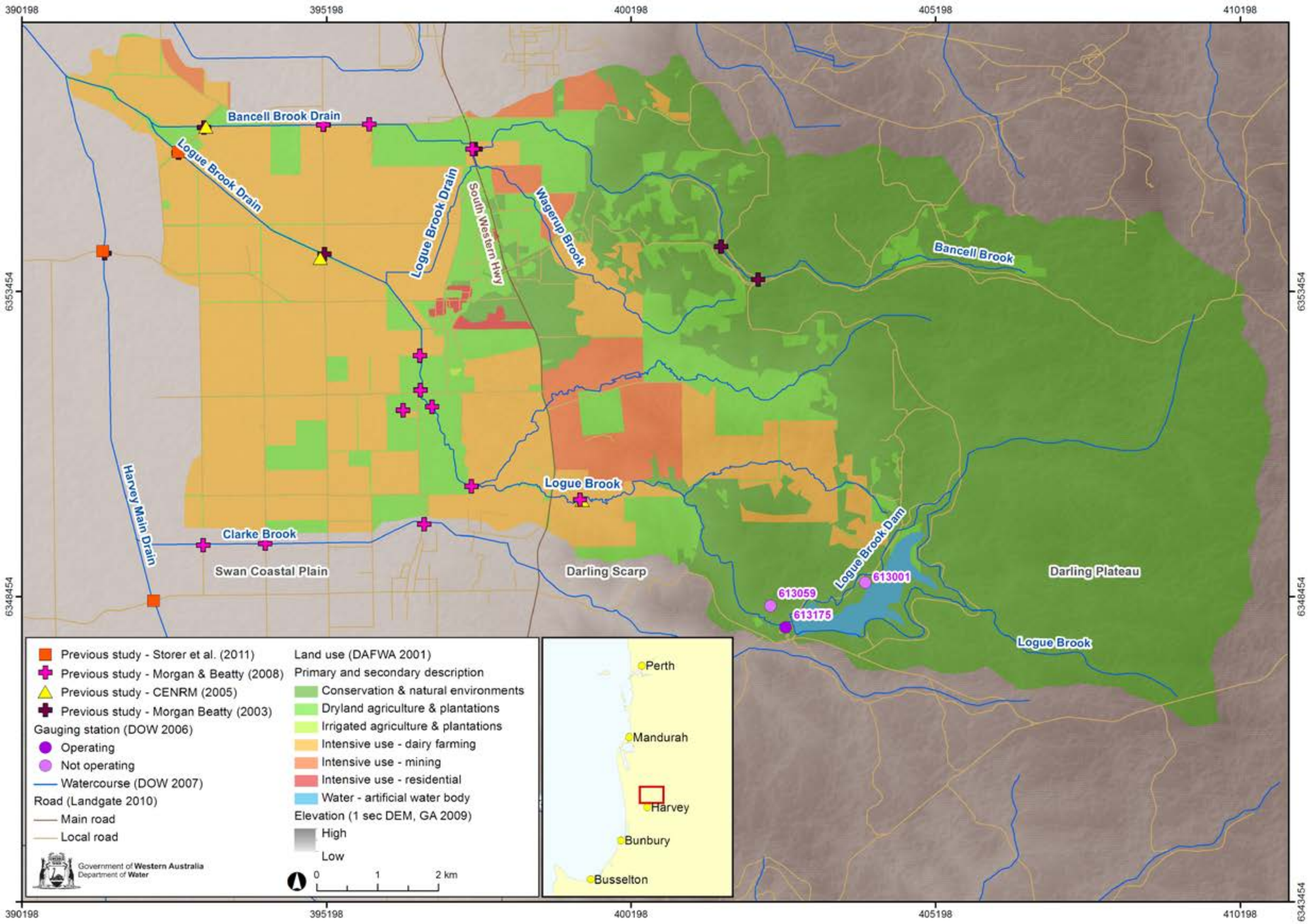

Figure 1 Logue Brook catchment – elevation, land use and previous study sites

2.3 Hydrological conditions

There is limited information about the Logue Brook's natural flow regime before the dam was built in 1963; the only data available are from two stream gauging stations that operated during the 1950s and early 1960s. Daily flow data collected during a 10-year period at gauge 613001 (located on the brook in the area now flooded by the reservoir, Figure 1) shows the minimum daily flow was 2 ML/day, while the maximum was 376 ML/day. Monthly flow volumes followed a seasonal pattern, with the highest flows occurring in July and August and the lowest in February and March (Figure 2). There were no days when flow ceased completely, suggesting the brook experienced a perennial flow regime during this period. Data collected during a four-year period (1957–61) at gauge 613059 (located downstream from the current gauging station, Figure 1) follows the same pattern as that seen at gauge 613001 (Figure 2).

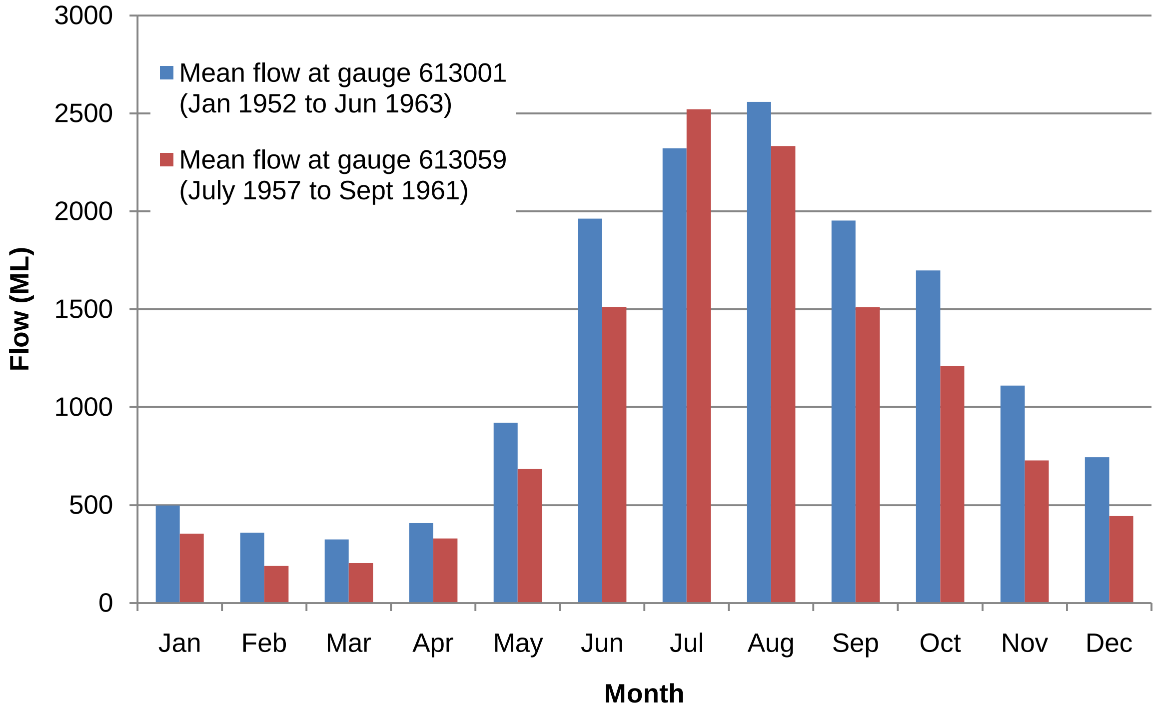

Figure 2 Daily flow recorded at gauging stations 613001 (1952–63) and 613059 (1957–61) on the Logue Brook

Between 1963 and 2009 the brook was used to transfer water from the reservoir to the irrigation network, resulting in an annual flow regime that included high flow volumes in summer ('irrigation flows') (Figure 3).

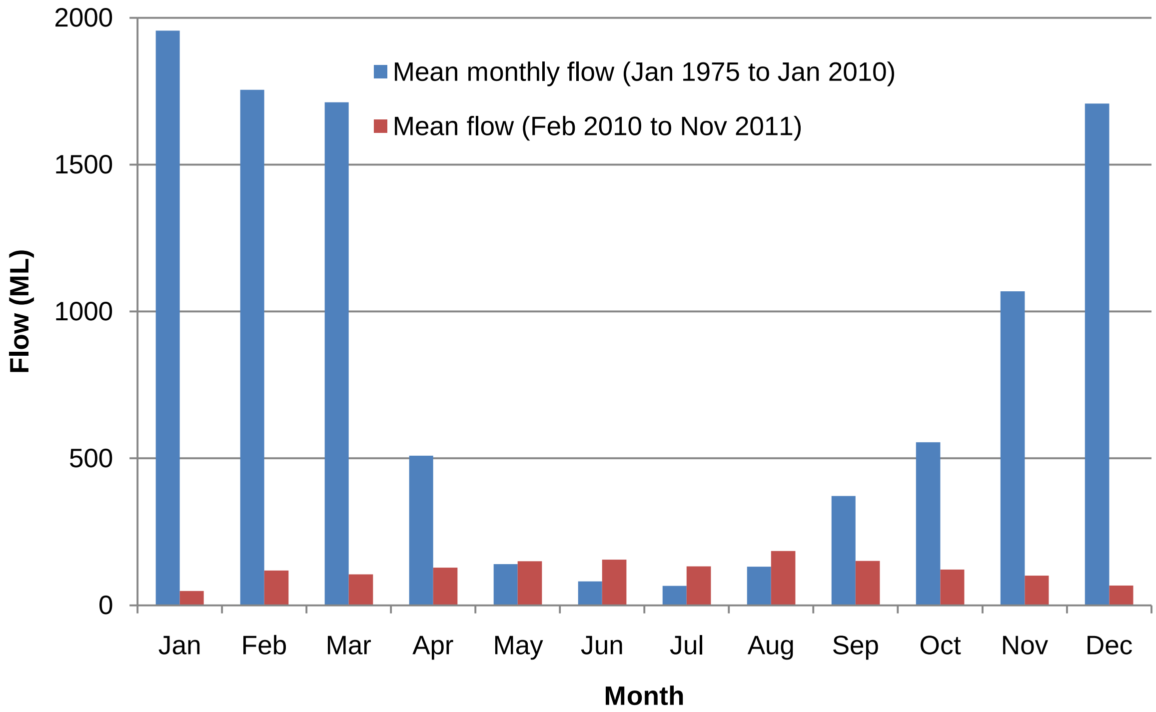

Figure 3 Daily flow recorded at Logue Below gauging station (W8000970) (Note: data for the period 1963 to 1974 was not available).

In 2010 a pipeline was completed to transfer water between the reservoir and the irrigation network and consequently the summer flow regime within the Logue Brook has altered significantly (Figure 3), and should correspond with the monthly EWP releases specified in the WRMOS (DoW 2009a).

In response to the dry winter of 2010, the EWP releases for the summer months were reviewed. The Department of Water and Water Corporation agreed on an approach to reduce the releases by 50% for December 2010 to March 2011, from 200 to 100 ML/day (Table 1). Releases returned to those specified in the WRMOS (DoW 2009a) in April 2011. The temporary reduction in the EWP releases coincided with the first summer season in which irrigation flows were not distributed via the brook.

Table 1 Monthly EWP releases to be made from Lake Brockman as specified in the WRMOS (DoW 2009a) and temporary reduction in EWP releases (in megalitres)

	Dec	**Jan**	**Feb**	**Mar**	**Apr**	**May**
EWP release in WRMOS (ML)	200	200	200	200	100	90
Dry season: reduced release (ML)	100	100	100	100	n/a	n/a

2.4 Ecological value and ecosystem services

To date, studies of the Logue Brook's ecology have focused on its lowland reaches, between the base of the scarp and the confluence with the Harvey River. The studies, summarised in Table 2, suggest that while the lowland reaches have been modified for irrigation and drainage purposes, they have retained some ecological value, including a diverse population of native freshwater fish and crayfish, all of which are endemic to SWWA.

In addition, there is anecdotal evidence that the water rat inhabits the brook's lower reaches, but this could not be verified in the literature before this study began. The water rat is listed as a Priority 4 species (in need of monitoring) under the provisions of the *Wildlife Conservation Act 1950* (DEC 2010).

It was not possible to find any ecological studies relating to the brook's upland reaches (both upstream and downstream of the dam) – thus the ecological values of this portion of the brook were unknown before this study began.

In addition to the quantification of ecological values, it is important to acknowledge the ecosystem services provided by waterways, including provision of clean water (e.g. nutrient use by aquatic and riparian vegetation), production of food and fibre (e.g. maintenance of water quality to a level suitable for agricultural and industrial use), maintenance of soil fertility (e.g. through flood events), maintenance of liveable climates, control of pests (e.g. mosquito larvae eaten by fish), and provision of cultural, spiritual and intellectual experiences (Cork et al. 2001).

Table 2 Summary of ecological values of the Logue Brook found during previous studies

Note: the Latin names of aquatic fauna are provided in the Species List at the end of this report.

Study	Summary of findings
Storer et al. (2011a)	Three native fish were found at the downstream end of Logue Brook: western minnow, western pygmy perch and Swan River goby. Two non-native fish species (mosquitofish and one-spot livebearer) and one non-native crayfish species (yabbie) were also found. A sample of macroinvertebrates comprised 10 taxa and a total abundance of 84 organisms. The population was dominated by midge larvae, forming 82% of the sample, while 7% were worms. The remaining organisms were three caddisfly larvae, two mayfly nymph and single individuals of: pea clam, snail, blackfly larvae and water boatman. The ecological health the reach, between the Darling Scarp and the confluence with Harvey River, was assessed using both field and desktop data. The assessment found that the hydrological change was 'largely unmodified' (the reach excluded the reservoir), the catchment disturbance was 'slightly modified' and the aquatic biota were 'moderately modified'. The physical form of the reach was 'substantially modified', and the fringing zone was found to be 'severely modified'.

Study	Summary of findings
Morgan & Beatty (2008)	Four native fish species and one native crayfish species were found: western minnow, western pygmy perch, nightfish, freshwater cobbler and gilgie. Five non-native fish species and one non-native crayfish species were found: mosquitofish, rainbow trout, one-spot livebearer, redfin perch, goldfish and yabbie.
CENRM (2005)	A qualitative assessment of EWRs found the Logue Brook's lowland reaches had 'high-quality riparian vegetation'.
Morgan & Beatty (2003)	Two native fish species, western minnow and western pygmy perch, and one native crayfish species, gilgie, were recorded. Three non-native fish and crayfish species were found: mosquitofish, goldfish and yabbie.

2.5 Flow-ecology relationships

Flow regime is recognised as a key driver of riverine ecosystem function (Puckridge et al. 1998; Bunn & Arthington 2002). Reduced flow or low flow (at the lower end of the hydrograph) can lead to a number of changes in the aquatic ecosystem including (from Rolls et al. in prep., summarised by Galvin & Storer 2012):

- Altered water quality, such as increased electrical conductivity, increased diurnal variation in water temperature and decreased dissolved oxygen (Lake 2003). Ecological consequences can include changes in the distribution and abundance of biota depending on differing species tolerances (McNeil & Closs 2007; Miller et al. 2007; Chessman 2003).
- Decreased amount of available habitat through decreased wetted width, depth and flow (Harvey et al. 2006; Hay 2009). Ecological consequences can include loss of taxa, particularly those with specialised requirements (Bunn & Arthington 2002).
- Reduced lateral connectivity with the riparian zone and floodplain and reduced longitudinal connectivity affecting the sources and transfer of energy. Ecological consequences can include an accumulation of organic matter (Boulton & Lake 1992) and changes in biotic community composition due to changes in allochthonous and autochthonous inputs (Reid et al. 2008; Walters & Post 2008).
- Restriction of the distribution (migration) of biota between habitats and river reaches (Bunn & Arthington 2002). Ecological consequences can include increased importance of refuges in maintaining biodiversity. Hence, sustainability relies on maintaining a number of good quality pools as refugia.

For the Logue Brook, the provision of 100 ML/month for December to March was low compared with the flows experienced in the past (refer Section 2.3), hence it is possible some of these changes in ecosystem function may have occurred in response to the absence of high irrigation releases and the temporary reduction in the EWP.

3 Methods

3.1 Assessment approach

This study focused on assessing the ecological health of pool environments, given they represent likely refugia for biota during times of low flow and drought (Bond & Cottingham 2008; Robson et al. 2008). If the flow conditions have a detrimental impact on the refugia within a river system it implies the non-refuge areas will also be affected (e.g. under low-flow conditions a riffle habitat may be dry and therefore unable to sustain aquatic organisms, while the deep water in a pool is more likely to persist and therefore provide habitat for biota).

The monitoring for this study was conducted between February and May 2011, encompassing the final two months of the temporary reduction in the monthly EWP releases (i.e. February and March) (and coinciding with highest annual temperatures), as well as two months with the releases as specified in the WRMOS (i.e. April and May) (refer Section 2.3).

3.2 Indicator selection

Reduced flow within a river system can lead to a number of changes in the aquatic environment that can affect ecosystem health (summarised in Section 2.5). To assess whether the temporary EWP release of 100 ML/month was sufficient to maintain the riverine environment, the following indicators of ecosystem health were selected: biota (fish and crayfish), habitat and water quality (described below). These indicators encompass biological, physical and chemical elements of the aquatic environment; as such they form an integrated approach to assessing river health.

Aquatic biota is used as a key indicator of river health because damage to biota is often the end-point of environmental degradation (NWC 2007). For this study, fish and crayfish were chosen to represent the biota of the system for a number of reasons:

- they are mobile and therefore reflect conditions in an extended area of the river system (Harris 1995) (as compared with less mobile biota such as macroinvertebrates that reflect more localised conditions)
- they can respond rapidly to changes in hydrology, such as moving into pools to seek refuge if flow reduces or ceases (White & Storer 2012)
- they are sensitive to changes in water quality, physical habitat and other components of the aquatic ecosystem (Harris 1995) and knowledge of specific tolerances can infer fluctuations in these components that may not be detected through spot sampling (CEAH & ID&A 1997)
- they have a long-enough lifespan to indicate long-term impacts through population structure (e.g. the absence of juveniles of a particular species can indicate the success of reproduction in the previous season(s)).

The availability and quality of habitat within a river system can affect the biotic community's characteristics (Maddock 1999; Boulton & Brock 1999); as such, evaluating habitat is an important component of ecosystem health assessment (Maddock 1999). This indicator was included to determine whether the temporary reduction in the EWP affected the habitat available, and to provide a general understanding of the habitat conditions in the Logue Brook (to help with the interpretation of biotic data).

Water quality (i.e. the physical and chemical properties of water) is a component of the physical habitat of a river system and thus can affect the biotic community present (see ANZECC & ARMCANZ 2000b for a review of biotic tolerances). Water quality data can provide information about the localised habitat conditions and also indicate the catchment-scale processes placing pressure on the aquatic ecosystem (e.g. high levels of suspended sediment may suggest that vegetation has been cleared from the upstream catchment).

The observation of flow at a system scale (as opposed to site scale) was also undertaken as a supplementary element of the assessment. The observations broadly indicate whether flow persisted along the length of the river system during the study period, and provide useful contextual information for interpreting the biotic data.

3.3 Reference condition

To assess ecosystem health a benchmark or reference is required against which observations can be compared. This 'reference condition' can be set at pristine health before any impact, or at a state with a certain degree of impact or change from historic form and function. The latter is a more pragmatic approach given the health of most river systems in SWWA has changed significantly due to anthropogenic pressure and recognising that some changes are outside of current control (e.g. climate change); it also reflects the need for ongoing allowances for competing values (e.g. social and economic values such as water supply). As the environmental condition associated with this type of reference is more achievable, it is therefore more useful for water resource management.

A pragmatic approach to defining reference condition was required for the Logue Brook given that the system has undergone significant hydrological change (primarily in response to Logue Brook Dam), is affected by climate change (CSIRO 2009) and has agricultural and mining operations occurring in the catchment.

In lieu of relevant baseline data, a reference condition was compiled for each ecological health indicator used in this assessment by considering data from previous studies, data from river systems of similar form and function, expert knowledge of biological requirements and guidelines for aquatic ecosystem protection. This includes the protection of critical ecosystem services (e.g. nutrient cycling and mosquito control). Reference conditions for each indicator are described in Section 4.

3.4 Site selection

Two likely refugia pools were selected: one in the upland section of the brook and one in the lowland section. The sites chosen represent the best-available pool habitats (i.e. most likely to be refugia) that were accessible (Figure 4) (site coordinates are provided in Appendix A).

The upland pool site was located approximately 0.6 km downstream from the dam wall on privately owned land surrounded by state forest. The site comprised a shallow pool (approximately 0.4 m deep), a riffle and a run in a steep-sided valley. The site was well vegetated with eucalypt trees interspersed with banksia trees and an understorey of tree ferns, tea tree bushes, rushes and sedges (Figure 5).

The lowland pool site was located approximately 7 km downstream from the dam wall on privately owned land. The adjacent land use is agriculture, including a dairy farm immediately upstream. The site comprised a sequence of riffles, a deep pool (approximately 2 m deep) and a run. The site was located on a flat plain with a deeply incised watercourse forming steep banks. The channel was sparsely vegetated with river red gum and other eucalyptus trees, and a limited understorey of tea tree bushes, swamp paperbark and exotic weeds (including blackberry and grass) (Figure 6). Adjacent to the riparian zone (at the top of the banks) the vegetation comprised a blue gum plantation on the right bank and a stand of sheoaks on the left bank.

For the assessment of system-scale flow, four observation points were chosen along the length of the brook. Locations were selected where the brook and roads/tracks converged, providing unimpeded access while representing potential barriers to flow (due to infrastructure associated with road/river intersection) (Figure 4).

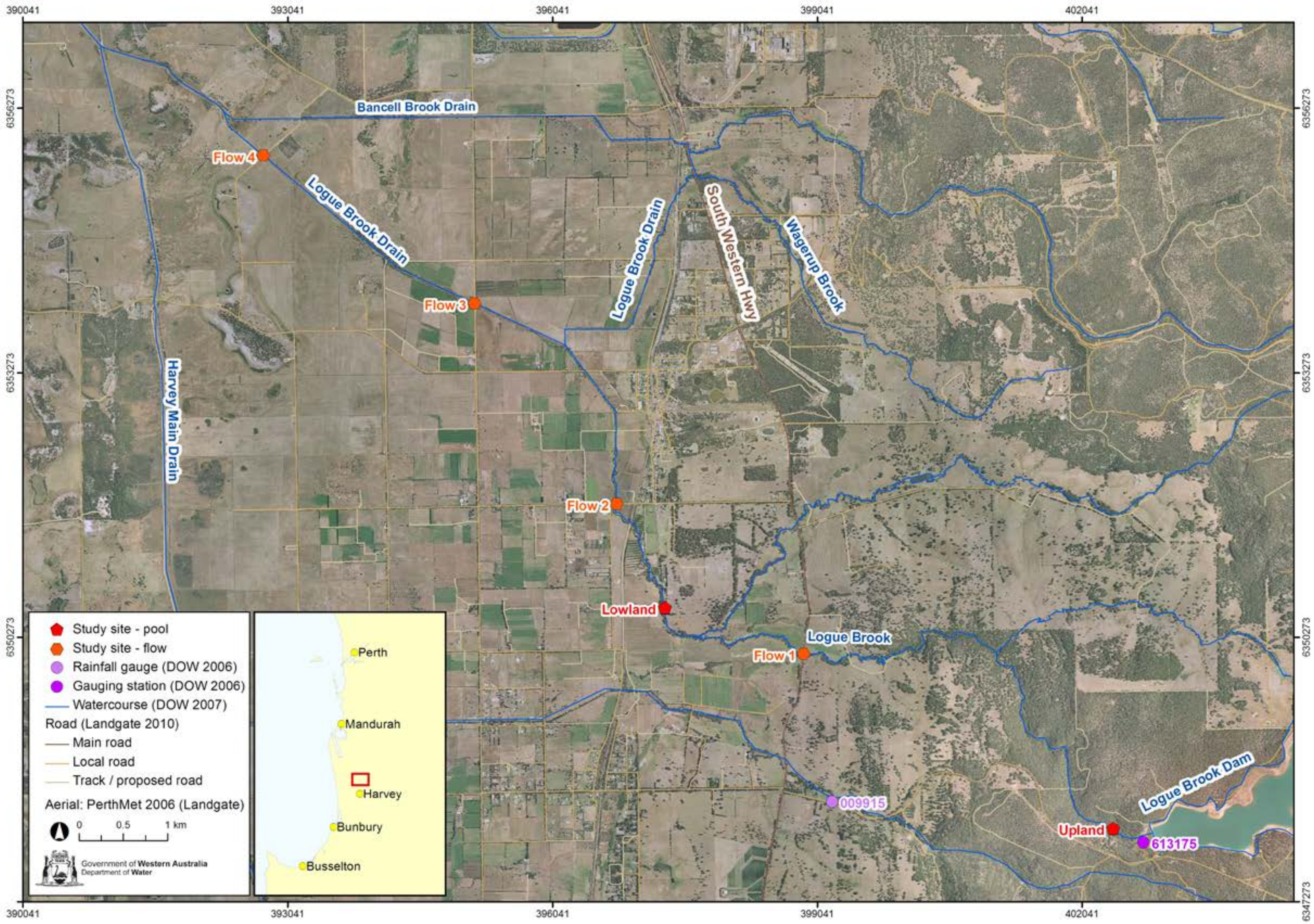

Figure 4 Study sites, stream gauging station and rainfall gauge

Figure 5 Upland site (pool)

Figure 6 Lowland site (pool) (with fyke net visible)

3.5 Hydrological assessment of system

Flow data were obtained from the Water Corporation gauging station, Logue Below (W8000970), located immediately downstream from the dam wall (hence it provides a measure of the water released from the reservoir).

Rainfall data were obtained from the Bureau of Meteorology gauge at Hillview Farm (009915). This gauge is located at the base of the Darling Scarp approximately 3.5 km downstream from the dam wall (Figure 4) and thus may not be representative of rainfall in the catchment’s upland portion, but it is the nearest rainfall gauge to the Logue Brook stream gauging station.

As introduced in Section 3.4, flow was assessed at the pool sites and at four additional observation points along the length of the system (Figure 4). These points were visited monthly between March and May 2011 and the presence or absence of flow was noted.

3.6 Ecological assessment of pools

Habitat

Habitat features were observed during the initial sampling event (14–15 February 2011) including bed substrate materials, woody debris, macrophytes, bank vegetation and shading. Characteristics of the riparian vegetation were noted including the width of the riparian zone, the cover provided by each layer of vegetation and the presence of exotic species. The field observation sheets used (Appendix B) were developed by the Department of Water for the South-West Index of River Condition (SWIRC) assessment protocol (Storer et al. 2011b). During subsequent visits any changes to habitat were noted.

Water quality

Dissolved oxygen (mg/L), turbidity (NTU), temperature (°C), specific conductivity (µS/cm) and pH data were collected at the following time intervals:

- continuous measurements were collected throughout the whole study period at the upland site, using a Manta2 multi-parameter water quality probe. (Note: equipment failure prevented collection of continuous water quality data at the lowland site)
- in-situ spot measurements were taken once per month at both sites (to calibrate logged data and examine spatial differences within each site), using a Hydrolab Quanta multi-parameter water quality probe.

In addition, a sample of water was taken at each site on one occasion for analysis of the biochemical oxygen demand. The collection method, location and time interval for each parameter is summarised in Table 3.

Table 3 Water quality parameters measured, data collection methods and collection frequency

Collection method and location	Frequency	Date(s)	Dissolved oxygen	Turbidity	Temperature	Specific conductivity	pH	Biochemical oxygen demand
Manta2 multiprobe: • at upstream end of pool • suspended horizontally in water column approx 0.1 m below the surface.	Continuous (10-minute intervals)	14 Feb – 10 May 2011	✓	✓	✓	✓	✓	
Hydrolab Quanta readings taken: • at two locations in pool • in accordance with DoW guidelines (DoW 2009b).	Once per month	15 Feb 14 Mar 12 Apr 10 May 2011	✓		✓	✓	✓	
Grab sample taken: • in pool 0.3 m above sediment surface • in accordance with DoW guidelines (DoW 2009b). *Sample analysed by National Measurement Institute laboratory*	Once during study	15 Feb 2011						✓

Fish and crayfish

Sampling was conducted once per month between February and May 2011 (on 14–15 February, 14–15 March, 11–12 April and 9–10 May 2011). On each sampling occasion fyke nets and box traps (Figure 7 and Figure 8) were deployed for a 24-hour period under the conditions outlined in Table 4.

All fish and crayfish collected were identified to species and the following information was recorded: abundance, direction of movement (upstream or downstream), size class (refer to categories in field sheets, Appendix B), visual reproductive condition (including presence of berried or gravid females, nuptial colours, reddened vents, conspicuous urogenital papillae) and any conspicuous signs of declining condition (presence of ectoparasites, disease, physical injury or behavioural symptoms of stress, such as moribund or lethargic individuals). All native fish and crayfish were returned live to the water; non-native species were euthanised with the exception of trout species.

Figure 7 Fyke net (deployed at the upland pool site)

Figure 8 Box traps (large and small size)

Table 4 Nets and traps used for fish and crayfish sampling.

Quantity and type	Dimensions	Deployment
Two dual-winged fyke nets	Opening (rectangular) – 75 cm H x 105 cm W Wings – 55 cm H x 400 cm L Mesh size – 0.3 cm	One within the pool and one approximately 100 m downstream from the pool to capture fish and crayfish moving into the study area. Located in the centre of the stream with the wings extending to each bank to direct the animals in the mouth of the fyke. Ball float inserted in tail of fyke to enable surface access for air-breathing by-catch.
Five large box traps	Opening (flexible mesh slit) – length of short side 21 cm H x 47 cm W x 60 cm L Mesh size 2 cm	Baited with chicken pellets. Two or three of each trap type placed within the section of the stream length enclosed by the fyke nets; remaining traps were placed upstream or downstream of the fyke nets. Traps were placed in all the in-stream habitat types present (e.g. bare bank, macrophytes, woody debris)
Five small box traps	Opening (circular) – diameter 5 cm 26 cm H x 26 cm W x 46 cm L Mesh size 0.3 cm	

Contextual environmental conditions

At each pool site observations about a range of environmental conditions were made during the initial sampling event (14–15 February) including physical form and catchment disturbance (refer to field observation sheets, Appendix B). The data collected provided contextual information to help with the interpretation of the fish and crayfish, water quality and habitat data; as such the data have not been analysed directly and consequently have not been presented in this report.

4 Results

4.1 Hydrological conditions

Flow data recorded at Logue Below gauging station, which provides a measure of the water released from the reservoir, are shown in Table 5 and Figure 9. The volume released was less than the agreed dry-season release volume between December 2010 and February 2011: this was due to calibration issues arising from project works at Logue Brook Dam (WC 2011). The volume released in May 2011 was slightly less than the EWP volume due to problems with the release valve readings (WC 2011).

Table 5 Total monthly EWP volume specified in the WRMOS, temporary release volume and flow recorded at Logue Below gauging station Dec 2010 to May 2011 (in megalitres)

Month	Dec	Jan	Feb	Mar	Apr	May
EWP release in WRMOS in ML/month	200	200	200	200	100	90
Expressed in ML/day	6.5	6.5	7.1	6.4	3.3	2.9
Dry season: reduced release in ML/month	100	100	100	100	100	90
Expressed in ML/day	3.2	3.2	3.6	3.2	3.3	2.9
Monthly flow at Logue Below in ML	65	49	81	109	105	89
Mean daily flow at Logue Below in ML	2.1	1.6	2.9	3.5	3.5	2.9

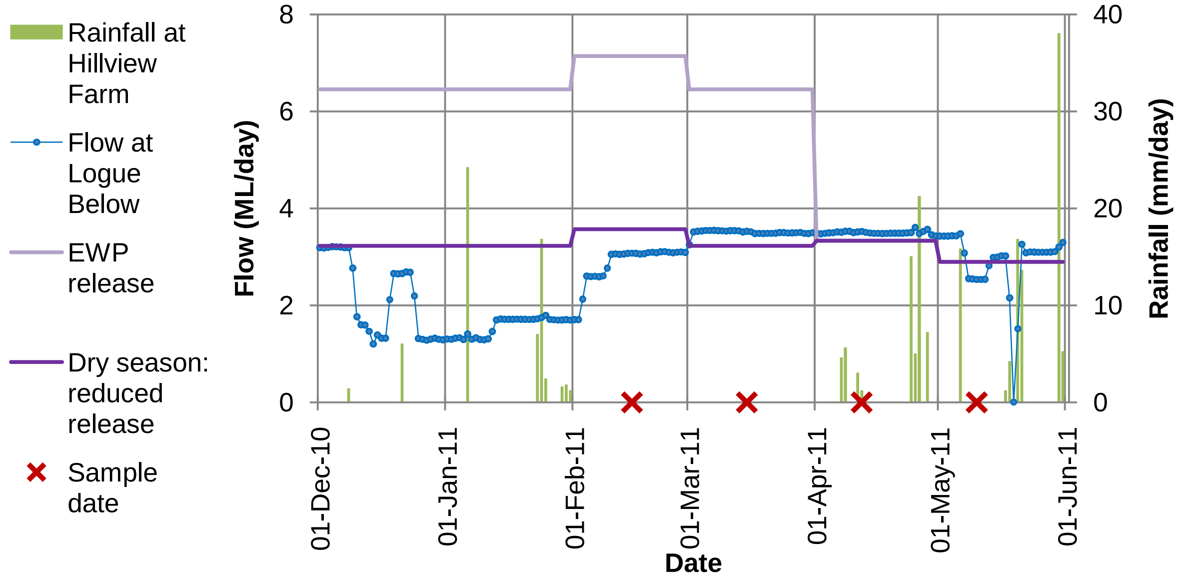

Figure 9 Daily flow recorded at Logue Below gauging station (in megalitres per day), monthly EWP release volume and reduced release volume (expressed as daily flow) and daily rainfall recorded at Hillview Farm (in millimeters per day)

Given that the Logue Brook gauging station is located immediately downstream from the dam outlet, the flow recorded is not influenced by rainfall in the catchment. The lack of flow gauges further downstream means it is not possible to quantify the relationship between rainfall in the catchment (downstream of the dam) and flow in the Logue Brook. Data are presented in Figure 9 to provide an indication of rainfall events that occurred during the sampling period.

Flowing water was present throughout the length of the system during the study period (as assessed at the four observation points and two pool sites, refer to Appendix C for photographs). Anecdotal evidence from a landholder indicates that during January 2011, when a total of 49 ML of water was released from the dam, a section of the river 0.6 km upstream from the lowland site became disconnected at a concrete spillway (part of a decommissioned stream gauging station).

4.2 Ecological assessment: habitat

No baseline habitat data exists for the study sites; as such, habitat health was assessed based on knowledge of habitat characteristics from observations made at similar river systems in the region during work reported in Storer et al. (2011b).

The general structural complexity of habitat observed at each study site is illustrated in conceptual diagrams in Figure 10 and Figure 11. The diagrams are based on specific conditions observed at the study sites, however they are generally representative of the broader conditions occurring in the upper and lower catchment.

Within the upland site there was no indication of significant impact to habitat structure or availability. All structural layers of the riparian vegetation (upper, mid and understorey) were present and a diverse range of species were observed. No exotic plant species were observed. Various in-stream habitats were observed including different flow velocity and depth, dense woody debris, emergent macrophytes and epiphytes, and a mix of bed substrate materials (bedrock, boulders, pebble, gravel, sand and silt). Draping vegetation (e.g. sedges draping over the bank into the water) covered approximately 95% of the bank length, and riparian vegetation shaded approximately 80 to 90% of the bank length (Figure 10).

At the lowland site the habitat is degraded, with riparian vegetation typically limited to a few remnant trees in the upper and mid storeys and an understorey dominated by bare ground, exotic grasses and blackberry shrubs. Accordingly, there was a loss of draping vegetation and shade. Various in-stream habitats were observed including different flow velocity and depth, woody debris and emergent macrophytes, however the habitat quality and availability was significantly reduced by the dominance of steep banks and a high proportion of bed substrate being covered by silt (Figure 11).

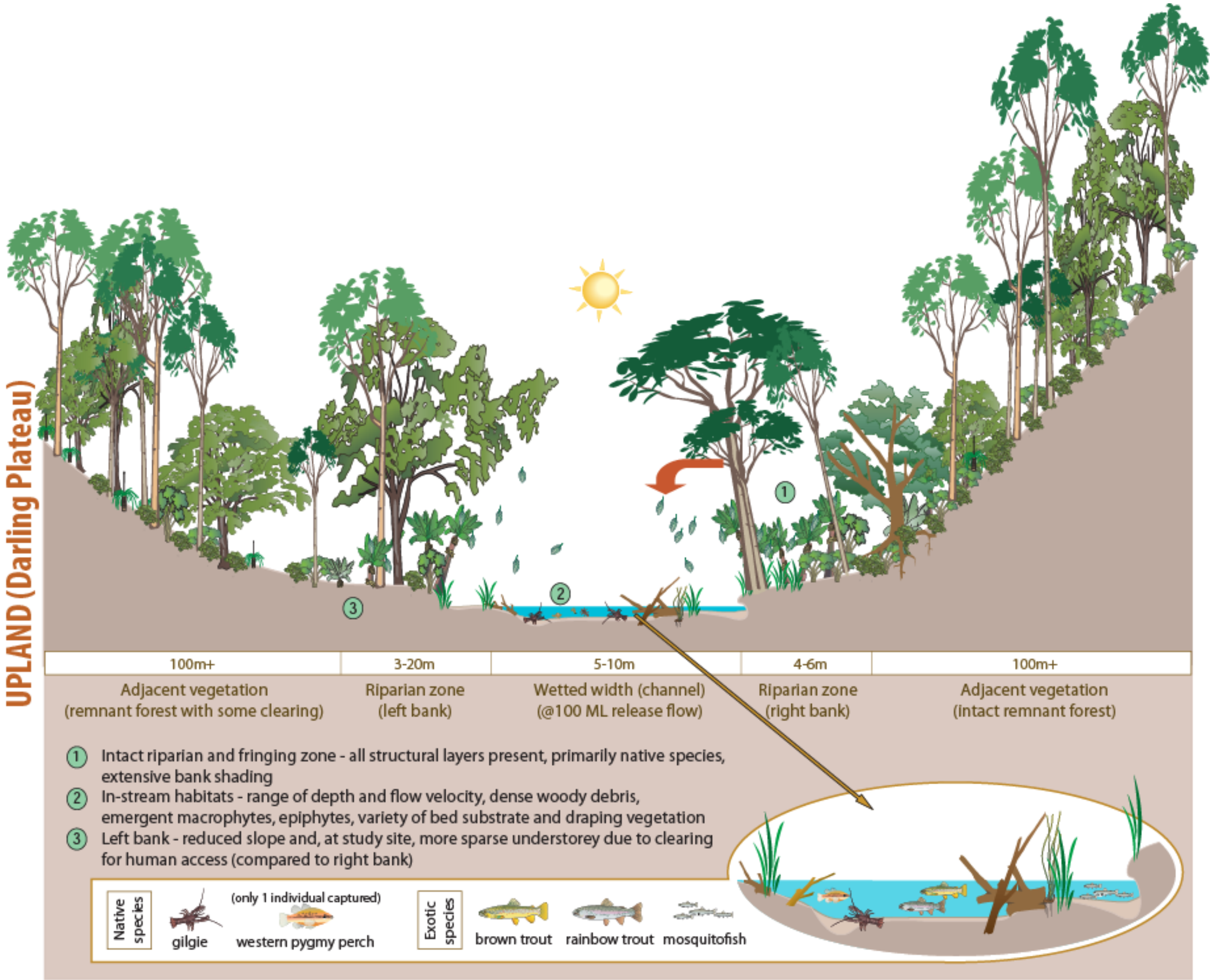

Figure 10 Conceptual diagram of the pool at the upland site

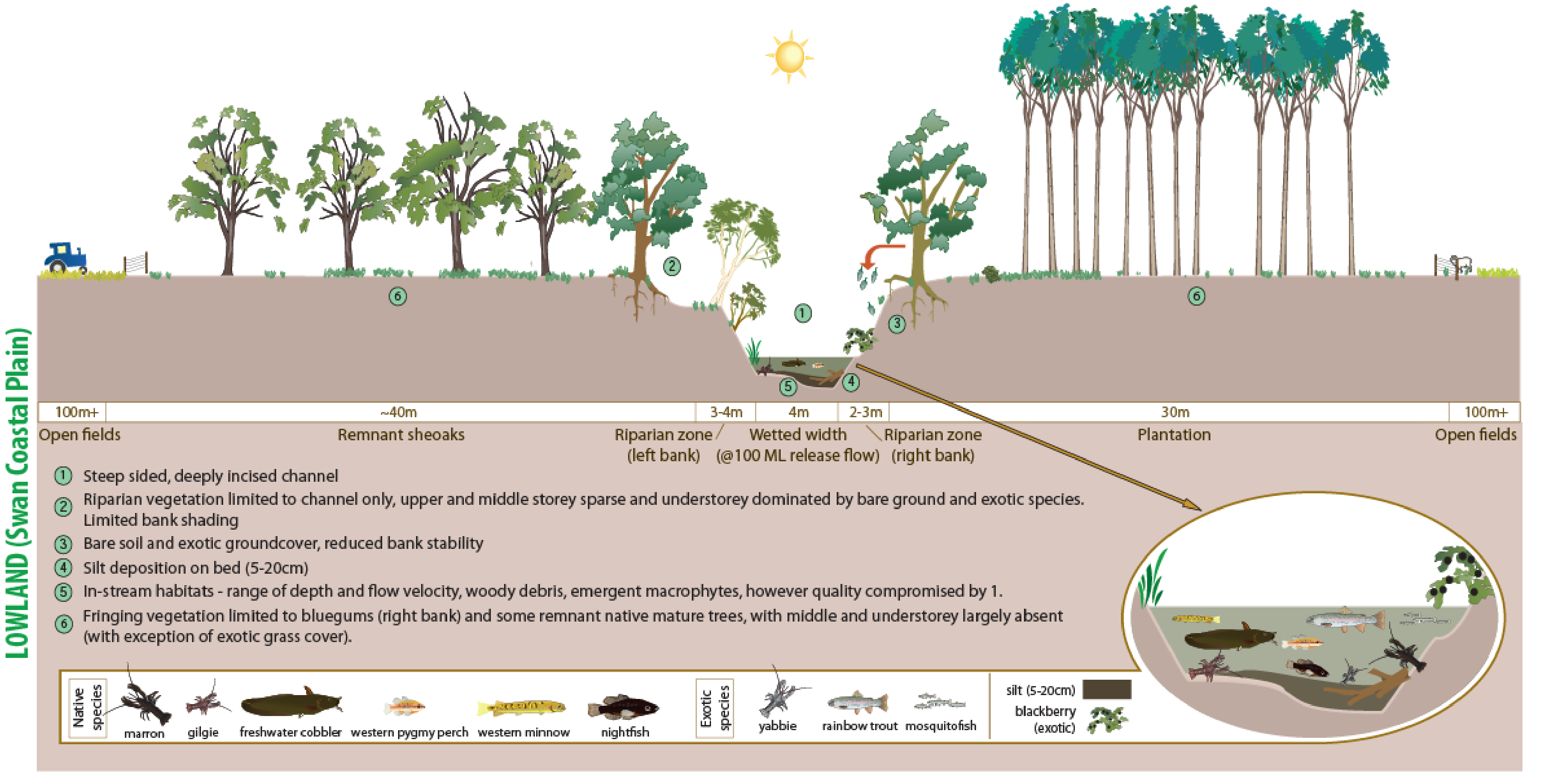

Figure 11 Conceptual diagram of the pool at the lowland site

4.3 Ecological assessment: water quality

Expected levels for the water quality parameters measured were compiled from literature about biotic tolerances, indicator thresholds used within river health assessments, and guideline values for protecting river ecosystems in SWWA (see Table 6 for reference guideline values and information sources).

Results for the water quality parameters measured at the upland and lowland sites are provided in Table 6, and summarised below:

- Dissolved oxygen was above the level thought to cause stress in aquatic fauna (Koehn & O'Connor 1990; Waterwatch 2002).
- Biochemical oxygen demand was below detection level (5 mg/L) and was in keeping with the level typical for unpolluted waterways (<5 mg/L (DoE 2003)).
- Specific conductivity was within the guideline values (ANZECC/ARMCANZ 2000a).
- pH was within the guideline values (ANZECC/ARMCANZ 2000a).
- The mean average turbidity recorded at the upland site was within the guideline values (ANZECC/ARMCANZ 2000a). Some temporary increases in turbidity occurred that were outside the guideline range.

  (Note: turbidity was not recorded at the lowland site).
- At the upland site the temperature remained within the 'normal' range for rivers in SWWA (DoE 2003), and the diel (24-hour) fluctuations in temperature were less than the 4°C fluctuation thought to be detrimental to biota (Galvin et al. 2009; Storer et al. 2011b). At the lowland site the minimum temperature was 0.8°C below the 'normal' range, however this range is a broad generalisation and thus a difference of 0.8°C does not raise concern.

  (Note: diel temperature was not recorded at the lowland site).

Table 6 Water quality parameters recorded at the study sites and reference condition values

	Upland site			Lowland site			
Parameter	**Data type**[1]	**Avg ± std dev**	**Range**	**Data type**[1]	**Avg ± std dev**	**Range**	**Reference condition**
Dissolved oxygen (mg/L)	C	7.6 ± 0.9	5.5–8.8	S	8.2 ± 0.4	6.9–8.8	<2 mg/L is unable to support fish (Waterwatch 2002) and rates of respiration slow (Davies et al. 2004) <5 mg/L causes stress to fauna (Koehn & O'Connor 1990); 5–6 mg/L are required for fish growth and activity (Waterwatch 2002)
Biochemical oxygen demand 5 day (total) (mg/L)	S	<5		S		<5	<5 mg/L is typical of unpolluted waterways (DoE 2003)
Specific conductivity (µS/cm)	C	223.1 ± 7.6	210.9–236.0	S	231.0 ± 15.5	214.0–253.0	120–300 µS/cm: ANZECC/ARMCANZ (2000a) trigger values for slightly disturbed river ecosystems in SWWA
pH	C	6.9 ± 0.3	6.6–7.7	S	7.2 ± 0.3	6.7–7.8	Lower limit pH 6.5; upper limit pH 8.0: ANZECC/ARMCANZ (2000a) trigger values for slightly disturbed river ecosystems in SWWA
Turbidity (NTU)	C	9.4 ± 24.4	0–915.9	n/a		No data	10–20 NTU: ANZECC/ARMCANZ (2000a) trigger values for slightly disturbed river ecosystems in SWWA
Temperature °C	C	20.7 ± 2.0	16.2– 25.4	S	17.7 ± 2.7	14.2– 22.1	15–25°C is the typical temperature of SWWA rivers in summer (DoE 2003)
Temperature °C (diel fluctuation)	C	2.3 ± 0.7	0.96– 3.86	n/a		No data	>4°C range likely to be detrimental to biota (indicator used by Galvin et al. 2009 and Storer et al. 2011b)

[1] *Data type: C = continuous recording; S = spot sample*

4.4 Ecological assessment: fish and crayfish

Species richness

Note: the Latin names of fish and crayfish species are provided in the Species List at the end of this report.

The reference condition for native fish and crayfish species richness for the lowland site is generated from expectations based on species recorded in previous studies (Table 2). Note that these studies were undertaken when the annual flow regime for the brook included high summer irrigation flows, and hence do not provide a direct comparison with conditions in the brook before the EWP was reduced.

This study is the first ecological assessment of the Logue Brook's upland reaches; as such, there are no data on the community composition of native fish and crayfish to directly inform expectations. In lieu of this, data from studies of the upland reaches of three nearby river systems with similar form and function were examined: Bancell, Samson and Drakes brooks. In the upper Bancell Brook the only native fish or crayfish present was the gilgie (Morgan & Beatty 2003), while data from the upland portion of Samson Brook showed a native community composition of gilgie and smooth marron (Beatty & Morgan 2005; Storer et al. 2011a). Similarly, data from a site on the upland part of Drakes Brook showed the absence of native fish and the presence of the native crayfish gilgie and smooth marron (White & Storer, unpublished data).

Note: the presence of non-native species is not included in the reference condition for sites regardless of presence in previous studies. This is because non-native species represent a decline in system health.

At the upland site the presence of a native crayfish and the absence of a native fish population (aside from a single western pygmy perch) is in keeping with river systems of similar form and function. Three species of non-native fish were also observed at the upland site: rainbow trout, brown trout and mosquitofish (Table 7).

At the lowland site the species of native fish and crayfish found were the same as those identified during previous studies (Table 7), except that the Swan River goby was absent. Two non-native fish species and one non-native crayfish species were also recorded: rainbow trout, mosquitofish and yabbie (Table 7). A water rat was also observed.

Table 7 Fish and crayfish species found at the study sites, and reference condition

	Species	**Upland site**		**Lowland site**	
		Species found	**Reference condition**	**Species found**	**Reference condition**
Native fish	Western minnow (*Galaxias occidentalis)*			✓	✓
	Western pygmy perch (*Nannoperca vittata)*	✓ [1]		✓	✓
	Nightfish (*Bostockia porosa)*			✓ [1]	✓
	Freshwater cobbler (*Tandanus bostocki)*			✓	✓
	Swan River goby (*Pseudogobius olorum*)				✓ [1]
Native crayfish	Smooth marron (*Cherax cainii)*		✓	✓ [1]	
	Gilgie (*Cherax quinquecarinatus)*	✓	✓	✓	✓
Non-native fish	Mosquitofish (*Gambusia holbrooki)*	✓	n/a [2]	✓	n/a
	Rainbow trout (*Oncorhynchus mykiss)*	✓ [1]	n/a	✓ [1]	n/a
	Brown trout (*Salmo trutta)*	✓ [1]	n/a		n/a
Non-native crayfish	Yabbie (*Cherax* sp.)		n/a	✓	n/a

1 indicates that only one or two individuals of this species were found on any one sampling occasion.

2 the reference condition was constructed for native species only, given that all non-native species have been introduced to the river systems and would not naturally occur there. They are included in this table to provide a complete list of species found during the study.

Population structure

It was not possible to define a reference condition for the population structure of fish and crayfish in the Logue Brook; instead the results were interpreted in the context of general population viability (e.g. abundance, presence of 'young of year' suggest recruitment).

Upland site

At the upland site the mean average of the total abundance of fish and crayfish per sampling event was 50 ± 10. There were small fluctuations in the relative abundance of the different species between sampling events, with fewer gilgie and more mosquitofish found in the March sample compared with the relative abundance in other months (Figure 12).

Gilgie were found in size classes equating to 'young of year' and adult, as were mosquitofish. The western pygmy perch, rainbow trout and brown trout were found in low abundance and in a limited range of size classes (Figure 13).

There were no signs of stress or disease observed in the fish and crayfish during the study, and no indication of individuals being in reproductive condition.

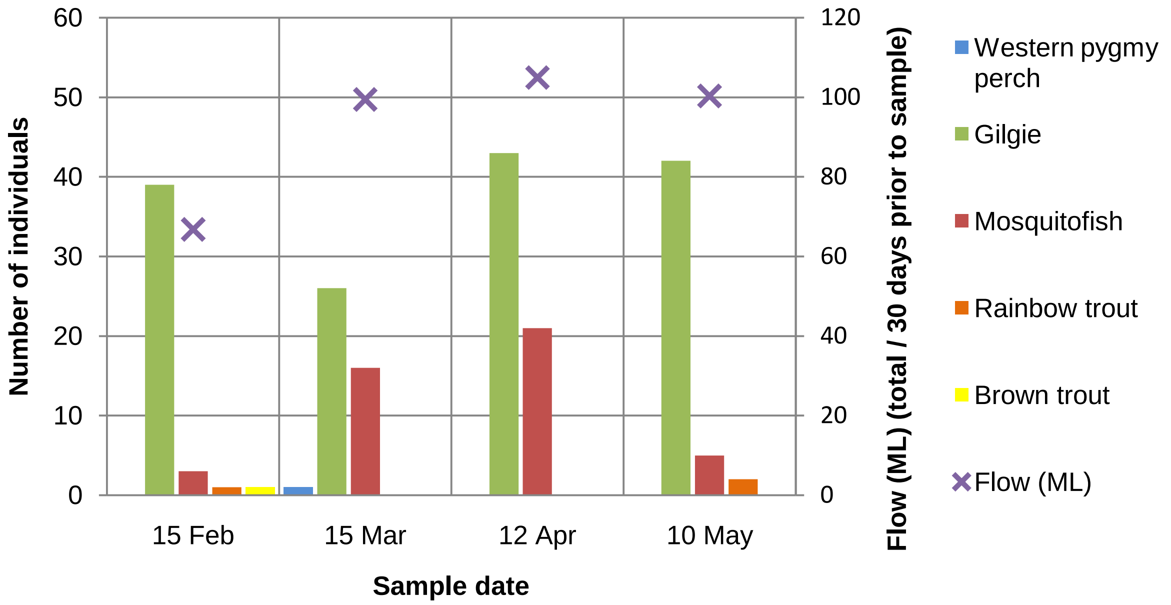

Figure 12 Abundance of fish and crayfish at the upland site and total flow (in megalitres) in the 30 days before the sample date, recorded at Logue Below gauging station

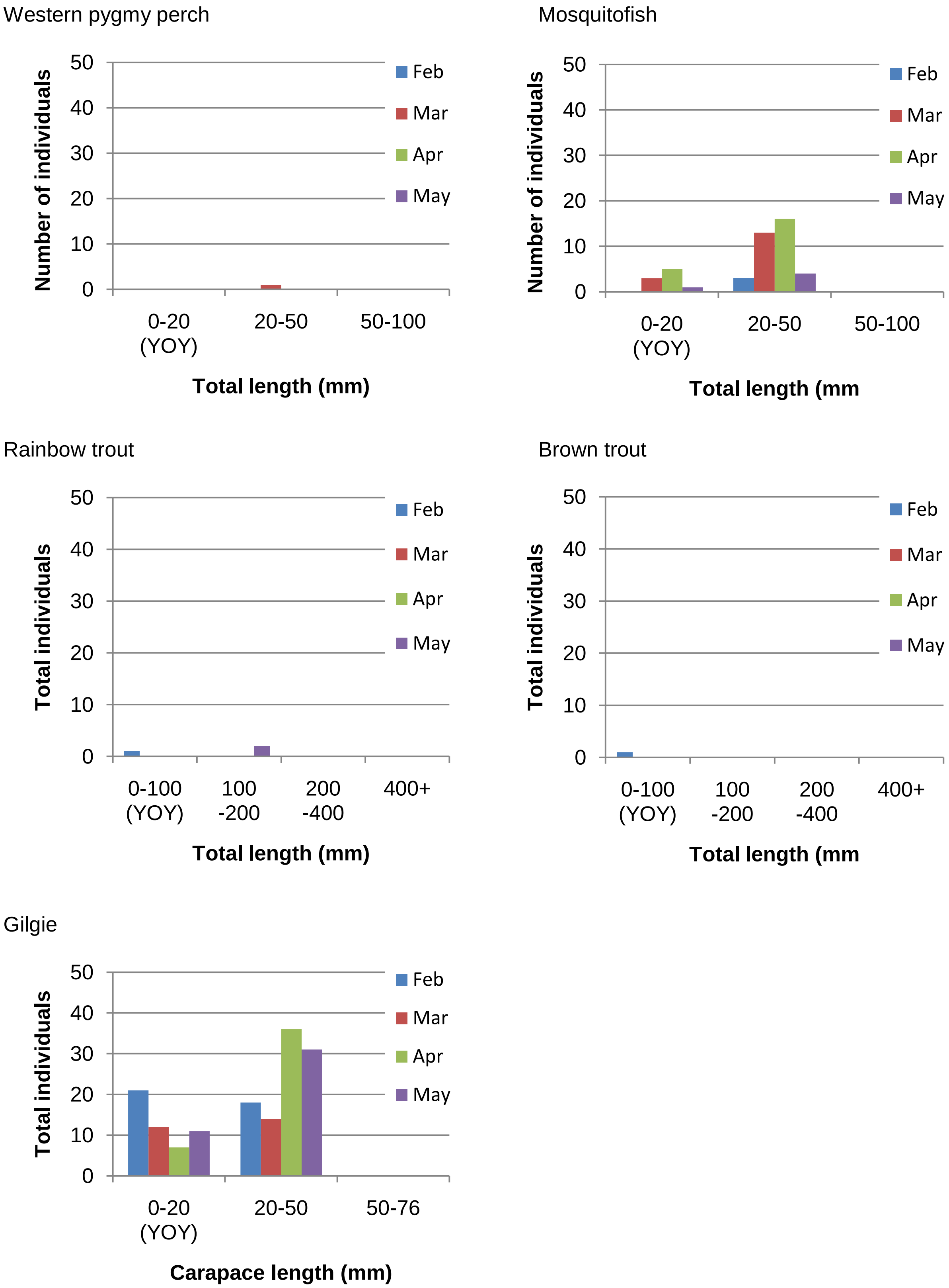

Figure 13 Length frequency distributions of fish and crayfish at the upland site

Lowland site

At the lowland site the mean average monthly abundance of fish and crayfish was 93 ± 38. The greatest total abundance occurred in the March sample (Figure 14) – largely due to increases in mosquitofish and western minnow compared with the February sample.

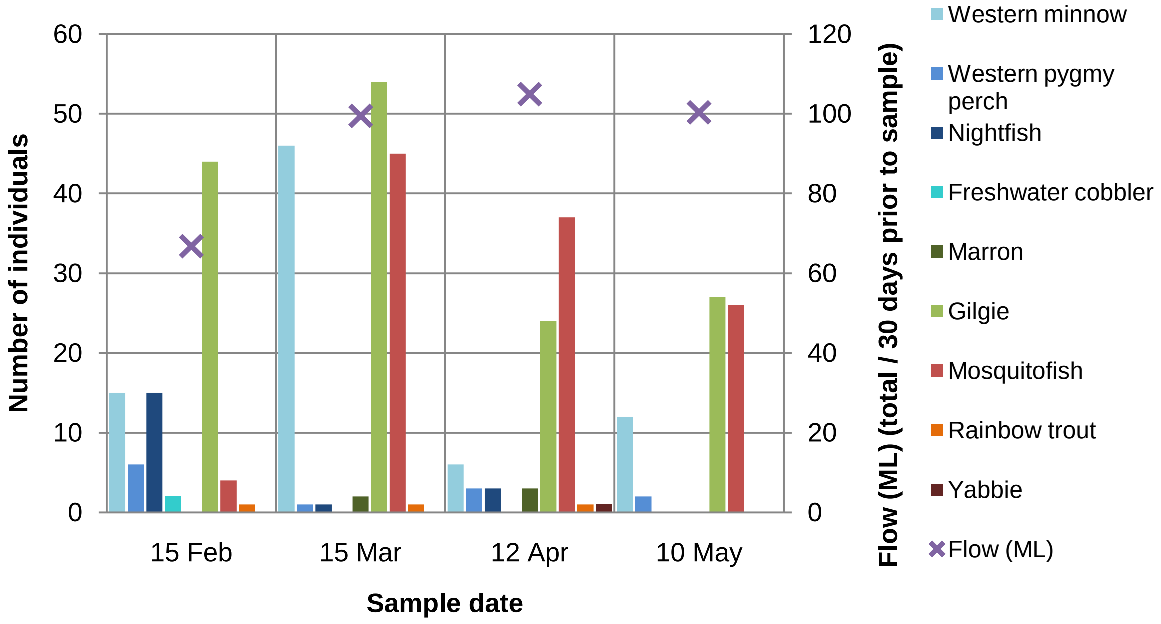

Figure 14 Abundance of fish and crayfish at the lowland site, and total flow (in megalitres) in the 30 days before the sample date, recorded at Logue Below gauging station

Of the native fish and crayfish present at the lowland site, two species were found in the full range of size classes relevant to the species: western minnow (Figure 15) and the gilgie (Figure 16). Western pygmy perch and nightfish were found in a range of size classes with the exception of the smallest (typically representing the 'young of year' (YOY)).

Freshwater cobbler were found in low abundance (two individuals): one was 'young of year' and the other was a juvenile (Figure 15). Five individuals of the smooth marron were found: one was 'young of year' and four were adults (Figure 16). The abundance and size classes of non-native fish and crayfish species are also shown in Figure 15 and Figure 16.

There were no signs of stress or disease observed in the fish and crayfish during the study period. Signs of reproductive condition were noted for western pygmy perch in February (nuptial colours), and for mosquitofish in March and nightfish in April (distended abdomen).

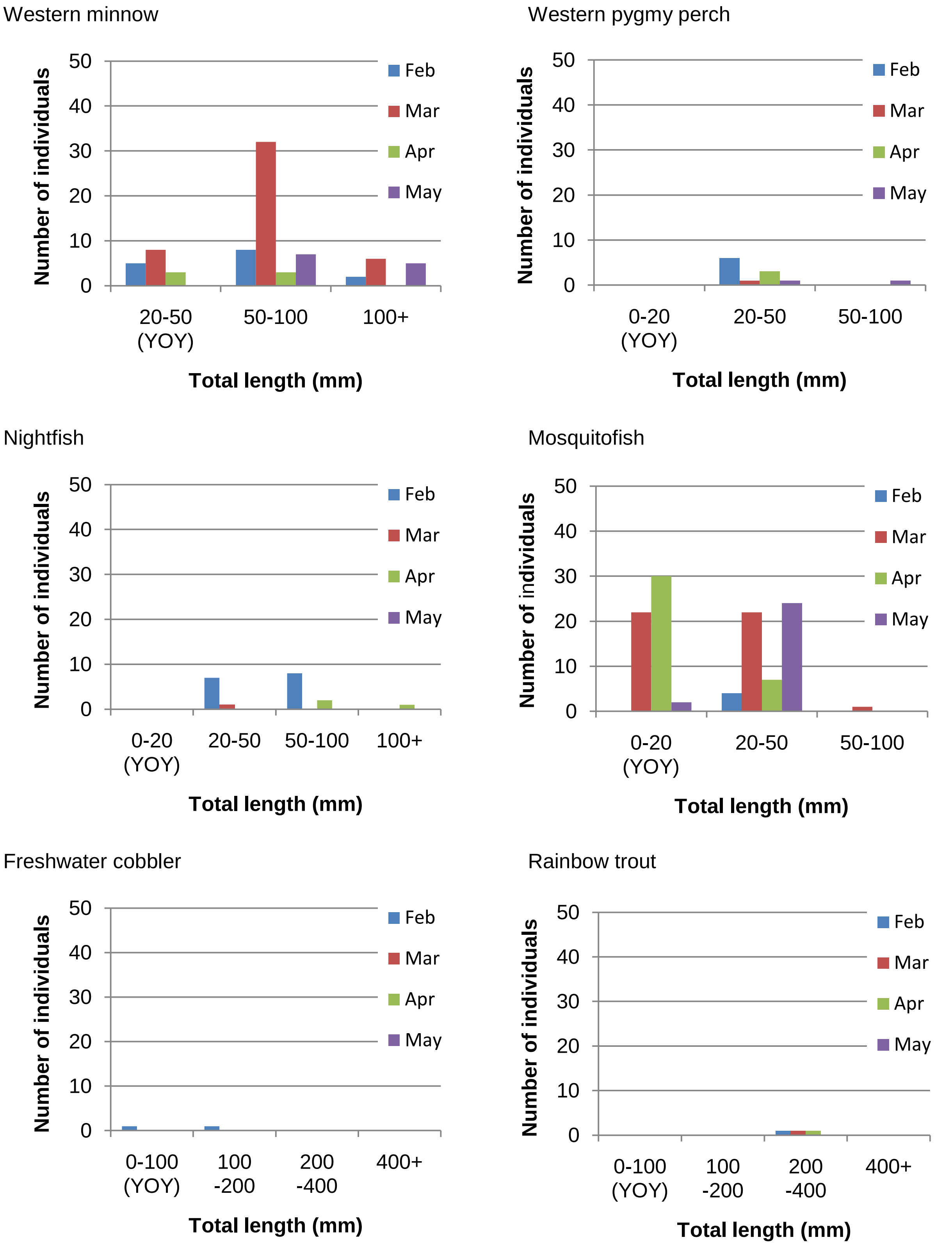

Figure 15 Length frequency distributions of fish at the lowland site

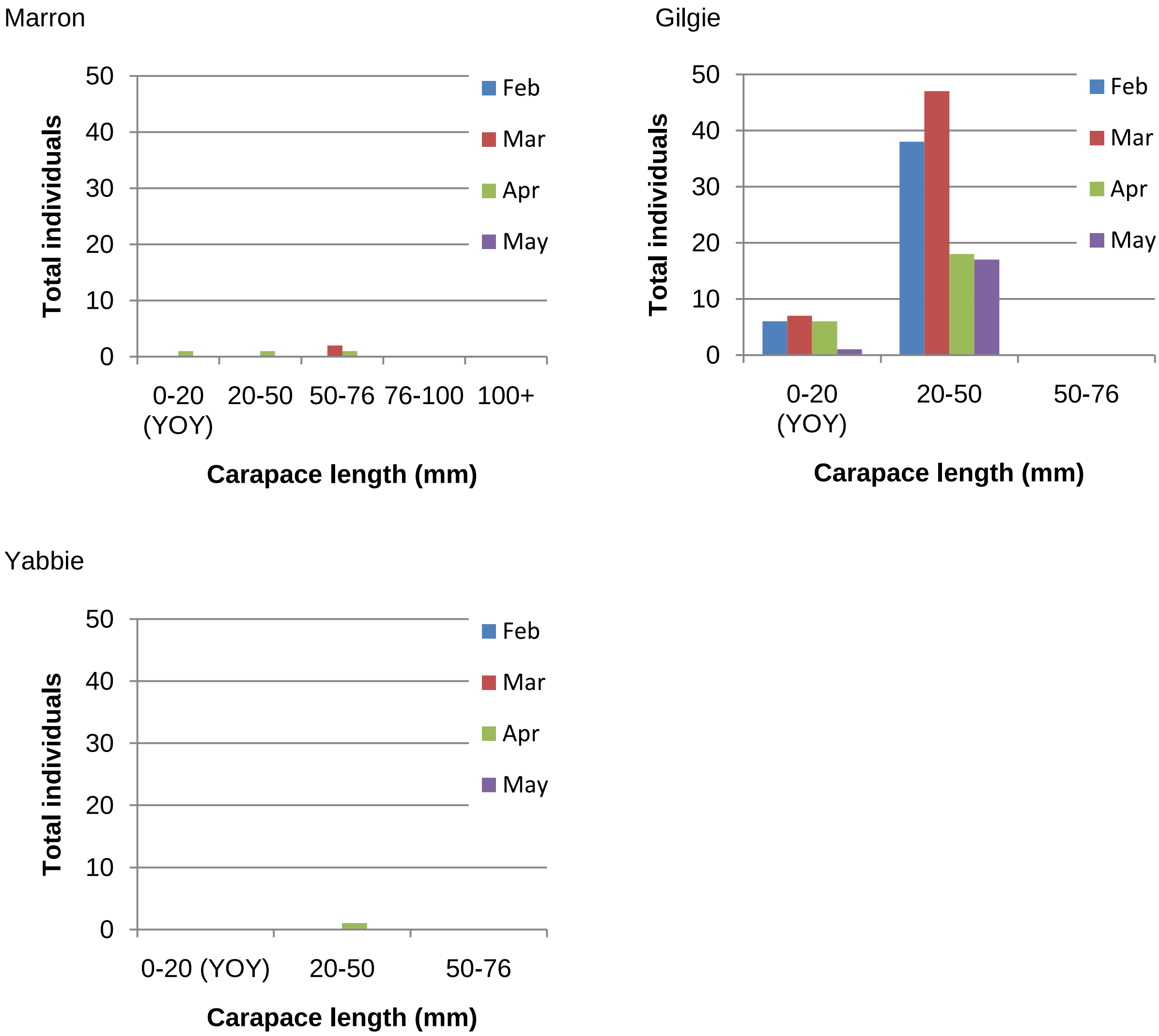

Figure 16 Length frequency distributions of crayfish at the lowland site

5 Discussion

In late 2010 the EWPs of a number of SWWA river systems were temporarily reduced in response to drying climate conditions and the associated reduction in water availability. For the Logue Brook, the EWP was reduced by 50% for the months of December 2010 to March 2011, from 200 ML/month specified in the WRMOS (DoW 2009a) to 100 ML/month. This study's objective was to assess whether the release of 100 ML/month of water was sufficient to maintain ecosystem health downstream from the dam during the study period.

Given that no relevant baseline data were gathered before the temporary reduction of the EWP, it was not possible to quantify any direct impacts of the reduction in flow. In lieu of this, the river system's status was assessed by comparison to a reference condition (compiled from a number of sources) that represents a reasonable expectation for the ecological health of a river system of this form and function with similar pressures (e.g. agriculture, mining) in the catchment.

The results are discussed in the context of addressing the study's objective, but have also highlighted some areas of concern regarding the long-term resilience of the aquatic ecosystem in the lowland reaches of the Logue Brook.

5.1 Ecological health

Upland site

The habitat at the upland site appeared to be in good condition (relative to the reference condition, refer Section 4.2) with structurally intact riparian vegetation and a range of different in-stream habitats available (e.g. pool, riffle, variation in flow and depth, inundation of woody debris, inundation of macrophytes and draping vegetation). Note that the release of 100 ML/month produced a water depth of <0.5 m in the pool and 0.1 m over the riffle at the site. Assuming this is typical of the upper Logue Brook, this part of the river system could be prone to drying if the releases were reduced significantly. Further study would be required to determine the minimum release required to maintain riffle and pool habitats.

The water quality parameters were within the guidelines established in the reference condition (refer Section 4.3) with the exception of turbidity, which showed some temporary increases outside the guideline range (ANZECC/ARMCANZ 2000a). High turbidity can lead to decreased photosynthesis (due to lower light penetration) and clogging of gills (Boulton & Brock 1999) and reduce the effectiveness of visual predators (Storer 2005) if levels persist, although temporary increases are unlikely to cause significant impacts. Peaks in turbidity can indicate catchment disturbance (e.g. stormwater discharge, pollution from urban development, physical disturbance to the riverbed or banks), however given that the catchment upstream of the site is designated as state forest there are no obvious sources for such a disturbance. Alternatively, peaks in turbidity could indicate the release of large volumes of water from the reservoir (disturbing the bed and bank material), however no large increases in release volumes occurred during the study (Figure 9). Further, the increased turbidity levels may have resulted from problems with the probe's calibration.

The occurrence of an aquatic biota community dominated by crayfish, and the lack of a viable native fish population, is in keeping with the reference condition (which is based on upland sites in river systems with similar form and function). The abundance and size-class data suggests the gilgie population is robust, with evidence of recruitment and maturity.

Smooth marron occurred in two of the three river systems used to inform the reference condition (Section 4.4), but were absent from the upland site in this study. This could be due to natural variability in the distribution of marron (supported by the absence of marron from the upper Bancell Brook). Alternatively, the presence of smooth marron in the upper Samson and Drakes brooks may have resulted from the movement of smooth marron upstream from reservoirs located downstream of the sample sites.

The observation of a single western pygmy perch suggests it may have moved to the site from elsewhere (e.g. from the reservoir), rather than it representing a viable population at the site. This is supported by a high degree of catchability for this species (based on data collected through Storer et al. 2011a); that is, if western pygmy perch were established in the system they are likely to have been caught in greater numbers than seen in this study.

As with the western pygmy perch, the low abundance of the brown trout and rainbow trout suggests they are likely to have moved into the site from the reservoir (used for recreational fishing), rather than being a self-sustaining population. The size-class data suggests a viable population of mosquitofish exists at the upland site: this species was introduced into Western Australia in the 1930s and is now found throughout the south-west (Morgan et al. 1998).

Based on the indicators assessed, aquatic ecosystem health at the upland site appeared to be 'good', with a range of in-stream habitats and water quality sufficient to sustain a robust population of the native gilgie. As such, the release of 100 ML/month from Logue Brook reservoir appeared to be sufficient to maintain ecosystem health.

Lowland site

The habitat at the lowland site was degraded (relative to the reference condition, refer Section 4.2), primarily due to the reduced cover of riparian vegetation, the deeply incised channel and the accumulation of silt. The reduced cover of riparian vegetation has various implications for aquatic ecosystems including:

- less shading leading to increased temperature (Davies et al. 2004)
- increased light available for aquatic plants and algal growth (Quinn et al. 1997)
- decreased allochthonous inputs and consequent impacts on the food web (Pusey & Arthington 2003)
- decreased bank stability (McKergow et al. 2003)

- less habitat provision; for example, woody debris (Pusey & Arthington 2003)
- decreased filtering of nutrients (Naiman & Decamps 1997).

As such, the resilience of the ecosystem to changes such as reduced flow is likely to be affected by the lack of intact riparian vegetation. Various in-stream habitats were present (e.g. pool, riffle, inundation of woody debris, inundation of macrophytes and draping vegetation, variation in flow and depth), however the habitat present was dominated by deep steep-sided banks that can affect biota; for example, by reducing the availability of edge habitat which is important for crayfish, particularly smaller individuals (Hicks 2003; Jowett et al. 2008), because it provides protection from predators via shallow water and proximity to shelter (e.g. draping vegetation and overhanging banks) (Englund & Krupa 2000; Parkyn et al. 2009).

In addition, the quality of the habitat available in the pool was lowered by the accumulation of silt, which fills interstitial spaces in the substrate and covers woody debris (Pen 1999). The WRMOS (DoW 2009a) specifies that in August of every third year an 'overbank flow event' should be generated to reduce the build-up of debris within the system and inundate riparian vegetation. It is possible this flow event would also flush sediment from the pool; further study before and after the overbank flow event would clarify whether sediment flushing had occurred and, if not, could inform a revised overbank flow volume.

The water quality parameters were within the guidelines established in the reference condition (Section 4.3). Given that this study coincided with the first summer season in which irrigation flow was not transferred via the brook, it is possible the water quality may change in the future as the system adjusts to the current flow regime. A likely trend in water quality is a decline in condition due to effects associated with the build-up of organic matter (from decomposition and clogging of benthic habitat) in pools – due to the lack of flushing by summer irrigation flows (although the 'overbank flow event' specified in the WRMOS may also flush the organic matter from the pool). In addition, water quality may deteriorate in the future due to non-flow related factors (e.g. increased nutrient inputs from surrounding agriculture, clearing of vegetation in the catchment). Given these confounding factors it is not possible to predict whether water quality would continue to remain within acceptable levels in the future; as such, further monitoring of water quality parameters would help with future decisions about water releases.

The fish and crayfish community composition at the lowland site was the same as that found by previous studies, except for the Swan River goby. This species was found during one previous study (Storer et al. 2011a), however only one individual was recorded and thus the data are insufficient to determine whether a viable population existed in the lower Logue Brook before this study. The limited population recorded could be attributed to reproductive cycles, with spawning reported to occur in upper estuarine environments during spring and autumn (Morgan et al. 2011); as such, the Swan River goby may have been downstream from the site (i.e. in the estuarine environment) at the time of sampling for both this study and work undertaken by Storer et al. (2011a). It is possible the changes to the flow regime, such as the cessation of irrigation flows and the temporary reduction in the EWP, have resulted in a greater number of structures (e.g. culverts, irrigation control points) forming barriers to fish movement (e.g. lower flow over a weir could result in a greater 'jump' height for fish trying to move upstream). In addition, the absence of a viable population of Swan River goby may indicate habitat degradation in the lower Logue Brook. In summary, further work is required to ascertain the following:

- distribution of the Swan River goby within the Logue Brook and lower Harvey River
- the timing of the movement of the species upstream into freshwater environments after spawning (in relation to the timing of fish passage flows specified in the WRMOS)
- the impact of the changes in flow regime on the passage of the species through the system.

This information will help clarify how fish species in the system will be affected by the current flow regime, as well as any future proposed changes to the flow regime.

The abundance and size-class data suggest the populations of western minnow and gilgie are robust, with evidence of recruitment. 'Young of year' of the western pygmy perch and nightfish were not found, however this could be a result of the timing of sampling compared with spawning. Both species have relatively long spawning periods – typically between July and November for western pygmy perch and between August and September for nightfish (Morgan et al. 2011) – hence if spawning in the Logue Brook largely occurred towards the start of these periods it is possible that 'young of year' have exceeded the smallest size category. Alternatively, the data could demonstrate that the lowland site is either not a natural nursery area or that the site's habitat has been degraded to the extent it is unable to support a nursery function. Given that both species reach sexual maturity after one year – or two years for female nightfish (Morgan et al. 2011) – and that larger individuals of both species were present, it is likely the populations have successfully recruited at least within the past few years. In addition, signs of reproductive condition were observed in both species during the study (western pygmy perch in February and nighfish in April). While this suggests the Logue Brook is able to sustain the populations of these species, further work would be required to clarify this point and to identify nursery areas for protection.

Only two individuals of the freshwater cobbler and five of smooth marron were found at the lowland site. Given their low abundance, and the limited spatial coverage of this study, there is insufficient data to determine the viability of these species. The presence of 'young of year' of both species suggests that recruitment is occurring to some degree within the lower Logue Brook, however further work is needed to clarify the sustainability of these populations. It is possible that freshwater cobbler were naturally absent from the site during the study period due to migration, although the migratory habits of this species have not been confirmed to date[2]. Alternatively, the freshwater cobbler may be unable to move into the site due to barriers created by in-stream structures (e.g. culverts, irrigation control points) and reduced flow. The spawning period and passage in the Logue Brook should be clarified because protection of summer spawning habitat is vital for the fitness of this species.

The presence of mosquitofish and a single yabbie is likely to be the result of these species being introduced into Western Australia in the 1930s (Morgan et al. 1998), while the presence of rainbow trout in low abundance is probably the result of dispersal from Lake Brockman (the reservoir formed by Logue Brook Dam) which is stocked with this species (DoF 2009). The presence of introduced non-native fish and crayfish species in the brook is not a direct function of modifications to flow; however their presence does warrant consideration in the management of EWPs given the potential for increased predator fitness if species congregate in refuge pools under low-flow conditions.

There was no evidence of a strong relationship between community composition and flow conditions recorded for this study. This was not unexpected given that the study began after the temporary reduction in releases was implemented, and that flow remained relatively stable during the study period (Figure 9). There were minor changes in the relative abundance of fish and crayfish species at the lowland site: a greater number of western minnow were found in the March sample compared with other samples, and there was an increase in mosquitofish and gilgie in March followed by a decline in the April and May samples (Figure 14). The increase in the abundance of these species in March could correspond with the increase in flow in the 30 days before sampling (which may reflect greater access to the pool), however the change in relative abundance could also be explained by natural seasonal variability. There was no marked increase in abundance during the period of the study, and no signs of stress or disease in the individuals; this suggests the reduced flow was not causing the biota stress or triggering them to move into the pool to seek refuge. The decline in abundance of these three species (western minnow, mosquitofish and gilgie) after March is minor (in terms of relative abundance), however it could be an early warning symptom of a decline in ecosystem health. Given that there is insufficient data to draw conclusions, further study would help with understanding the natural variability of fish and crayfish species in the system and their relationship with flow.

[2] Data collected by Storer et al. (2010) suggest that freshwater cobbler migrate on mass in spring (based on observation made in Moore River, Gingin Brook and Capel River in October 2008 and 2009), which may relate to spawning, given that spawning occurs between October and December in the Blackwood River (Beatty et al. 2009) and November to December in Wungong Reservoir (Morrison 1988; Hewitt 1992). However Beatty et al. (2009) suggest the movements of freshwater cobbler in the Blackwood River were highly localised and that movements through riffles may be related to both feeding and spawning activity, given that strong movements were observed both within and outside of the spawning period, and that the individuals were from a range of size classes (including smaller immature individuals).

Based on the indicators assessed, the release of 100 ML/month of water from the reservoir appeared to be sufficient to sustain aquatic life in the lower Logue Brook during the study period, given that water quality remained within reference guidelines, inundation of habitat was maintained and fish and crayfish species were present. However, the results indicate some areas of concern for the long-term resilience of the ecosystem. The lack of intact riparian vegetation, the presence of deeply incised banks and the accumulation of silt have compromised the quality of the habitat available at the lowland site, which can affect the ecosystem's capacity to withstand subsequent pressures such as land use change and climate change. For example, a system with intact riparian vegetation has the capacity to mitigate impacts from reduced flow (e.g. increased temperature and low dissolved oxygen) due to shading (Davies et al. 2004). Accordingly, a healthy ecosystem is likely to adjust to the changes associated with reduced flow (refer Section 2.5) more readily than a degraded system. In addition, uncertainty about the robustness of some of the fish and crayfish populations at the lowland site adds to concerns about the resilience of the biota to changes in flow. As such, it is unclear whether the release of 100 ML/month would be sufficient to maintain ecosystem health in the future.

5.2 Additional management considerations

Fish passage

An assessment of the impact of reduced flows on fish passage through the Logue Brook system was beyond the scope of this study, however it is important to consider fish passage in future management scenarios. Six barriers to fish passage were identified by Morgan & Beatty (2008), and a number of other potential barriers were observed during the reconnaissance for this study. An assessment of the potential natural and artificial barriers to fish passage would provide valuable data for determining the minimum flow required to maintain connectivity for biota.

Riparian vegetation

While this study considered the structural intactness of the riparian vegetation, an assessment of the impact of reduced flow on riparian vegetation condition (i.e. plant health) was beyond its scope, however it is important to consider the supply of water for riparian vegetation growth in future management scenarios. Revegetation work had been undertaken at various locations along the Logue Brook, but anecdotal evidence suggests the vegetation has been adversely affected by reduction of the summer flow volumes when irrigation flows were transferred to the pipe network.

Water rats

A water rat was observed at the lowland site. The water rat is listed as a Priority 4 species (in need of monitoring) under the provisions of the *Wildlife Conservation Act 1950* (DEC 2010). Further study would be needed to confirm the presence of a water rat population in the Logue Brook, and to clarify the relationship between their habitat and flow conditions.

6 Conclusions

The results of this study suggest the temporary EWP release of 100 ML/month from Lake Brockman between December 2010 and March 2011 was sufficient to maintain aquatic ecosystem health in the Logue Brook in the short term, based on the following: water quality was within reference condition guidelines, there was sufficient water to inundate the habitats present, the native fish and crayfish present did not show signs of stress or disease, and the species richness was equal to the reference condition.

However, the results indicate some areas of concern regarding the longer-term resilience of the riverine ecosystem in the lowland part of the Logue Brook. The degraded habitat (lack of intact riparian vegetation, deeply incised banks and accumulation of silt) is likely to affect the ecosystem's capacity to withstand subsequent pressures such as reductions in flow. (It is acknowledged that the habitat degradation has been caused by pressures external to the current flow regime, such as land use and the past flow regime, however these pressures must be taken into account so that the EWP can maintain ecosystem health). In addition, there is some uncertainty about the sustainability of some of the fish and crayfish populations (primarily Swan River goby, freshwater cobbler and smooth marron, but also western pygmy perch and nightfish). It is acknowledged that this uncertainty has arisen due to a lack of data and that further study is required to provide clarity (refer Section 7); however, at present it is not known whether the populations of these species are viable or not.

Given these concerns, it would be imprudent to suggest that environmental water releases could be reduced to 100 ML/month for December to March in future years. Based on the current status and knowledge of the ecosystem, it is not possible to confidently predict that ecosystem health would be maintained if the temporary reduction in flow were repeated in future summer seasons.

If restoration work was undertaken (e.g. bank re-shaping and revegetation), the riverine ecosystem's resilience may be improved sufficiently to allow ecosystem health to be maintained at release volumes lower than those in the current WRMOS (DoW 2009a).

Note: the Logue Brook's current EWP was based on the EWR study conducted for Drakes Brook, with scaling applied to ensure the EWP was appropriate to the size of the Logue Brook catchment (Ian Loh pers. comm. 2011). While Drakes Brook has a similar form and function to Logue Brook, the specific pressures on the aquatic ecosystem (e.g. structural intactness of riparian vegetation, channel erosion, barriers to fish passage) are likely to be different and may require a different provision of environmental water.

7 Recommendations

Based on the results of the study it is recommended that:

- the EWP releases remain as specified in the WRMOS (DoW 2009a)
- if, in future, a temporary reduction from the EWP releases specified in the WRMOS (DoW 2009a) is required, ecosystem health monitoring should be undertaken (using this study's results as a baseline) and adaptive management arrangements put in place to respond if ecosystem health declines (e.g. increasing the release volume)
- an EWR study of the Logue Brook be conducted and the EWP specified in the WRMOS modified if necessary
- consideration be given to other waterway management interventions such as restoring riparian vegetation and reforming the bank shape to improve habitat condition, thereby improving the resilience of the aquatic ecosystem to changes in flow and climatic conditions.

A number of knowledge gaps were identified during the course of the study. It is recommended that the following gaps be addressed:

- clarify the viability of populations of Swan River goby, western pygmy perch, nightfish, freshwater cobbler and smooth marron and investigate the location of nursery sites for these species to ensure EWPs provide adequate flow to maintain the nursery function
- determine the natural variability in abundance of fish and crayfish in the Logue Brook and the relationship to changes in flow
- assess the natural and artificial barriers in the river system to determine whether they present a barrier to biota movement, and to calculate the minimum flow required to maintain fish passage along the length of the brook during seasons relevant to fish spawning
- assess the effectiveness of the 'overbank flow event' specified in the WRMOS (DoW 2009a) at flushing sediment and organic material (for habitat and water quality)
- assess the condition of riparian vegetation in relation to the changes in flow regime
- confirm the presence of a water rat population.

Appendices

Appendix A — Coordinates of study sites

Table A1 Coordinates of sites assessed as part of this study

Site name (and code)	Location description	Easting*	Northing*
Lowland pool (LOGUE01)	163 Clifton Rd	397318.31	6350607.09
Upland pool (LOGUE02)	447 Logue Brook Dam Rd	402399.11	6348101.97
Flow 1	South Western Highway bridge	398889.74	6350083.17
Flow 2	Clifton Rd bridge	396772.88	6351784.14
Flow 3	Brockman Rd bridge	395160.06	6354059.96
Flow 4	Trotter Rd bridge	392765.92	6355738.38

* Coordinate system: Geocentric Datum of Australia 1994 (GDA 94) Map Grid of Australia (MGA) zone 50

Appendix B — Field sheets

Date _______________ Site code _______________

SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
COVER SHEET

SITE CODE ___________________

SWMA ___________________

RIVER SYSTEM ___________________

RIVER/STREAM NAME ___________________

SITE NAME ___________________

DATE ___________________ COC ___________ SAMPLE NUMBER ___________________

NAME OF SAMPLERS ___________________

NOT ASSESSED IN FIELD

ALTITUDE _______ (m) SLOPE _________ (m/km) DFS _________ (km) STREAM ORDER ________ (km)

NEAREST RAINFALL STATION __________ (name) DISTANCE AWAY _____ km AVERAGE ANNUAL RAINFALL _____ (mm)

FLOW PATTERN CATEGORY ___________________ DISCHARGE CATEGORY __________ (mm)

ORDER OF SAMPLING – DAY 1

1. Take water quality samples: grab followed by in-situ
2. Collect macroinvertebrates
3. Deploy water quality loggers. *Note: after loggers have been deployed only enter river downstream.*
4. Process macroinvertebrate sample
5. Deploy fish/crayfish traps and fyke nets
6. Site photos (important to capture conditions on first day as factors such as water level and flow can change rapidly)
7. Field sheets (if time permits)

ORDER OF SAMPLING – DAY 2

1. Collect fish/crayfish traps and fyke nets
2. Collect water quality loggers: after 25 hours (144 logged measurements)
3. Complete field sheets
4. Complete site photos: fill-in checklist below.

Photo checklist

[ ] Upstream and downstream photos; taken at the top, middle and bottom of the 100m sampling site (6 photos total)
[ ] Representative site photos
[ ] Macroinvertebrate sampling area
[ ] Representative video taken
[ ] Canopy shots (taken from edge of stream of both sides – representative of density of canopy throughout site)

Acronyms
LB: Left Bank, **RB:** Right Bank

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Date ________________ Site code ________________

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SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS

GPS DATUM ________________

LONGITUDE (°E) or EASTING ________________

LATITUDE (°S) or NORTHING ________________

MAP NAME and YEAR OF PUBLICATION ________________ SCALE ________________

PAGE REFERENCE OR MAP NUMBER ________________

ACCESS DETAILS ________________

PROPERTY OWNER ________________

PHONE NUMBER ________________

ADDRESS ________________

NOTIFY BEFORE EACH VISIT [ ] Yes [ ] No PERMISSION REQUIRED [ ] Yes [ ] No

KEY REQUIRED [ ] Yes [ ] No KEY NUMBER / AVAILABLE FROM ________________

ACCESS MAP – SKETCH ROUTE BELOW OR ATTACH MAP TO BACK OF FIELD SHEET

Include flow direction, site location, roads, crossings, north arrow, distances and landmarks.

MAP ATTACHED ☐

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Date ______________ Site code ______________

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SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
GENERAL SITE ASSESSMENT – 100m sampling site

Artists name ______________________

LONGITUDINAL DIAGRAM (AERIAL VIEW)

Essential features	Legend
Flow direction	→ → →
Loggers	(L)
Macroinvertebrate sample	(M)
Water quality sample	(W)
Fyke nets	▶ or ◀
North arrow	↑ N

Possible features	DIY legend	*Possible features*	DIY legend
Macrophyte habitat		Vegetation type A: ______	
Large trees		Vegetation type B: ______	
Woody debris		Vegetation type C: ______	
Riffles			
Sandbars/sediment deposits			
Significant erosion			
Natural or artificial barriers			

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Date ______________ Site code ______________ Government of Western Australia Department of Water

SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
GENERAL SITE ASSESSMENT – 100m sampling site

CROSS SECTION DIAGRAM

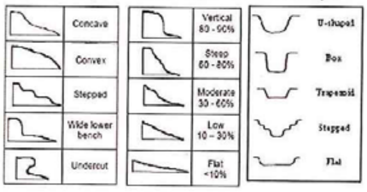
Representative of sampling region (where high variability exists draw two cross-sections).

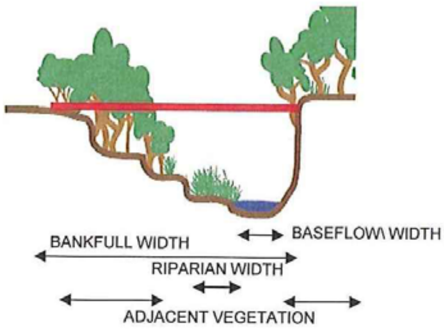
Suggested information to include on cross section diagram above

- Bank shape (see below)
- Bank slope (see below)
- Channel shape (see below)
- Base-flow and bank-full width (m)
- Streamside and adjacent vegetation width and structure
- Presence of bars, benches, toes

Circle diagrams below

Bank Shape Bank slope Channel shape





STREAM WIDTH MEASURMENTS

	Top	Middle	Bottom
Bankfull width (m)	_____	_____	_____
Current water width (m)	_____	_____	_____

Water width compared to base-flow (circle)				
No flow dry isolated	Low < low water mark	Moderate Equal to base-flow	High > high water mark	Flood

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Date ______________ Site code ______________

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SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
AQUATIC HABITAT ASSESSMENT – 100m sampling site

STREAM HABITAT DIVERSITY

Habitat area	%
Channel (Includes woody debris)	
Macrophytes	
Riffle	
Pool	
Total	100

Macrophyte types	%
Emergent	
Submerged	
Floating	
Total	100

Large woody debris ☐ present ☐ absent (Size relative to 'un-impacted' conditions for specific area)	
Diversity (circle)	**Abundance** (circle) *
Wood of similar size	Sparse (few pieces)
2-3 different sizes	Moderate *
Variety of sizes	Dense (throughout most of site)

* A few sections of moderate density or low density across most of site

Bank vegetation draped in water ** (percentage of bank length)	

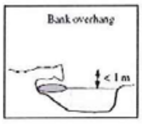
*Note: section relates to habitat (not shading). ** Dead vegetation not included*

Roots overhanging and draped in water			
None	Limited	Moderate	Extensive
Overhanging banks			
None	Limited	Moderate	Extensive

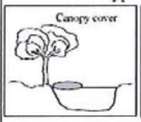
Limited = 1-10% of bank length, Moderate = 11-50%, Extensive >50% of bank.

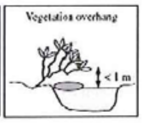
Flow (circle)
Uniform flow (e.g. drain)
Moderately varied flow
Varied flow (eg eddies, backwaters, fast, slow)

Depth (circle)
Uniform depth (eg drain)
Moderately varied depth
Varied depths



Stream shading	Percentage of bank length		Average distance from bank (m) **Average stream width** ______ m	
	LB	RB	LB	RB
Tree cover #				
Shrub overhang				
Grass overhang (rushes/sedges)				





Note: density of canopy will be determined from canopy photographs; therefore only total area should be assessed.

Physical substrate DIVERSITY	Increasing complexity (circle one number)
Mainly bedrock or artificial substrate	1 2 3 4 5
Silt or sand or a mixture of silt and sand	6 7 8 9 10
Mainly sand with some pebbles &/or boulders	11 12 13 14 15
Mix of boulders, pebbles & sand etc	16 17 18 19 20

Note: increasing complexity or density are not a direct indication of health (i.e. boulders are not expected at all sites)

Biological substrate DENSITY *Tip: try breaking site into sub-sections (i.e. 10 x 10m sections for a 100m sampling site), to estimate cover*	Increasing density (circle one number)
<10% of substrate cover	0 1 2 3 4 5
11-30%	6 7 8 9 10
31-60%	11 12 13 4 15
>60%	16 17 18 19 20

Biological substrate DIVERSITY (circle)				
leaves	twigs	branches	detritus *	Epiphytes

* *Detritus relates to undifferentiated organic material*

Sediment deposition	None or minor	Not obvious	Obvious	Type (sand/silt): ______________

WATER AND SEDIMENT

Circle the appropriate description under each category.

Water odours	*Water Oils*	*Turbidity*	*Tannin staining* *	*Algae in water column*	*Algae on substrate*	*Plume***	*Sediment oils*	*Sediment odours*
Normal/None	None	Clear	Clear	0%	0%	Small	Absent	Normal/None
Anaerobic	Slick	Slight	Slight	1 to 10%	1 to 10%	Moderate	Light	Sewage
Sewage	Sheen	Turbid	Light tea	11 to 50%	11 to 50%	Large	Moderate	Petroleum
Petroleum	Globs	Opaque	Dark tea	51 to 75%	51 to 75%		Profuse	Chemical
Chemical	Flecks		Black	> 75%	> 75%			Anaerobic

* tannin staining can be confused when combined with systems containing fine suspended sediment (if problematic assess from filtered water sample)
** relates to amount of fine sediment generated and time take to settle (i.e. a large plume may extend for a meter diameter and remain suspended for 5 seconds or more)

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Date ______________ Site code ______________

Government of Western Australia
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SW-WA RIVER HEALTH ASSESSMENT – FIELD SHEETS
PHYSICAL FORM/CATCHMENT IMPACT ASSESSMENT – 100m sampling site

BANKS AND PHYSICAL FORM

AMOUNT of erosion Length of bank affected (%)		
0 to 5%	LB	RB
>5 to 20%	LB	RB
21 to 50%	LB	RB
> 50%	LB	RB

SEVERITY of erosion, and bank stability	Circle	
Severe: ***LITTLE TO NO STRUCTURAL INTEGRITY*** Banks are predominantly bare. Significant sections of erosion (undercutting/slumping) on both outside bends and straight stretches (sediment deposits in river). Exposed roots obvious (where applicable), with significant loss of vegetation in eroding areas. Channel shape, bank shape and depth likely to change in near future.	LB	RB
High: POOR STRUCTURAL INTEGRITY Evidence of bank instability (undercutting/slumping); with signs of soil loss from banks, and possibly areas of sedimentation (i.e. sandbars or toes) and scouring. Some exposed roots (where applicable), with loss of vegetation in eroding areas. Erosion typically around outside bends.	LB	RB
Low-Moderate: GOOD STRUCTURAL INTEGRITY Banks relatively stable – exposed and superficially eroding bank (erosion doesn't penetrate deeply into bank wall) or stabilised by only exotic grasses. Little likelihood of significant change to channel/bank shape, depth or loss of bank material in near future.	LB	RB
Minor: EXCELLENT STRUCTURAL INTEGRITY Banks stable and mostly intact (minor slumping, undercutting or bare banks expected naturally): stabilised by vegetation or bedrock.	LB	RB

Factors affecting bank stability	Circle	
Feral animals	LB	RB
Livestock access (if yes, compete table below)	LB	RB
Human access	LB	RB
Cleared vegetation	LB	RB
Runoff		
Irrigation draw-down		
Flow and waves		
Culvert, bridge, dam		
Drain pipes	LB	RB
Other (specify)		

Stabilisation works Yes ☐ No ☐		
Choose one or more	Circle	
Rock wall protection	LB	RB
Bank matting	LB	RB
Logs/planks strapped to bank	LB	RB
Concrete lining	LB	RB
Revegetation plantings	LB	RB
Fenced human access (deterrent)	LB	RB
Fenced livestock access	LB	RB
Fenced stock watering points	LB	RB
Other (specify)	LB	RB

Indicate livestock types ______________________________ & indicate their impact (major or minor) for each category below.

CATEGORY	MINOR	Tick box	MAJOR	Tick box
Vegetation damage	Only small patches of vegetation grazed		Most groundcover vegetation grazed.	
Bank damage	Isolated areas (1 or 2) of livestock damage		Near continuous livestock damage to stream	
Pugging	Isolated (1or 2) areas of pugging		Extensive pugging along the stream length	
Manure	≤2 significant manure deposits per site		>2 significant manure deposits per site	
Tracks	≤1 track per site		>1 track per site	

POLLUTION SOURCES

Local point source pollution		*None evident* ☐
Potential	**Obvious**	**Indicate type/s:**
Within site	Within site	
Upstream	Upstream	
Downstream	Downstream	

Local non-point source pollution		*None evident* ☐
Potential	**Obvious**	**Indicate type/s:**
Within site	Within site	
Upstream	Upstream	
Downstream	Downstream	

LANDUSE AT SITE - WITHIN 50m FROM EDGE OF STREAM

Circle all applicable for each bank

LB	Conservation	Remnant vegetation	Water Catchment	State Forest	Aboriginal Reserve	Vacant. Crown Land	Agriculture	Pastoralism	Tourism	Mining	Industrial	Urban
RB	Conservation	Remnant vegetation	Water Catchment	State Forest	Aboriginal Reserve	Vacant. Crown Land	Agriculture	Pastoralism	Tourism	Mining	Industrial	Urban

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Date _______________ Site code _______________

Government of Western Australia
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SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
VEGETATION ASSESSMENT - 100m sampling site

RIPARIAN VEGETATION

Riparian zone = a clear distinction in vegetation type between water dependant and non-water-dependent vegetation

Riparian zone ABSENT ☐ >>>> Due to: **human impact** ☐ **natural feature (eg bedrock)** ☐ **fire/flood...** ☐ **unknown** ☐

Riparian zone PRESENT ☐ [complete rest of box]

Indicate riparian layers PRESENT*?	circle			**Width of riparian zone** Left bank _____m Right bank _____m
Ground layer (i.e. sedges, rushes)	yes	no	reduced	**Dominant riparian species** (if unknown write: refer to photographs):
Shrub layer (woody)	yes	no	reduced	
Tree layer	yes	no	reduced	

* this refers to the presence of riparian species (intactness is incorporated below). Note: if only 1 or 2 shrubs remain (for example) circle 'no'.

STREAMSIDE ZONE VEGETATION (FIRST 10m) - NATIVE AND EXOTIC VEGETATION

Percentage cover	0%		1 - 10%		10 to 50%		50 - 75%		> 75%	
	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
Bare ground (not bedrock)										
Ground cover/grasses/sedges/rushes										
Shrubs (woody, multi-stem)*										
Trees < 10m										
Trees > 10m										

*Shrubs include Blackberry, Tea trees

STREAMSIDE ZONE VEGETATION (FIRST 10m) - EXOTIC VEGETATION

Proportion (%) of exotic vegetation in each vegetation layer	0%		1 - 10%		10 to 50%		50 - 75%		> 75%	
	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
Ground cover/grasses/sedges/rushes										
Shrubs (woody, multi-stem)*										
Trees < 10m										
Trees > 10m										

STREAMSIDE ZONE VEGETATION (FIRST 10m) - NATIVE WOODY VEGETATION

Recruitment evidence	*Recruitment type*	*Extent of recruitment*	*Recruitment health*
None	Trees	Limited	Poor
Natural	Shrubs	Moderate	Moderate
Planted	Both	Abundant	Healthy

ADJACENT ZONE VEGETATION (10 to 100m)

Tick box for the DOMINANT feature in each zone	10 to 50m		50 to 100m		100m +	
	LB	RB	LB	RB	LB	RB
Minimal vegetation Typical of areas of urban development / industry / mining						
Weeds/Grasses May have a few scattered trees (typical of agriculture)						
Remnant vegetation Mostly native trees and/or shrubs (may have exotic understorey).						
Forest Native trees, shrubs and understorey. Few or no exotics.						
Plantations **Type:** _______________						
Other (describe)						

COMMENTS (VEGETATION IN ADJACENT ZONE): _______________

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Date ________________ Site code ________________

Government of Western Australia
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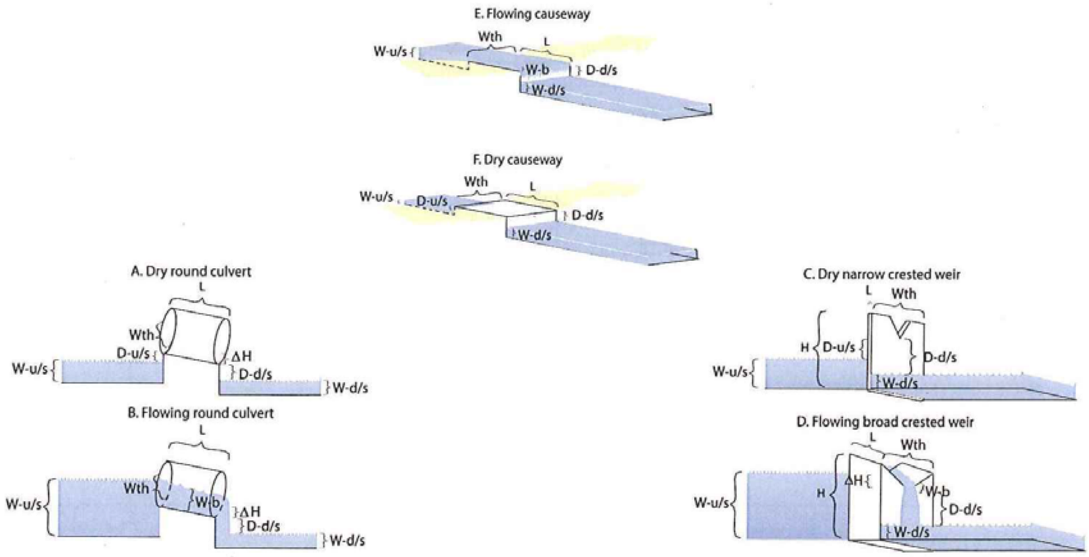
SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
BARRIER ASSESSMENT - 100m sampling site

NATURAL AND ARTIFICIAL BARRIERS IN 100m SITE

No barriers ☐

Description		Barrier 1	Barrier 2	Barrier 3
	Type of Barrier – artificial (see bottom of page for types) or natural			
	Longitude or Northing			
	Latitude or Easting			
	Tick when photo taken			
L	Length (longitudinal) (m)			
ΔH	Height difference across barrier (m)			
Wth	Width or diameter (cross-section) (m)			
H	Height (m)			
W – b	Water depth across barrier (m)			
D – d/s	Downstream drop (bottom of barrier to water) (m)			
W – d/s	Water depth – downstream (m)			
D – u/s	Upstream drop (bottom of barrier to water) (m)			
W – u/s	Water depth – upstream (m)			
	Blockage – overgrowth or sedimentation % cross-sectional area			
	Flow over barrier (either measure or describe)			
	Structure material (e.g. concrete, timber, steel, plastic, loose rock)			
	If culvert, number or pipes or boxes			
	Barrier floods at flow condition (extremely high, high, medium, low flows)			

Note: Not all of the above measurements will apply to natural barriers.



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Department of Water

SW-WA RIVER HEALTH ASSESSMENT – FIELD SHEETS
100m sampling site

NATURAL OR ARTIFICIAL BARRIERS OUTSIDE 100m SITE

Artificial barriers outside 100m site (upstream or downstream)		Circle
Unknown	None	Yes (see below)
Description and distance from site (if time, assess as per previous page).		

Natural barriers outside 100m site (upstream or downstream)		Circle
Unknown	None	Yes (see below)
Description and distance from site (if time, assess as per previous page).		

CHANNELISATION

Signs of channelisation	No ☐	Yes ☐ (describe below)

Note whether channelisation is due:

1. **Direct causes**: deepening and straightening by humans to increase water flow (e.g. to reduce flooding), or
2. **Indirect causes:** deepened systems with more vertical banks due to bank erosion and bed scouring; a result of increased flows from changes such as catchment clearing or hydrological modifications.

WATER VELOCITY (FLOW) ACROSS 100m SAMPLE SITE

Flow information is recorded on the Macroinvertebrate Sampling Sheet and WQ 2 Sheet, if neither is being used for this assessment use space provided below.

Meter or Method used ______________________ units ________ Velocity__________

WEATHER CONDITIONS

Rain in past week	Tick box
Yes	
No	
If known, mm	

Cloud cover	%
Day 1	
Day 2	

Rain	Tick box
Day 1	Yes ☐ No ☐
Day 2	Yes ☐ No ☐

Weather comments ______________________________

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Date ________________ Site code ________________

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SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
WATER QUALITY 1: GRAB AND IN-SITU SAMPLES

Recorders name ____________________________

PRE - INSTRUMENT CALIBRATION

Instrument Type ____________________________ Instrument Number ____________________________

Pre – field calibration	Electrical Conductivity (mS/cm)	pH 7	pH 10	Dissolved Oxygen (% sat)	Salinity	Temperature
Pre reading						
Post reading						

NOTE: In most cases salinity and temperature are not calibrated prior to use.

Circle:

Conductivity units	uncomp	comp (25°C)	
Conductivity setting	fresh	salt	none
Salinity setting	2311	Other (indicate):	
Electrical conductivity calibration solution used	1.413 mS/cm	Other (indicate):	
Dissolves oxygen calibrated to	100% sat. in air	Other (indicate):	

Barometric pressure from BOM (if required) for DO calibration

Full state: 1900 955 366
Coastal: 1900 969 902

_________ hPa ______ mmHg
(mmHg = hPa x 0.7502)

GRAB WATER QUALITY

Water quality samples taken

Date ______________________ Time ______________________

Sample number ______________________ COC ______________________

IN-SUTU WATER QUALITY

	Date	Time (24 hrs)	Salinity (ppt)	pH	Dissolved oxygen (mg/L)	Dissolved Oxygen (% sat)	Electrical Conductivity (mS/cm)	Temperature (°C)	Add any others here	
Surface										
Bottom										

Note: Usually only surface water samples are taken.

POST - INSTRUMENT CALIBRATION

Post – field calibration	Electrical Conductivity (mS/cm)	pH 7	pH 10	Dissolved Oxygen (% sat)	Salinity	Temperature (°C)
Pre reading						
Post reading						

NOTE: In most cases pH 10 does not require post calibration. Dissolved oxygen is only checked, not post calibrated

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Date ______________ Site code ______________

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SW-WA FARWH – FIELD SHEETS
WATER QUALITY 2: DIEL DISSOLVED OXYGEN AND TEMPERATURE

Recorders name ______________________

PRE-DEPLOYMENT MEASUREMENTS

Deployment date ______________ Deployment time ______________

Probe Letter	Pump Number	Field air calibration			Water readings (mg/L)	Pump running (yes or no)	Water depth to first inlet hole (cm)	Actual water depth (m)
		Pre-cal (mg/L)	Span (%)	Post-cal (mg/L)				

LOCATION OF LOGGERS

Circle one each category (except for in-stream vegetation)

Location in stream	In main flow	Off main flow	Other (describe)	
Angle loggers deployed	90° (vertical)	45 to 90°	< 45°	
Canopy cover over loggers	0%	10 to 50%	50% to 80%	100%
In-stream vegetation* (tick all applicable)	None	Emergent	Submerged	Floating
Density of in-stream, vegetation*	N/A	Sparse	Medium	Dense
Density of algae in water column*	None	Sparse	Medium	Dense
Riffles/cascades (upstream of loggers)**	None		If yes ____________	m upstream

* within 1m from loggers. ** within 50m from loggers

Notes ____

WATER VELOCITY (FLOW) AT LOGGER SITE

Meter or Method used ____________________ units ________ Velocity__________

POST DEPLOYMENT MEASUREMENTS

Retrieval date ____________ Retrieval time ____________

Probe Letter	Pump running	Condition of HOUSING	Condition of MEMBRANE		Water reading (mg/L)	Air reading (mg/L)
	No Slow Fast	Clean Slightly dirty Very dirty	Clean Slightly dirty Very dirty	Bubbles No bubbles		
	No Slow Fast	Clean Slightly dirty Very dirty	Clean Slightly dirty Very dirty	Bubbles No bubbles		

Weather observations in past 24 hours and/or any noticeable changes to site or loggers ______________________________

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Date ______________ Site code ______________

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SW-WA FARWH – FIELD SHEETS
WATER QUALITY 3: MULTI PARAMETER LOGGING

Recorders name ______________________

PRE-DEPLOYMENT INSTRUMENT CALIBRATION

Instrument Type ________________ Logger Number ____________ Handpiece Number ____________

Pre – field Calibration	Salinity	pH 7	pH 10	Dissolved Oxygen (% sat)	Electrical Conductivity (mS/cm)	Temperature (°C)
Reading						
Calibrated to						

Barometric pressure from BOM (if required) for DO calibration

Full state: 1900 955 366
Coastal: 1900 969 902

________ hPa ______ mmHg
(mmHg = hPa x 0.7502)

NOTE: In most cases salinity and temperature are not calibrated prior to use.

LOGGING INFORMATION

Deployment date ______________ Deployment time ______________

Parameters set to log (tick)
[ ] Dissolved Oxygen [ ] Temperature [ ] Electrical conductivity
[ ] pH [ ] Turbidity [ ] Other ______________

Loggers set to record every ______________ mins for ______________ days / hours (circle)

LOCATION OF LOGGERS

Circle one option for each category (except for in-stream vegetation)

Location in stream	In main flow	Off main flow	Other (describe)	
Angle loggers deployed	90° (vertical)	45 to 90°	< 45°	
Canopy cover over loggers	0%	10 to 50%	50% to 80%	100%
In-stream vegetation* (tick all applicable)	None	Emergent	Submerged	Floating
Density of in-stream, vegetation*	N/A	Sparse	Medium	Dense
Density of algae in water column*	None	Sparse	Medium	Dense
Riffles/cascades (upstream of loggers)**	None		If yes ____________	m upstream

* within 1m from loggers. ** within 50m from loggers

Notes ____

WATER VELOCITY (FLOW) AT LOGGER SITE

Meter or Method used ________________ units ______ Velocity __________

LOGGER REMOVAL

Logger removal date __________ Logger removal time __________

Weather observations in past 24 hours and/or any noticeable changes to site or loggers ______________________
____

Post – field Calibration	Salinity	pH 7	pH 10	DO%	Electrical Conductivity (mS/cm)	Temperature (°C)
Reading						
Calibrated to						

NOTE: In most cases pH 10 does not require post calibration. Dissolved oxygen is only checked, not post calibrated

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Date ______________ Site code ______________

Government of Western Australia
Department of Water

SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
FISH AND CRAYFISH

Recorders name ____________________ Date traps deployed ____________________

☐ (tick) Local Fisheries WA officer called (1800 815 507) up to one day prior (need permit number, car registration and samplers names)

TRAP SETTING – BOX TRAPS

Trap #	Small trap (S) or Large trap (L)	Left bank (LB) Right bank (RB) or Centre (C)	Water Depth (cm)	Describe location of trap e.g. in woody debris, under log, amongst emergent macrophytes, in full sun, % shaded, under overhanging vegetation, amongst tree roots.

TRAP SETTING – FYKE NETS

TYPE		Water Depth (cm)	% stream width *	Comments e.g. fyke in eddy, gaps between wings and bank or river bottom
Dome (D) or Rectangle (R)	Upstream (US) or Downstream DS)			

*If both wings are fully extended to edge of bank this would be 100%. If spaces exist between wings and bank or between wings and surface of water (due to depth), estimate coverage and provide explanation of set-up.

LIST FISH/CRAYFISH SPECIES OBSERVED BUT NOT CAUGHT

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Date ______________ Site code ______________

Government of Western Australia
Department of Water

SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
FISH AND CRAYFISH

Recorders name ______________________ Date traps collected ______________________

TRAP COLLECTION

Trap #		Size class (mm)					Evidence of Reproduction*	Comments (for example) • staining, parasites, disease, injury • smallest size gravid individual • size of largest individual *Note size of marron over 76mm*
	Fish	0-20	20 - 50	50 - 100	100 +	Other	none	
	Crayfish	0-20	20 - 50	50 - 76	76 - 100	100+	✓ (few)	
	Large fish	0-100	100-200	200-400	400+	Other	✓✓ (many)	

**Evidence of reproductive condition includes gravid females &/or characteristic colours*

Legend
WM = Western Minnow, **TM** = Trout Minnow, **BSM** = Black-stripe Minnow, **NF** = Nightfish, **WPP** = Western Pygmy Perch, **BPP** = Balstons Pygmy Perch, **SWG** = South West Goby, **SRG** = Swan River Goby, **COB** = Cobbler, **JOL** = Jollytail, **GAM** = Gambusia, **1SPOT** = One spot live bearer, **WH** = Western Hardy Head, **ELONG** = Elongata, **BB** = Black Bream, **RP** = Redfin Perch, **RT** = Rainbow Trout, **BT** = Brown Trout, **MM** = Mud Minnow, **GIL** = Gilgie, **GH** = Hybrid Gilgie, **MAR** = Marron, **HMAR** = Hairy Marron, **K** = Koonac, **KX** = Koonac sp X, **Y** = Yabbie, **FS** = Freshwater Shrimp.

Large fish include: cobbler, trout, redfin, lamprey.

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Date ________________ Site code ________________

Government of Western Australia
Department of Water

SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
MACROINVERTEBRATES: AUSRIVAS FIELD SHEET

Recorders name ____________________________

DATE SAMPLE TAKEN ____________________________ TIME SAMPLE TAKEN ______________________________

COLLECTED BY ______________________________ PICKED BY __________________ AND ________________

HABITAT __________________________________ % OF 100 m reach __________________________________

SAMPLE NUMBER ____________________________ COC NUMBER ______________________________________

SAMPLING CONDITIONS [ ] good [ ] average [ ] poor

PICKING CONDITIONS [ ] good [ ] average [ ] poor

BREAKDOWN OF 10m SAMPLING AREA

Mineral Substrate	%	**Habitat surface area**	%	*Density (circle) (1= sparse, 5 = dense)*
Bedrock		Mineral substrate		
Boulders (>256mm or scorer ball)		Emergent macrophyte		1 2 3 4 5
Cobble (64 to 256mm or cricket to soccer ball		Submerged macrophyte		1 2 3 4 5
Pebble (16 to 64mm or 5c piece to cricket ball)		Floating macrophyte		1 2 3 4 5
Gravel (4 to 16mm or raw sugar to 5c piece)		Detritus		1 2 3 4 5
Sand (1 to 4mm)		Algal Cover		1 2 3 4 5
Silt (<1mm)		Riparian veg draped in water		
Clay		Other (e.g. woody debris)		
Total	100%	Total (may be > 100%)		

DEPTH

Depth macroinvertebrate sample taken (circle) <25cm <50cm <100cm < 200cm > 200cm

WATER VELOCITY (FLOW) AT MACROINVERTEBRATE SITE

Meter or Method used ________________________ units ________ Max velocity ______________ Min velocity____________

BOX SUB-SAMPLER TALLY

Number of cells picked ______________

Number of cells in box ______________

Total number of macroinvertebrates picked ______________

Comments (if any)

____

____

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Appendix C — System scale flow observations

Photographs of flow observation points (refer to Figure 4 for locations).

14 February 2011

12 April 2011

14 March 2011

10 May 2011

Figure C1 Upland site (447 Logue Brook Dam Road), pool, looking upstream

February 2011

No image

14 April 2011

18 March 2011

12 May 2011

Figure C2 Flow site 1, South Western Highway bridge, looking upstream

15 February 2011

12 April 2011

14 March 2011

10 May 2011

Figure C3 Lowland pool (163 Clifton Road), pool, looking downstream

15 February 2011

12 April 2011

14 March 2011

10 May 2011

Figure C4 Lowland pool (163 Clifton Road), riffle, looking upstream

February 2011

No image

14 April 2011

18 March 2011

12 May 2011

Figure C5 Flow site 2, Clifton Road bridge, looking downstream

February 2011

No image

14 April 2011

18 March 2011

12 May 2011

Figure C6 Flow site 3, Brockman Road bridge, looking downstream

February 2011

No image

14 April 2011

18 March 2011

12 May 2011

Figure C7 Flow site 4,Trotter Road bridge, looking downstream

Appendix D — Dissolved oxygen at the upland site and flow at Logue Below gauge

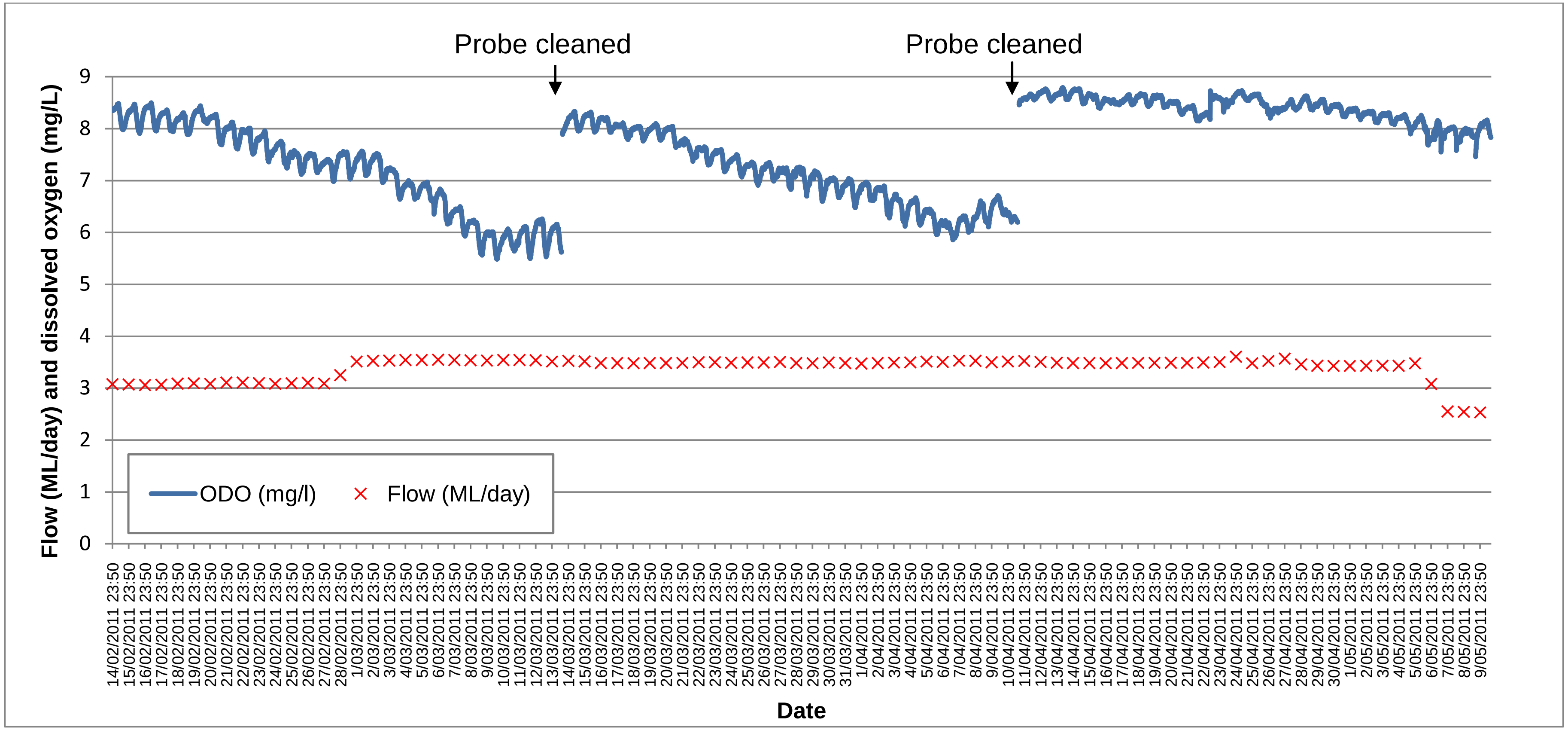

Figure D1 Flow recorded at Logue Below gauge (megalitres per day) and dissolved oxygen recorded at the upland site (milligrams per litre)

Note: dissolved oxygen levels appeared to decline at the upland site between monthly visits; this is likely to be due to accumulation of silt on the surface of the optical dissolved oxygen probe which was cleaned during each visit.

Appendix E — Map disclaimer and data acknowledgements

The maps in this publication were produced by the Department of Water with the intent that they be used as illustrations in this report *Assessment of ecological health and environmental water provisions in the Logue Brook*, *February to May 2011*. While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

The Department of Water acknowledges the following datasets and their custodians in the analysis of data and production of the maps:

Dataset Name	Custodian acronym	Metadata year
Hydrography, linear (hierarchy)	DoW	2007
Road centrelines	Landgate	2010
Western Australian towns	Landgate	2001
WA Coastline	DoW	2006
Water Information Network sites	DoW	2006
Land use in Western Australia, version 2	DAFWA	2001
1 second SRTM derived digital elevation model (DEM) v1.0	GA	2009
Perth metro zone 2006 50cm z50	Landgate	2009

The maps have been produced using the following data and projection information:

Vertical Datum: Australian Height Datum (AHD)

Horizontal Datum: Geocentric Datum of Australia (GDA) 1994

Projection System: Map Grid of Australia (MGA) 1994 Zone 50

Original ArcMap documents (*.mxd):
GIS_projects\gisprojects\Project\B_Series\B5047\000_related_tasks\
011_Harvey_Logue\mxds

Shortened forms

AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BoM	Bureau of Meteorology
CEAH	Centre of Environmental Applied Hydrology
CENRM	Centre of Excellence in Natural Resource Management
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFWA	Department of Agriculture and Food Western Australia
DEC	Department of Environment and Conservation
DEM	digital elevation model
DoE	Department of Environment (former)
DoF	Department of Fisheries
DoW	Department of Water
EWP	environmental water provision
EWR	ecological water requirement
FARWH	Framework for the Assessment of River and Wetland Health
GA	Geoscience Australia
GDA	Geocentric Datum of Australia
IOCI	Indian Ocean Climate Initiative
MGA	Map Grid of Australia
MDFRC	Murray Darling Freshwater Research Centre
NTU	nephelometric turbidity units
NWC	National Water Commission
ODO	Optical dissolved oxygen
SRTM	Shuttle Radar Topography Mission
SWIRC	South-West Index of River Condition
SWWA	south-west Western Australia
WC	Water Corporation
WRMOS	water resource management operating strategy
YOY	young of year

Glossary

Abstraction	The permanent or temporary withdrawal of water from any source of supply, so that it is no longer part of the resources of the locality.
Allochthonous source	A source of organic matter that arises from outside of the waterway i.e. leaf litter, woody debris.
Autochthonous source	A source of organic matter that arises from within the waterway i.e. macrophytes, phytoplankton, periphyton.
Baseline data	Data representing the existing elements, characteristics and trends in an area to provide a measure against which change can be assessed.
Benthic habitat	Habitat available to biota that dwell on or in the sediment at the bottom of a water body.
Berried	Bearing eggs.
Biota	Living things e.g. flora and fauna.
Carapace (freshwater crayfish)	Protective shell covering the head and thorax of freshwater crayfish.
Confluence	Running together, flowing together; such as where a tributary joins a river.
Diel	Relating to 24 hour period.
Dissolved oxygen	The concentration of oxygen dissolved in water or effluent, measured in milligrams per litre (mg/L) or % saturation.
Diurnal cycle	A pattern that recurs every 24 hours.
Ecological health	The extent to which ecological processes and functions are resilient and adaptive, giving rise to self-regulation, stability and diversity in populations and ecosystems.
Ecological values	The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of these systems.
Ecological water requirements	The water regime needed to maintain the ecological values (including assets, functions and processes) of water-dependent ecosystems at a low level of risk.

Ecological water provision	The water regime provided as a result of the water allocation decision-making process taking into account ecological, social and economic values. It may meet in part or in full the ecological water requirements.
Ecosystem	A community or assemblage of communities of organisms, interacting with one another, and the specific environment in which they live and with which they also interact (e.g. a lake). Includes all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Ectoparasite	A parasite that lives on the exterior of another organism.
Endemic species	Unique to a particular geographic location.
Epiphtye	A plant or other organism that lives on the surface of plants without deriving nutrition from them.
Flow	Streamflow; may be measured as m^3/yr, m^3/d or ML/yr. May also be referred to as discharge.
Grab sample	Manual water sample obtained in a bottle for the purpose of analysing its water quality. Usually taken in flowing water just below, but not touching the surface.
Gravid	The condition of a fish when carrying eggs internally.
Habitat (aquatic)	Environments in which aquatic species live, influence or use.
Harvey Water	Harvey Water is the trading name for the South West Irrigation Management Cooperative Ltd. It is a private irrigators' cooperative.
Interstitial space	An opening or space, especially a small or narrow one, within sediments or soil.
Macrophyte (aquatic)	Rooted aquatic plants e.g. eelgrass.
Native species	A species occurring in a region or ecosystem as a result of natural processes only.
Nuptial colours	Colouring relating to mating or occurring during the mating season.

pH	A symbol denoting the logarithmic concentration of hydrogen (H) ions in solution. A measure of acidity or alkalinity in water in which pH 7 is neutral, values above 7 are alkaline and values below 7 are acid.
Refugia (in a waterway)	Sections of a stream that provide habitat and sufficient water quality and quantity to preserve aquatic biota during low-flow periods.
Riparian vegetation	Vegetation growing along banks of watercourses, including the brackish upstream reaches of estuaries..
Species richness	Number of species in a sample or population.
Substrate (in a waterway)	Physical substrate: the silt, sand and stone components of the streambed; biological substrate: organic matter such as woody debris, sticks, leaves and decomposing matter.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Turbidity	Opaqueness of water due to suspended particles in the water causing a reduction in the transmission of light. The units of measurement are NTU (nephelometric turbidity units).
Urogenital papillae	A small tube near the anus through which eggs or sperm are released.
Water Corporation	A government-owned organisation that supplies water, wastewater and drainage services in Western Australia.
Water quality	The physical, chemical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and/or to any human need or purpose.
Water resource management operating strategy	A signed agreement between a licensee and the Department of Water regarding the management of specific water resources.
Young of year	Animals born within the past year.

Volumes of water

One litre	1 litre	1 litre	(L)
One thousand litres	1000 litres	1 kilolitre	(kL)
One million litres	1 000 000 litres	1 Megalitre	(ML)
One thousand million litres	1 000 000 000 litres	1 Gigalitre	(GL)

Species list

Aquatic fauna collected or observed during this study or previous studies

Common name	Latin name	Organism type	Native or non-native (or distribution)
Brown trout	*Salmo trutta*	Fish	Non-native [3]
Freshwater cobbler	*Tandanus bostocki*	Fish	Native
Goldfish	*Carassius auratus*	Fish	Non-native
Mosquitofish	*Gambusia holbrooki*	Fish	Non-native
Nightfish	*Bostockia porosa*	Fish	Native
One-spot livebearer	*Phalloceros caudimaculatus*	Fish	Non-native
Redfin perch	*Perca fluviatilis*	Fish	Non-native
Rainbow trout	*Oncorhynchus mykiss*	Fish	Non-native
Swan River goby	*Psuedogobius olorum*	Fish	Native
Western minnow	*Galaxias occidentalis*	Fish	Native
Western pygmy perch	*Nannoperca vittata* [1]	Fish	Native
Gilgie	*Cherax quinquecarinatus*	Crayfish	Native
Smooth marron	*Cherax cainii*	Crayfish	Native
Yabbie	*Cherax* sp. *(yabbie)* [2]	Crayfish	Non-native
Water rat	*Hydromys chrysogaster*	Mammal	Native [4]
Blackfly larvae	*Simuliidae* spp.	Macroinvertebrate	Australia wide [5]
Caddisfly larvae	*Oecetis* sp. and *Ecnomus* sp.	Macroinvertebrate	Australia wide
Freshwater shrimp	*Palaemontes australis*	Macroinvertebrate	Australia wide
Mayfly nymph	*Tasmanocoenis* sp.	Macroinvertebrate	Australia wide
Midge larvae	Chironomidae family	Macroinvertebrate	Australia wide
Pea clam	*Sphaeridae* spp.	Macroinvertebrate	Australia wide
Snail	*Physidae* spp.	Macroinvertebrate	Non-native [6]
Water boatman	*Corixidae* spp.	Macroinvertebrate	Australia wide
Worm	Oligochaeta class	Macroinvertebrate	Australia wide

Notes:

[1] Previously *Edelia vittata.*

[2] Individuals found could be *C. albidus* or *C. destructor;* the appropriate species name for yabbies present in Western Australia is currently under review.

[3] For fish and crayfish refer to Morgan et al. (2011).

[4] DEC (2010).

[5] There is limited information available about the nativeness of macroinvertebrate species; in lieu of this the distribution of each species is listed (refer to MDFRC 2009).

6 Smith (1992) cited in Davis and Christidis (1997).

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Personal communications

Ian Loh

Program Manager, Water Allocation Planning, Department of Water

Water Science
technical series

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Department of **Water**
168 St Georges Terrace, Perth, Western Australia
PO Box K822 Perth Western Australia 6842
Phone: (08) 6364 7600
Fax: (08) 6364 7601
www.water.wa.gov.au

8430 26 0512