Rich-Avon Weir Connection Feasibility Study

NORTH CENTRAL CMA

Final

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Introduction

The Rich-Avon Weir, which is located downstream of the confluence of the Richardson and Avon Rivers in central Victoria, was designed to direct flows from the Avon-Richardson River into Lake Batyo Catyo to supply Stock and Domestic water to the region. The construction of the Wimmera-Mallee Pipeline, which was completed in 2010, means that Lake Batyo Catyo is no longer required for water supply purposes. As a consequence, the Richardson River is not needed to convey water supply flows *en route* to Lake Batyo Catyo and therefore the Rich-Avon Weir Pool no longer receives managed inflows. The weir pool last filled during the 2011 floods, but has since dried completely (as of September 2015).

When it was operating as a water supply and transfer system and hence full, the Rich-Avon Weir Pool was highly valued by the local community for its ecological, recreational and amenity values. The weir pool supported a number of significant species including Murray Cod (*Maccullochella peelii*) and the federally listed Growling Grass Frog (*Litoria raniformis*). The weir pool was also popular with anglers and was a highly valued camping spot.

The Wimmera-Mallee Pipeline has made the supply system far more efficient and achieved greater supply security for water users and the environment. However, some of the weir pools, water storages and water supply channels that formed part of the old Stock and Domestic Supply System coincidentally supported environmental and recreational values. Decommissioning the old Stock and Domestic Supply System meant that some of those values no longer received that additional water.

A 1000 ML environmental entitlement was established as part of the Wimmera-Mallee Pipeline Project to mitigate impacts to off-stream wetlands associated with the decommissioning of the old Stock and Domestic Supply System. The local community has proposed that some or all of that environmental entitlement should be used to maintain water levels in the Rich-Avon Weir Pool in the hope that it may once again support high ecological, recreational and amenity values.

Aim and structure of this study

To assist in managing the Rich-Avon Weir Pool into the future, the North Central CMA engaged Jacobs to assess the feasibility of supplying the weir pool with water from the Wimmera-Mallee Pipeline. To do this, Jacobs have reviewed the species and communities historically supported by the weir pool, the species and communities that would have been supported prior to the weir's construction and those that would be likely to return should the weir pool be inundated. To inform this assessment, the following activities were undertaken.

1. Consultation with the local community to understand their expectations and visions for the weir pool.
2. A combination of literature, database searches, consultation with local stakeholders and field surveys to describe the environmental values that were associated with the weir pool.
3. A hydrological and hydrogeological assessment to estimate how frequently the weir pool would fill without managed transfers and to estimate how long the weir pool would hold water.
4. A detailed bathymetric survey to assess whether there were any deep pools in the downstream half of the weir pool. Deep pools are likely to be important ecological features, and could act as refuges during dry conditions for fish and other aquatic biota.

Management scenario assessment

The feasibility of five management scenarios were assessed by considering the major benefits and risks associated with each scenario. Each scenario is summarised below, including the hydrology underpinning each one, the amount of environmental water required, the major ecological benefits and risks and an assessment of the scenario's feasibility.

Scenario 1: Provide environmental water to keep the weir pool at or near the previous operational level

- Intent of scenario: This scenario mimics, as far as is practical, the situation as it would have been at the weir pool during its operation as part of the Stock and Domestic supply when it was a highly valued community asset and supported a range of aquatic species and communities.

- Hydrology: The water depth in the centre of the weir pool would be between 2 and 3 m.

- Amount of environmental water required: As a 'best case', with only limited loss from seepage, it is estimated that about 500 ML of water would need to be provided to the weir pool each year to keep it near the previous operational level (more than 3,000 ML/year may be needed under a 'worst case' seepage rate).

- Major benefits: This scenario would benefit the water dependent vegetation that has developed at the weir pool over the time of its operation. The deep water with engaged vegetation and inundated snags would also provide habitat suitable to support fish and frogs. A range of common frogs, turtles, birds and mammals would also benefit. The weir pool would also have social value, once again being a good place to camp and swim (assuming the water quality is suitable).

- Major risks: The major risks are that water is provided but the weir pool still does not support the highly valued species and communities it did when it was in operation. For example, all of the fish species that were present in the weir pool were the result of stocking or introductions (the natural fish community of the Richardson River is likely to be limited). These species would therefore need to be stocked again. This may not be a problem, however, it does rely on the involvement of an additional agency (likely Fisheries Victoria).

  Surveys conducted as part of this study suggest that is unlikely that sustainable populations of Growling Grass Frogs persist in the landscape and there is a risk that water could be provided but Growling Grass Frogs do not colonise. Another major risk is that water quality could decline significantly without the passing flow that was typical when the weir pool was in operation.

- Assessment of feasibility: As this scenario requires a relatively large volume of environmental water and is likely that only common species would benefit, it is not assessed to be feasible. The cost of connecting the pipeline to the weir pool is also likely to reduce the feasibility of this scenario.

Scenario 2: Provide environmental water to keep the weir pool at or near the 50% of the previous operational level

- Intent of scenario: The second management scenario is designed to use less water than the first scenario, but to provide refuges for aquatic biota between natural filling events.
- Hydrology: At half the previous operational level, the water depth in the centre of the channel would be approximately 1.5 m. The weir pool fills naturally to greater than 300 ML on average approximately three out of four years.

- Amount of environmental water required: The 'best case' is that about 240 ML of water is needed each year to keep the weir pool at a minimum half of the previous operational level (more than 2,000 ML/year may be required under a 'worst case' seepage rate).

- Major benefits: As with Scenario 1, the water dependent vegetation that has developed at the weir pool would benefit. The permanent inundation between natural filling events would provide some habitat suitable to support fish and frogs. A range of common frogs, turtles, birds and mammals would also benefit. The weir pool would also retain some social value when it was full.

- Major risks: The major risks for Scenario 2 are the same as Scenario 1, namely that water is provided but the weir pool still does not support the highly valued species and communities it did when it was in operation (e.g. fish and Growling Grass Frogs). Water quality degradation without the passing flow is also a risk.

- Assessment of feasibility: As with Scenario 1, it is assessed that the volume of environmental water required for scenario 2 is relatively high considering that only marginal environmental value is likely to be realised. The cost of connecting the pipeline to the weir pool is also a factor in reducing the feasibility of this scenario.

Scenario 3: Do not provide environmental water but retain the weir

- Intent of scenario: The third environmental water scenario retains the weir but does not provide environmental water. As the weir gates are closed, essentially the weir pool is currently being managed as per this scenario.
- Hydrology: The weir pool fills completely naturally on average 1 in 2 years and to greater than 300 ML 3 in 4 years. Filling generally occurs in winter. Under a ‘best case’ seepage rate, the weir pool could hold water up to 22 months with no inflows, but would dry completely in dry periods (such as is currently).

- Amount of environmental water required: Not applicable.

- Major benefits: This scenario would likely support the water dependent vegetation that has developed at the weir pool, although some retraction is likely, especially during dry times. The frequent inundation would also benefit a range of common species such as frogs, turtles, birds and mammals. Although there would be occasional dry times, the weir pool would also provide social value for good proportions of the year following inundation.

- Major risks: This scenario would not be suitable to support fish as the weir pool dries occasionally (and there are no refuge pools to hold water). The inconsistent inundation pattern at the weir pool is also unlikely to support Growling Grass Frogs, assuming they colonise at all.

- Assessment of feasibility: This scenario is feasible because although the environmental values are limited, it does not require a significant investment in environmental water. This scenario would also provide some social value. The major consideration with this scenario is regarding the weir structure, which would require ongoing maintenance to ensure its safe operation.

Scenario 4: Do not provide environmental water and remove or decommission the weir

- Intent of scenario: The fourth scenario returns the river flow to closer to its natural state (nothwithstanding diversions and farm dams) by removing or decommissioning the weir and allowing all natural flows to pass downstream. The passing of the flow could be achieved by opening the weir gates, removing the weir entirely or reinstating the natural path of the river.
- Hydrology: Flow in the river is flashy and it frequently doesn’t flow (only 2% of flows exceed 300ML/day, and the stream ceases to flow 77% of the time).

- Amount of environmental water required: Not applicable.

- Major benefits: This major benefit of this scenario is that it would return the river to a state not reliant on environmental water. The river would over time resemble the rest of the catchment and would be typical of an ephemeral, event driven system.

- Major risks: This scenario would see a decline in biodiversity compared to the artificial aquatic habitat of the weir pool. Over time the weir pool would not support any more species than the rest of the system (although the riparian fencing that has been undertaken at the weir pool is likely to maintain greater biodiversity compared to unfenced areas). The weir pool would provide only limited social value under this scenario.

- Assessment of feasibility: This scenario is feasible because it returns the system to a state not reliant on environmental water or significant management.

Scenario 5: Ecological consequences if deep refuge pools were present in the weir pool

- Intent of scenario: The final scenario considers the ecological consequences if deep refuges were present in the weir pool, which is likely to have been the case in this part of the river prior to the weir's construction. A large amount of sediment has deposited in the channel, filling in these deep pools and making the bed depth uniform throughout the weir pool. Reinstating the deep pools would therefore require excavation works.

- Hydrology: This scenario considers the ecological consequence of having deep pools present in the weir pool that held water for longer than the rest of the channel. Deep pools may provide important refuge habitat for aquatic biota, especially fish, turtles, macroinvertebrates and possibly frogs between natural filling events.

- Amount of environmental water required: Hypothetical deep pools have been considered which would hold water up to 1 m depth when much of the rest of the channel was very shallow or even dry completely. No additional hydrological analysis has been conducted for this scenario. We have considered both a scenario where environmental water keeps these deep pools full and one where eventually these deeper pools would also dry but would provide some habitat for a time between dry periods (which would be the case unless environmental water was supplied). This scenario does not consider whether the weir structure is maintained or decommissioned.

- Major benefits: This scenario would support water dependent vegetation, on account of the environmental water provided. It would also provide habitat for fish and frogs, possibly with a lower volume of environmental water, to support populations between natural filling events.

- Major risks: Although this scenario could provide refuge habitat for fish and frogs between natural filling events, the significant sedimentation that has built up in the bottom of the weir pool would mean that the deep pools would need to be excavated. The major risk is that these deeper pools would fill with sediment relatively quickly, meaning that significant management would be required to maintain them. There are also risks regarding intercepting groundwater and changing the permeability of the bed of the weir pool.

- Assessment of feasibility: Although it is not feasible to provide environmental water to keep the deep pools full, it might be feasible to excavate pools that hold water following natural events (like the river would have historically).

Feasibility summary

It is our assessment that the environmental values that could be supported by the weir pool do not warrant a significant investment in environmental water. The species that made it a highly valued community asset, namely the fish species, were stocked or introduced and may not re-establish at the weir pool even if water was provided.

The other highly significant species, the Growling Grass Frog, although historically present at the weir pool, is unlikely to be currently forming sustainable populations in the local area. As a consequence, there is a high risk that even if water was provided that they still may not recolonise the weir pool.

Environmental water would support the water dependent vegetation communities that have developed at the weir pool over the period of its operation, however, these communities would not have been present historically and would be unsustainable without environmental water. Providing environmental water to the weir pool would also likely benefit a range of common frogs, turtles, birds and mammals.

It is our assessment that three of the five options considered are feasible. Maintaining the weir and allowing the weir pool to fill and empty would provide benefit to the range of common species mentioned above. It would also mean that when inundated, which during wet periods is likely to be often, the weir pool would retain some social and community value.

The second feasible option is to remove or decommission the weir. Over time the river in this area would resemble the rest of the catchment and would assume a state not reliant on environmental water or other significant management intervention. A major risk with this option is the mobilisation of the sediment that has built up in the weir pool and it’s deposition downstream. This would need to be considered futher to fully understand the feasibility of this option.

Finally, it may be feasible to re-establish deep refuge pools that hold water following natural events. These deep pools would have been present in the channel prior to the construction of the weir and would provide ecological benefit to a range of species as refuges in dry conditions.

Acknowledgements

Acknowledgement of Country

The North Central Catchment Management Authority (North Central CMA) acknowledges the Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to the Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.

Contributions to the Rich-Avon Weir Pool Feasibility Assessment

The North Central CMA is grateful to a number of people for providing input into the Rich-Avon Weir Pool Feasibility Assessment.

- Chris Guthrie
- John Morgan
- Kim Walters
- Chris Wood
- Tom O’Shannesy
- Don McAlister
- Rob Loates
- Keith McPherson
- Fiona Burchell

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to assess the feasibility of connecting the Rich-Avon Weir Pool in accordance with the scope of services set out in the contract between Jacobs and the North Central Catchment Management Authority. That scope of services, as described in this report, was developed with the North Central CMA.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the North Central CMA and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the North Central CMA and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

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1. Introduction

The Rich-Avon Weir is located downstream of the confluence of the Richardson and Avon Rivers in central Victoria, approximately 20 km south of the town of Donald. Constructed in 1913, the weir was designed to direct flows from the Avon-Richardson River into Lake Batyo Catyo, which is located approximately 4 km to the east. Lake Batyo Catyo was operated as a balancing water storage from the time the weir was constructed until the completion of the Wimmera Mallee Pipeline Project and supplied Stock and Domestic water to the region.

The construction of the Wimmera-Mallee Pipeline, which was completed in 2010, meant that Lake Batyo Catyo is no longer required for water supply purposes. As a consequence, the Richardson River is not needed to convey water supply flows *en route* to Lake Batyo Catyo and therefore the Rich-Avon Weir Pool no longer receives managed inflows. The weir pool last filled during the 2011 floods, but has since dried completely (as of September 2015).

When it was operating as a water supply and transfer system and hence full, the Rich-Avon Weir Pool was highly valued by the local community for its ecological, recreational and amenity values. The weir pool used to support a number of significant fish species including Murray Cod (*Maccullochella peelii*), Golden Perch (*Macquaria ambigua*), Freshwater Catfish (*Tandanus tandanus*) and Australian Smelt (*Retropinna semoni*) (DEPI 2014). It also sustained populations of the EPBC (vulnerable) and FFG (endangered) listed Growling Grass Frog (*Litoria raniformis*) (GWMWater 2010; VBA 2014). The weir pool also used to be popular with anglers, who targeted Murray Cod, Golden Perch and the introduced Redfin Perch (*Perca fluviatilis*) (DEPI 2014). There are also a number of good camping spots along the weir pool.

The Wimmera-Mallee Pipeline has made the supply system far more efficient and achieved greater supply security for water users. Most of the water savings from the pipeline are being used to improve flow regimes in rivers and streams that had significantly lower than natural flow regimes under the old Stock and Domestic Supply System. However, some of the weir pools, water storages and water supply channels that formed part of the old Stock and Domestic Supply System coincidentally supported environmental and recreational values. Decommissioning the old Stock and Domestic Supply System meant that some of those values no longer received that additional water.

A 1,000 ML environmental entitlement was established as part of the Wimmera-Mallee Pipeline Project to mitigate impacts to **off-stream** wetlands associated with the decommissioning of the old Stock and Domestic Supply System. The local community has proposed that some or all of that environmental entitlement should be used to maintain water levels in the Rich-Avon Weir Pool in the hope that it may once again support high ecological, recreational and amenity values.

1.1 Purpose and scope of the Rich-Avon Weir Pool Connection Feasibility Study

To assist in managing the Rich-Avon Weir Pool into the future, the North Central CMA engaged Jacobs to assess the feasibility of supplying the weir pool with an environmental water entitlement from the Wimmera-Mallee Pipeline.

This assessment has a number of components.

1. We consulted with the local community to understand their expectations and visions for the weir pool. As a high value community asset, it is important that the views and objectives of the local community are considered.
2. A combination of literature, database searches and consultation with local stakeholders were used to describe the environmental values that were associated with the weir pool before it dried up, and brief field surveys in November 2014 and September 2015 were conducted to describe current vegetation, frog, reptile and bird values. We used this review to estimate what species and communities could be reasonably predicted to be supported by the weir pool if it was supplied with environmental water.
3. We conducted a hydrological and hydrogeological assessment to understand how frequently the weir pool would fill without managed transfers and to estimate how long the weir pool would hold water.

4. We conducted a detailed bathymetric survey to assess whether there were any deep pools in the downstream half of the weir pool. Deep pools are likely to be important ecological features, and could act as refuges during dry conditions for fish and other aquatic biota.
5. We used our understanding of the likely inundation and drying cycles of the weir pool and our estimation of the species and communities that could be supported by the weir pool to assess the benefits and risks of a number of different environmental watering scenarios.
6. Finally, we provided an assessment of the feasibility and benefit of providing environmental water and provide recommendations of how the weir pool could be managed into the future.

1.2 Structure of this plan

This report is divided into ten main parts.

- Following this introduction, Section 2 describes the catchment and the landscape surrounding the Rich-Avon Weir Pool.
- Section 3 outlines the hydrology and hydrogeology of the system relevant to the feasibility assessment, including the natural flow regime, operational history and groundwater-surface water interactions.
- The regulatory background of providing environmental water to the weir pool is reviewed briefly in Section 4.
- In sections 5 to 7, the main values of the weir pool are reviewed. Section 5 reviews the social value of the weir pool and Section 6 examines the historic water quality, based on primarily on routine water quality monitoring. In Section 7, we identify the ecological values that would have been present before and during the weir pools operation and currently.
- Section 8 describes our method for determining the inundation duration following inundation of the weir pool.
- Section 9 considers in detail five different management scenarios and outlines the benefit and risk of each.
- In Section 10, we review the overall feasibility of each scenario.
- Finally, Section 11 provides our recommendation for how the weir pool could be managed into the future and outlines future work that needs to be undertaken to

2. Site overview

The following section presents an overview of the catchment of the Rich-Avon Weir Pool.

2.1 Catchment setting

2.1.1 Climate

The Wimmera region has warm to hot summers, with average daily summer temperatures around 28-30°C (DSE 2008). Winter maximums are around 14°C, with frosts occasionally occurring (DSE 2008). The average annual rainfall varies considerably across the catchment from 330 mm/year in the north to 560 mm/year in the south (Egis 2000). Most of the rain falls in winter and spring (DSE 2008).

2.1.2 Hydrophysical characteristics

The Avon and Richardson Rivers both rise on the northern slopes of the Great Dividing Range, west of the township of St Arnaud. The Avon River flows approximately 60 km before joining the Richardson River near Banyena. In total the Avon-Richardson River flows approximately 120 km before terminating at Lake Buloke, north of Donald.

The Richardson River flows mainly through the marine and flat clay plains near Callawadda and Marnoo before flowing through Mallee and flat clay plains into Lake Buloke. Flat clay plains surround Lake Buloke to the north and west, and lunettes to the south and east (Halliwell, 1998).

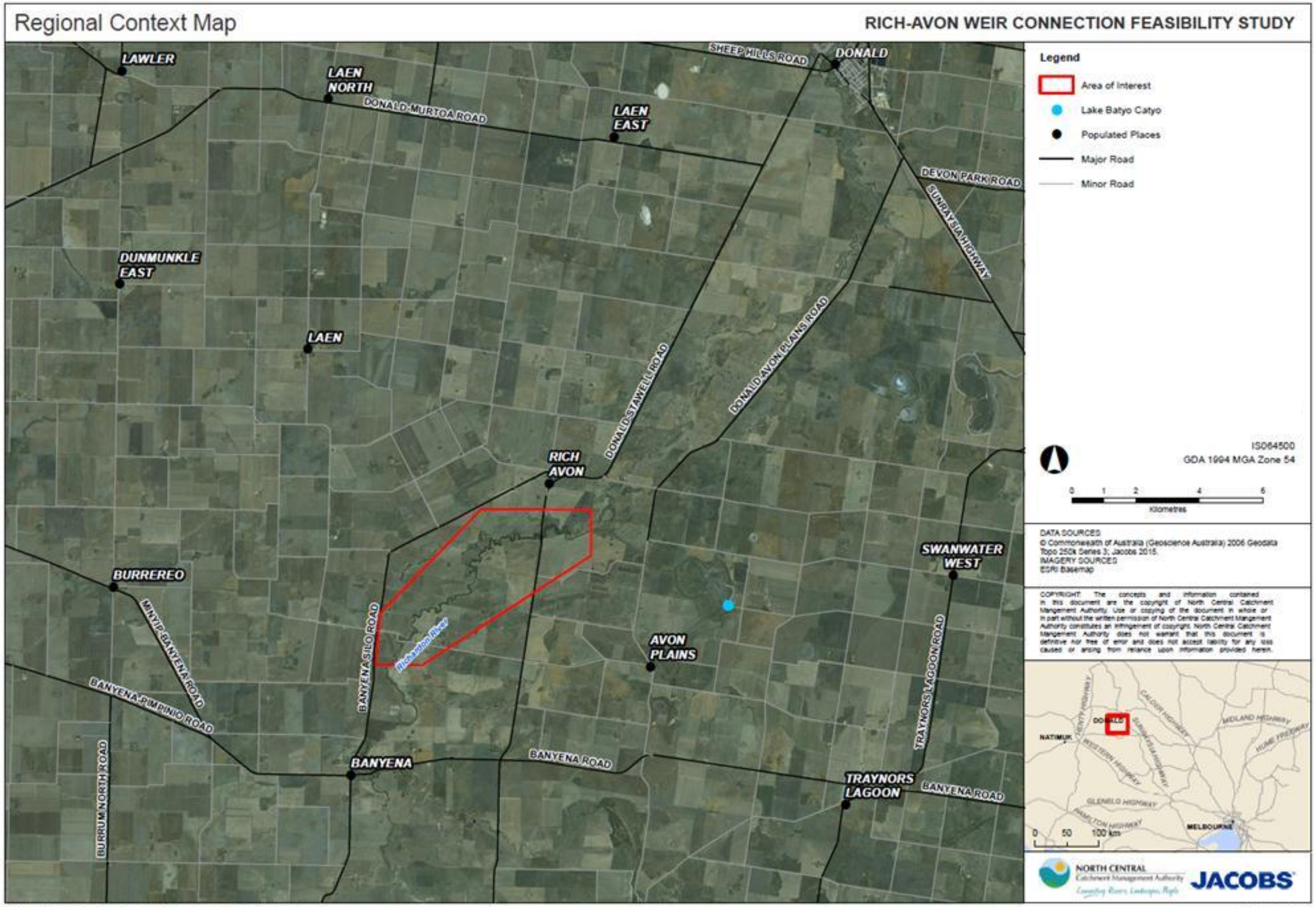
The major tributaries flowing into the Avon River are the Sandy, Paradise and Faulkner Creeks. The major tributaries flowing into the Richardson River are the Wallaloo and Swedes Creeks.

In total the system descends approximately 160 m, however, much of that is in the upper reaches. The lower reaches, downstream of the confluence of the two rivers, has a much shallower grade. The Rich-Avon Weir Pool is located approximately 20 km downstream of the confluence of the Richardson and Avon Rivers (Figure 2-1).

2.1.3 Natural morphology of the river in the area near the weir pool

The Richardson River system would have naturally had deep holes along its course that were 10-100 m long and several metres deeper than the surrounding bed. These deep holes would have held water for longer than the rest of the channel and would have provided refuge habitat for fish, frogs, turtles, macroinvertebrates and aquatic vegetation when the rest of the system dried. Such pools can retain water for several years after a flow event and therefore allow local populations to persist during dry periods. Biota that persist in these refuges become an important source of colonists for when flows return and connect the whole river. Some of the deeper pools in the system were known to be extremely deep (greater than 10 m) and held water for extended periods after natural high flow events (D. McAlister, pers. comm.).

A combination of higher sediment loads from the surrounding catchment, reduced natural river flows and reduced flow velocity in the river channel have caused those pools to fill over time. As a result there are much fewer refuges in the system now and those refuges do not persist for a long period after high flow events. Infilling of pools has occurred throughout the whole system, but is particularly noticeable within the weir pool, because the artificially low flow velocity within the weir pool has caused sediments in the water column to settle and smother the bed (see Section 2.2.3).



DATA SOURCES
© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Jacobs 2015.
IMAGERY SOURCES
ESRI Basemap

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Figure 2-1 Rich-Avon Weir Pool.

2.2 Physical characteristics of the weir pool

2.2.1 Weir construction

Constructed in 1913, the original timber Rich-Avon Weir has been upgraded and replaced over time and in 1961 the bank of the weir pool and of Lake Batyo Catyo was raised to increase the capacity of Lake Batyo Catyo from 2724 to 4788 ML. The current Rich-Avon Weir has a concrete apron with a line of 12 radial gates that can be adjusted to divert water to Lake Batyo Catyo or allow it to pass downstream (Figure 2-2). During its time in operation, the Rich-Avon Weir Pool extended 14 km upstream, and was up to 4 m deep in some places (GWMWater 2010; DEPI 2014).

Figure 2-2 Rich-Avon Weir.

2.2.2 Physical surveys carried out as part of previous studies

GWMWater (2010) estimated the volume of the Rich-Avon Weir Pool by dividing the weir pool into five sections that had relatively consistent width and depth. A number of cross-sections within each section were surveyed to estimate the average cross-sectional area for each section. Next, aerial imagery was used to estimate the length of each section (Figure 2-3).

Using that method, the volume of the entire weir pool was estimated to be approximately 600 ML (the precise estimate was 577 ML; GWMWater 2010). The volume estimates for each of the five sections are presented in Table 2-1.

Figure 2-3 Rich-Avon Weir Pool indicating river sections as defined in GWMWater (2010) to estimate weir pool volume (Figure from page 57 of the Draft *Lake Batyo Catyo and Rich-Avon Weir Management Plan*; GWMWater 2010).

Table 2-1 Volume estimates for the weir pool as determined as part of the Draft *Lake Batyo Catyo and Rich-Avon Weir Management Plan* (GWMWater 2010). Table from GWMWater 2010, page 57).

River Section	1	2	3	4	5
Width (m)	35	25	15	10	10
Length (m)	4,140	2,812	1,240	3,330	2,858
Average cross sectional area (m^2)	64.13	61	36	20	10
Calculated volume (m^3)	265,526	171,525	44,664	66,607	28,578
Total volume	**576,900 m^3 or 577 ML**				

2.2.3 Physical surveys carried out as part of the current study

One of the major questions pertinent to the current study was whether there were any deep pools in the weir pool that could act as refuge habitats for fish and other aquatic biota over dry periods. With the weir pool nearly dry in December 2014, it was possible to complete a detailed survey of the downstream half of the weir pool.

We comprehensively surveyed a 6.5 km length of the weir pool from near Brewster Road to the Rich-Avon Weir. Survey was conducted using a combination of RTK-GPS and traditional terrestrial techniques. The survey specifically focussed on key features of the channel (i.e. banks, watercourse and terrain variations). Survey data were processed into a Triangular Integrated Network (TIN) and further compiled into a surface model or digital terrain model (DTM) that was used to describe the physical character of the weir pool (Figure 2-4).

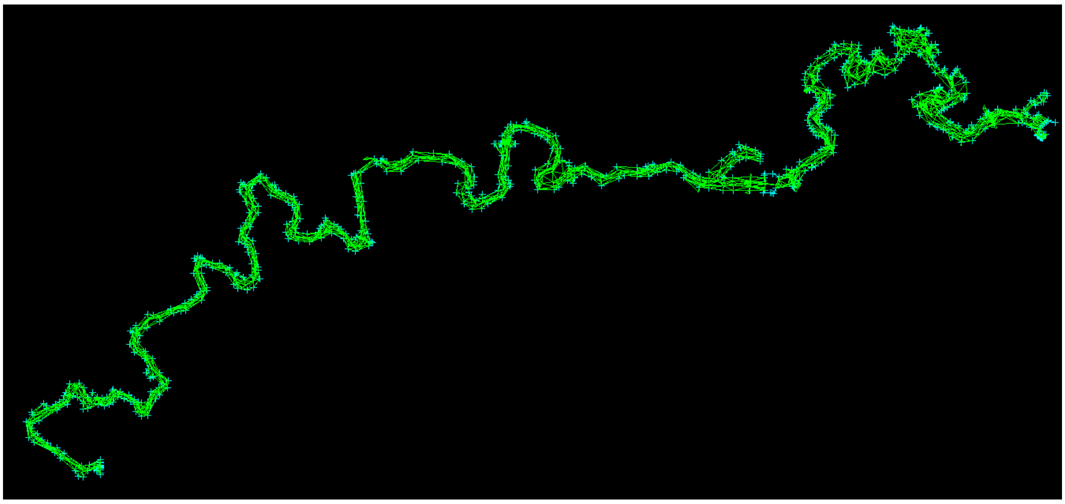


Figure 2-4 Digital Terrain Model (DTM) of the surveyed area of the Rich-Avon Weir Pool (DTM created via 12d).

The survey and analysis captured 6,478 m of the weir pool. The bed level through that section ranged between 119 and 120m, with no obvious grading trend. Several sections of the bed had large accumulations of silt, which appeared to have filled any deep refuge pools that may have previously existed in the channel. In some places the silt had dried and cracked, but in areas that still held some water the silt formed a bed of very fine, soft mud that was more than 1 m deep. Figure 2-5 shows the flatness of the bed of the weir pool with very few deep areas that would act as refuge pools under low water level (it should be noted that the bed depth shown is exaggerated 100 times). The important thing to note in Figure 2-5 is that the bed of the weir pool does not vary more than one metre from the upstream end of the surveyed area to the weir.

The accumulation of sediment are shown in Figure 2-6.

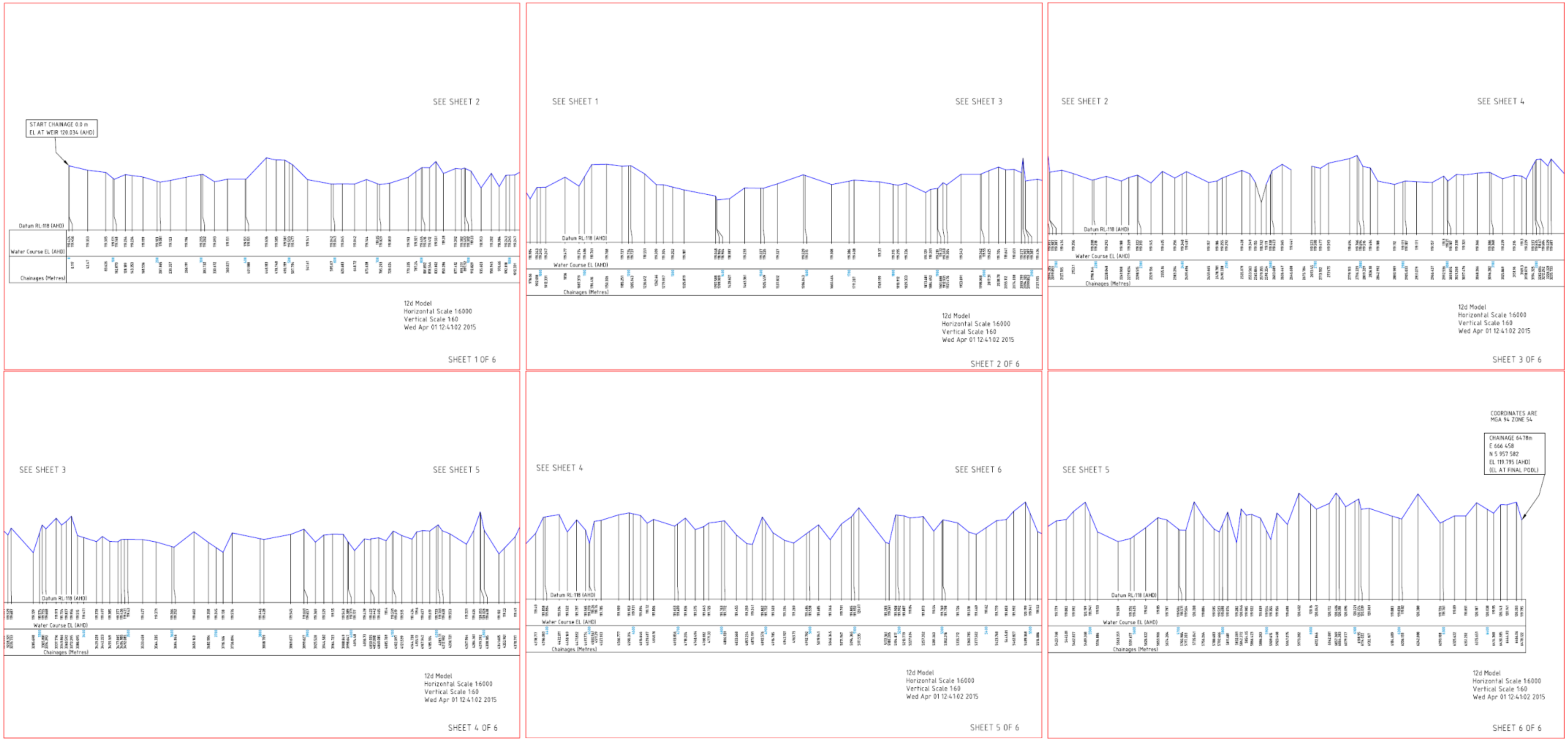


Figure 2-5 Profile (at 100x Exaggeration) of weir pool bed. Weir is at 0 m (left side of the top left figure). Blue line represents weir pool bed elevation. The bed level through that section ranged between 119 and 120m, with no obvious grading trend.

Figure 2-6 Photos of the Rich-Avon Weir Pool showing the build-up of sediment. The bottom of the channel was consistently flat, with only a few slightly deeper areas.

2.3 Land status and management

Over 90% of the broader Avon-Richardson catchment has been cleared for broadacre farming, primarily cattle and sheep grazing and crop production (wheat, oats, legumes and barley) (Halliwell 1998). The area from the Rich-Avon Weir to the Donald-Stawell Road on the northern side of the weir pool (from the top of the bank) is freehold land. The southern side of the weir pool is crown land frontage that is licenced to the neighbouring landholder (GWMWater 2010).

Upstream of the Donald-Stawell Road there is crown land frontage along the southern bank to Rich-Avon West, and then on both sides of the river to the township of Banyena (GWMWater 2010). The majority of camping used to occur on the southern side of the weir pool (GWMWater 2010).

The Department of Environment, Land, Water and Planning (DELWP) is the nominated land manager for the crown frontages at the Rich-Avon Weir Pool (GWMWater 2010). Local angling groups also took an active role in managing the area (GWMWater 2010).

3. Hydrology and hydrogeology of the Rich-Avon Weir Pool

3.1 Operational history

During its operation as a balancing storage, the Rich-Avon Weir Pool was filled from a combination of natural catchment run-off and inter-basin transfers from the headworks of the Wimmera-Mallee system (GWM Water 2010). Water was channelled via the Rocklands-Lubeck channel (16,000 – 37,000 ML/year) and the Taylors Lake channel (3000 – 7500 ML/year) to the mid reaches of the Richardson River (Figure 3-1; GWMWater 2010). Most transfers were made in the winter Stock and Domestic supply period (usually between May and November) when the majority of inflows were directed to Lake Batyo Catyo primarily for use over the summer months (GWMWater 2010). Water from Lake Batyo Catyo was released into the Donald Main channel to supply urban, and domestic and stock requirements.

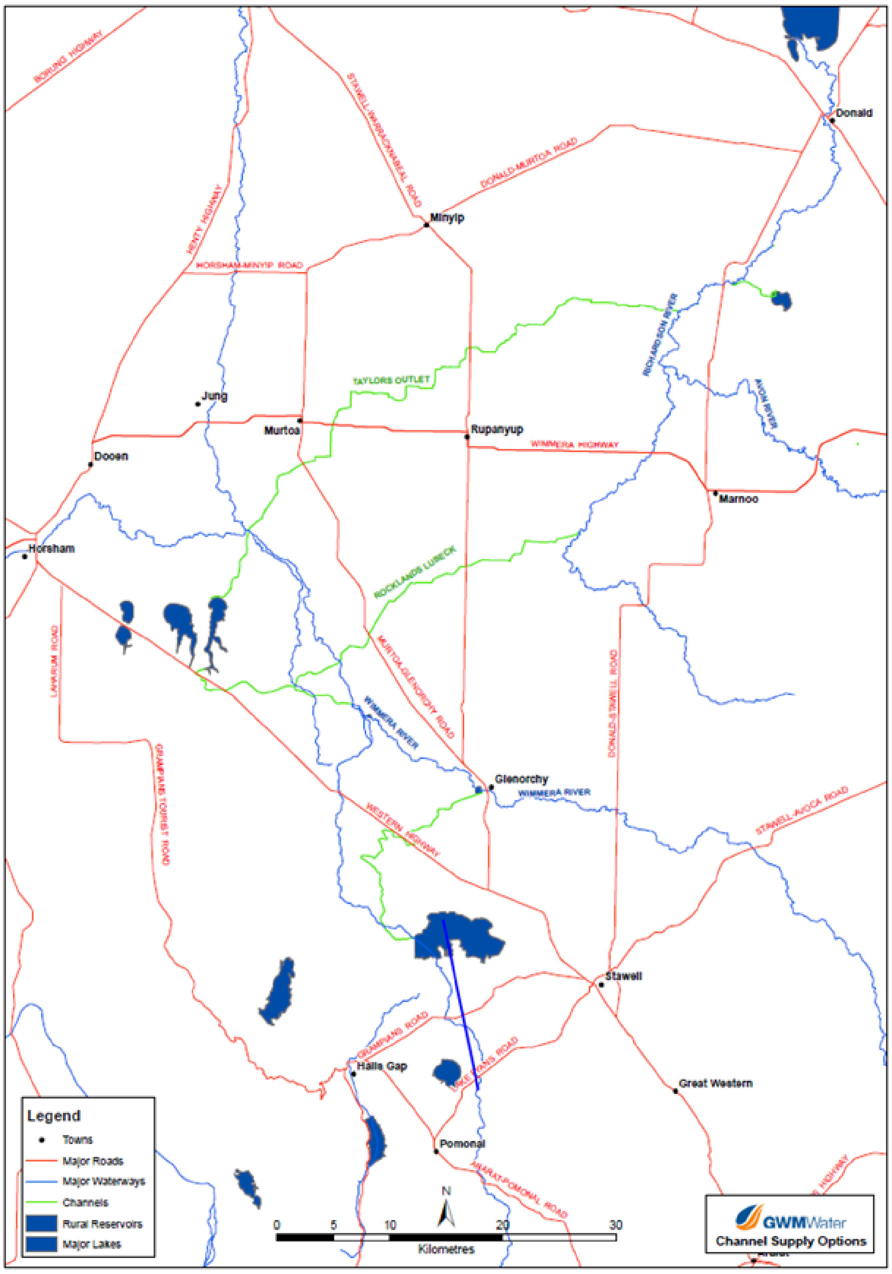
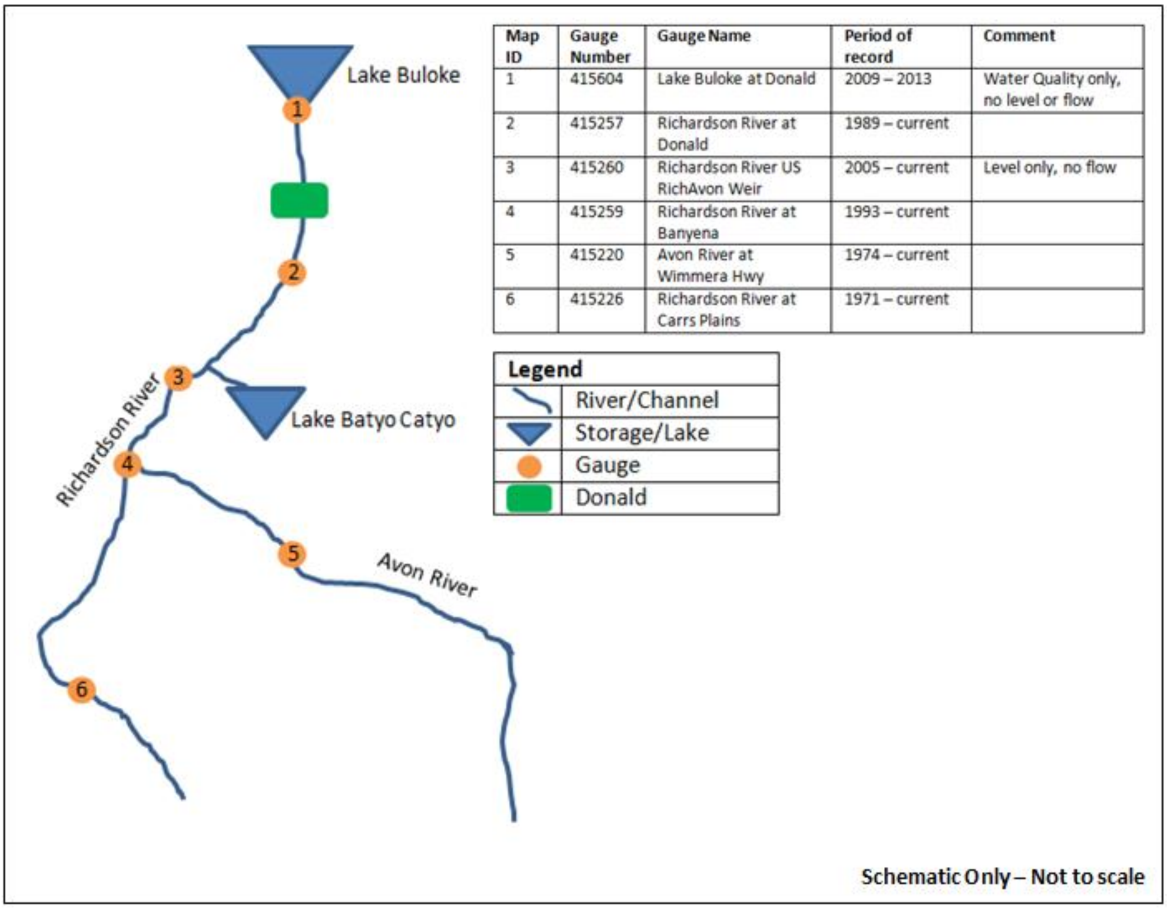


Figure 3-1 Delivery pathways to the Rich-Avon Weir Pool and Lake Batyo Catyo (figure GWMWater). Delivery from the headworks was made to the Richardson River along the Rocklands Lubeck channel and Taylors Outfall.

The first flushing flow along the Richardson River, either from natural sources or channel sources after a period of no flow, historically created a slug of highly saline water (see Section 6.1.2). Rather than transferring that water to Lake Batyo Catyo, the first 1-3 days of a new flow were allowed to pass downstream of the Rich-Avon Weir. Once the weir pool was full and flowing with fresher water, up to 200 ML/day (but up to a maximum of 600 ML/day) could be diverted to Lake Batyo Catyo (SKM 2005a). Very little flow was historically passed into the Richardson River and therefore flows downstream of the weir were greatly reduced compared to natural and were usually only the result of high flushes and flood events (GWMWater 2010).

3.2 The natural flow regime

There are six gauges in the Richardson and Avon Rivers relevant to determining the flow regime of the system. The location of these gauges and their period of record are presented in Figure 3-2.



Map ID	Gauge Number	Gauge Name	Period of record	Comment
1	415604	Lake Buloke at Donald	2009 – 2013	Water Quality only, no level or flow
2	415257	Richardson River at Donald	1989 – current	
3	415260	Richardson River US RichAvon Weir	2005 – current	Level only, no flow
4	415259	Richardson River at Banyena	1993 – current	
5	415220	Avon River at Wimmera Hwy	1974 – current	
6	415226	Richardson River at Carrs Plains	1971 – current	

Figure 3-2 Schematic of the location of relevant gauges and the period of record.

Natural flows have previously been modelled in the upper Avon River, at the Wimmera Highway which extend from the start of the gauge record and finish in 2000. Additionally, the Carrs Plains gauge records natural flow conditions as there are no diversions upstream of that point.

The Avon River (shown in Figure 3-3) ceases to flow for approximately 60% of the time under natural conditions. The Richardson River (shown in Figure 3-4) ceases to flow approximately 80% of the time under natural conditions.

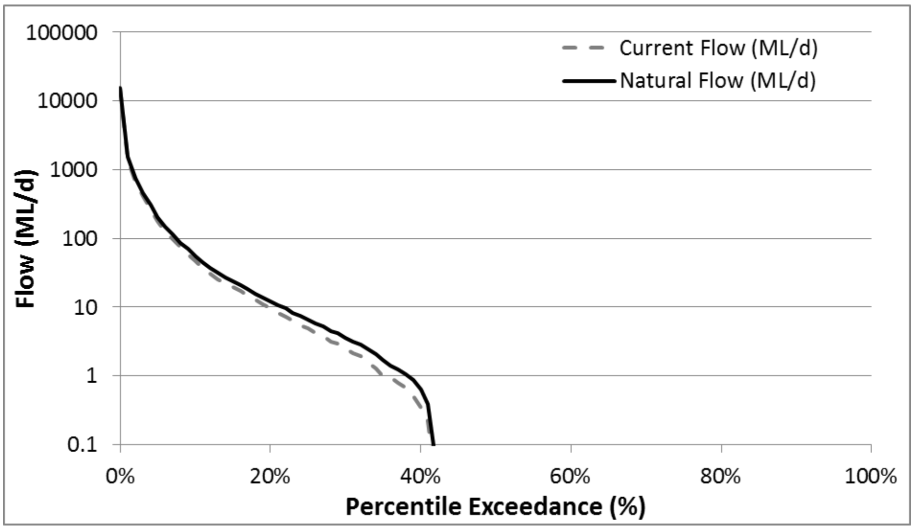


Figure 3-3 Flow duration curve for Avon River at the Wimmera Highway.

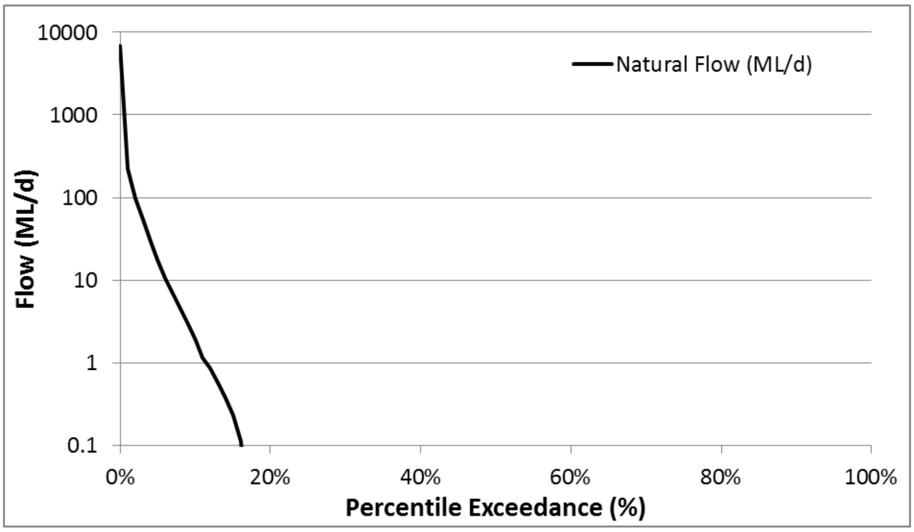


Figure 3-4 Flow duration curve for Richardson River at Carrs Plains.

3.3 Diversions from the system

Water is harvested from the Avon and Richardson catchments for Stock and Domestic and irrigation purposes through direct extraction of surface water. Based on records in the Victorian Water Register, direct diversions from the Avon River account for 97 ML/year. There are currently three irrigation entitlements totalling 86 ML per year for extraction from the Rich-Avon Weir (see Table 3-2). Several small off-waterway dams are also filled from the Richardson River, but they only account for approximately 2.2 ML/day (see Table 3-2). Diversions from the Richardson River account for 2.2 ML/year (Table 3-1).

Farm dam volumes in this catchment have previously been reported at 2,813 ML (SKM 2005a) which could significantly reduce catchment inflows to the system. The exact location of these farm dams is not known, however, it is expected that they are most likely to exist on the Avon River upstream of the Richardson River and will therefore not affect the flows at Carrs Plain gauge.

Table 3-1 Direct extractions from surface water in the Richardson and Avon Rivers (ML) (Source: State of Victoria 2015b)

	Domestic and stock	Irrigation	Total
Avon	11	86	97
Richardson	2.2	0	2.2

Table 3-2 Harvesting using an off-waterway dam in the Richardson and Avon Rivers (ML) (Source: State of Victoria, 2015b)

	Domestic and stock	Irrigation	Total
Avon	2.2	0	2.2
Richardson	0	0	0

3.4 Climate change

The *Water Supply Demand Strategy* guidelines include estimated climate change impacts per river basin in Victoria (DSE 2011). Under the 2030 climate change scenario (50th percentile median), the mean annual runoff in the rivers in the Wimmera Basin is expected to fall by 19%. Under 2060 (50th percentile median) climate change scenario, the mean annual runoff in the river is expected to fall by 32%. Both scenarios would result in substantial increases in the duration and frequency of cease to flow events in the Avon-Richardson River.

3.5 Groundwater surface water interactions

Interactions between groundwater and surface water at the Rich-Avon Weir Pool are strongly associated with the salinity processes in the Avon-Richardson River catchment. The salinity processes are largely driven by the regional groundwater system (Pannell and Ridley 2005), in particular the main regional aquifer underlying the catchment, the saline Parilla Sand or more broadly called the ‘Loxton-Parilla Sands’.

3.5.1.1 Hydrogeological Setting

The Parilla Sands are comprised of layers of sand, silt and clay, which were deposited on top of older sedimentary units (e.g. lower tertiary and basement aquifer systems) approximately 2-4 million years ago as a result of a retreating shoreline across the landscape. The retreat of the sea and sea level decline have left clearly distinguishable north-south trending stranded beach dunes of Parilla Sand in locations where the sea level halted temporarily (Evans 2012). Dissection of the landscape, following the shoreline retreat, occurred during a major wet phase approximately 50,000-30,000 years ago. This led to the development of rivers and lake systems and the deposition of sands and clays known as the Shepparton Formation (Quaternary aquifer). Following this, more recent alluvial sediments were deposited and now flank the existing waterways dissecting the older floodplain of the Shepparton Formation (Muller 2002).

At a regional scale the gradient of the Parilla Sand Aquifer is very flat with a fall in head of less than 80 m across a distance of approximately 350 km. The low hydraulic gradient together with its high hydraulic conductivity (i.e. it is highly permeable, which allows groundwater to moves freely through it) means that the aquifer system is very responsive to recharge events (e.g. localised infiltration by rainfall and large flood events) and local stresses such as drought. The effects of rising groundwater levels can be seen across both a local and regional scale (Evans 2012). Figure 3-5 shows episodic recharge events on the floodplain causing a rise in the local water-table.

Salinity of groundwater within the regional Parilla Sand aquifer system varies between 10,000 and 30,000 (EC) (Muller 2002). The discharge of the saline groundwater from the Parilla Sands aquifer to overlying land occurs where the surface elevation lies up to two metres below the regional groundwater elevation. Lakes and streams in the Avon-Richardson catchment that intersect the watertable are typically saline. Lakes and streams that do not intersect the watertable are generally fresh as they are filled by surface runoff and act as recharge points to the Parilla Sand Aquifer (Muller 2002).

Recharge to the aquifer is the principal driver of groundwater movement and salt mobilisation in the Avon-Richardson catchment. Recharge increases the hydraulic pressure on the underlying saline Parilla Sand aquifer displacing regional saline groundwater towards the discharge sites (Evans 2012).

Prior to European settlement, only a small amount of recharge was able to pass below the roots of the native vegetation due to the ability of this vegetation to access and utilise the soil moisture (Evans 2012). However, landuse change following European settlement has led to a substantial increase in root-zone drainage. Shallow rooted grasses cannot intercept as much rainfall as native vegetation and fallow/cropping rotations are less able to use subsoil moisture. Long term changes in climatic conditions (e.g. variation in rainfall) may have also contributed to landscape-scale increases to recharge rates. The combined effect of changed land-use and long term climatic conditions has resulted in a rise of the regional water-table depths since European settlement.

The regional water table is now within 5 m of the surface and more locally within 2-4 m depending on recharge events. This relationship is illustrated in the hydrographs provided in Figure 3-5 and Figure 3-6 for three bores located in the Parilla Sands aquifer within the vicinity of the Rich-Avon Weir Pool (see Figure 3-7 for the locations of the groundwater bores). The historical local data, shown in the hydrographs, are consistent with regional trends, in particular the more recent trends indicating a decrease in the water table from the mid-1990s as the result of drier climatic conditions and an increase between 2010 and 2011 during above average wet conditions, followed by a recent decrease in water levels.

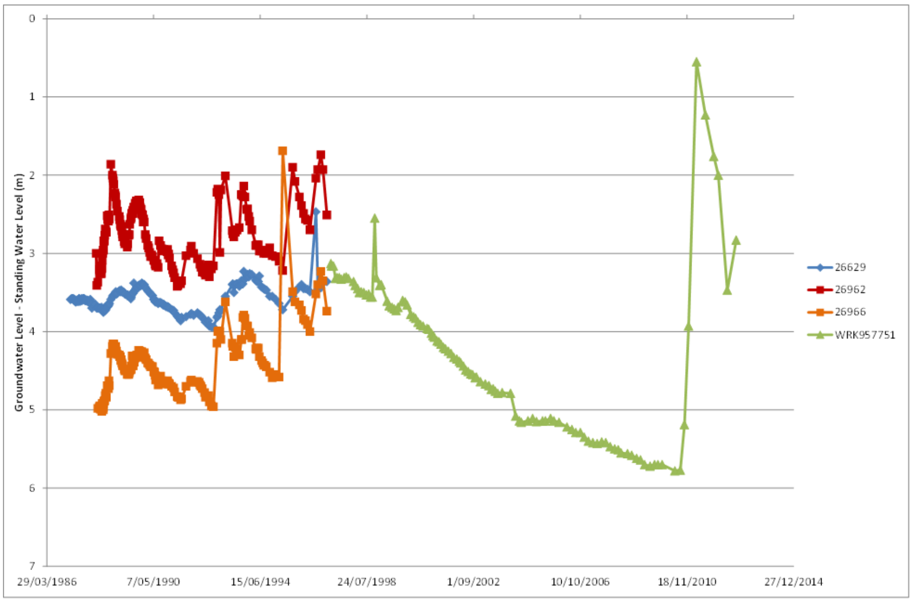


Figure 3-5 Plot of groundwater levels from 1987 to 2013 for groundwater monitoring bores for the Parilla Sands aquifer in the vicinity of Rich-Avon Weir.

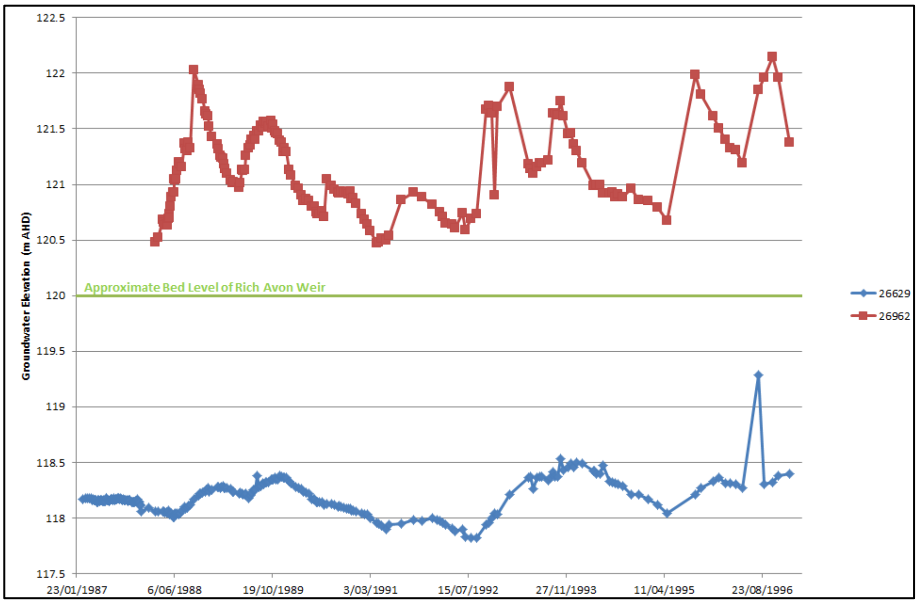


Figure 3-6 Comparison of available groundwater elevation data and the approximate elevation of the Rich-Avon Weir.

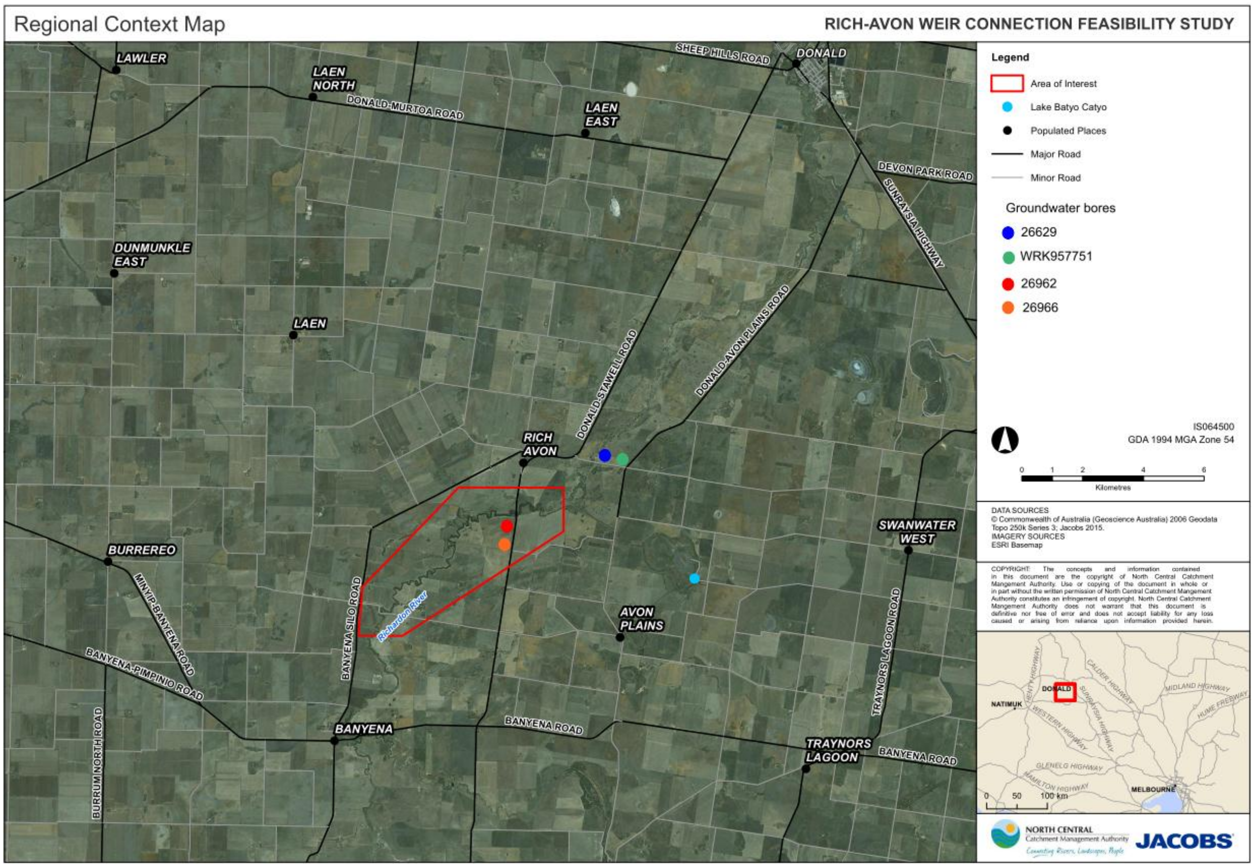


Figure 3-7 Locations of groundwater bores near the Rich-Avon Weir pool.

3.5.1.2 Potential impacts of groundwater on surface water

In areas where the water table is at or above the river bed (Figure 3-6), both the Avon and Richardson Rivers will be gaining streams (i.e. groundwater will discharge to the River). When the water table is below the river bed, it is likely the rivers would be a losing stream disconnected system (i.e. any surface water will recharge the aquifer). The nature of connection (i.e. gaining or losing) is driven by the frequency and duration of recharge events and the associated rise in water table. The rivers are more likely to be connected (i.e. gaining) in periods of high recharge (e.g. increased rainfall periods) and disconnected (i.e. losing) during periods of low recharge (e.g. decreased rainfall periods, droughts).

The frequent occurrence of very high salinities (up to 35,000 EC during periods of low flow; Waterwatch 2015, see Section 6.1.2) in the weir pool confirms that this section of the river has historically received saline groundwater discharge because salinity levels such as this would not normally occur in runoff-supplied surface water systems.

4. Management of environmental water

The purpose of this study is to assess the feasibility of providing environmental water to the Rich-Avon Weir Pool. This section reviews the policy framework around providing the environmental water and discusses briefly options for providing environmental water to the weir pool.

4.1 Management of environmental water

Environmental water management in Victoria involves collaboration between local Catchment Management Authorities, State and Commonwealth Departments and local water authorities. The five agencies responsible for allocating and delivering environmental water to the Avon-Richardson catchment are described in Table 4-1.

Table 4-1 Responsibilities of agencies associated with the delivery of environmental water in Victoria (adapted from North Central CMA 2014, Table 1, p16.)

Agency / Group	Responsibilities
Department of Environment, Land, Water and Planning (DELWP)	Manage the water allocation and entitlement framework. Develop state policy on water resource management and waterway management approved by the relevant ministers. Develop state policy for the management of environmental water in regulated and unregulated systems. Act on the behalf of relevant ministers to maintain oversight of the VEWH (Victorian Environmental Water Holder) and waterway managers (in their role as environmental water managers). Land manager for the crown frontages of the Rich-Avon Weir Pool.
Victorian Environmental Water Holder (VEWH)	Make decisions about the most effective use of the water holdings, including use, trade and carryover. Authorise waterway managers to implement watering decisions. Liaise with other water holders to ensure coordinated use of all sources of environmental water. Publicly communicate environmental watering decisions and outcomes.
Commonwealth Environmental Water Holder (CEWH)	Make decisions about the use of Commonwealth water holdings, including providing water to the VEWH for use in Victoria. Liaise with the VEWH to ensure coordinated use of environmental water in Victoria. Report on management of Commonwealth water holdings.
North Central Catchment Management Authority (North Central CMA) **Waterway Manager**	Identify regional priorities for environmental water management in the regional Waterway Strategies (e.g. Regional Catchment Strategy). In consultation with the community assess water regime requirements of priority rivers and wetlands to identify environmental water needs to meet agreed objectives. Identify opportunities for, and implement, environmental works to use environmental water more efficiently. Propose annual environmental water actions to the VEWH and implement the VEWH environmental watering decisions. Provide critical input to management of other types of environmental water (passing flows management, above cap water) and report on environmental water management activities undertaken.
Grampians Wimmera Mallee Water (GWMWater)	Rural and Urban Water corporation – Storage Manager and Resource Manager Work with the VEWH and waterway managers in planning for the delivery of environmental water to maximise environmental outcomes. Operate water supply infrastructure such as dams and distribution systems to deliver environmental water.
Non-agency stakeholders	
Traditional owners / Community groups (e.g. local landholders, fishing and field and game groups)	The delivery of environmental water is likely to produce other benefits, dependent on the condition of the waterway, for example supporting social or cultural values.

4.2 Related agreements, policy, plans and activities

There are a range of policies, plans, legislation and strategies that are relevant to the delivery of environmental water for the Rich-Avon Weir Pool (North Central CMA 2014). These are described below.

State legislation

Water Act (1989), Catchment and Land Protection Act (CALP) Act 1994, Flora and Fauna Guarantee (FFG) Act 1988, Aboriginal Heritage Act 2006, Traditional Owner Settlement Act 2010, Conservation, Forest and Lands Act 1987, Crown Land Reserves Act 1978.

National legislation

Water Act 2007, Water Amendment Act 2008 (Cth), Environment Protection and Biodiversity (EPBC) Act 1999, Native Title Act 1993.

Strategies

Victorian Waterway Management Strategy 2013 (VWMS) outlines the investment that will be made by the Victorian Government between 2012 and 2020. The overarching goal is to improve or maintain the environmental condition of waterways to support environmental, cultural, social and economic values (North Central CMA 2014).

North Central Waterway Strategy (2014-2022) addresses the CMAs obligations under the VWMS and provides a framework for improving or maintaining river condition in the North Central CMA region.

Bulk Entitlements and Environmental Entitlements

Bulk Entitlements (BEs) specify the water shares and volumes available for a given authority within a river system. There are four relevant BEs for the Wimmera and Glenelg Rivers, which include Avon and Richardson Rivers. The BEs are listed below and full documentation is available via the Victorian Water Register (State of Victoria, 2015a):

- Bulk Entitlement (Wimmera and Glenelg Rivers – Coliban Water) Order 2010
- Bulk Entitlement (Wimmera and Glenelg Rivers – GWMWater) Order 2010
- Bulk Entitlement (Wimmera and Glenelg Rivers – Wannon Water) Order 2010
- Wimmera and Glenelg rivers Environmental Entitlement 2010.

In particular, the *Wimmera and Glenelg rivers and environmental entitlement 2010* includes conditions related to the Rich-Avon Weir. Schedule 6 of the environmental entitlement specifies that *“Unregulated flow in the Avon-Richardson River”* is *“to be used to maintain the weir pool at a level of 2.2 m on the weir gauge.”.* Where *“unregulated flow is the flow naturally occurring in the in the Avon-Richardson River”*.

4.3 Environmental watering delivery

During operation, water was transferred along the historic delivery pathways from the headworks to the mid reaches of the Richardson River (via the Rocklands-Lubeck channel and the Taylors Lake channel; See Section 3.1). These channels have been decommissioned and therefore water is no longer able to be delivered this way.

Environmental water could be delivered from the Wimmera-Mallee Pipeline to the weir pool if delivery infrastructure including pipeline and associated water supply infrastructure was constructed (Bernie Dunn, GWMWater pers. comm.). Theoretically environmental water could be delivered at any point in the weir pool. It would be most feasible to deliver it at the location where the Donald-Stawell Road crosses the weir pool, because this requires the least distance of supply pipe to be constructed.

The cost of supplying water to the Rich Avon Weir pool via a new pipeline alongside the Donald-Stawell Rd branching off from the Avon Plains Road (see Figure 4-1) was calculated by GWMWater (B. Dunn, GWMWater, pers. comm.). The infrastructure that would be required includes:

- an inlet control valve (ICV) capable of pressure sustaining and flow control)
- flow meter
- SCADA (Supervisory Control And Data Acquisition)
- Cage or fencing around ICV
- 3.9 km of 100mm pipework to the pool outfall
- Concrete outfall structure and beaching to prevent scouring

As of November 2015, the estimated cost to connect the weir pool to the Wimmera-Mallee Pipeline via the pathway described above was $292,000 (B. Dunn, GWMWater, pers. comm.).

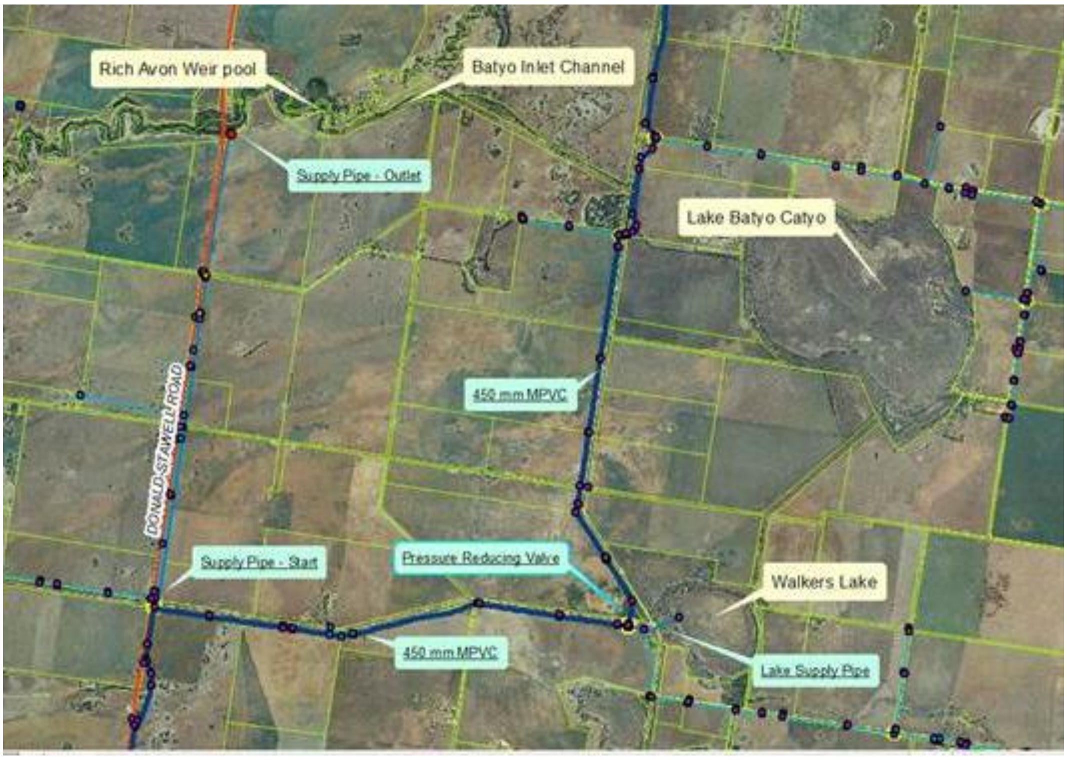


Figure 4-1 Infrastructure required to connect the weir pool to the Wimmera-Mallee Pipeline via the Donald Stawell Road.

5. Social values

5.1 Cultural heritage

Aboriginal cultural heritage

The Avon-Richardson River area was occupied by the *Dja Dja Wurrung* and *Jardwadjali* language groups (GWMWater 2010). These language groups were made up of separate, smaller clans, which shared common linguistic, cultural and social practices (Clark 1990). Many of the Jardwadjali people were forced to relocate to missions outside the region in the 1860s and 1870s, primarily the Ebenezer Mission on the Wimmera River and the Lake Condah Mission near Portland (Clark 1995).

Jardwadjali men played an important part in Australian sport, making up much of the first Australian cricket side to tour England in 1868 (Clarke 1995). Figure 5-1 shows an early Australian cricket team in 1866 or 1867, with Tom Wills, one of the founders of Australian Rules Football (Clarke 1995).

Today, many of the Dja Dja wurrung and Jardwadjali people live in the Horsham area. The Brambuk National Park and Cultural Centre in Halls Gap, is owned and managed by five Aboriginal communities from these language groups (Brambuk National Park and Cultural Centre 2015).

There is anecdotal evidence that there are areas of cultural significance at the Rich-Avon Weir Pool, however, these locations are not officially registered with Aboriginal Affairs Victoria (GWMWater 2010).

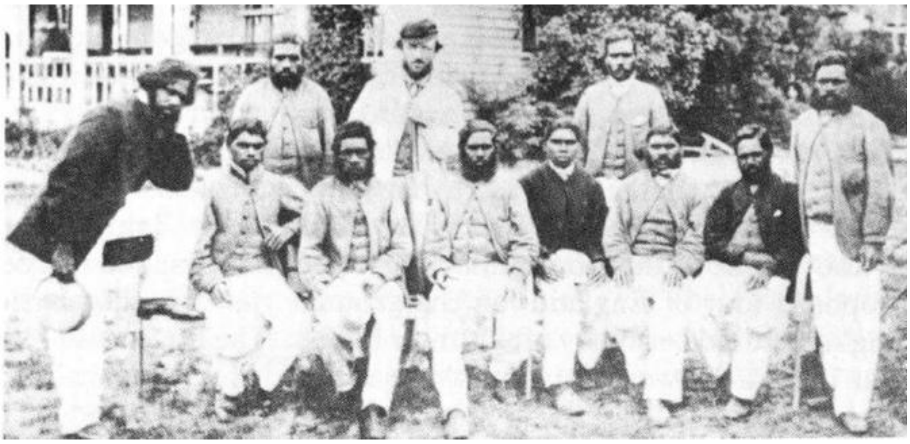


Figure 5-1 Aboriginal cricket team at the MCG (c 1866-67) (Source: MCG Museum, copyright expired).

European cultural heritage

The European cultural heritage of the area began with the exploration of the region by Major Thomas Mitchell in 1836. According to Bob McIvena (2007), Major Mitchell's party crossed the Avon River on 12 July 1836 and the Richardson River the following day. The Richardson River was named after John Richardson, the party's botanist and a former convict. According to Mitchell's diaries, Richardson slipped from his horse as he crossed the river and with some difficulty reached the bank (McIlvena 2007). Mitchell, impressed by Richardson's good humour following his 'dunking', named the river for him (McIlvena 2007).

Major Mitchell was also impressed by the landscape around the Avon-Richardson basin, commenting that the he had "discovered a country ready for the immediate reception of civilised man, and destined perhaps to become eventually a portion of a great empire" (McIlvena 2007).

5.2 Recreation

Historically, when full the weir pool was a highly valued community asset. In addition to being a popular bush camping spot the weir pool was a valued angling location with Murray Cod, Golden Perch and Redfin Perch all prized species. Fishing competitions were an annual event on the weir pool since the 1970s (GWMWater 2010). During the Millennium Drought the weir pool was the only surface water in the district for up to 100 km and was even more valued during these times.

Duck hunting is a popular pastime at the weir pool. The area is also frequented by local field naturalists and canoeists (GWMWater 2010).

With the weir pool currently dry, it unsurprisingly does not have the same recreation value as when it was full. Fishing and duck hunting are no longer able to be conducted at the weir pool and the area is far less used for camping than when the weir pool held water (Tom O’Shannessy pers. comm.). The area is currently used occasionally for four wheel driving when the access road becomes damp, however, this practice is not encouraged because of the damage it does to the access road that runs alongside the weir pool (Tom O’Shannessy pers. comm.).

5.3 Economic assessment

5.3.1 Value

During its operational life, the Rich-Avon Weir Pool had considerable economic value, forming an important part of the Stock and Domestic water supply system of the region. The construction of the Wimmera-Mallee Pipeline meant the weir pool was no longer needed as part of the supply system.

Other economic values associated with the Rich-Avon Weir Pool include:

- Contribution to the local economies of Donald and St. Arnaud from recreational visitors (campers, duck hunters, anglers).
- Providing water to local diverters. Pumping infrastructure was observed at the weir pool to supply users either side of the weir.

The only known economic value provided by the weir pool currently is as grazing land for sheep (Figure 5-2).

Figure 5-2 Stock grazing in the dry channel of the weir pool.

5.3.2 Asset management

During the site assessment in November 2014 and September 2015, we observed cracking in the concrete at the base of the weir (Figure 5-3). It is unclear what impact this cracking would have on the safe operation of the weir but it is likely that at least a detailed safety assessment and maintenance would be required prior to reinstatement.

The Draft *Lake Batyo Catyo and Rich-Avon Weir Management Plan* (GWMWater 2010) recommended that a dam safety risk assessment be carried out of the Rich-Avon Weir. To our knowledge this has not been completed to date.

Figure 5-3 Rich-Avon Weir. Lower panels clearly show significant cracking in the concrete base of the weir and to the side of the gates.

6. Review of historic water quality in the weir pool

Water quality has been an issue in the broader Avon-Richardson catchment and within the Rich-Avon Weir Pool. Water quality within the Avon-Richardson catchment was not included in the latest Index of Stream Condition (ISC) report completed by DEPI (now DELWP), but has been rated as poor in the past (see SKM 2005a). The poor water quality in the catchment is a combination of several factors, primarily agriculture and groundwater intrusion and manifests in high salinity and high turbidity (SKM 2005a).

Water quality has been measured in the weir pool monthly since 1996 (until it dried in 2013) as part of the *Waterwatch* program (Waterwatch 2015). The following section reviews these data to investigate the historic water quality in the weir pool.

6.1.1 pH

pH in the weir pool over the period from 1996 to 2013 was at the higher end of the SEPP guidelines and often above the guidelines (Figure 6-1). Elevated pH can occur naturally in soils high in salts and so it is likely that the high pH in the weir pool is a natural feature of the catchment.

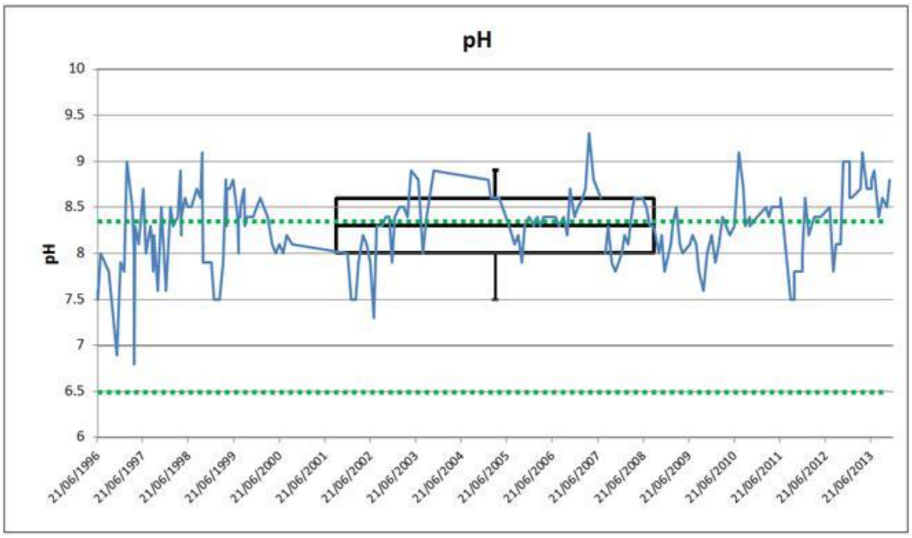
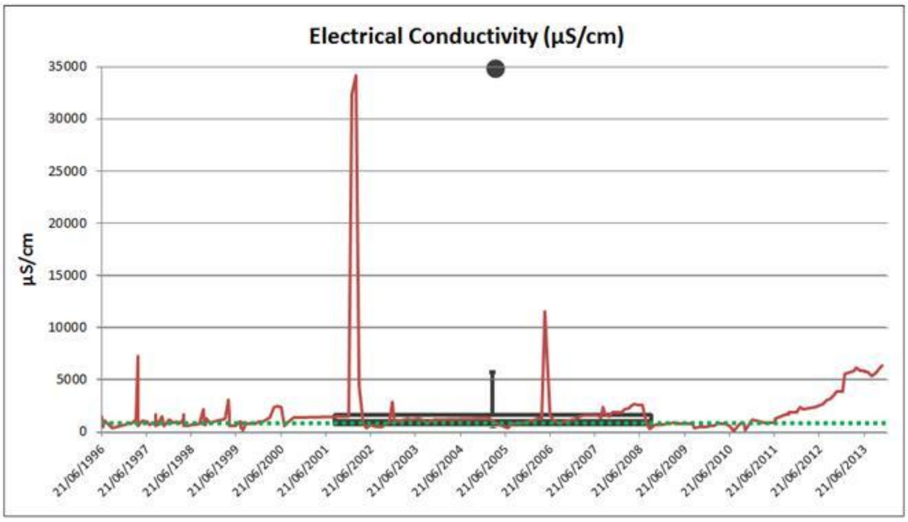


Figure 6-1 pH measured in the weir pool from 1996 to 2013. Box plot represents the 25th, 50th and 75th percentile values. Whiskers represent the 5th and 95th percentiles. Green dotted line represents the SEPP guideline range of 6.5 and 8.4.

6.1.2 Salinity

Salinity levels in the catchment have been high historically, so much so that when the Stock and Domestic system was operational, the first flush into the weir pool was allowed to pass downstream rather than being transferred to Lake Batyo Catyo (GWMWater 2010). Water quality data collected as part of the *Waterwatch* program showed that salinity can get very high for short periods, it reached nearly 35,000 EC for several months in 2002 during the Millennium Drought (Figure 6-2). As outlined in Section 3.5.1.2, when the groundwater level is high, the Rich-Avon Weir Pool is likely to receive intrusion of saline groundwater which probably explains this occasionally high salinity.

When operational as a transfer channel, however, the weir pool was flushed frequently (with most of the water diverted to Lake Batyo Catyo). The frequent flushing would have meant that salinity remained low in the weir pool. For most of the period where data has been recorded, salinity in the weir pool has remained below the *State Environmental Protection Policy (*SEPP) guideline of 1,500 EC (Figure 6-2).



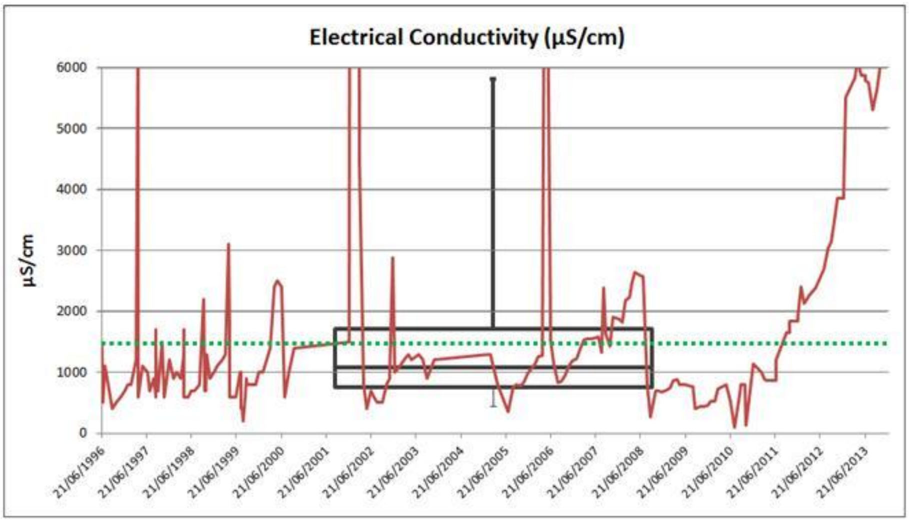


Figure 6-2 Salinity (Electrical Conductivity) measured in the weir pool from 1996 to 2013. Top figure shows the full range of data, the bottom figure emphasises data at the lower end of the range. Box plot represents the 25th, 50th and 75th percentile values. Whiskers represent the 5th and 95th percentiles. Green dotted line represents the SEPP guideline value of 1500 µs/cm.

6.1.3 Nutrients

Farming practices can lead to nutrients running off into streams, which can then accumulate in areas such as weir pools. Combined with high temperatures, excessive nutrient accumulation can lead to algal blooms. Algal blooms can have serious consequences for fish and other biota, both by smothering habitat but also leading to large fluctuations in dissolved oxygen (related to algal photosynthesis). To our understanding there are no records of algal blooms in the weir pool, but they have been observed in Lake Batyo Catyo (GWMWater 2010).

The flushing of the water in the weir pool probably meant that algal blooms would not have been an issue during operation. However, in the absence of the flushing it is possible that algal blooms may occur. To our knowledge there are no systematic data collected of the nutrient levels in the weir pool, meaning that this risk cannot be discounted.

6.1.4 Turbidity

Sedimentation is an issue in the catchment, with high turbidity recorded in both the Avon and Richardson Rivers (GWMWater 2010) and the weir pool (Figure 6-3). The high turbidity is indicative of significant erosion and highly degraded catchments (GWMWater 2010). Recent advances in land management have likely seen a reduction in the amount of sediment reaching the waterways (K. Walters, pers. comm.).

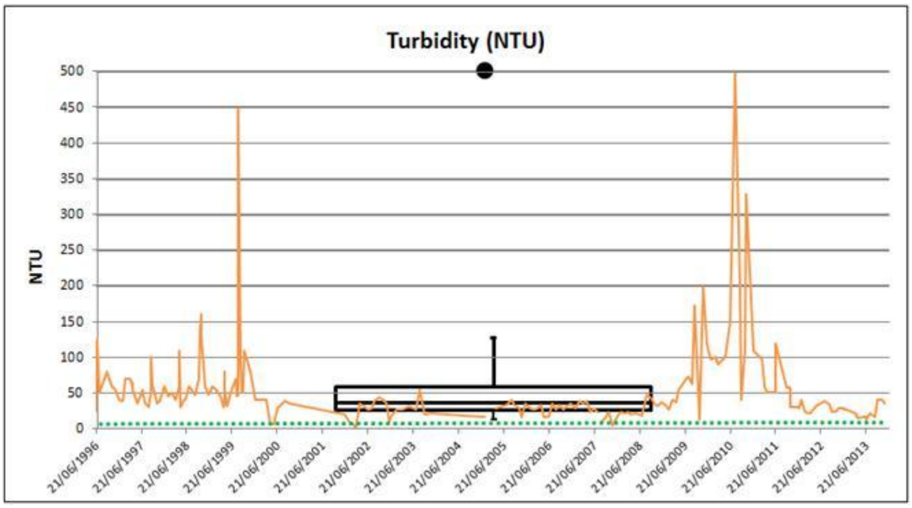


Figure 6-3 Turbidity in the weir pool from 1996 to 2013. Box plot represents the 25th, 50th and 75th percentile values. Whiskers represent the 5th and 95th percentiles. Green dotted line represents the SEPP guideline value of 1,500 µs/cm.

6.1.5 Potential Acid Sulfate Soils

The nation-wide Acid Sulfate Soil mapping undertaken by CSIRO indicated that the Rich-Avon Weir Pool is rated as extremely low probability of having acid sulfate soils inferred from national and state soils, hydrography and landscape coverage data (CSIRO 2015).

7. Review of ecological values

Under the previous operation, the Rich-Avon Weir Pool held water near permanently, a significant change from the ephemeral character of the rest of the Richardson and Avon Rivers. As a consequence of this permanent inundation, the weir pool supported more diverse aquatic flora and fauna communities than elsewhere in the Richardson-Avon River. Since the installation of the Wimmera-Mallee Pipeline, the change in operation of Lake Batyo Catyo and a series of dry years the weir pool has almost completely dried. It now supports very few aquatic plants or animals.

To allow us to estimate which species and communities could be supported by the weir pool should it be provided with environmental water, it is necessary to review what was supported in this part of the river prior to the construction of the Rich-Avon Weir, the values that would have been present when the weir pool was permanently inundated and being used as part of the water supply system and the values that are present now. To do this, we have reviewed known records from databases such as the Victorian Biodiversity Atlas, other surveys, anecdotal reports and species distribution predictions. For simplicity, we have considered aquatic species and communities and terrestrial species and communities separately.

7.1 Water dependent fauna and flora values

7.1.1 Values expected prior to the installation of the Rich-Avon Weir

The Avon and Richardson rivers are ephemeral systems and would have ceased to flow frequently (see Section 3.2). The area which later became the weir pool would have likely contracted to a series of pools that provided refuge habitat for aquatic biota in most years, but it is also possible that those refuge pools dried during severe droughts.

Fish

The ephemerality of the river prior to the construction of the weir means that it was unlikely to have ever supported populations of large bodied fish. It is possible that the deep refuge pools that would have held water following flood and high flow events would have supported Northern River Blackfish (*Gadopsis marmoratus*), Flat-headed Gudgeon (*Philypnodon grandiceps*) and Australian Smelt (*Retropinna semoni*). However, as these pools would have most likely dried during extreme droughts, recolonisation from outside the system would have been required occasionally.

Frogs and reptiles

The only species of frog recorded at the weir pool on the Victorian Biodiversity Atlas is the Growling Grass Frog (*Litoria raniformis*). This species is unlikely to use fast flowing stretches of river, but does use backwaters and slow flowing areas. It is therefore likely that this species would have been present in the area prior to construction of the weir. The Growling Grass Frog is listed as vulnerable federally (EPBC Act) and endangered at a state level (FFG Act).

Although not recorded on the Victorian Biodiversity Atlas, it is possible that a range of other frog species may have used the area prior to the construction of the weir. These include the Eastern Sign-bearing Frog (*Crinia parinsignifera*), the Eastern Common Froglet (*Crinia signifera*), the Eastern Banjo Frog (*Limnodynastes dumerilii*), and the Spotted Marsh Frog (*Limnodynastes tasmaniensis*).

Frogs are able to breed in back waters and slow flowing stretches of rivers as well as any associated small pools or wetlands. These habitats may have been provided occasionally by this section of the river prior to the construction of the weir pool, particularly any deeper refuge pools and therefore it is possible that a range of frog species would have been supported.

Three turtle species are found in Victoria, the Eastern Long-necked Turtle (*Chelodina longicollis*), the Broad-shelled Turtle (*Chelodina expansa*) and the Murray Turtle (*Emydura macquarii*). The Eastern Long-necked Turtle is common and widespread and is likely to have been present in the river prior to the construction of Rich-

Avon Weir. Turtles would have benefitted from any deeper pools that held water longer than the rest of the channel.

The Broad-shelled Turtle and the Murray Turtle have much smaller distribution in Victoria and are usually associated with the Murray River. It is unlikely that these species would have been present in the Richardson River prior to the construction of the weir.

Mammals

Water rats (*Hydromys chyrogaster*) are common and have a varied and generalist diet. It is likely that they would have been present in the area prior to the construction of the Rich-Avon Weir.

Macroinvertebrates

The macroinvertebrate communities of the Avon-Richardson River prior to the construction of the Rich-Avon Weir were likely to have been dominated by species that are able to tolerate periods of no flow. Most species are likely to have life history stages that enable them to cope with complete drying or have dispersal mechanisms that allow them to rapidly colonise the stream from other source populations when water is present. The major in-stream substrates for macroinvertebrates are likely to be fallen trees, leaf packs at the margin of the channel and fringing and emergent vegetation.

The river in this location also likely supported freshwater crayfish (yabbies) and mussels prior to the construction of the weir.

Birds

Bird communities along the Richardson River prior to the construction of the Rich-Avon Weir would have comprised typical woodland communities (Honey-eaters, Fairy Wrens, Cockatoos etc.) that would have used the river and its riparian zone for its relatively abundant food sources such as insects, nectar and seeds. The river would have become an increasingly important habitat for woodland birds as vast areas of the surrounding plains were cleared for agriculture. Kookaburras would likely have been resident along the river channel as well. Some waterbirds would have used the river when it held water, but obligate wetland species and migratory birds would primarily have used larger waterbodies and more permanent lakes and wetlands dotted through the landscape.

Vegetation communities and flora

Prior to the construction of the Rich-Avon Weir, the vegetation dependant on the river system would likely have been restricted to the river banks and low-lying areas between bends that would have been periodically flooded. These areas would have supported River Red Gum (*Eucalyptus camaldulensis*) woodland communities with a diverse understorey. The banks of the river, and potentially the channel in drier periods, would have supported a range of grasses, rushes and sedges such as Southern Cane-grass (*Eragrostis infecunda*), Common Reed (*Phragmites* australis), Cumbungi (*Typha spp.*) and Po'ongort (*Carex tereticornis*) with occasional shrubs such as Sweet Bursaria (*Bursaria spinosa*). The lower lying areas between bends of the river would likely have supported Red Gums over a grassy understorey with many species able to take advantage of periodic inundation e.g. Copper-backed Wallaby-Grass (*Rytidosperma duttoniana*), Southern Cane-grass (*Eragrostis infecunda*), rushes (*Juncus spp.*), Grey Germander (*Teucrium racemosum*) and Small Loosestrife (*Lythrum hyssopifolia*). Outside the river channel and associated flats, the vegetation would have been dominated by plains woodland type species as can be seen from the remnant boxes (*Eucalyptus macrocarpa* and *E. largiflorens*) and Sheoaks (*Allocasuarina leuhmanii*) that still exist in the surrounding paddocks.

Settlement of the area prior to 1913 would have involved the gradual clearing of the surrounding woodlands and the introduction of stock. The presence of stock on what was likely one of the more reliable water sources in the region even given its ephemeral nature, would have likely degraded the banks of the river.

7.1.2 Values expected to be supported after the Rich-Avon Weir was constructed and during its operation as a permanent weir pool.

Following the construction of the weir in 1913, the weir pool would have held water throughout most years. The near permanent water would have significantly increased biodiversity in the river and its immediate surrounds.

Fish

The more permanent water regime in the Rich-Avon Weir Pool supported populations of large-bodied native species, which would have been introduced to the weir pool by humans and in some cases would have been actively stocked. These species include Murray Cod (*Maccullochella peelii*), Golden Perch (*Macquaria ambigua*), Silver Perch (*Bidyanus bidyanus*), Freshwater Catfish (*Tandanus tandanus*) and Northern River Blackfish (GWMWater 2010). A range of small bodied native species were also known from the weir pool; Flat-headed Gudgeon, Common Galaxias (*Galaxias maculatus*) and Australian Smelt. These small bodied species may have colonised from other catchments naturally but are more likely to have been introduced by humans. It is unlikely that any fish species would have used the Avon-Richardson Rivers more than opportunistically prior to the construction of the weir.

The weir pool also supported a range of exotic species; Carp (*Cyprinus carpio*), Redfin Perch (*Perca fluviatilis*), Eastern Gambusia (*Gambusia holbrooki*), Goldfish (*Carassius auratus*) and Tench (*Tinca tinca*).

The high numbers of desirable angling species made the weir pool a prized fishing location. It was actively managed by local angling and field and game groups (including the Wimmera Angling Association and the Donald Angling Club). Some species would have been able to breed in the weir pool, such as Freshwater Catfish and possibly Murray Cod and therefore may have formed self sustaining populations. Other recreationally valuable species, for example Golden Perch and Silver Perch would not breed in the weir pool and therefore populations of those species would need to be maintained by annual stocking. Approximately 10,000 Golden Perch were stocked annually into the weir pool by the then Department of Primary Industries (GWMWater 2010), however, the period that this stocking took place is not clear.

The Rich-Avon Weir Pool had particularly high recreation values because it was the only reliable angling water in the region. During the drought the Rich-Avon Weir Pool was the only water body for approximately 100 km that held water (GWMWater 2010).

Frogs and reptiles

Permanent, slow flowing water in the Rich-Avon Weir Pool and the high amount of fringing vegetation would have provided high quality habitat for a range of frog species. It is likely that each of the species described in Section 7.1.1 would have been present and probably more abundant than prior to the construction of the weir due to the slow flowing, reliable water.

Growling Grass Frogs are usually associated with deep pools with open water (i.e. not marshlands) in still or slow flowing streams, lakes swamps and billabongs (Pyke 2002) and would have probably benefited from more permanent water in the Rich-Avon Weir Pool. Growling Grass Frogs breed in spring to summer with tadpoles metamorphosing after approximately two-three months on average (Heard *et al.* 2010). Recruitment (based on studies near the Murray River) is generally highest when hydro-period is longer than 6 months (i.e. when water persists in a habitat for more than 6 months) (Wassens 2011). In fact, there is a strong negative relationship between wetland hydroperiod and extinction probability at a wetland (i.e. wetlands with short hydroperiod are more likely to be unoccupied than permanent wetlands, Heard *et al.* 2010).

Large areas of fringing vegetation would provide foraging and calling stages for adult Growling Grass Frogs and would act as attachment points for eggs. The constant water level of the weir pool likely led to the development of large areas of fringing vegetation which, like the permanent water, would also have benefited this species.

Three populations of Growling Grass Frog were recorded in the Rich-Avon Weir Pool prior to it drying up (GWMWater 2010), however, it is unclear exactly where those populations were located. Anecdotal reports indicate that one large population was located just to the west of the Donald-Stawell Road, in the section constructed during the upgrading of the road (K. Walters and R Loates pers. comm.).

Growling Grass Frogs form metapopulations, meaning that the persistence of the species at the local scale relies on dispersal between populations and the existence of suitable sites, even if these sites are not always occupied. The metapopulation structure is so important to this species, that the best predictor of whether a suitable site will be occupied is its distance to another occupied site (Heard *et al.* 2010). The recording of three distinct populations of Growling Grass Frogs associated with the weir pool when it was full suggests that the metapopulation, at the landscape scale, would likely have been in good condition. Coupled with this, there were a number of off-stream water storages (i.e. farm dams) that would have held water and would likely have been suitable for Growling Grass Frogs and would have formed an important part of the species' metapopulation structure.

Eastern Long-necked Turtles would likely have been very common in the weir pool. The increased habitat availability and food sources are likely to have increased the size of these turtle populations.

Mammals

The permanent weir pool may have improved conditions for water rats (i.e. provided more habitat and a more abundant food source) and therefore the water rat population would likely have increased after the Rich-Avon Weir was built. During the field surveys completed as part of this project, we observed large numbers of freshwater mussels (shells), which along with small fish are likely to have been a valuable food resource for water rats.

Macroinvertebrates

The macroinvertebrate communities at the weir pool would probably have been more diverse than prior to the weir's construction. This is because the near permanent weir pool could support species that do not tolerate drying. Further, the weir pool likely acted as a refuge or source of colonists for other waterbodies throughout the catchment.

A high number of shells of Freshwater Mussels were observed during at the weir pool during the site assessments for the current study. Freshwater Mussels would have been far more common in the weir pool than in the river prior to its construction. Similarly, given the increase in permanent, high quality habitat, Freshwater Crayfish would also have been more common.

Birds

There are no records from the weir pool for the period 1913 to 2014 which makes it difficult to determine with certainty what birds would have used the weir pool when full. Records in the Victorian Biodiversity Atlas from the surrounding areas (10 km) are primarily focussed on the surrounding wetlands at Lake Batyo Catyo and Avon Plains. The wetland and migratory birds that were observed at these locations would potentially have foraged in the weir pool, but probably didn't use the wetland as a permanent habitat or major breeding habitat. Those birds would more likely have used other wetlands in the catchment for breeding and feeding.

Woodland species (Honey-eaters, Fairy Wrens, Cockatoos/Corellas etc.) and common riparian species (Kingfishers and Kookaburras) are known from the surrounding areas and are likely to have been resident along the river as one of the primary remnants of woodland in the area.

Vegetation communities and flora

Turning a 16 km section of the Avon-Richardson River into a more permanently inundated channel would have altered the composition of the vegetation community. These changes would have coincided with a period of greater land clearing and the introduction of irrigated crops on the surrounding floodplain.

The riparian zone along the edge of the weir pool would have supported Floodplain Riparian Woodland. Riverine Swampy Forest/Sedgy Riverine Forest complexes would have occurred on lower lying terraces in the river bends. River Red Gums also flourished in this period. Regular flows through the weir pool would have maintained water quality and promoted the growth of Cane Grass, Common Reed and Cumbungi along the banks. The lower lying terraces would have supported a predominantly sedge understorey (Po'ongort, Rushes, Spike-sedges) capable of flourishing above a shallow water table whilst the higher terraces would have supported a predominantly grassy understorey with wetland elements such as Loosestrife (*Lythrum hyssopifolia*) and Nardoo (*Marsilea drummondii*). Water Ribbons (*Triglochin procera*) and Water-Milfoils (*Myriophyllum spp.*) would likely have established in the silty sediment that built up in the channel following construction of the weir.

Weeds would also have invaded over this period as a result of land clearing and increased human traffic. Major weeds affecting the quality of the wetland would likely have been pasture grasses such as Rye and Barley grasses.

7.1.3 Current environmental values (determined from site assessments in November 2014 and September 2015)

The current condition of the weir pool and an estimate of the species and values still present were determined via a rapid field assessment conducted over 4 days in November 2014 and a one day site assessment in September 2015. In November 2014, the weir pool was dry except for a few, very shallow pools. These pools were completely dry as of September 2015. Survey methods are outlined in the relevant sections below.

Fish

No fish surveys were completed as part of the November 2014 site assessment because the remnant pools were too small (see Figure 7-1 and Figure 7-2) and the water quality is likely to have been too poor to sustain any fish. Moreover, we did not observe any movement in those pools that would suggest that fish were present. Schools of small-bodied fish such as Gambusia are easily and often observed in shallow pools if they are present, and the pools were definitely too small to support any medium or large fish. None of the pools remained in September 2015.

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Figure 7-1 Remnant pool in the weir pool in November 2014 (top) and the same area dry in September 2015 Photo taken at the location of vegetation Transect 1.

Figure 7-2 Shallow, isolated pools in the Rich-Avon Weir Pool in November 2014 (top) and the same areas in September 2015 (bottom). Left photos taken at the location of vegetation Transect 2.Right photos taken at the location of vegetation Transect 5.

Frogs and reptiles

Nocturnal surveys (commencing at sunset) were conducted for frogs on 16 and 17 November 2014. Surveys were conducted in accordance with the method described in Heard *et al.* (2010) and recommended by the EPBC Act Policy Statement 3.14 (DEWHA, 2009), which is designed to detect with high probability the presence of Growling Grass Frogs. Surveys at selected sites lasted for 40 minutes. The first five minutes involved passively listening for frog calls at the water's edge. The second five minutes involved playing recorded frog calls and listening for any response. The last 30 minutes involved two people (equates to 60 person minutes) actively searching frog habitat at the margin of the waterbody with the aid of head torches. According to Heard *et al.* (2010), two surveys at a site conducted under good conditions (air temperature greater than 12°C and no or little wind) in the period between October and December are required to be 95% confident that Growling Grass Frogs would be detected if present.

For each survey, wind speed was estimated using the Beaufort Scale and air temperature and relative humidity were measured using a sling psychrometer. The visibility and phase of the moon, cloud cover and rain intensity (when relevant) were also recorded. Air temperature during both surveys was within the acceptable range (16 November - 18°C to 14°C, relative humidity from 57% to 70%; 17 November - 19°C and 13°C, relative humidity 57% to 69%). There was a half-moon during the survey period, but it was not visible in the sky during the surveys. There was little wind (ranging from 'still' to a 'light breeze') and scattered cloud cover on both nights. These conditions are considered suitable for detecting Growling Grass Frogs if they are present. The surveys specifically targeted Growling Grass Frogs but the methods are also likely to detect other frog species if they are present.

Surveys were conducted at four locations in the vicinity of the historic weir pool and the surrounding landscape; two isolated pools within the weir pool, another pool in the Richardson River immediately downstream of the weir wall (which was holding water at the time of the survey) and a farm dam on a property owned by Kim Walters north of the weir pool (Figure 7-3). The isolated remnant pool in the weir pool immediately east of the

Donald-Stawell Road is very close to a previously known population of Growling Grass Frogs (K. Walters and R Loates pers. comm.). The other sites were selected as they were the only areas in the immediate landscape that were holding water at the time of the surveys. The locations of the frog surveys are shown in Figure 7-3.

Water quality was not measured in these isolated pools during the survey period, but it is likely that salinity would have been very high as a result of evaporation and possibly groundwater intrusion. The salinity tolerance of Growling Grass Frogs is not well understood, however some evidence suggests that they may tolerate electrical conductivity levels up to 10,000 µs/cm (Smith *et al.* 2008) and in fact slightly saline pools may buffer this species against skin-borne bacterial disease (*Chytridiomycosis*; Heard *et al.* 2014). As the electrical conductivity was not measured in these isolated pools and the tolerances of Growling Grass Frogs are not definitively understood, it is unknown whether the high salinity in these pools would have excluded frogs. However, it is probably reasonable to expect that the water quality in these small pools is unlikely to have been favourable for frogs.

Figure 7-3 Frog survey locations. Top left: Immediately downstream of the weir wall; Top right: pool just west of the Donald-Stawell Road; Bottom left: pool 2-3 km west of Donald-Stawell Road; Bottom right: farm dam on Kim Walters' property.

No Growling Grass Frogs were heard or observed at any of the sites during the field surveys. Based on these results we are 95% confident that Growling Grass Frogs are not present at any of the surveyed sites (based on Heard *et al.* 2010). Detection probabilities have not been determined for the other species that may use the weir pool, however, we can assume that if Growling Grass Frogs or any other frogs are present in the study area, they are not abundant. The only frog species that we could not confidently assess was the Southern Brown Tree Frog, which has different calling cues to the other frogs that are likely to occur in the region.

During the site visit we observed a number of turtles in the pool immediately downstream of the weir and in the farm dam on Kim Walters' property where frog surveys were conducted. We also observed many dead turtles near the weir pool, which probably died as they tried to search for other habitat once the weir pool dried Figure 7-4.

Figure 7-4 Deceased turtle observed near the weir pool in November 2014.

Figure 7-5 Locations of frog surveys at the weir pool and in the surrounding landscape.

Mammals

No targeted mammal surveys were carried out as part of the current project.

Water rats are unlikely to currently be present at the weir pool due to the lack of food resources and suitable aquatic habitat.

Macroinvertebrates

Macroinvertebrate surveys were not undertaken at the weir pool as part of the current project.

There is very little aquatic habitat left and the only macroinvertebrates that are likely to persist in the few remaining pools are likely to be able to tolerate very poor water quality. The overall abundance and diversity of macroinvertebrates in the remnant pools is expected to be very low and much poorer than was present when the weir pool was permanently full.

The lack of standing water means that the weir pool is not currently suitable for yabbies or freshwater mussels. Some freshwater mussel species can survive extended dry periods by closing their shells and burrowing into the mud (NSW DIPNR Undated). Some other macroinvertebrates and zooplankton also lay eggs or have resting life cycle stages that can survive in mud and the dry stream bed when aquatic habitats dry out. It is possible therefore that some individuals may currently persist in the mud and others may rapidly re-appear when flow returns to the river.

Birds

Opportunistic observations of birds were recorded during the field assessment. Several woodland species including Cockatoos, Honey Eaters, Magpies and Magpie-larks were observed. Kookaburras were also heard. No waterbird species such as ducks, spoonbills, ibis or cormorants were observed, which is unsurprising given the lack of water available. Waterbirds and woodland birds are likely to move into the area and use the Rich-Avon Weir Pool when it holds substantial amounts of flowing or standing water, but will be absent or present in very low abundance at other times. Such a pattern is similar to what would have probably occurred before the Rich-Avon Weir was built.

Vegetation communities and flora

Vegetation field assessments were conducted according to the requirements of the Index of Wetland Condition (DEPI 2013), and through 10 transects undertaken at locations marked on Figure 7-6 according to Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) methods (SKM 2014). The following is a brief description of the results of those surveys.

The vegetation communities present along and in the weir pool are currently in a state of flux. Although the Floodplain Riparian Woodland, Riverine Swampy Forest and Sedgy Riverine Forest EVCs that would have characterised the banks and riparian zone of the weir pool when it was full are still present, their condition and extent is changing. Floodplain Riparian Woodland, which previously grew near the weir pool and on its associated terraces appears to be becoming more widespread, while the extent of Riverine Swampy Forest and Sedgy Riverine Forest, which require wetter conditions is declining. Lower lying terraces that would have had shallow water tables when the weir pool was full, are now drying out and the grasses, sedges and rushes that relied on the wetter conditions are dying. Little new growth was observed for either sedges or rushes across the terraces during the assessment and a subsequent visit in September 2015 showed little regeneration of the tussocks. The current extent of the three main EVCs is shown in Figure 7-6 and the component species observed are shown in Appendix A.

Aquatic species such as Water Ribbons and Milfoils that would have persisted in the weir pool when it held water are not present, although it is not clear whether there are turions and seeds in the sediments that could grow if the weir pool is inundated again. The sides and bed of the channel that would have been inundated when the weir pool was full are largely bare, although there is some new growth in places where the silt beds have dried and become friable. These habitats are being colonised by River Red Gum seedlings, sedges and rushes, which would have previously been restricted to the weir pool terraces and high banks. Based on the size of the seedlings observed, most of the regeneration has occurred in the past year and it is likely that these plants will colonise more of the channel as the muddy and cracked sediments continue to dry. There is considerable risk however, that the weeds common in the surrounding areas, including pasture grasses and common weeds such as Spear Thistle (*Cirsium vulgare*) will become dominant

The shift in where species are growing within the weir pool was observed through the surveyed transects (see Figure 7-6 for locations) which are shown diagrammatically in Figure 7-8, Figure 7-10 and Figure 7-12. Whilst the established River Red Gums along the banks of what was the weir pool are still in good health thanks to the deep roots common to this species and ability to access groundwater, species such as Cane Grass, Common Reed and the sedge and rush species have dried out as the water level has receded. A revisit of the site in September 2015 did not identify any regeneration of these species along the terraces or banks indicating that it is unlikely that the species will persist at those locations without inundation of the weir pool. As water levels have receded, River Red Gums have established down the banks as suitable substrate becomes available and stands of one to two years of age were visible on some banks. As stated above, sedges and rushes have established over the past year in the drier silts as soil conditions become conducive to seedling establishment; seeds commonly require friable soils and no surface water to germinate. The regeneration of new seedlings is seemingly related to the dependence of a species upon the shallowness of the water table.

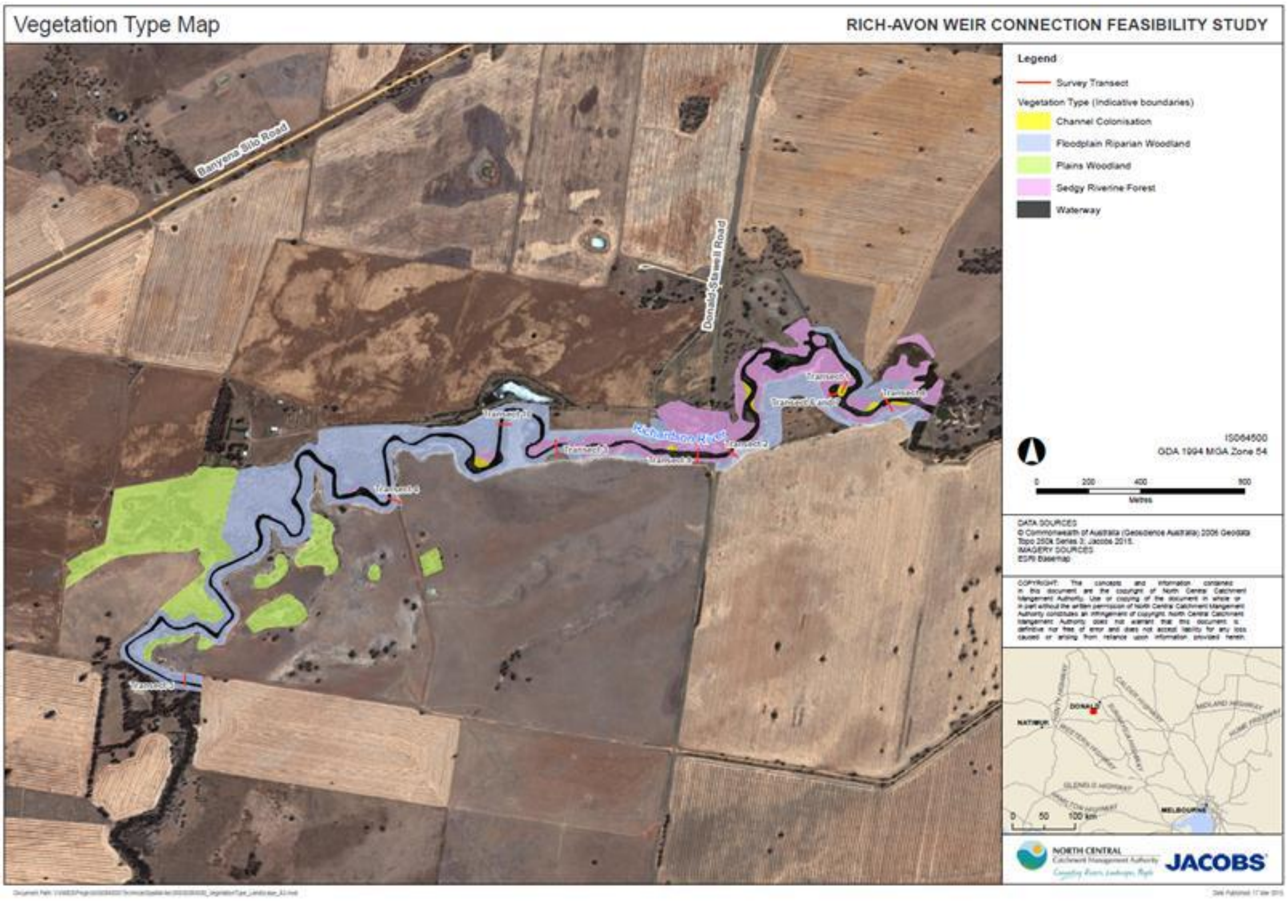


Figure 7-6 Vegetation communities and transect locations along the weir pool (previous page).

Vegetation Transects

The ten vegetation transects surveyed for the current project assessed vegetation community composition from the top of one bank to the top of the opposite bank in three different habitat types within the Rich-Avon Weir Pool. Those habitat types are: 1) remnant pools (as at November 2014), 2) dry sections of channel that are regenerating, and 3) dry open sections of channel with little regeneration. Survey results for each habitat type are discussed below.

Remnant Pools (T1, T2, T3, T4, T5)

The upper banks adjacent to remnant pools (in November 2014) still support relatively healthy River Red Gums. The lower banks and adjacent sections of streambed that were inundated when the weir pool was full have large accumulations of leaf litter and bark, but have very little live vegetation. The remnant pools also do not appear to support any obligate aquatic species such as Milfoils (*Myriophyllum sp.*) or Pondweeds (*Potamogeton* *sp.*). A photo of Transect 4 taken in November 2014 is shown below (Figure 7-7) and a simplified diagrammatic representation of the transect is presented in Figure 7-8.

The remnant pool was completely dry in September 2015. There was no plant growth in the lower part of the channel and no noticeable difference in the condition or extent of the riparian vegetation other than the seasonal difference in grass growth along the banks (i.e. the grass is greener in earlier spring).

Figure 7-7 Transect 4 at the Rich-Avon Weir Pool in November 2014 (left) and September 2015 (right).

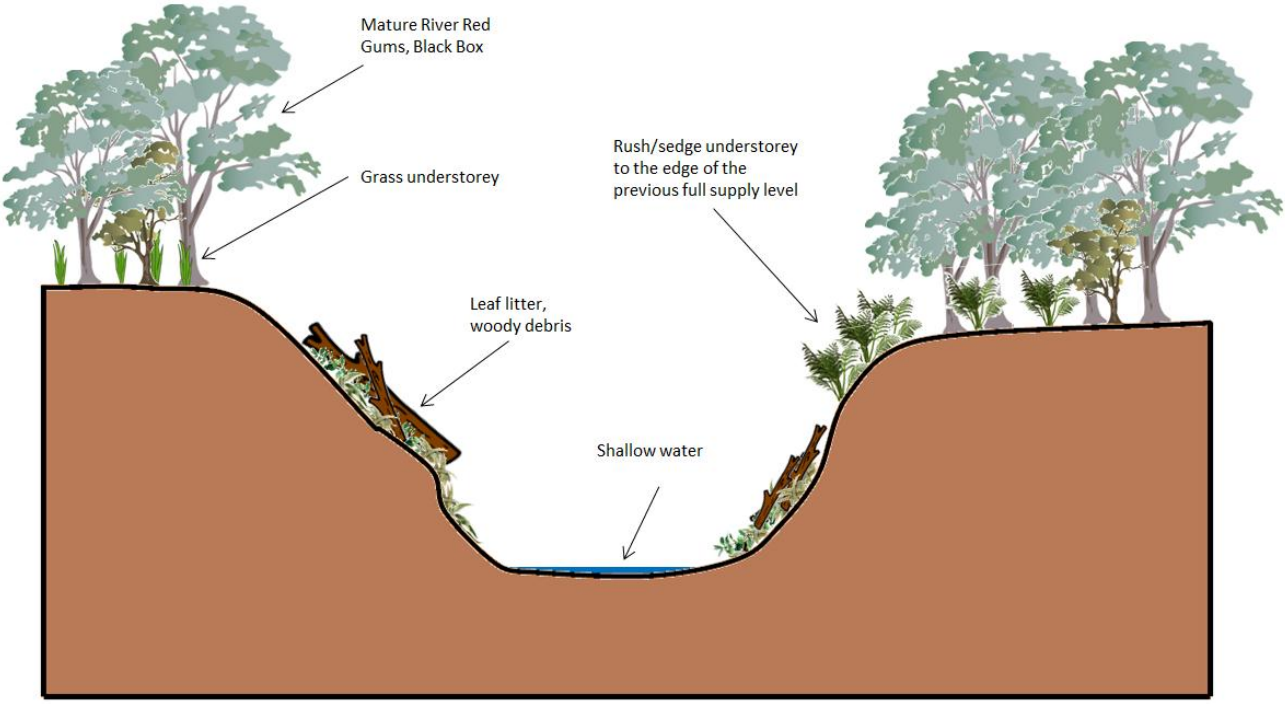


Figure 7-8 Diagrammatic representation of Transect 4 as it was in November 2014.

Regenerating areas (T 6, 7, 8, 10)

The sections of the weir pool that have been dry for the longest time have the greatest amount of regenerating vegetation. That vegetation is mainly growing in the dried silt beds that probably developed in the bottom of the weir pool during its operation and on benches that would have been inundated or saturated when the weir pool held water.

As with other parts of the weir pool, the upper banks support mixed age River Red Gums and the channel underneath these trees has a large to moderate accumulation of leaf litter. The new vegetation growing in the crumbling, but potentially fertile sediments in lower parts of the channel include River Red Gums that are probably 1-2 years old, and a mix of younger sedges, rushes and other non-woody riparian species. Transect 7 is shown in Figure 7-9. A diagram showing a cross-section of the channel at this transect is provided in Figure 7-10.

Also pictured in Figure 7-9 is the transect as it was in September 2015. Of note is the rapid growth of River Red Gum saplings and the persistence of the rushes and sedges previously noted.

Figure 7-9 Transect 7 at the Rich-Avon Weir Pool in November 2014 (left) and September 2015 (right).

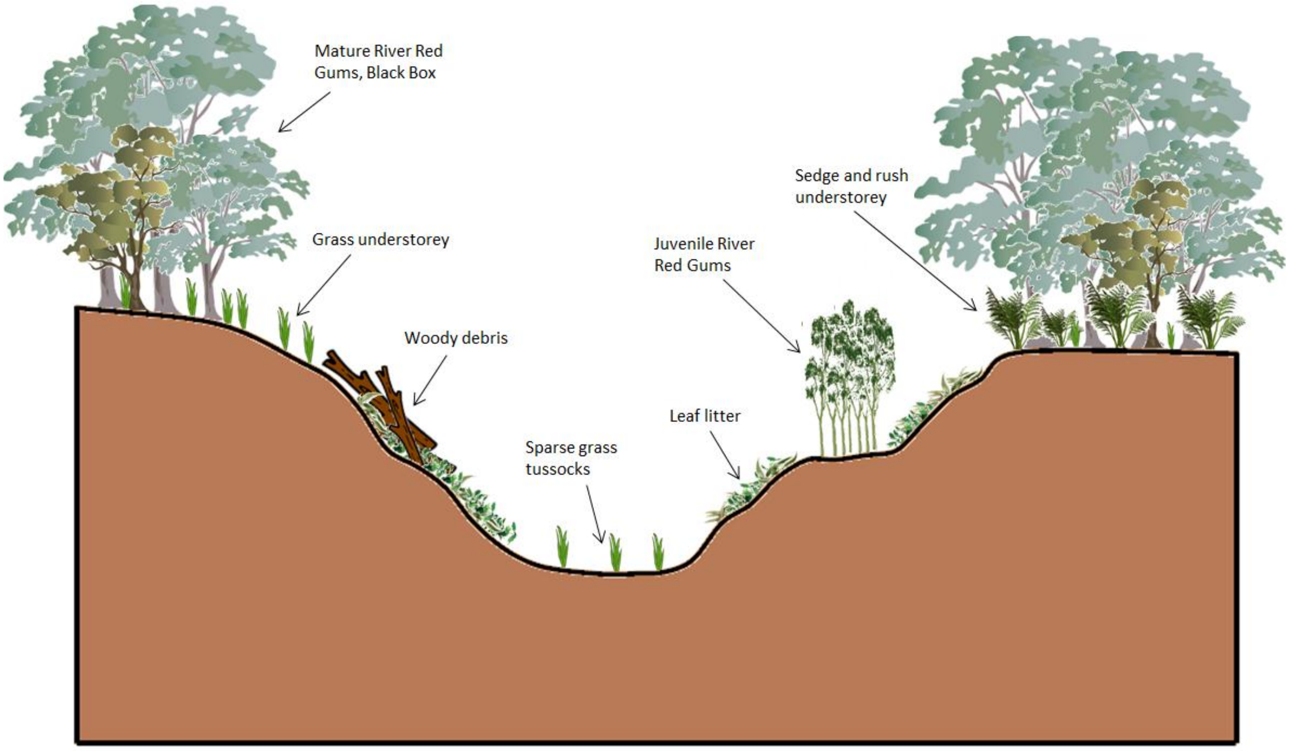


Figure 7-10 : Transect 7 (as it was in November 2014) showing regenerating River Red Gums on the upper banks (1-2 years old) and new sedges and rushes in the drying channel.

Open Channels (T9)

Most of the Rich-Avon Weir Pool is characterised by bare open channels that are dry, but so far have relatively little vegetation. It is unclear whether these areas have dried more recently than the areas with substantial regeneration or whether the sediments are less fertile and less able to support much new growth. Transect 9, as it was in November 2014 is shown below (Figure 7-11) and is represented diagrammatically in Figure 7-12.

Also pictured in Figure 7-11 is the transect as it was in September 2015. As a site where the soils have been more friable (i.e. the breakdown of the drying silts has progressed to the point there are no identifiable cracks) over the intervening period, it is important to note the greening of the banks and river bed. Whilst patchy at present, this greening will likely progress over time. The issue will be, however, that weeds could be the primary colonisers of the new soil in the absence of regular inundation.

Figure 7-11 Transect 9 at the Rich-Avon Weir Pool in November 2014 (left) and September 2015 (right).

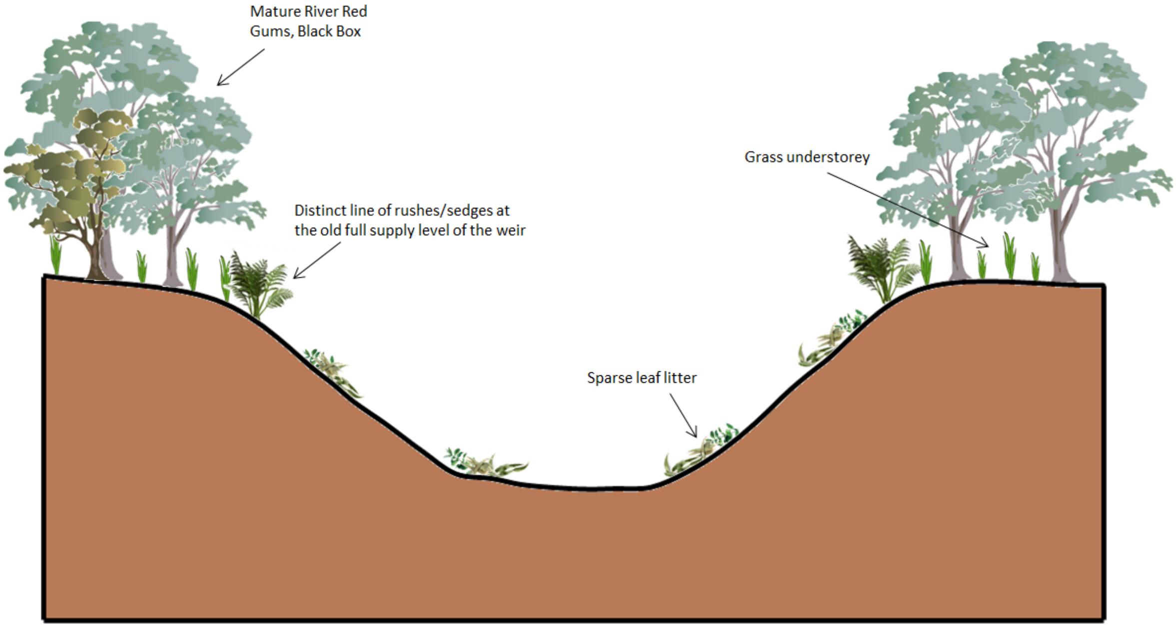


Figure 7-12 Transect 9 (as it was in November 2014) showing River Red Gums over sedges and grasses on the upper banks and sediment filled channel currently devoid of vegetation

Index of Wetland Condition

An Index of Wetland Condition (IWC) assessment was also applied to the whole Rich-Avon Weir Pool to further understand the condition of the site and to act as a baseline for future monitoring. This assessment was carried out at the weir pool and adjacent floodplain wetlands in November 2014. The weir pool was not mapped as an extant wetland on the Index of Condition System (DEPI 2014) although several wetlands were mapped adjacent to the river (Figure 7-13). Of these wetlands, only 40074, 40075, 40076 and 40078 were included in the area assessed. Wetland 40537 is a shallow depression separated from the weir pool by a levee with no wetland constituents remaining, whilst areas 40077, 40079 and 40080 are woodland remnants with no wetland constituents. No wetlands have previous scores or assessments associated with them indicating they have not been formally assessed previously.

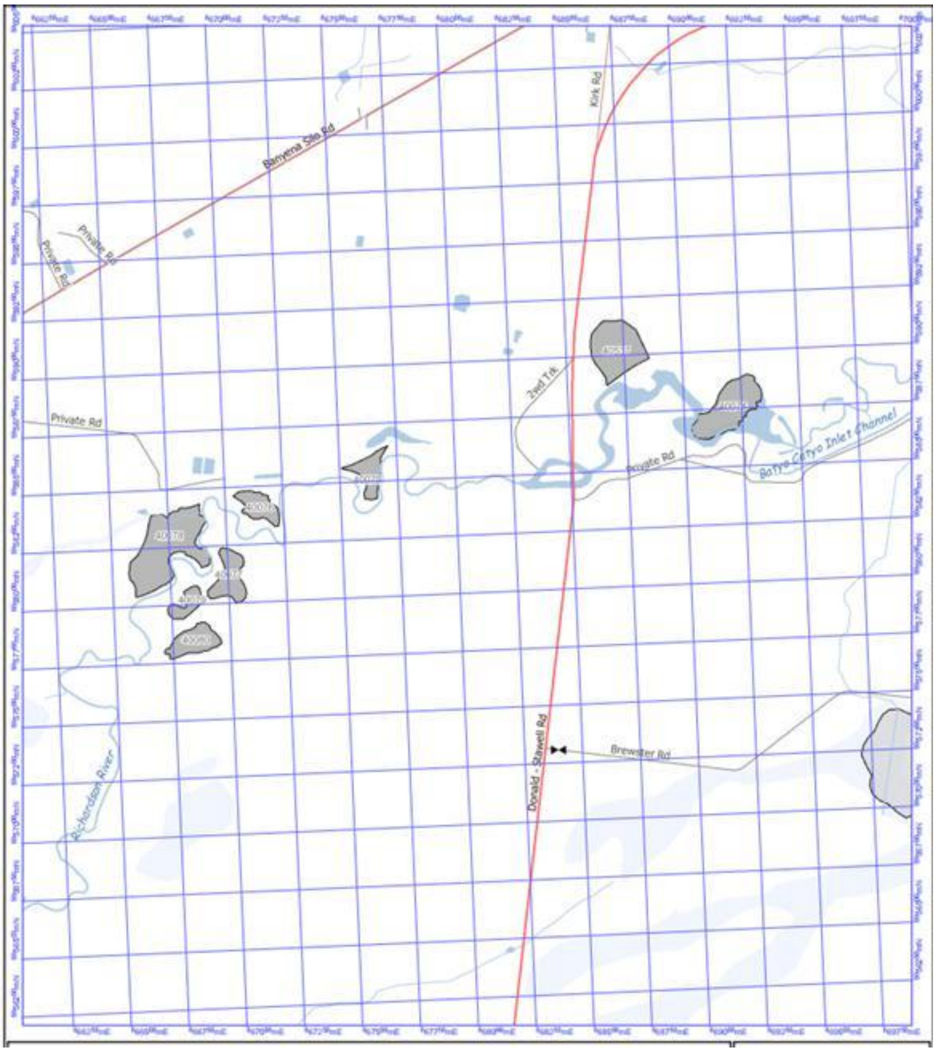


Figure 7-13 Extant wetlands present along the Richardson River according to Index of Wetland Condition Mapping Tool (DEPI 2014).

The Index of Wetland Condition score for the weir pool as a whole is detailed in Table 7-1 below, with full results in Appendix B. These values consider a range of ecological, physical and land use criteria to score the health of a wetland. The current values for the weir pool represent the current transition state and are likely to change if reassessed in the future. The buffer and catchment criteria values scored are average at the present and unlikely to change in the absence of major land use changes. The high score for physical form and soils relate primarily to the limited impact from stocking and other major impacts at the weir pool and no change in bathymetry in the recent past (i.e. no recent erosion or land-slipping). The low hydrology score relates primarily to the changing water regime on which this report is predicated whilst the biota scores are average due to the fact that the EVCs are in a state of flux with severe stressors in the form of changing hydrology affecting the scores. Overall the weir pool is in average condition as a wetland.

Table 7-1 Index of Wetland Condition score for the weir pool as a whole (full results presented in Appendix B).

Component	Score
Wetland buffer	2 (of 5)
Wetland catchment	6 (of 10)
Physical form	16 (of 20)
Hydrology	5 (of 20)
Water properties	10 (of 20)
Soils	19.5 (of 20)
Biota	12 (of 20)
Total	70.5 (of 115)

7.1.4 Summary (including listings)

The following section summarises the water dependent flora and fauna species that are likely to have been supported by the Richardson River prior to the construction of the weir pool ('pre-1913'), during its operation (1913-2010 – 'Post 1913') and since it has dried ('Current'). If species have been confirmed as occurring, they are defined as 'Recorded'. In the absence of confirmed records, species presence has been estimated as being 'Likely', 'Possible' or 'Unlikely'. As outlined, these predictions are made on the species' distribution and the presence of suitable habitat at the weir pool. In instances where we are reasonably confident that a species would not have been present historically, or are not present now, 'No' has been recorded (Table 7-2). If a species has been predicted to occur, but has not been recorded at any time at the weir pool or nearby, 'Possible' has been designated, reflecting the imprecise nature of this predictive method. Any relevant legislative protection associated with the species discussed is also recorded in Table 7-2.

Table 7-2 Predictions of species presence at the Rich-Avon Weir Pool (EPBC = Environmental Protection and Biodiversity Act, FFG = Flora and Fauna Guarantee Act. Introduced species have been identified. ^ Stocked).

Species	Scientific name	Listed	Pre 1913	Post 1913	Current
Fish					
Flat-headed Gudgeon	*Philypnodon grandiceps*		Unlikely	Recorded^	No
Common Galaxias	*Galaxias maculatus*		Unlikely	Recorded^	No
Australian Smelt	*Retropinna semoni*		Unlikely	Recorded^	No
Freshwater Catfish	*Tandanus tandanus*	FFG	Unlikely	Recorded^	No
Northern River Blackfish	*Gadopsis marmoratus*		Unlikely	Recorded^	No
Murray Cod	*Maccullochella peelii*	EPBC, FFG	No	Recorded^	No
Golden Perch	*Macquaria ambigua*	FFG*	No	Recorded^	No
Silver Perch	*Bidyanus bidyanus*	FFG	No	Recorded^	No
Carp	*Cyprinus carpio*	Introduced	No	Recorded	No
Redfin Perch	*Perca fluviatilis*	Introduced	No	Recorded	No
Eastern Gambusia	*Gambusia holbrooki*	Introduced	No	Recorded	No
Goldfish	*Carassius auratus*	Introduced	No	Recorded	No
Tench	*Tinca tinca*	Introduced	No	Recorded	No
Frogs and reptiles					
Growling Grass Frog	*Litoria raniformis*	EPBC, FFG	Likely	Recorded	Unlikely

Species	Scientific name	Listed	Pre 1913	Post 1913	Current
Eastern Sign-bearing Frog	*Crinia parinsignifera*		Possible	Possible	Unlikely
Eastern Common Froglet	*Crinia* signifera		Possible	Possible	Unlikely
Eastern Banjo Frog	*Limnodynastes dumerilii*		Possible	Possible	Unlikely
Spotted Marsh Frog	*Limnodynastes tasmaniensis*		Possible	Possible	Unlikely
Eastern-snake Necked Turtle	*Chelodina longicollis*		Likely	Recorded	Recorded**
Mammals					
Water Rat	*Hydromys chyrogaster*		Possible	Possible	Unlikely
Macroinvertebrates					
Yabbies			Possible	Possible	Unlikely
Freshwater Mussels			Likely	Recorded	Possible
Birds#					
Little Pied Cormorant	*Microcarbo melanoleucos*		Possible	Possible	Possible
Crested Pigeon	*Ocyphaps lophotes*		Possible	Possible	Possible
Buff-banded Rail	*Gallirallus philippensis*		Possible	Possible	Possible
Black-tailed Native-hen	*Gallinula ventralis*		Possible	Possible	Possible
Dusky Moorhen	*Gallinula tenebrosa*		Possible	Possible	Possible
Purple Swamphen	*Porphyrio porphyrio*		Possible	Possible	Possible
Eurasian Coot	*Fulica atra*		Possible	Likely	Possible
Great Crested Grebe	*Podiceps cristatus*		Possible	Possible	Possible
Australasian Grebe	*Tachybaptus novaehollandiae*		Possible	Possible	Possible
Hoary-headed Grebe	*Poliocephalus poliocephalus*		Possible	Possible	Possible
Great Cormorant	*Phalacrocorax carbo*		Possible	Possible	Possible
Little Black Cormorant	*Phalacrocorax sulcirostris*		Possible	Possible	Possible
Pied Cormorant	*Phalacrocorax varius*		Possible	Possible	Possible
Darter	*Anhinga novaehollandiae*		Possible	Possible	Possible
Australian Pelican	*Pelecanus conspicillatus*		Possible	Possible	Possible
Whiskered Tern	*Chlidonias hybridus javanicus*		Possible	Likely	Possible
Silver Gull	*Chroicocephalus novaehollandiae*		Possible	Possible	Possible
Masked Lapwing	*Vanellus miles*		Possible	Possible	Possible
Red-capped Plover	*Charadrius ruficapillus*		Possible	Possible	Possible
Black-fronted Dotterel	*Elseyornis melanops*		Possible	Possible	Possible
Banded Stilt	*Cladorhynchus leucocephalus*		Possible	Possible	Possible
Red-necked Avocet	*Recurvirostra novaehollandiae*		Possible	Possible	Possible
Bar-tailed Godwit	*Limosa lapponica*		Possible	Possible	Possible
Marsh Sandpiper	*Tringa stagnatilis*		Possible	Possible	Possible
Sharp-tailed Sandpiper	*Calidris acuminata*		Possible	Possible	Possible
Brolga	*Grus rubicunda*	FFG	Possible	Possible	Possible
Glossy Ibis	*Plegadis falcinellus*		Possible	Possible	Possible
Australian White Ibis	*Threskiornis molucca*		Possible	Possible	Possible
Straw-necked Ibis	*Threskiornis spinicollis*		Possible	Possible	Possible
Royal Spoonbill	*Platalea regia*		Possible	Possible	Possible
Yellow-billed Spoonbill	*Platalea flavipes*		Possible	Possible	Possible
Little Egret	*Egretta garzetta nigripes*	FFG	Possible	Possible	Possible
Intermediate Egret	*Ardea intermedia*	FFG	Possible	Possible	Possible
Eastern Great Egret	*Ardea modesta*	FFG	Possible	Possible	Possible
White-faced Heron	*Egretta novaehollandiae*		Possible	Possible	Possible
White-necked Heron	*Ardea pacifica*		Possible	Possible	Possible
Nankeen Night Heron	*Nycticorax caledonicus hillii*		Possible	Possible	Possible
Australian Wood Duck	*Chenonetta jubata*		Possible	Likely	Possible
Black Swan	*Cygnus atratus*		Possible	Likely	Possible
Australian Shelduck	*Tadorna tadornoides*		Possible	Likely	Possible
Pacific Black Duck	*Anas superciliosa*		Possible	Likely	Possible

Species	Scientific name	Listed	Pre 1913	Post 1913	Current
Chestnut Teal	*Anas castanea*		Possible	Likely	Possible
Grey Teal	*Anas gracilis*		Possible	Likely	Possible
Australasian Shoveler	*Anas rhynchotis*		Possible	Likely	Possible
Pink-eared Duck	*Malacorhynchus membranaceus*		Possible	Likely	Possible
Freckled Duck	*Stictonetta naevosa*	FFG	Possible	Likely	Possible
Hardhead	*Aythya australis*		Possible	Likely	Possible
Blue-billed Duck	*Oxyura australis*	FFG	Possible	Likely	Possible
Musk Duck	*Biziura lobata*		Possible	Likely	Possible
Swamp Harrier	*Circus approximans*		Possible	Possible	Possible
Vegetation communities and flora					
Riparian Swampy Forest/ Sedgy Riparian Forest***			Likely	Present	Present
Grassy Riverine Forest***			Possible	Present	Present

* Natural populations of Golden Perch are listed under the FFG Act. ** Individuals observed in poor condition or recently deceased.
*** Constituent species of these communities are listed in Appendix A # A range of bird species could use the weir pool or river should it become inundated.

7.2 Terrestrial flora and fauna that depend on the riparian woodland habitat

Near permanent water in the Rich-Avon Weir Pool would have likely attracted terrestrial plants and animals to the area or increased the abundance of terrestrial species whose populations would normally be restricted by the ephemeral flow in the Richardson River. The following section reviews the terrestrial values that are likely to have been supported in the area prior to the construction of the weir pool, during its operation and since the weir pool has dried.

7.2.1 Values expected prior to the installation of the Rich-Avon Weir

Prior to the construction of the Rich-Avon Weir, the riparian woodland surrounding the Richardson River would have supported a range of terrestrial plant and animal species.

Frogs and reptiles

There are no additional frog species that are likely to have used habitat surrounding the current location of the weir pool. Two other frog species have ranges that overlap the weir pool; the Common Spadefoot Toad (*Neobatrachus sudelli*) and Bibron's Toadlet (*Pseudophryne bibroni*) (Cogger 2000), however, these species usually emerge in flooded depressions after rain, with limited suitable habitat observed near the weir pool.

While a number of reptiles would have been supported by the riparian woodland habitat it is unlikely that any of them would be obligate riparian species. The species that are likely to have been present in this part of the Richardson River prior to the construction of the Rich-Avon Weir has been estimated based on their expected range and habitat preferences as described by Cogger (2000). It should be noted that as species ranges are often difficult to determine accurately, this method of estimation may miss some species and may falsely identify some species as being possibly present. We have adopted the naming convention used by Cogger (2000) for this review. The species that may have been present in the area prior to the formation of the weir pool are presented in Table 7-3.

Mammals

Estimating the mammal assemblages which would have used the riparian zone of the river prior to 1913 is difficult because of the significant changes, especially land clearing for agriculture, that have occurred since European settlement. As with the reptile assessment, the mammal species that may have been supported in the riparian zone prior to the construction of the Rich-Avon Weir has been estimated based on published records of species' range and habitat preferences (Van Dyck and Strahan 2008). Again, note that this method may underestimate or falsely predict the species that may have been present. The species that may have been present in the area prior to the formation of the weir pool are presented in Table 7-3.

Birds

As discussed previously, the primary bird species and groups that would have used the riparian woodlands in the vicinity of the Rich-Avon Weir Pool would have been terrestrial woodland species. Those likely to occur has been estimated using an assessment of the records within 10 km of the weir pool listed in the VBA coupled with an assessment of likely habitat needs as listed in Pizzey and Knight (2012). Due to the large numbers of potential birds, these are not listed here but are shown in Table 7-3.

Vegetation communities and flora

Prior to the construction of the Rich-Avon Weir, the landscape beyond the Richardson River riparian zone probably supported Plains Woodland and some Riverine Chenopod Woodland and Lignum Swamp EVCs (DEPI 2014). Based on the large remnant trees (e.g. Box Eucalypts and Bulloke) present throughout the surrounding landscape, these communities would have grown to within 50 m of the riverbank.

No rare or threatened communities (based on current listings) are likely to have been present prior to the construction of the weir, however, the large scale land clearing that was taking place at the time means the extent of most plains vegetation communities has been greatly decreased and most communities are considered endangered or vulnerable in the local area if not formally listed. These communities would have supported a range of flora species (211 native species are known from the surrounding 10 km and therefore not listed here) including 10 species currently considered rare or threatened (VBA 2014).

7.2.2 Values expected to be supported after the Rich-Avon Weir was constructed and during its operation as a permanent weir pool

It is expected that permanent water in the weir pool would have provided additional habitat and resources that would have increased the biodiversity in the area. The assemblage at the weir pool cannot however be considered in isolation from the other catchment processes. The weir pool is located in a highly agricultural environment, with much of the riparian area currently subject to stock access. Although some of the riparian zone has now been fenced off, it appears as though stock access was the norm in the past (and still is in some places). Furthermore, agricultural activities on some properties extend very close to the river and therefore the riparian woodland zone is very narrow in some places. It is likely that these agricultural activities would have reduced the available riparian habitat and fragmented the remnant habitat, with a consequent decline in biodiversity. Moreover, introduced species, particularly foxes, rabbits and feral cats have placed significant pressure on native species, particularly native mammals. This would also have had a significant impact on the biodiversity of the weir pool.

There are very few publicly available records of terrestrial plant and animal species in the vicinity of the Rich-Avon Weir Pool and as far as we know no comprehensive surveys have been conducted. It is therefore difficult to estimate the species assemblages with more precision than the predictions outlined above. For the purposes of the current assessment, we have reported the species recorded in the Victorian Biodiversity Atlas (VBA) from within approximately 100 m of the weir pool (accessed 11-12-2014). The VBA records are not necessarily comprehensive or accurate and it possible that a number of the species identified in Section 7.2.1 would also have been present after the weir was built.

Frogs and reptiles

The only reptiles recorded under the VBA for the area around the Rich-Avon Weir Pool are Boulenger's Skink and the Stumpy-tailed Lizard.

Mammals

The VBA does not have any records of mammals in the vicinity of the Rich-Avon Weir Pool

Birds

The VBA has records of birds in the vicinity of the Rich-Avon Weir Pool from a single assessment in 2005. They include the following species:

- Crested Pigeon (*Ocyphaps lophotes*)
- Sulphur-crested Cockatoo (*Cacatua galerita*)
- Galah (*Eolophus roseicapilla*)
- Australian Wood Duck (*Chenonetta jubata*)
- Red Wattlebird (*Anthochaera carunculata*)
- Black-shouldered Kite (*Elanus axillaris*)

Vegetation communities and flora

According to DEPI modelling, the extent of native vegetation around the weir pool as of 2005 was similar to the current corridor of River Red Gum forest along the river. It is likely that the surrounding areas had been largely cleared well prior to 2005 however (which was the time stamp of the DEPI modelling).

Three FFG listed flora species are known from the surrounding area, namely Bulloke (*Allocasuarina leuhmanii*) and Downy Swainson-pea (*Swainsona swainsonioides*) and Hairy Tails (*Ptilotus erubescens*) which would occur in Plains Woodland surrounding the weir pool. No EPBC listed species or communities are known to occur in close proximity to the weir pool.

7.2.3 Current environmental values (determined from site assessment in November 2014)

The loss of water from the Rich-Avon Weir Pool is likely to have reduced the quality of riparian habitat and may have reduced the biodiversity of terrestrial plants and animals in the area. No targeted surveys were carried out to determine what species are currently using the riparian zone of the weir pool. A number of incidental observations were recorded and they are described below.

Frogs and reptiles

Lizard searches were conducted around the weir pool by haphazardly turning logs and disturbing leaf litter. A number of small skinks were observed, likely to be Boulenger's Skink. Two Brown Snakes were also observed.

One Bearded Dragon was recorded sitting on a fence post on Banyena Road, approximately 8 km from the weir pool. Suitable habitat for this species is found near the weir pool.

Mammals

Eastern Grey Kangaroos were commonly observed at the weir pool and in the surrounding area. A small number of Swamp Wallabies were also observed.

Birds

A number of terrestrial woodland bird species were observed during the field assessment namely White-naped Honeyeater (*Melithreptus lunatus*), Galah (*Eolophus roseicapilla*), Sulphur-crested Cockatoo (*Cacatua galerita*), Australian Magpie (*Cracticus tibicen*), Crimson Rosella (*Platycercus eximius*), Magpie Lark (*Grallina cyanoleuca*) and Willie Wagtail (*Phipidura leucophrys*).

While FFG and EPBC listed species (see Table 7-3) were not observed, the weir pool may form habitat for some species dependant on the river for food and the large trees that have been retained along the river bank.

Vegetation communities and flora

Most of the land surrounding the Rich-Avon Weir Pool is used for cropping (wheat and beans) and pasture for livestock. Patches of native vegetation in this landscape are rare except for some sites on the north side of the river west of the Donald Stawell Road that have been re-vegetated. The only remaining native vegetation left in the landscape are large trees, predominantly Black and Grey Box and Bulloke trees. These are remnants of Plains Woodland. There is little evidence of Riverine Chenopod Woodland (i.e. patches of Lignum or saltbushes) that would have naturally characterised the area. The loss of Riverine Chenopod Woodland is probably due to a combination of land clearing and the construction of levees that have significantly reduced the frequency of inundation on the floodplain. .

No EPBC listed species or communities were observed or are considered likely to occur in the area. One FFG listed species namely Bulloke (*Allocasuarina leuhmanii*), was observed on private land adjacent to the river, and one species, Pale Flax-Lily (*Dianella sp. aff. longifolia* (Riverina), listed on the DEPI Advisory list of rare and threatened species (DEPI 2014) was observed growing along both banks of the river amongst grassy understoreys. Pale Flax-Lily is recognised in Victoria as being vulnerable to extinction but has not yet been formally described.

Whilst the observed terrestrial communities and species are likely to be supported by the river and increased water availability and flooding events that proximity to the river represents, these do not appear to be dependent on the raised water table that would have been present when the weir pool was full.

7.2.4 Summary (including listings)

The following section summarises the terrestrial flora and fauna species that are predicted to have possibly occurred in the immediate area prior to the construction of the Rich-Avon Weir (‘pre-1913’), during its operation (‘Post-1913’) and since the weir pool dried (‘Current’). If species have been confirmed as occurring, they are defined as ‘Recorded’. In the absence of these confirmed records, species presence has been estimated as being ‘Likely’, ‘Possible’ or ‘Unlikely’. As outlined, these predictions are made on the species’ distribution and the presence of suitable habitat at the weir pool. In instances where we are reasonably confident that a species would not have been present historically, or are not present now, ‘No’ has been recorded (Table 7-3). If a species has been predicted to occur, but has not been recorded at any time at the weir pool or nearby, ‘Possible’ has been designated, reflecting the imprecise nature of this predictive method. As there are 211 known or recorded native flora species at the weir pool or in close proximity, these have been considered separately in Appendix A.

Table 7-3 Predictions of species presence in the riparian/terrestrial zone at the Rich-Avon Weir Pool.

Species	Pre-European settlement	Listed	Pre 1913	Post 1913	Current
Frogs and reptiles					
Common Spadefoot Toad	*Neobatrachus sudell*		Unlikely	Unlikely	Unlikely
Bibron's Toadlet	*Pseudophryne bibroni*		Unlikely	Unlikely	Unlikely
Marbled Gecko	*Christinus marmoratus*		Possible	Possible	Possible
Tessellated Gecko	*Diplodactylus tesselatus*		Possible	Possible	Possible
Bynoe's Gecko	*Heteronotia binoei*		Possible	Possible	Possible
'Legless Lizard'	*Delma inornata*		Possible	Possible	Possible
Jacky Lizard	*Amphibolurus muricatus*		Possible	Possible	Possible
Painted Dragon –	*Ctenophorus pictus*		Possible	Possible	Possible
Bearded Dragon	*Pogona barbata*		Likely	Likely	Obs. nearby
'Earless Dragon'	*Tympanocryptis lineata*		Possible	Possible	Possible
Sand Monitor	*Varanus goldii*		Possible	Possible	Possible
Lace Monitor	*Varanus varius*		Possible	Possible	Possible
'Skink'	*Cryptoblepharus carnabyi*		Possible	Possible	Possible
'Skink'	*Ctenotus robustus*		Possible	Possible	Possible
White's Skink	*Egernia whitii*		Possible	Possible	Possible
Boulenger's Skink	*Morethia boulengeri*		Likely	Recorded	Recorded
'Skink'	*Morethia obscura*		Possible	Possible	Possible
'Skink'	*Pseudomoia duperreyi*		Possible	Possible	Possible
Blotched Blue-tongued Lizard	*Tiliqua nigrolutea*		Possible	Possible	Possible
Eastern Blue-tongued Lizard	*Tiliqua scicoides*		Possible	Possible	Possible
Western Blue-tongued Lizard	*Tiliqua occipitalis*		Possible	Possible	Possible
Eastern Shingleback	*Tiliqua (Trachydosaurus) rugosus asper*		Likely	Recorded	Possible
'Blind Snake'	*Ramphotyphlops australis*		Possible	Possible	Possible
'Blind Snake'	*Ramphotyphlops bituberculatus*		Possible	Possible	Possible
'Blind Snake'	*Ramphotyphlops nigresens*		Possible	Possible	Possible
Yellow-faced Whip Snake	*Demansia psammophis*		Possible	Possible	Possible
Easter Tiger Snake	*Notechis scutatus*		Possible	Possible	Possible
Red-bellied Black Snake	*Pseudechis porphyriacus*		Possible	Possible	Possible
Easter Brown Snake	*Pseudonaja textilis*		Likely	Likely	Recorded
Mammals					
Inland Free-tailed Bat	*Mormopterus sp.*		Possible	Possible	Possible
Lesser Long-eared Bat	*Nyctophilus geoffroyi*		Possible	Possible	Possible
White-striped Free-tailed Bat	*Tadarida australis*		Possible	Possible	Possible
Echidna	*Tachyglossus aculeatus*		Possible	Possible	Possible
Eastern Grey Kangaroo	*Macropus giganteus*		Likely	Likely	Recorded
Western Grey Kangaroo	*Macropus fuliginosus*		Possible	Possible	Possible
Swamp Wallaby	*Wallabia bicolour*		Likely	Likely	Recorded
Common Wombat	*Vombatus ursinus*		Possible	Possible	Possible
Bush Rat	*Rattus fuscipes*		Possible	Possible	Possible
Western Pygmy Possum	*Cercartetus concinnus*		Possible	Possible	Possible
Common Ringtail Possum	*Pseudocheirus peregrinus*		Possible	Possible	Possible
Common Brushtail Possum	*Trichosurus vulpecula*		Possible	Possible	Possible
Brush-tailed Phascogale	*Phascogale tapoatafa*		Possible	Possible	Possible
Silky Mouse	*Pseudomys apodemoides*		Possible	Possible	Possible
Dusky Antechinus	*Antechinus swainsonii*		Possible	Possible	Possible
Fat-tailed Dunnart	*Sminthopsis crassicaudata*		Possible	Possible	Possible
Southern Ningaui	*Ningaui yvonneae*		Possible	Possible	Possible
Yellow-faced Antechinus	*Antechinus flavipes*		Possible	Possible	Possible
Birds #					
Little Pied Cormorant	*Microcarbo melanoleucos*		Possible	Possible	Possible

Species	Pre-European settlement	Listed	Pre 1913	Post 1913	Current
Crested Pigeon	*Ocyphaps lophotes*		Possible	Possible	Possible
Buff-banded Rail	*Gallirallus philippensis*		Possible	Possible	Possible
Black-tailed Native-hen	*Gallinula ventralis*		Possible	Possible	Possible
Dusky Moorhen	*Gallinula tenebrosa*		Possible	Possible	Possible
Purple Swamphen	*Porphyrio porphyrio*		Possible	Possible	Possible
Eurasian Coot	*Fulica atra*		Possible	Possible	Possible
Great Crested Grebe	*Podiceps cristatus*		Possible	Possible	Possible
Australasian Grebe	*Tachybaptus novaehollandiae*		Possible	Possible	Possible
Hoary-headed Grebe	*Poliocephalus poliocephalus*		Possible	Possible	Possible
Great Cormorant	*Phalacrocorax carbo*		Possible	Possible	Possible
Little Black Cormorant	*Phalacrocorax sulcirostris*		Possible	Possible	Possible
Pied Cormorant	*Phalacrocorax varius*		Possible	Possible	Possible
Darter	*Anhinga novaehollandiae*		Possible	Possible	Possible
Australian Pelican	*Pelecanus conspicillatus*		Possible	Possible	Possible
Whiskered Tern	*Chlidonias hybridus javanicus*		Possible	Possible	Possible
Silver Gull	*Chroicocephalus novaehollandiae*		Possible	Possible	Possible
Masked Lapwing	*Vanellus miles*		Possible	Possible	Possible
Red-capped Plover	*Charadrius ruficapillus*		Possible	Possible	Possible
Black-fronted Dotterel	*Elseyornis melanops*		Possible	Possible	Possible
Banded Stilt	*Cladorhynchus leucocephalus*		Possible	Possible	Possible
Red-necked Avocet	*Recurvirostra novaehollandiae*		Possible	Possible	Possible
Bar-tailed Godwit	*Limosa lapponica*		Possible	Possible	Possible
Marsh Sandpiper	*Tringa stagnatilis*		Possible	Possible	Possible
Sharp-tailed Sandpiper	*Calidris acuminata*		Possible	Possible	Possible
Brolga	*Grus rubicunda*	FFG	Possible	Possible	Possible
Glossy Ibis	*Plegadis falcinellus*		Possible	Possible	Possible
Australian White Ibis	*Threskiornis molucca*		Possible	Possible	Possible
Straw-necked Ibis	*Threskiornis spinicollis*		Possible	Possible	Possible
Royal Spoonbill	*Platalea regia*		Possible	Possible	Possible
Yellow-billed Spoonbill	*Platalea flavipes*		Possible	Possible	Possible
Little Egret	*Egretta garzetta nigripes*	FFG	Possible	Possible	Possible
Intermediate Egret	*Ardea intermedia*	FFG	Possible	Possible	Possible
Eastern Great Egret	*Ardea modesta*	FFG	Possible	Possible	Possible
White-faced Heron	*Egretta novaehollandiae*		Possible	Possible	Possible
White-necked Heron	*Ardea pacifica*		Possible	Possible	Possible
Nankeen Night Heron	*Nycticorax caledonicus hillii*		Possible	Possible	Possible
Australian Wood Duck	*Chenonetta jubata*		Possible	Possible	Possible
Black Swan	*Cygnus atratus*		Possible	Possible	Possible
Australian Shelduck	*Tadorna tadornoides*		Possible	Possible	Possible
Pacific Black Duck	*Anas superciliosa*		Possible	Possible	Possible
Chestnut Teal	*Anas castanea*		Possible	Possible	Possible
Grey Teal	*Anas gracilis*		Possible	Possible	Possible
Australasian Shoveler	*Anas rhynchotis*		Possible	Possible	Possible
Pink-eared Duck	*Malacorhynchus membranaceus*		Possible	Possible	Possible
Freckled Duck	*Stictonetta naevosa*	FFG	Possible	Possible	Possible
Hardhead	*Aythya australis*		Possible	Possible	Possible
Blue-billed Duck	*Oxyura australis*	FFG	Possible	Possible	Possible
Musk Duck	*Biziura lobata*		Possible	Possible	Possible
Swamp Harrier	*Circus approximans*		Possible	Possible	Possible
Wedge-tailed Eagle	*Aquila audax*		Likely	Possible	Possible
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	FFG			

Species	Pre-European settlement	Listed	Pre 1913	Post 1913	Current
Whistling Kite	*Haliastur sphenurus*		Likely	Possible	Possible
Black-shouldered Kite	*Elanus axillaris*		Likely	Possible	Possible
Australian Hobby	*Falco longipennis*		Likely	Possible	Possible
Black Falcon	*Falco subniger*		Likely	Possible	Possible
Brown Falcon	*Falco berigora*		Likely	Possible	Possible
Nankeen Kestrel	*Falco cenchroides*		Likely	Possible	Possible
Barking Owl	*Ninox connivens connivens*	FFG	Likely	Possible	Possible
Pacific Barn Owl	*Tyto javanica*		Likely	Possible	Possible
Sulphur-crested Cockatoo	*Cacatua galerita*		Likely	Likely	Recorded
Little Corella	*Cacatua sanguinea*		Likely	Likely	Likely
Long-billed Corella	*Cacatua tenuirostris*		Likely	Likely	Likely
Galah	*Eolophus roseicapilla*		Likely	Likely	Recorded
Eastern Rosella	*Platycercus eximius*		Likely	Likely	Recorded
Red-rumped Parrot	*Psephotus haematonotus*		Likely	Likely	Likely
Swift Parrot	*Lathamus discolor*	FFG, EPBC	Likely	Likely	Likely
Budgerigar	*Melopsittacus undulatus*		Likely	Likely	Likely
Laughing Kookaburra	*Dacelo novaeguineae*		Likely	Likely	Recorded
Sacred Kingfisher	*Todiramphus sanctus*		Likely	Likely	Likely
Rainbow Bee-eater	*Merops ornatus*		Likely	Likely	Likely
Welcome Swallow	*Petrochelidon neoxena*		Likely	Likely	Likely
Tree Martin	*Petrochelidon nigricans*		Likely	Likely	Likely
Fairy Martin	*Petrochelidon ariel*		Likely	Likely	Likely
Willie Wagtail	*Rhipidura leucophrys*		Likely	Likely	Likely
Restless Flycatcher	*Myiagra inquieta*		Likely	Likely	Likely
Grey Shrike-thrush	*Colluricincla harmonica*		Likely	Likely	Likely
Magpie-lark	*Grallina cyanoleuca*		Likely	Likely	Recorded
White-bellied Cuckoo-shrike	*Coracina papuensis*		Likely	Likely	Likely
White-fronted Chat	*Epthianura albifrons*		Likely	Likely	Likely
Yellow Thornbill	*Acanthiza nana*		Likely	Likely	Recorded
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*		Likely	Likely	Likely
Rufous Songlark	*Cincloramphus mathewsi*		Likely	Likely	Likely
Clamorous Reed Warbler	*Acrocephalus stentoreus*		Likely	Likely	Likely
Silvereye	*Zosterops lateralis*		Likely	Likely	Likely
Fuscous Honeyeater	*Lichenostomus fuscus*		Likely	Likely	Likely
White-plumed Honeyeater	*Lichenostomus penicillatus*		Likely	Likely	Recorded
Noisy Miner	*Manorina melanocephala*		Likely	Likely	Recorded
Red Wattlebird	*Anthochaera carunculata*		Likely	Likely	Likely
Australasian Pipit	*Anthus novaeseelandiae*		Likely	Likely	Likely
Australian Magpie	*Gymnorhina tibicen*		Likely	Likely	Recorded
Australian Raven	*Corvus coronoides*		Likely	Likely	Recorded
Little Raven	*Corvus mellori*		Likely	Likely	Likely
Rock Dove	*Columba livia*	Introduced	Likely	Likely	Likely
Striated Pardalote	*Pardalotus striatus*		Likely	Likely	Likely
House Sparrow	*Passer domesticus*	Introduced	Likely	Likely	Likely
Common Starling	*Sturnus vulgaris*	Introduced	Likely	Likely	Likely
Vegetation communities and flora					
Plains Woodland*			Present	Present	Present
Riverine Chenopod Woodland*			Present	Possible	No
Bulloke	*Allocasuarina leuhmanii*	FFG	Present	Present	Present
Pale Flax-lily	*Dianella sp. aff. longifolia* (Riverina)		Likely	Likely	Present

*Constituent flora are considered in Appendix A # A range of bird species could use the weir pool or river should it become inundated.

7.3 Significance

The following section summarises the significance of the weir pool in a regional, state and national context.

When full, the Rich-Avon Weir was a highly valued asset for the local people, particularly as a place to undertake recreational activities like fishing, hunting and camping. The value of the weir pool was particularly high during the Millennium Drought, where the weir pool was the only surface water in the district for up to 100 km.

The weir pool also supported a range of species recognised under federal and state regulation. The Growling Grass Frog is listed as vulnerable federally (EPBC Act) and endangered at a state level (FFG Act) and was known to form at least three distinct populations at the weir pool (GWMWater 2010). The weir pool also supported a number of large bodied native fish species that were introduced to the weir pool over the near 100 years of its operation (GWMWater 2010). The Murray Cod is listed under the EPBC and FFG acts, and Freshwater Catfish and Silver Perch are FFG listed.

A number of significant wetland bird species could also have occasionally used habitat at the weir pool as listed in Table 7-2. In addition, significant woodland birds may have also used the habitat surrounding the weir pool, and will likely continue to do so, particularly when water returns to the river or weir pool, for example the White-plumed Honeyeaters observed around one of the remaining pools.

Now the weir pool has dried out, the significance has declined. It is no longer a prized recreational asset for the local community with fishing, canoeing and swimming no longer possible. It is also not currently a common camping spot.

In addition, many of the significant flora species are no longer supported by the weir pool. The weir pool was almost completely dry during the field assessment for the current project (December 2014) with only a few small pools persisting that are unlikely to support fish. Surveys were completed for Growling Grass Frogs, however, they were not detected from any of the surveyed sites.

The vegetation associated with the weir pool is significant in that it, along with the wider Richardson River corridor, is some of the last remaining native vegetation through a predominantly cleared landscape. The weir pool has promoted Riverine Swampy Forest in certain areas, a community that is both rare and naturally restricted in areas it occurs as a result of the requirement for regular inundation. This community, however, exists only as a result of the weir pool being built and water supplied regularly down the Richardson River. The Floodplain Riparian Woodland occurring in less regularly inundated areas is more representative of the natural vegetation communities along the Richardson River. Also, no rare or threatened flora species were observed or considered likely to occur that are dependent on the weir pool. The FFG listed Buloke and vulnerable Pale Flax-lily observed are components of the surrounding terrestrial vegetation.

8. Estimating the inundation duration of the weir pool

To allow us to assess the feasibility of environmental watering options for the weir pool, we first need to estimate how long the weir pool would stay full following filling. We also need to estimate how much water needs to be provided to the weir pool to maintain a particular fill volume.

To do this, we first estimated losses from the weir pool, which are predominantly via two processes:

1. Net evaporation (Evaporation – Rainfall)

2. Seepage

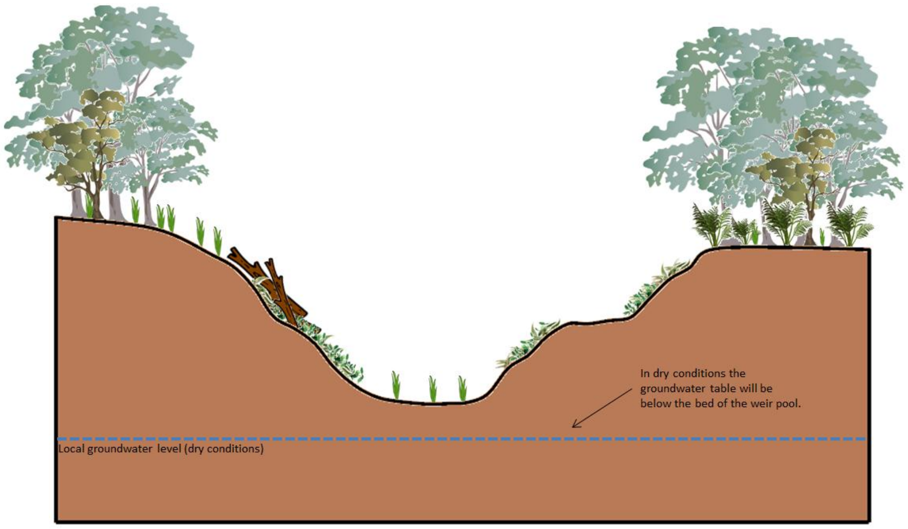
This section describes the loss calculations and inputs, the outputs of this model are presented in Section 9.

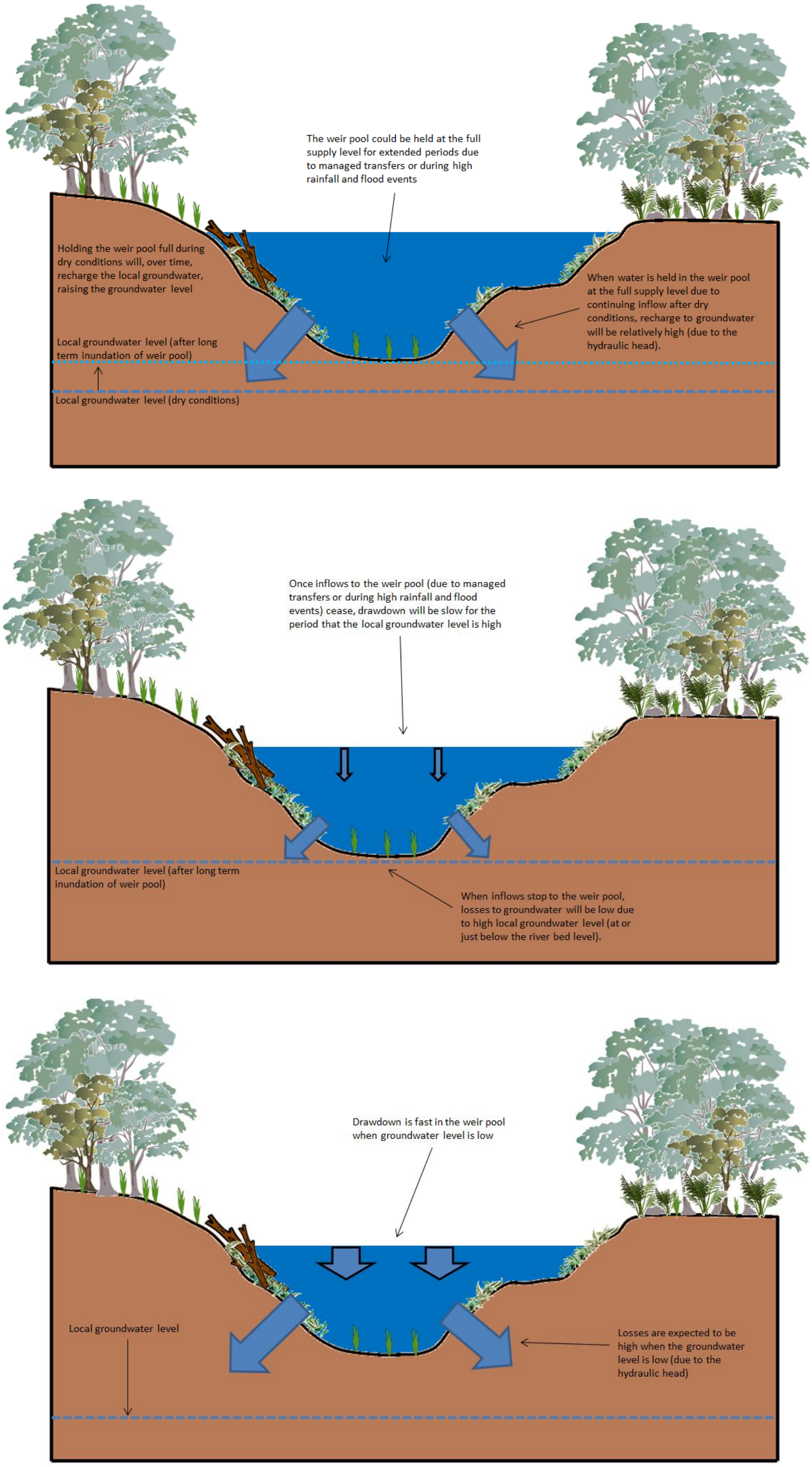
We have used two different techniques for estimating the inundation period in the weir pool. The first estimate is based on an annual loss rate based on GWMWater's operational experience of the weir, which was verified during the 2011 event. On an annual basis, GWMWater estimate 1.3 m of loss through evaporation and seepage (B. Dunn, GWMWater, pers comm.).

While this loss estimate is based on GWMWater's long experience in the system and is consistent with the situation following the floods in 2011, for a number of reasons we think this estimate represents a 'best case' loss scenario and current conditions are likely to be quite different to those observed in the past.

One of the major factors controlling how quickly water will drain from the weir pool once inflows cease is the height of the local groundwater. When groundwater is high, the hydraulic head is low and water will drain relatively slowly. Conversely, when the local groundwater is low and the saturated zone is well below the bed of the weir pool, drainage out of the weir pool will be relatively quick.

Local groundwater around the weir pool would be high following natural rainfall events, such as the 2011 floods. Holding water in the weir pool artificially over an extended period would also recharge the local groundwater. Under the current conditions, where the groundwater level is relatively low (the water table is below the river bed), we may see the weir pool lose more water to seepage than when the water table is high. Conceptual models further explaining the impact of groundwater level on inundation period in the weir pool is presented in Figure 8-1.





The weir pool could be held at the full supply level for extended periods due to managed transfers or during high rainfall and flood events

Holding the weir pool full during dry conditions will, over time, recharge the local groundwater, raising the groundwater level

When water is held in the weir pool at the full supply level due to continuing inflow after dry conditions, recharge to groundwater will be relatively high (due to the hydraulic head).

Local groundwater level (after long term inundation of weir pool)

Local groundwater level (dry conditions)

Once inflows to the weir pool (due to managed transfers or during high rainfall and flood events) cease, drawdown will be slow for the period that the local groundwater level is high

Local groundwater level (after long term inundation of weir pool)

When inflows stop to the weir pool, losses to groundwater will be low due to high local groundwater level (at or just below the river bed level).

Drawdown is fast in the weir pool when groundwater level is low

Local groundwater level

Losses are expected to be high when the groundwater level is low (due to the hydraulic head)

Figure 8-1 Conceptual models explaining the impact of relative groundwater level on seepage rates.

As we think the 1.3 m loss per year from the weir pool may represent a best case scenario, we have also completed a theoretical estimate of seepage based on the permeability of the bed of the weir pool and the driving head between the water level in the weir pool and the current groundwater height. This has allowed us to determine a 'worst case' estimate of loss from the weir pool to feed into a conservative estimate of the volume of water required to maintain levels in the weir pool. The rest of this section describes how we have calculated the 'worst case' scenario.

As there is uncertainty over the seepage rates, we recommend that monitoring is undertaken when an event flows into the system or should environmental water be provided to the weir pool to track the water retention over time.

It should also be noted that loss calculations are based on average data and not daily data. The average data forms our best estimate based on the limited information available. Another limitation was the lack of a rating table (relationship between height, volume and surface area) for the weir pool. As average losses were being adopted, these were calculated for two volume ranges of the pool:

1. Full to half full

2. Half full to empty

8.1.1 Surface Area

We undertook a detailed feature and cross section survey of the weir pool from the weir to Brewsters Road. Detailed survey information of the weir pool from Brewsters Road to its estimated most upstream extent, Reseigh Road, is not available however.

To determine the approximate surface area of the full weir, the average cross sectional width was applied from the cross sections in the surveyed part of the weir. For the unsurveyed section of the weir, the cross sectional width at the two must upstream cross sections was adopted. These widths were then multiplied by the length of the channel. The values adopted for cross sectional width and length are presented in Table 8-1. The surface area has then been used to convert evaporation and loss values (mm) into a volume (ML).

Table 8-1 Surface area calculation.

	Surveyed section		Unsurveyed section		Entire weir length
	Approximate cross sectional width (m)	Approximate Length (m)	Approximate cross sectional width (m)	Approximate Length (m)	Surface Area (m2)
Full	38	6036	30	5650	401,455
Half full	17	6036	15	5650	188,224

8.1.2 Net evaporation

Net evaporation is included in the 1.3 m estimated annual loss, as per GWMWater's operation experience. For the theoretical, 'worst case' scenario, net evaporation is calculated using the equation:

Net evaporation (mm) = Evaporation (mm) – Rainfall (mm)

Daily evaporation data was adopted from the Tottington gauge (079079), with a period of record that extends from January 1973 to August 2014. Daily rainfall data was adopted from the Donald gauge (078072), with a period of record from January 1966 to August 2014. Net evaporation was determined on a daily timestep and then assessed seasonally to determine a daily average net evaporation for each of winter and summer. Typically flow events occur in winter, and hence this value is more readily adopted during our loss assessment. The summary statistics for net evaporation are shown in Table 8-2.

Table 8-2 Net evaporation summary statistics

Statistic	Winter Net Evaporation (mm)	Summer Net Evaporation (mm)
Minimum	-56.6	-94
5th percentile	-5.6	-2.4
20th percentile	0.2	1.6
Average (adopted)	1.18	4.32
80th percentile	3.8	8.0
95th percentile	6.4	10.0
Max	19.2	17.8

8.1.3 Volume

The weir pool was usually managed at 2.2 m at the weir wall, which corresponded to a volume of approximately 600 ML (GWMWater, 2010). There is no rating table (relationship between volume, depth and surface area) available for the weir pool, which makes it difficult to determine the volume or surface area of water lower than the previous operational level. Therefore, we estimated that the volume of the half full storage is 300 ML. This is likely to be a slight overestimate, based on the typical cross sectional area of the weir pool, but will if anything provide a conservative (over-estimate) of loss due to increased driving head.

8.1.4 Seepage

As with evaporation, a component of the 1.3 m loss from the weir pool under the ‘best case’ scenario is due to seepage.

For the ‘worst case’ scenario, estimates of seepage out of the weir pool to groundwater were undertaken using the Darcy analytical solution. This is a fundamental equation of groundwater flow, which describes the rate of flow as dependent on the permeability of the material which the water flows through, the hydraulic gradient across the interval of flow and the area of the interface between the aquifer and the weir (orthogonal to flow). The Darcy solution is:

$$\mathbf{Q = K \times (\Delta head / L) \times A}$$

Where, Q = flux (m^3/day)
K = vertical hydraulic conductivity (m/day) for the sediments/aquifer over which the change in head is measured
Δhead = change in water level between the watertable aquifer at some depth (L) and the weir pool, measured at the edge of the weir pool
L = length over which the change in head is measured (m)
A = surface area of the weir pool (as a proxy for interface between the watertable aquifer and the wetland) (m^2)

The change in head is measured at the edge of the weir, and therefore assumes that vertical (as opposed to horizontal) flow is the primary direction of groundwater exchange with the weir. This is realistic since the weir is more shallow and flat, rather than being deep and intersecting horizontal flow paths. The following schematic show the inputs to the Darcy solution, for a weir that loses water to the watertable aquifer (Figure 8-2).

In order to identify the gradient between the weir and the aquifer (i.e. Δhead), it is necessary to measure the head in the watertable aquifer at some depth (L) below the weir pool. The depth may need to be several metres to be able to discern a difference in water level.

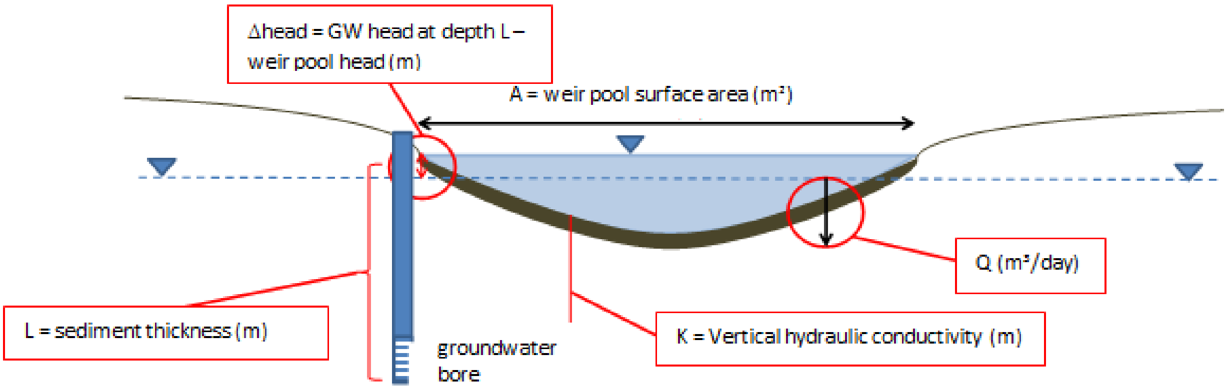


Figure 8-2 Schematic show the inputs to the Darcy solution, for a weir that loses water to the watertable aquifer.

The (vertical) hydraulic conductivity of the sediments was estimated from the closest bore with lithology data (26966), approximately 800 m south of the weir. In the upper 10m of the profile, the log shows a variety of alluvial sediments ranging from silty clay to gravels. A representative value of 0.1 m was selected for the analysis, however, sensitivity testing using values of 0.05 and 0.5 m/day was also undertaken.

A value of 10m for the *L* term was adopted as the length over which the gradient is dissipated. Without bore data this is somewhat arbitrary, however, can be constrained within a reasonable range - it is very unlikely to be as small as a few metres and unlikely to exceed the aquifer thickness. Based on the lithology in the closest bore log (26966), a significant clay layer is present at 12m below surface, and hence an upper aquifer thickness of 10m was estimated.

The change in gradient is based on the difference between the weir level and the head in the aquifer (at distance L, in this case 10m) below the weir. As the weir level changes as the water level declines, this was simulated in two steps, one for the first half of the weir emptying (122 m) and one for the second half (120m). The groundwater level was assumed to be at the base of the weir (119m). Bore records closest to the weir (Bore 26963) indicate groundwater levels fluctuating between 122 – 123m from the late 1980s to 1997, when the record ceased. However, there is evidence of significant decline in other groundwater hydrographs in the region (due to the Millennium Drought) in the order of 2 – 3 m. (This is consistent with shallow groundwater trends across much of Victoria during the period). Further, there was the local effect of the weir ceasing to be filled after the construction of the Wimmera-Mallee Pipeline. This would also have the effect of lowering groundwater levels compared to those observed in Bore 26966.

Finally, the surface area (A) was estimated based on the weir pool width. As per the gradient, this was calculated in two parts, one for the weir pool declining from 100 to 50% and the second for the 50% to empty period. These widths and ultimate surface areas were consistent with those detailed in Table 8-1.

This analysis has assumed that groundwater levels do not change as the weir pool seeps into the groundwater. Given other assumptions in this analysis, and consistent with the conservative approach adopted, this is considered an appropriate assumption. However, as outlined above, after multiple years of filling of the weir, groundwater mounding beneath/around the weir will occur and to some degree will reduce the rate of loss to groundwater.

8.1.5 Water retention

Water retention for the ‘worst case’ was calculated as the total storage volume divided by the average daily loss, where loss was the sum of daily evaporation (ML) and daily seepage (ML). This produced the number of days in which water is likely to be retained in the weir pool.

8.1.6 Changes to volumes of loss and water retention

To provide an indication of the volume of loss, and therefore water retention, we have adopted average values which will not represent all conditions. Changes to volumes of loss, and therefore water retention will be based on the factors listed below.

- Wet or dry climate conditions will alter net evaporation, which will in turn alter the loss
- Groundwater levels over time may increase, which will mean less driving head and therefore less loss to groundwater; conversely they may decrease, which will mean more loss to groundwater

9. Ecological consequences of different management scenarios

The following section discusses what is likely to happen to the environmental values of the weir pool under a range of environmental watering and management scenarios. Our assessment is based on our understanding of the ecology of the weir pool and the tolerances and habitat preferences of the species and communities that are, or were, supported.

Five management scenarios have been considered:

1. Provide water at or near the previous operational level of the weir pool and keep it full throughout the year.
2. Provide a smaller volume of environmental water that does not inundate the whole pool but that provides water in the weir pool between natural filling events.
3. Provide no environmental water but retain the weir so that the weir pool will fill during natural high flow events.
4. Provide no environmental water and remove or decommission the weir to allow natural river flows to pass through the system.
5. Although not a stand-alone environmental watering scenario, an additional scenario is considered where deep pools are present which could act as refuges between natural high flow events.

The following sections describe the hydrology which would underpin each of the management scenarios (e.g. how frequently such events would occur naturally, how long the weir pool would hold water, volume of water required). Following this, the benefits and risks of each scenario for the major environmental values are considered in detail.

9.1 Scenario 1: Provide environmental water to keep the weir pool at or near the level it was operated at

The first broad environmental watering scenario considered is to provide water at or near the level the weir pool was kept during operation (2.2 m at the weir) and to maintain that level in the weir pool (as was the case when the weir pool was operational as part of the Stock and Domestic supply system). It is assumed that the offtake to Lake Batyo Catyo will be closed.

Hydrology

To determine how much environmental water would be required to keep the weir pool at this level, it is necessary first to understand the natural hydrology of the system, specifically, how often the weir pool would fill. In addition, it is necessary to estimate how long the weir pool would remain full.

For the purpose of the current assessment, we have looked at the historic flow record to estimate how many natural flow ‘events’ would fill the weir pool. Events are classed as flows greater than zero for more than two days and events that have a cumulative flow greater than 50 ML are shown in Figure 9-1.

As can be seen, the historic river inflows (excluding channel transfers) to the weir pool would have seen the weir pool filled (to 600 ML) 13 times over the 20 year period of record. These events occurred in 10 of 20 years (Figure 9-1).

It should be noted that several of these events would have resulted in the Avon and Richardson Rivers flowing for an extended period and therefore the weir pool would have been full throughout the event. For example, event 41, which corresponds with the floods of 2011, extends from August 2010 to September 2011 (identified by a red star in the figure below) and although some low flows occurred during these periods, the weir pool was likely to be full and overtopping.

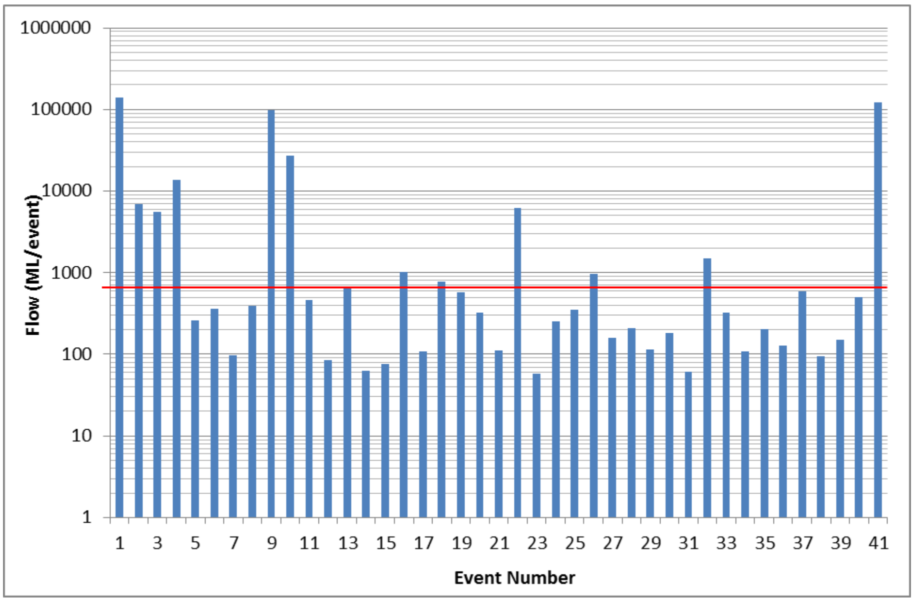


Figure 9-1 Flow events greater than 50 ML/day, highlighting those above 600 ML (the red line) which would fill the weir pool.

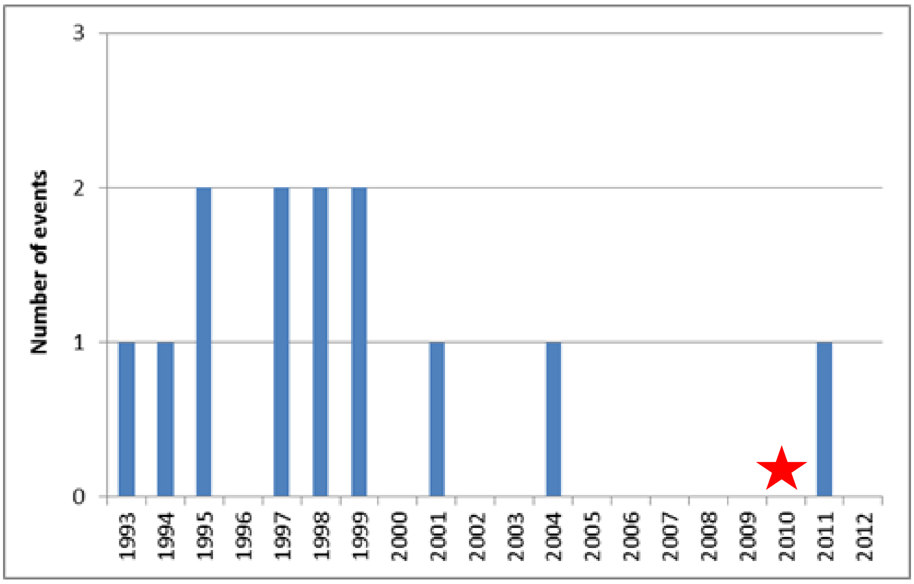


Figure 9-2 Distribution of events across the period of record that would fill the weir pool. The red star indicates the event which began in August 2010 through to September 2011.

Based on the method described in Section 8, when the weir is full and receiving no inflow, seepage and net evaporation are the only losses from the weir pool. Under the ‘best case’ loss estimate (provided by GWMWater), average daily loss rates are estimated to be 3.56 mm/day, or 1.43 ML/day.

As the objective of this scenario is to keep the weir pool full and given the unpredictability of natural flows, it would not be possible to only provide water between events. In reality water to compensate for the daily losses would need to be provided each day. Any natural inflows would therefore pass downstream. Providing water to cover losses would equate to a maximum likely volume of 520 ML/day per year to be provided if the weir is to be maintained at the previous operational level.

Under the ‘worst case’ loss scenario, which adopts a conservative seepage value, losses could be greater than 10 ML/day, which would equate to a volume of greater than 3,650 ML over a year.

From an ecological perspective, the important results for this scenario are:

- When full, water depth in the centre of the channel would be up to between 2 and 3 m.

The benefits and risks to each group of environmental value are outlined below.

Water quality

Benefits

- The daily flow that would be required to keep the weir pool at the previous operational level may be sufficient to mix the weir pool and prevent water quality from declining significantly. If this is the case, the water in the weir pool would be suitable to support a range of aquatic biota (as it did when the weir pool was operating as part of the Stock and Domestic system).

Risks

- Under the original operation of the weir pool, water was transferred to Lake Batyo Catyo and therefore would not sit in the weir pool for very long (up to 600 ML/day could be transferred; GWMWater 2010). Without this passing flow, or sufficient flow to mix the weir pool, water quality in the weir pool may decline significantly. .
- Salinity has been an issue in the weir pool in the past and would likely be high if water was left for long periods (historically the first flush was passed downstream and not to Lake Batyo Catyo, see Section 6.1.2). High salinity can be toxic to a range of aquatic biota.
- Nutrients may also build up in the weir pool over time, which may lead to algal blooms, especially if temperatures are high and the water is stagnant. To our knowledge algal blooms have not been an issue in the weir pool historically, but have been recorded in Lake Batyo Catyo.
- Blackwater events are a potential risk following the inundation of the weir pool. Blackwater results from the decay or organic matter (e.g. leaves, wood) and can lead to significant reductions in dissolved oxygen with severe consequences for fish. Blackwater may be a particular issue in the weir pool had been dry prior to refilling.

Fish

Benefits

- Water depth in the weir pool would be between 2 m and 3 m in the middle of the channel, which would provide a range of habitat for fish. Snags and emergent vegetation would be inundated, which would form cover and breeding habitat and the deep water in the channel would provide foraging habitat, particularly for pelagic species.
- The range of habitats inundated would also promote the growth of macroinvertebrates and periphyton, which would form an important part of the diet of any fish communities in the weir pool.

Risks

- Colonisation by native fish is unlikely. The ephemeral nature of the rest of the system means that there are unlikely to be any suitable source populations nearby. Furthermore, the numerous fish barriers in the system (such as the weir wall) would mean that movement would be prevented except under flood conditions. Colonisation by introduced species, such as Carp and Eastern Gambusia may be more likely, especially if there are potential source populations nearby, for example in farm dams.
- The large bodied, recreationally valuable fish species such as Golden Perch and Murray Cod will not colonise the weir pool naturally nor breed in the weir pool if they were introduced. Populations of these species would therefore need to be managed entirely through stocking programs. While this may not be a major risk, however, as it relies on the resources of the agencies (likely Fisheries Victoria) that would need to stock the weir pool, it is not definite.

Frogs and reptiles

Benefits

- Water near the previous operational level in the weir pool would engage fringing vegetation, which would provide important breeding, foraging and cover habitat for frogs.
- Most of the frog species that have been recorded from the weir pool (with the exception of Growling Grass Frogs) are relatively common and widespread. Many of these species can use a variety of habitats such as ephemeral, rain filled depressions and are likely to be tolerant of poor water quality conditions. These common species are more likely to be still present in the landscape than Growling Grass Frogs and may therefore be able to recolonise the weir pool once it is inundated, provided that there are source populations in the nearby landscape.
- The slow flowing, permanent water would also give tadpoles sufficient time to develop and metamorphose.
- Frogs are important food resources for higher order predators such as birds, snakes and fish.
- Water in the system which engaged fringing vegetation and snags would support turtle populations.

Risks

- Water could be provided to the weir pool and Growling Grass Frogs would still not recolonise.
- Given the length that the weir pool has been dry, it is not certain that Growling Grass Frogs are still in the area (see Section 7.1.3). Growling Grass Frogs are relatively short lived (likely to be only one or two years) and it is therefore unlikely that populations could persist for many years in a row of unfavourable conditions (e.g. drought or high flows severely disrupting reproduction).
- Translocation of Growling Grass Frogs has been attempted occasionally in the past (Koehler *et al.* 2014), but is rarely successful.
- Growling Grass Frogs may be impacted by very high salinity in pools (although the tolerances of this species is not known definitively, see Section 7.1.3).
- Growling Grass Frogs form metapopulations, which means that local persistence of the species relies on movement and colonisation across the landscape (see Section 7.1.2). Colonisation processes may break down if populations or suitable breeding sites are too far apart from each other or are separated by unfavourable landscapes.

Mammals

Benefits

- Water Rats will likely return to the weir pool provided that food resources also return.
- Terrestrial mammals (kangaroos, wallabies, small mammals) would likely use the weir pool in greater numbers if it was inundated than if it was left dry.

Risks

- If the food resources do not return, or viable populations are not currently found in the area to supply colonists, then mammal populations will not recover even if water is supplied to the weir pool.
- Usage of the weir pool will be strongly dependent on the surrounding landuse. It is likely that pressure on many of the mammal species will only be partly related to water availability and will be primarily controlled by resources in the broader landscape.

Macroinvertebrates

Benefits

- Over time the diversity of species that was supported by the weir pool will return, although the timescale over which this will occur is difficult to predict. The species that rely on permanent water will recolonise from other water bodies in the area. Desiccation tolerant taxa may still be present at the weir pool and may recolonise quickly. Some mussel species are able to survive dry conditions by burrowing and therefore may still be present at the weir pool and may recolonise quickly following inundation.

Risks

- If water quality became very poor, then pollution sensitive species may decline, reducing the overall diversity of the macroinvertebrate communities.

Birds

Benefits

- Waterbirds are likely to use the weir pool whenever it has sufficient water. It is likely that birds will predominantly use the weir pool as foraging habitat. Some ducks and similar types of birds may breed in or near the weir pool, but it is not expected to become a significant breeding site for colonial nesting waterbirds.
- Woodland birds may become more abundant if the condition of the riparian zone improves and food resources (e.g. nectar, seeds and insects) increase.

Risks

- Despite the provision of water, depending on water availability in the landscape (e.g. Avon Plains wetlands) the weir pool is likely to only ever be secondary habitat.

Vegetation communities and flora

Benefits

- Holding water at the previous operational level is likely to raise the local water table in close proximity to the weir pool, enabling the sedge communities along the lower terraces and fringing grasses and rushes to regenerate.
- With the weir pool inundated there would be little contraction in the more highly water-dependent Sedgy Riverine Forest and Riverine Swamp Forest communities.
- Higher water tables would assist in the regeneration of River Red Gum communities along the northern banks where land has been made available in close proximity to the weir pool.
- Aquatic flora would likely return to the weir pool.

Risks

- Without the higher flows through the weir pool that would have traditionally occurred during the transfer of water to Lake Batyo Catyo, there is a risk that water quality variables, including salinity would become potentially toxic to many of the plant species present along the banks and low lying areas.

Conceptual model

A conceptual model, illustrating some of the major habitat consequences of filling the weir pool to the previous operational level is provided in Figure 9-3.

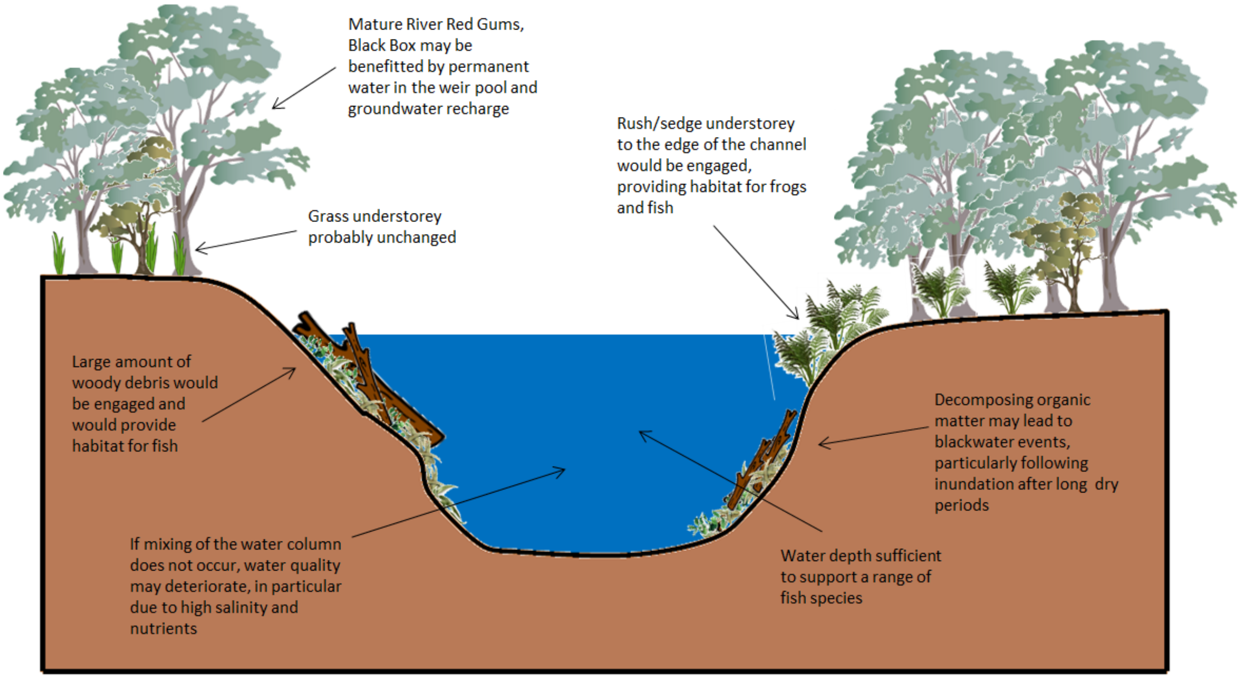


Figure 9-3 Conceptual model illustrating some of the important consequences of filling the weir pool to the previous operational level.

9.2 Scenario 2: Provide sufficient environmental water to fill the weir pool to 50% of the previous operational level between natural filling events

This second environmental watering scenario provides water to fill the weir pool to approximately half its previous operational level. The ecological aim of this scenario is to maintain habitats for aquatic biota (particularly fish, macroinvertebrates and frogs) between natural events that would fill the weir pool.

Ideally, a lower volume scenario would involve filling a few refuge pools that would provide a diversity of habitats (e.g. water depths, snags) between natural filling events. However, as outlined in Section 6.1.4, significant sedimentation was apparent in the weir pool during the site assessment. This sedimentation has built up behind the weir over the 100 years of its operation and has filled any naturally deep sections that would have existed along this stretch of the river. As a consequence, there are no obvious deep pools which would be suitable refuges for aquatic biota between natural filling events. Therefore providing a lower volume of environmental water would result in reasonably consistent water depth throughout the weir.

The ecological consequence of providing water to a weir pool with refuge pools is discussed in Section 9.5, however, for the current scenario we have considered a scenario which holds the weir pool at a lower volume between natural events. We have adopted a value of approximately 50% of the previous operational level (300 ML) as this volume and assumed that the volume would be maintained throughout the year. Filling the weir pool to 300 ML would provide water depth of about 1.5 m in the middle of the channel, which would approximate the habitat provided by the deeper refuge pools that would have been present in this part of the river prior to the construction of the weir.

Under this scenario, the weir pool would occasionally be full following natural events but in between these events would be kept at a lower water level.

Hydrology

The historical record indicates that events that would provide greater than 300 ML to the weir pool have occurred 22 times over the 20 years (Figure 9-4). These events took place in 14 of the 20 years (Figure 9-5).

Based on the method described in Section 8, when the weir pool is full and receiving no inflow, seepage and net evaporation are the only losses from the weir pool. The average loss is approximately 0.67 ML/day (when starting from half capacity). If no natural inflows are provided, this would require 240 ML per year to be provided if the weir is to be maintained at half of the previous operational level.

Under the ‘worst case’ loss scenario, which adopts a conservative seepage value, losses could be up to approximately 6 ML/day, which would equate to a volume of approximately 2,200 ML over a year.

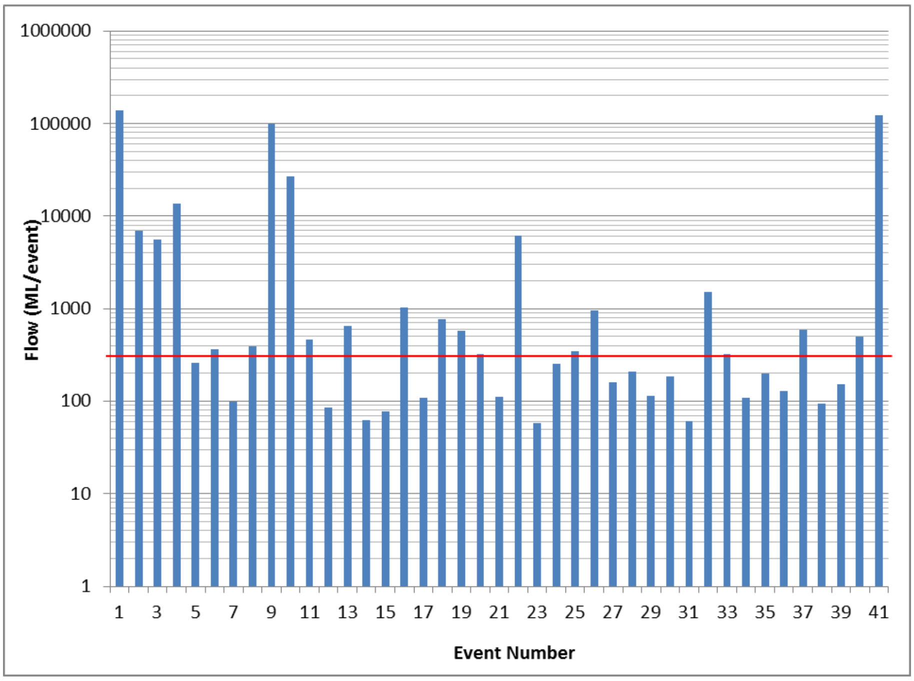


Figure 9-4 Flow events greater than 50 ML/day, highlighting those above 300 ML (the red line) which would fill the weir pool to greater than half the previous operational level.

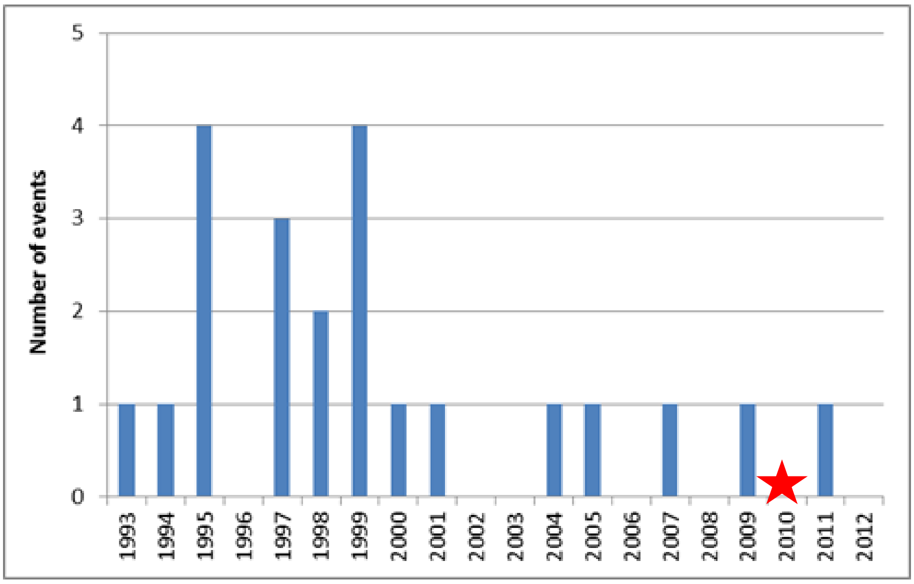


Figure 9-5 Distribution of events across the period of record that would fill the weir pool. The red star indicates the event which began in August 2010 through to September 2011.

From an ecological perspective, the important results for this scenario are:

- The water depth in the centre of the channel would not fall below approximately 1 to 1.5 m.
- The weir pool fills naturally to greater than 300 ML on average approximately three out of four years. As this fill frequency is a long term average, there may be a number of years in sequence when the weir pool receives events each year, as well as periods of years when it would empty if not for the environmental water and therefore will remain at half the previous operational level.
- Filling occurs generally in winter.

The benefits and risks to each group of environmental value are outlined below.

Water quality

Benefits

- Under the original operation of the weir pool, water was transferred to Batyo Catyo and therefore would not sit in the weir pool for very long (up to 600 ML/day could be transferred; GWMWater 2010). Without this passing flow, water quality in the weir pool may decline significantly. The daily flow that would be required to keep the weir pool at the reduced level may be sufficient to mix the weir pool and prevent water quality from declining significantly.

Risks

- If the flow into the weir pool is not sufficient to mix the water column, water quality could decline significantly. Salinity has been an issue in the weir pool in the past and would likely be high if water was left for long periods (historically the first flush was past downstream and not to Lake Batyo Catyo, see Section 6.1.2).
- Nutrients may also build up in the weir pool, which may lead to algal blooms, especially if temperatures are high and the water is stagnant (to our knowledge algal blooms have not been an issue in the weir pool historically, but have been recorded in Lake Batyo Catyo).

Fish

Benefits

- Some habitat would be provided for small fish as some snags and vegetation would be engaged at the lower water level.

Risks

- Colonisation by native fish is unlikely. The ephemeral nature of the rest of the system means that there are unlikely to be any suitable source populations nearby. Furthermore, the numerous fish barriers in the system (such as the weir wall) would mean that movement would be prevented except under flood conditions. Colonisation by introduced species, such as Carp and Eastern Gambusia may be more likely, especially if there are potential source populations nearby, for example in farm dams.
- The lower water level between filling events is unlikely to provide habitat that is suitable for the stocking of large-bodied, recreational valuable species.
- The lower water level with limited flushing may lead to high salinity and nutrient load in the water column which could be toxic to a range of aquatic biota.
- The lower water depth is unlikely to be sufficient to provide refuge habitat for anything but small and hardy fish species. Sediment which has accumulated in the weir pool means that there are few deeper areas that would act as refuges for fish (see Section 6.1.4). (See Section 9.5 for a discussion of the ecological consequences if deep refuge pools were present).

Frogs and reptiles

Benefits

- Shallow water is likely to provide breeding and foraging habitat for some species, particularly if over time suitable emergent vegetation establishes lower in the channel.
- Many of the hardy frog species are able to tolerate relatively poor water quality and provided that vegetation is engaged at the right times of year, these species could tolerate variable water level.
- Frogs are important food resources to higher order predators such as birds, snakes and fish.
- Shallow water could provide some habitat for turtles in between events, but unlikely to provide high quality habitat.

Risks

- Water could be provided to the weir pool and Growling Grass Frogs would still not recolonise.
- Frog species need to be present in the system to recolonise. It is unclear if Growling Grass Frogs are still in the area given the long period of dry condition; Growling Grass Frogs are thought to be short lived (likely to be only two years) and therefore populations cannot persist over only a few years without successful breeding.
- Growling Grass Frogs form metapopulations, which means that local persistence of the species relies on movement and colonisation across the landscape (see Section 7.1.2). Colonisation processes may break down if populations or suitable breeding sites are too far apart from each other or are separated by unfavourable landscapes.
- Frog habitat that establishes over time in the bottom of the channel such as fringing vegetation may be scoured or drowned out during natural high flow events.

Mammals

Benefits

- Water rats may return to the weir pool provided that food resources, such as freshwater mussels also return.
- Terrestrial mammals (kangaroos, wallabies, small mammals) would likely use the weir pool in greater numbers if it was inundated than if it was left dry.

Risks

- If the food resources do not return, or viable populations are not currently found in the area to supply colonists, then mammal populations will not recover even if water is supplied to the weir pool.

- Colonisation and usage of the weir pool will be strongly dependent on the surrounding landuse. It is likely that pressure on many of the mammal species will only be partly related to water availability and will be primarily controlled by resources in the broader landscape.

Macroinvertebrates

Benefits

- Over time the diversity of species that was supported by the weir pool will return, although the timescale over which this will occur is difficult to predict. The species that rely on permanent water will recolonise from other water bodies in the area. Desiccation tolerant taxa may still be present at the weir pool and may then recolonise quickly.
- Freshwater Mussels may be supported by the weir pool when operated under a lower water level, but unlikely to be in the high numbers as would have been supported during the operation of the weir pool.

Risks

- The lower water level under this scenario would provide less habitat for macroinvertebrates than under Scenario 1.
- If water quality became very poor, then pollution sensitive species may decline, reducing the overall diversity of the macroinvertebrate communities.

Birds

Benefits

- The weir pool may once again become attractive to wetland species should food resources (frogs, fish) return and possibly for woodland species should habitat (trees, food) also improve in condition/extent.

Risks

- Despite the provision of water, depending on water availability in the landscape (e.g. Avon Plains wetlands) the weir pool is likely to only ever be secondary habitat.

Vegetation communities and flora

Benefits

- Supplying water would encourage sedge communities and water dependant grasses and rushes to regenerate along the banks of the river though in different locations to those observed during the field assessment, probably leading to colonisation lower down the bank.
- Additional water supplies would assist in the regeneration of River Red Gum communities along the northern banks where land has been made available.
- Aquatic flora may return to the weir pool in some places.

Risks

- The lower water level would result in at least some contraction in the more highly water-dependent Sedgy Riverine Forest and Riverine Swamp Forest communities including some scattered tree deaths.
- Regular flows would be needed to be provided in order to support reliant vegetation.
- Weeds may be encouraged to grow in the weir pool due to regular water supply at the lower water level although filling in winter when most weeds germinate will limit the extent of weed growth.
- Depending on the timing between natural filling events, there may be limited loss of some regenerating River Red Gums (i.e. thinning of existing stands, not contraction of area) that have become established while the weir pool was full. Larger River Red Gums will unlikely be affected overall as they will have developed deep tap roots able to access groundwater, however, some scattered individual tree deaths may occur as a result of the changing hydrological conditions.
- Vegetation communities that develop lower in the bank would be scoured or drowned during natural high flow events and the inundation of the weir pool.

Conceptual model

- A conceptual model, illustrating some of the major habitat consequences of filling the weir pool to half the previous operational level to buffer between filling events is provided in Figure 9-6.

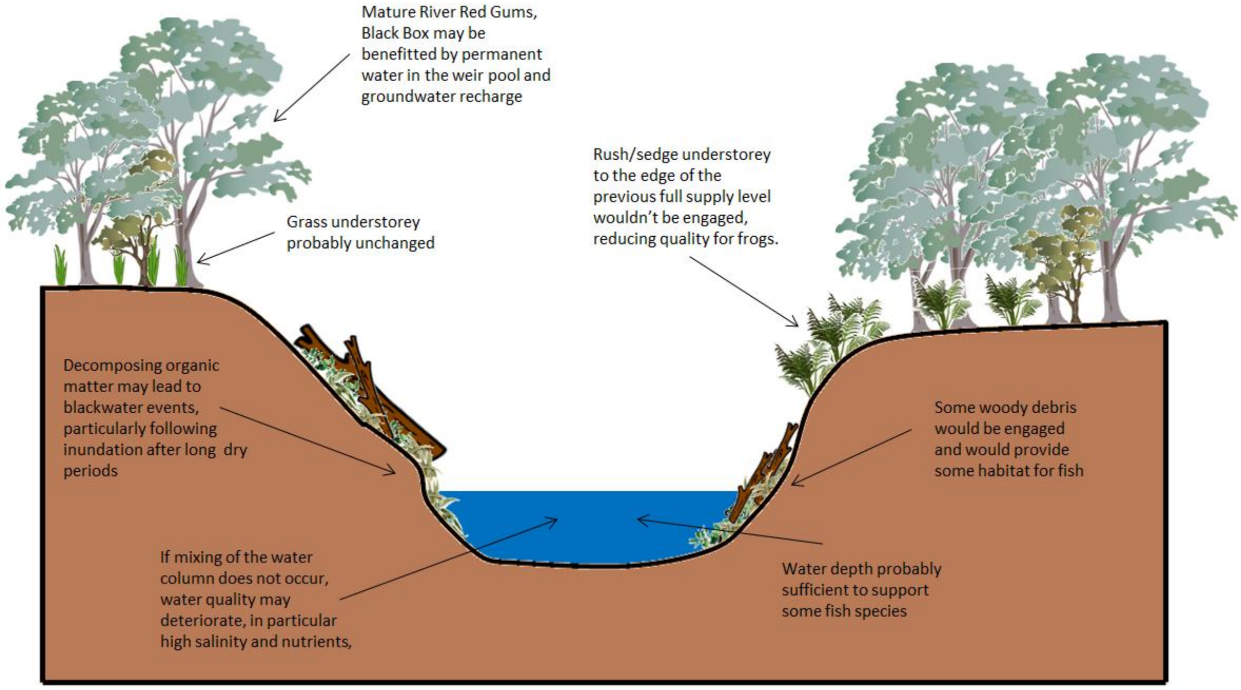


Figure 9-6 Conceptual model illustrating some of the important consequences of filling the weir pool to a volume of about 300 ML (figure not to scale).

9.3 Scenario 3: Do not provide environmental water but retain the weir

The third scenario considered is one where environmental water is not provided to the weir pool but the weir is left in place and therefore water is retained in the weir pool following natural events. As the weir gates are currently closed and all the inflows are captured, this is essentially how the weir pool is currently being managed.

Hydrology

By adopting the 'best case' average losses and streamflow, provided as operational estimates from GWMWater, the approximate volume in the weir can be estimated. The approximate volume between 1993 and 2012, based on no channel transfers is shown in Figure 9-7 and summarised in Figure 9-8. It can be seen that natural stream flows only fill the weir approximately 20% of the time; the weir pool would be more than half full for approximately 70% of the time, and some water is within the weir almost all of the time.

Based on the estimates of seepage and evaporation loss, provided as operational estimates from GWMWater, following complete filling of the weir pool (to approximately 600 ML), it is estimated that 1.43 ML of water would be lost each day. This rate of loss would mean that if there was no inflow into the weir pool, that water would be retained in the weir poll for approximately 22 months (when starting full).

From a fill volume of 300 ML, the daily loss is estimated to be 0.67 ML/day. This rate of loss would mean that water is estimated to be retained in the weir poll for 15 months (when starting from half full).

Under the 'worst case' loss scenario, the weir is likely to be full for only 10% of the time, and the weir pool would be completely empty for 60% of the time.

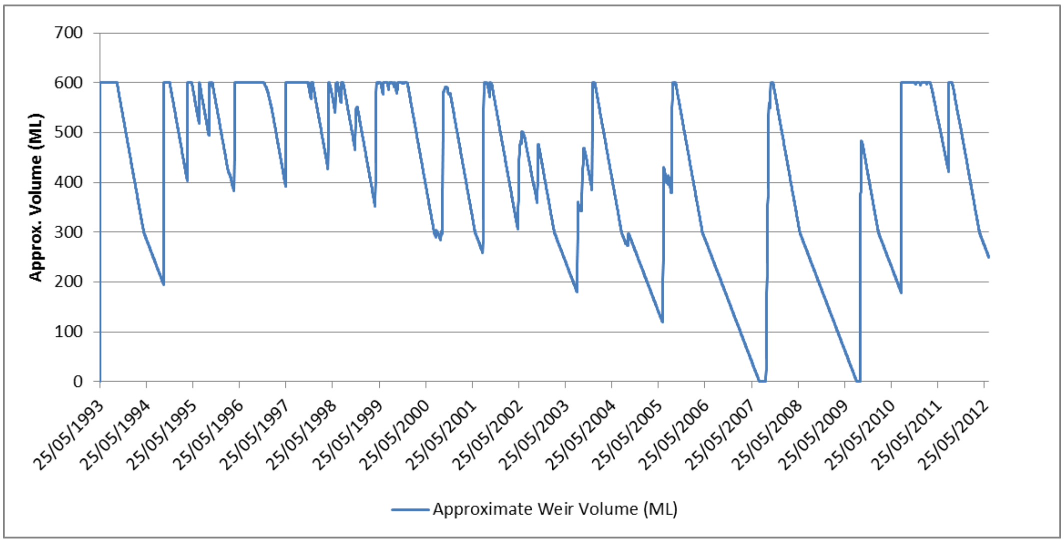


Figure 9-7 Approximate weir volume based on historical streamflow (excluding channel transfers) and average losses.

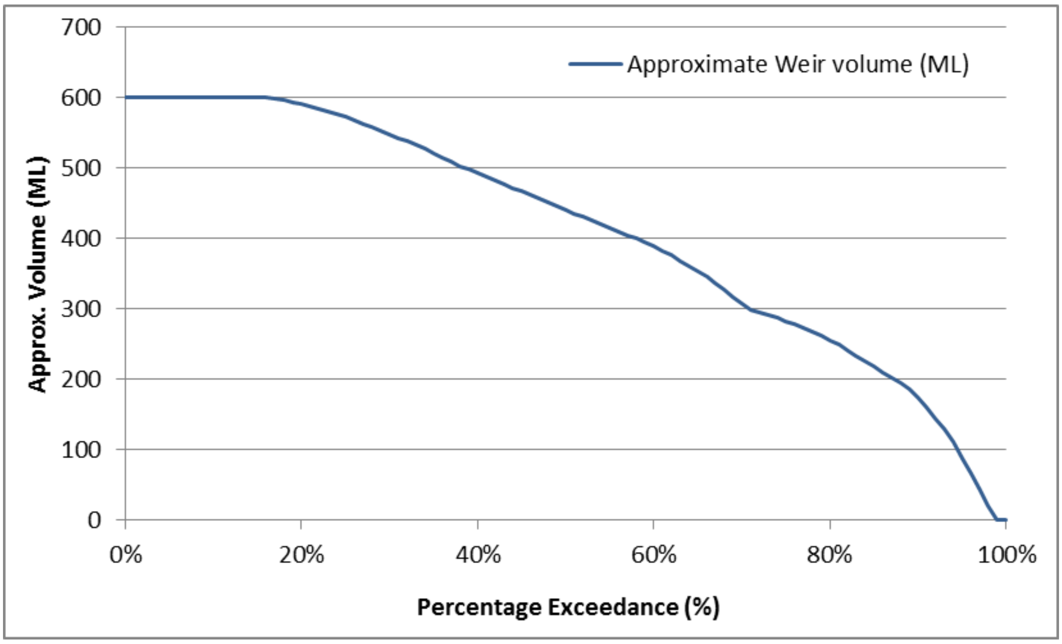


Figure 9-8 Percentage exceedance plot of estimated weir volume based on historical streamflow (excluding channel transfers) and average losses.

From an ecological perspective, the important results for this scenario are:

- The weir pool fills completely naturally on average approximately once every two years and to greater than 300 ML on average approximately three out of four years. As this fill frequency is a long term average, there may be a number of years in sequence when the weir pool receives events each year, as well as a number of years when no natural events will occur that would fill the weir pool.
- Water depth would fluctuate over the year. Events that would fill the weir pool are generally short and we estimate that drawdown would be fast (as the local groundwater level would be quite low).
- Filling occurs generally in winter and the weir pool is likely to hold water for up to 22 months when starting full (‘best case’ estimate) and with no other inflows, but is almost certain to dry completely if there are more than two years without any substantial natural flows (as is the case now).

The benefits and risks to each group of environmental value are outlined below.

Water quality

Benefits

- The natural inundation and drawdown of the weir pool means that water quality is unlikely to deteriorate significantly.

Risks

- It is possible that salinity and nutrients could build up in the weir pool during inundation periods, but probably not to a degree that would be problematic for aquatic biota.

Fish

Benefits

- There are unlikely to be any major benefits to fish from this watering scenario.

Risks

- The weir pool is likely to dry completely during prolonged droughts, meaning that fish populations would not be able to establish. Fish could be stocked when the weir pool is full but this would require some effort and cost (and would result in significant mortality when drying).

Frogs and reptiles

Benefits

- The weir pool is likely to fill to some level each year, which if deep enough and persisted long enough would provide breeding habitat for common and hardy frog species (e.g. Common Frog). Provided that these species are present in the landscape they are likely to use the weir pool. Tadpoles take a number of months to develop, and if water is held in the weir pool for a few months then breeding is likely to be successful.
- Populations of common and hardy frog species could probably survive a number of years without water in the weir pool as these species are able to use a number of different breeding habitats (e.g. farm dams, rain filled depressions) and can persist in dry landscapes for a number of years.
- Many of the hardy frog species are able to tolerate relatively poor water quality and provided that vegetation is engaged at the right times of year, could tolerate variable water level.
- Frogs are important food resources to higher order predators such as birds, snakes and fish.
- Turtles are likely to opportunistically use habitat at the weir pool when it is inundated, provided that they are present in the landscape and are able to colonise over land.

Risks

- Frog species need to be present in the system to recolonise. It is unclear if Growling Grass Frogs are still in the area given the long period of dry condition; Growling Grass Frogs are thought to be short lived (likely to be only two years) and therefore populations cannot persist over only a few years without successful breeding.
- Natural filling may not occur sufficiently frequently to support populations of Growling Grass Frogs. Fill events would need to occur in most years to support successful breeding and even 2-3 years without successful reproduction may lead to local extinction.
- Growling Grass Frogs form metapopulations which rely on colonisation across the landscape (see Section 7.1.2). Colonisation processes may break down if other populations are too far or are separated by unfavourable landscapes.

Mammals

Benefits

- Terrestrial mammals (kangaroos, wallabies, small mammals) would likely use the weir pool in greater numbers if it was inundated than if it was left dry.

Risks

- If the food resources do not return, or viable populations are not currently found in the area to supply colonists, then mammal populations will not recover even if water is supplied to the weir pool.
- Colonisation and usage of the weir pool will be strongly dependent on the surrounding landuse. It is likely that pressure on many of the mammal species will only be partly related to water availability and will be primarily controlled by resources in the broader landscape.

Macroinvertebrates

Benefits

- The macroinvertebrate communities supported by the periodically inundated weir pool would consist primarily of hardy, desiccation tolerant species but other taxa would be able to colonise during periods of inundation.

Risks

- Unlikely that large populations of Freshwater Mussels would be able to establish during periodic inundation.

Birds

Benefits

- The weir pool may once again become attractive to wetland species should food resources (e.g. frogs) return and possibly for woodland species should habitat (trees, food) also improve in condition/extent.

Risks

- Despite the provision of water, depending on water availability in the landscape (e.g. Avon Plains wetlands) the weir pool is likely to only ever be secondary habitat.

Vegetation communities and flora

Benefits

- Vegetation on the banks of the weir pool would transition to a community that is more commonly found on the banks of wetlands that are adapted to regular wetting and drying cycles. The periodically inundated weir pool would encourage sedge communities and water dependant grasses and rushes to regenerate along the banks of the river though in different locations to those observed during the field assessment, probably leading to colonisation lower down the bank.
- There would be some expansion of Grassy Riverine Woodland along the banks of the river and colonisation of the existing channel with sedges and rushes.

Risks

- Vegetation communities that develop lower in the bank would be scoured or drowned during natural high flow events and the inundation of the weir pool.
- Contraction in the highly water-dependent Sedgy Riverine Forest and Riverine Swamp Forest communities as they are replaced by Grassy Riverine Woodland.
- There would be a potential loss of some regenerating River Red Gums (i.e. thinning of existing stands, not contraction of area) that have become established while the weir pool was full. Larger River Red Gums will unlikely to be affected overall as they will have developed deep tap roots able to access groundwater, however, individual trees may die as a result of the changing hydrological conditions.

- It is likely that the change in conditions would encourage weed growth in the weir pool as vegetation communities adapt to change in conditions. There is a significant weed presence in the surrounding areas that could contribute to this risk.

9.4 Scenario 4: Do not provide environmental water and remove or decommission the weir

Under the fourth scenario, the weir could be removed completely, allowing any natural flow to pass downstream. The natural path of the river, which has been blocked off with an embankment, could also be reinstated. This option would need to be considered in the context of future management of Lake Batyo Catyo and the Batyo Inlet Channel.

A further alternative for this scenario is to open the weir gates to allow water to pass through. This would see some water retained within the pool, maintained at the sill height, and lost at rates similar to those seen for Scenario 2. Some flows would pass through the weir, but these would only occur when the water is above sill height.

It should be noted that this scenario would require a change to the Wimmera and Glenelg environmental entitlement. While this would need to be considered if this scenario is enacted, it has not been considered as part of the assessment of feasibility.

Hydrology

Essentially under this scenario the river in this section is returned to closer to its natural flow regime, although the river is still subject to upstream regulation of private diverters and farm dams, which have a minor impact on flows. The stream flows are shown in Figure 9-9 and Figure 9-10 (zoomed in); they are also summarised in Figure 9-11. It can be seen that the stream is very flashy, and frequently doesn't flow. There were several large events in the period of 1993 to 2012, including the 2010/11 flood event, which caused flooding in the region. Only 2 % of flows exceed 300 ML/day, and the stream ceases to flow 77 % of the time. This scenario would infrequently see a large volume of water in the channel at this location, but it would reflect the river channel in the upstream catchment.

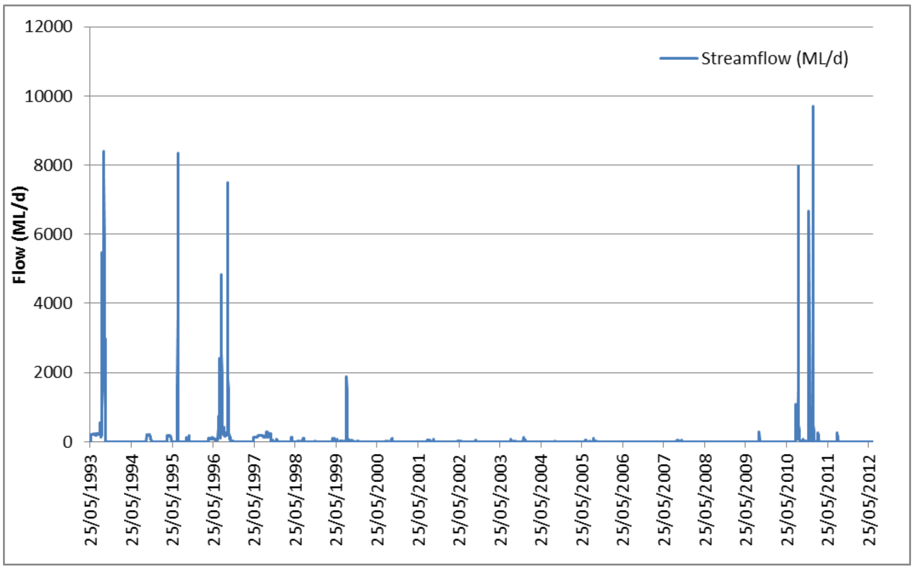


Figure 9-9 Streamflow through weir pool if gates are fully opened or weir is removed.

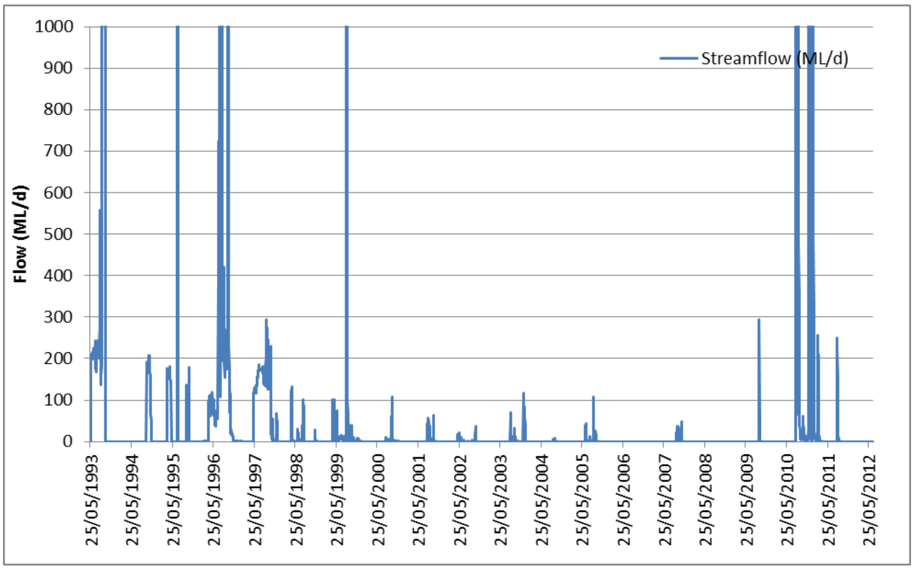


Figure 9-10 Streamflow through weir pool if gates are fully opened or weir is removed (zoomed to flows less than 1,000 ML/day).

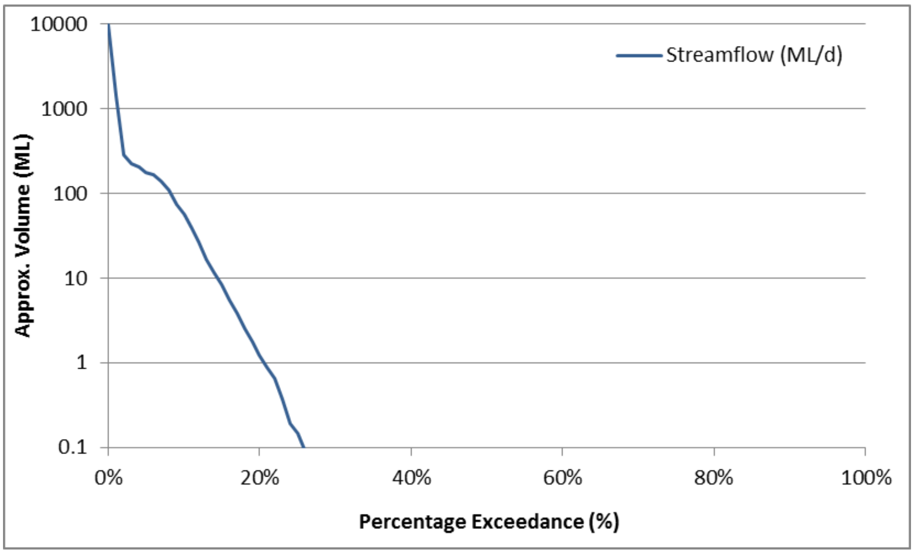


Figure 9-11 Percentage exceedance plot of streamflow through the weir pool.

From an ecological perspective, the important results for this scenario are:

- Flow in the river is flashy and it frequently doesn't flow (only 2 % of flows exceed 300 ML/day, and the stream ceases to flow 77 % of the time).

The benefits and risks to each group of environmental values are outlined below.

Water quality

Benefits

- The natural flow pattern in the river is unlikely to lead to significant water quality benefits. There are no significant deep refuge pools, and so it is not likely that water would pool in this section of the river for very long following cease to flow.

Risks

- The removal or decommissioning of the weir could lead to significant risks to the river downstream of the weir pool if the sediment that has built up in the weir pool over the 100 years of operation becomes mobilised during high flow. This risk is discussed further in Section 10.4.

Fish

Benefits

- There are unlikely to be any major benefits to fish from this watering scenario.
- The Richardson and Avon River systems probably never supported large fish populations due to the ephemeral nature of the flow and the long dry periods but probably supported some populations of small fish which could take refuge in deep pools and colonise from outside the system.

Risks

- The weir pool was a high value fishery only because of the artificial water regime and stocking of fish from outside the catchment. Returning the area to a more natural water regime with wet and dry periods means that it will not be a high value fishery.

Frogs and reptiles

Benefits

- There are unlikely to be any major benefits from this watering scenario for frogs or turtles.
- The river probably rarely supported frog or turtle species prior to the weir’s construction.

Risks

- Some common and hardy frog species may be able to use this part of the river when there is flow, but flow velocity is likely to be too high during events.
- The lack of refuge pools following sedimentation of the channel means that there would not be much standing water during the drying phase.
- If there is a long period of dry conditions in between natural filling events, sensitive species may be lost entirely from the local area if other surface water habitats (e.g. dams, wetlands) dry as well.

Mammals

Benefits

- The area of the weir pool is unlikely to support more mammal species than the other sections of the river.

Risks

- The lack of permanent water would reduce the number of mammal species that would likely use the area surrounding the weir pool.
- Adjacent landuse (riparian fencing and regrowth) is likely to be a more important factor controlling mammal use of the area than water availability under this scenario.

Macroinvertebrates

Benefits

- The area of the current weir pool will eventually support species similar to those in the rest of the river (e.g. hardy, desiccation tolerant species).

Risks

- Species that rely on permanent water are likely to be lost from the system.

Birds

Benefits

- There are unlikely to be any major benefits to birds from this watering scenario.
- The area surrounding the weir pool is unlikely to support more bird species than the other sections of the river.

Risks

- The lack of permanent water compared to other sections of the river would reduce the number of bird species that would likely use the area compared to when the weir pool was kept full.
- Adjacent landuse (riparian fencing and regrowth) is likely to be a more important factor controlling bird use of the area than water availability under this scenario.

Vegetation communities and flora

Benefits

- No pooling of water behind the weir and no provision of environmental water would return the riparian communities to a state not reliant on environmental water.
- Expansion of Grassy Riverine Woodland along the banks of the river and colonisation of the existing channel with sedges and rushes.
- Promotion of communities more likely to be adaptable to a likely drying climate in north-west Victoria.
- Communities that develop lower in the channel not likely to be drowned out so frequently following inundation of the weir pool.

Risks

- Aquatic flora would be unlikely to return.
- Contraction and probable loss of the highly water-dependent Sedgy Riverine Forest and Riverine Swamp Forest communities.
- There would likely be a loss of some regenerating River Red Gums (i.e. thinning of existing stands, not contraction of area) that have become established while the weir pool was full. Larger River Red Gums will mostly be unaffected as they will have developed deep tap roots able to access groundwater however some scattered individual tree deaths may occur as a result of the changing hydrological conditions.
- It is likely that the change in conditions would encourage weed growth along the banks and in the channel of the weir pool as vegetation communities adapt to change in conditions. There is a significant weed presence in the surrounding areas what could contribute to this risk.

9.5 Scenario 5: Provide water to keep deep refuge pools full

The final scenario considered is one where there are deep refuge pools in the area of the current weir pool. It is likely that prior to the sedimentation of the weir pool that deep pools would have been present that would have held water for much longer than the rest of the channel. These deep pools likely provided important refuge habitat for aquatic biota, especially fish, turtles, macroinvertebrates and possibly frogs.

Deep refuge pools in the weir pool would have to be re-instated, probably by excavating some of the sediment. The feasibility of excavating deep pools is considered in more detail in Section 10.5, but the ecological consequences of excavating deep refuge pools is considered in the following section.

Hydrology

For this scenario, hypothetical deep pools have been considered which would hold water up to 1 m depth when much of the rest of the channel was very shallow or even dry completely. No additional hydrological analysis has been conducted for this scenario.

We have considered both a scenario where environmental water keeps these deep pools full and one where eventually these deeper pools would also dry but would provide some habitat for a time between dry periods (which would be the case unless environmental water was supplied). This scenario does not consider whether the weir structure is maintained or decommissioned.

Water quality

Benefits

- Water in the weir pool between large natural filling events would provide habitat for a range of aquatic biota, in particular fish, turtles, frogs and macroinvertebrates.
- If the time between filling events is short, then these deep pools are likely to provide suitable conditions to support aquatic biota.

Risks

- Water quality could decline significantly in refuge pools. Salinity could become elevated, especially if the deeper pools intercept the groundwater, leading to the intrusion of saline groundwater. This would be a particular concern if excavation is undertaken to produce these deep pools, and the bed depth is lowered to below the water table.
- Nutrients may also build up in the refuge pools. Temperature is also likely to become high in these pools over summer, which may lead to algal blooms.

Fish

Benefits

- Deep pools could provide refuge habitat for a range of fish species between events. Provided the pools were deep enough and the water quality remained good, the deep pools may allow fish to persist between natural events.

Risks

- If environmental water is not supplied, the refuge pools are likely to dry during extreme droughts. Therefore fish would need to recolonise or be re-stocked.
- Colonisation by native fish is unlikely. The ephemeral nature of the rest of the system means that there are unlikely to be any suitable source populations nearby. Furthermore, the numerous fish barriers in the system (such as the weir wall) would mean that movement would be prevented except under flood conditions. Colonisation by introduced species, such as Carp and Eastern Gambusia may be more likely, especially if there are potential source populations nearby, for example in farm dams.
- The water in the refuge pools may become highly saline and nutrient load may increase in the water column, potentially leading to toxic effects on fish or algal blooms.
- Eventually the deep pools would fill in with sediment and therefore would require ongoing management and excavation if they are to remain as refuge pools. This would be very difficult while the pools were inundated.

Frogs and reptiles

Benefits

- Deep pools could provide refuge habitat for turtles between filling events.
- Deep pools may provide breeding habitat for frogs between filling events if they persist long enough to allow tadpoles to reach metamorphosis.
- Many of the hardy frog species are able to tolerate relatively poor water quality and provided that vegetation is engaged at the right times of year, these species could tolerate variable water level.
- Frogs are important food resources to higher order predators such as birds, snakes and fish.

Risks

- Refuge pools may not engage vegetation that would support frog breeding (vegetation is required for egg attachment sites and cover).
- Water quality may become unsuitable to support frogs or turtles.
- Frog habitat that establishes over time in the bottom of the channel such as fringing vegetation may be scoured or drowned out during natural high flow events.

Mammals

Benefits

- Terrestrial mammals (kangaroos, wallabies, small mammals) would likely use the weir pool in greater numbers if it held some water than if it was left dry.

Risks

- If the food resources do not return, or viable populations are not currently found in the area to supply colonists, then mammal population will not recover even if water is supplied to the weir pool.
- Colonisation and usage of the weir pool will be strongly dependent on the surrounding landuse. It is likely that pressure on many of the mammal species will only be partly related to water availability and will be primarily controlled by resources in the broader landscape.

Macroinvertebrates

Benefits

- Refuge pools that hold water would provide habitat for macroinvertebrates.

Risks

- If water quality became very poor, then pollution sensitive species may decline, reducing the overall diversity of the macroinvertebrate communities.
- Unless environmental water is supplied, the deep pools are also likely to dry occasionally, meaning that colonisation from outside the system would be required.

Birds

Benefits

- Holding water in refuge pools may make the weir pool attractive to wetland species, particularly if food resources (frogs, fish) are present. It is unlikely that water in the bottom of the weir pool will impact riparian condition and is therefore not likely to result in a benefit for woodland species.

Risks

- Despite the provision of water, depending on water availability in the landscape (e.g. Avon Plains wetlands) the weir pool is likely to only ever be secondary habitat.

Vegetation communities and flora

Benefits

- The refuge pools may help to maintain condition in some riparian communities.
- Aquatic flora may be able to persist through dry conditions.

Risks

- The lower water level may result in at least some contraction in the more highly water-dependent Sedgy Riverine Forest and Riverine Swamp Forest communities including some scattered tree deaths.
- Depending on the timing between natural filling of the refuge pools, there may be limited loss of some regenerating River Red Gums (i.e. thinning of existing stands, not contraction of area) that have become established while the weir pool was full.

- Vegetation communities that develop lower in the bank would be scoured or drowned during natural high flow events and the inundation of the weir pool.

Conceptual model

A simple conceptual model is presented in Figure 9-12 showing the difference in habitat available when deep pools are present and when they are absent.

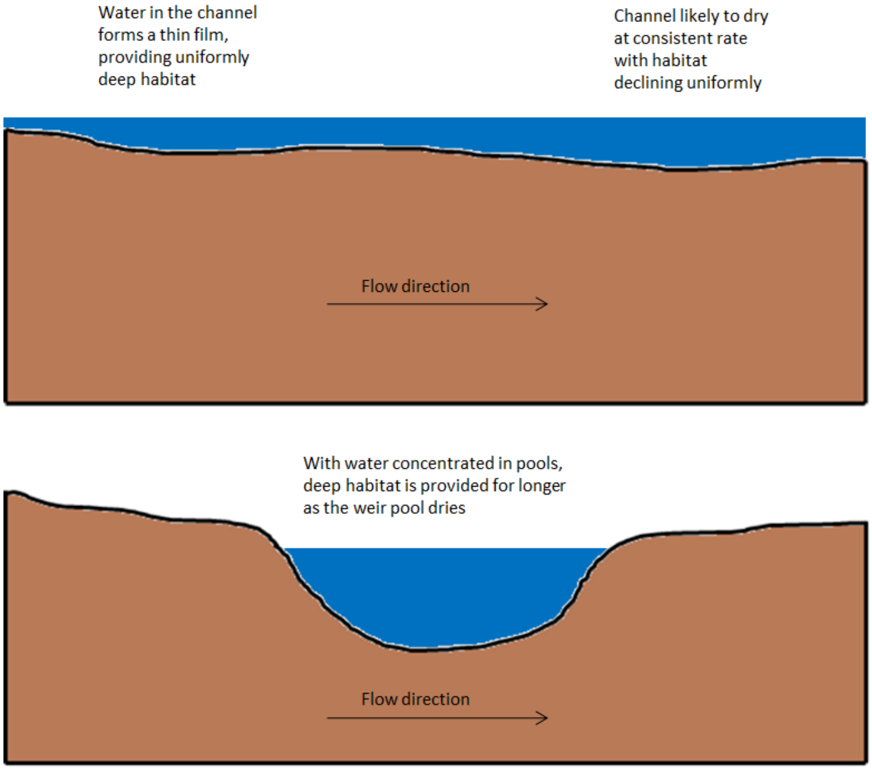


Figure 9-12 Conceptual model showing water depth in the presence and absence of deep pools. Note that the diagram is not to scale.

10. Feasibility of providing environmental water to the Rich-Avon Weir Pool

The following section of the report discusses broadly the overall benefit and risk of providing environmental water to the weir pool. While each of the scenarios were considered in detail in Section 9 to ensure that the major risks and benefits were identified, in this section we consider the benefits and risks in a more integrated manner in order to assess the overall feasibility of each environmental watering option.

10.1 Scenario 1: Provide environmental water to keep the weir pool at or near the previous operational level

This scenario mimics, as far as is practical, the situation as it would have been at the weir pool during its operation as part of the Stock and Domestic supply. The weir pool was a highly valued community asset for camping, swimming, fishing and shooting. Furthermore, it supported significant species, including the federally protected Growling Grass Frog and Murray Cod and a range of valuable angling species. Providing water near the previous operational level would theoretically provide habitat which would once again support these species.

One of the major ecological benefits we identified as part of this scenario is that the high volume of water in the weir pool would support the water dependent Sedgy Riverine Forest and Riverine Swamp Forest communities that have developed around the weir pool over the time of the its operation. Furthermore, this scenario would likely support the large River Red Gum stands that have established on low lying terraces on the northern banks of the weir pool. A full weir pool would also support a range of semi-aquatic flora species that rely on regular water availability to persist. Wetland birds, common frog species, turtles, mussels and Water Rats as well as a range of terrestrial mammals and reptiles would all also likely benefit. Not providing environmental water would reduce the extent and condition of these communities and available habitat compared to what was historically available.

Although not a specific focus of the current study, the social value of the weir pool may also be returned. This is likely to be somewhat dependent on the presence of recreationally valuable fish in the weir pool (which would require stocking), but an inundated weir pool would provide a pleasant camping spot and place to swim, provided that water quality was suitable.

While we identified a number of benefits of this scenario, we also identified a number of key risks which we think reduces the feasibility of this scenario. One of the major risks is that there is no certainty that the significant species would recolonise the weir pool even if it was provided with environmental water. None of the recreationally valuable angling species would have naturally been supported by the river system and would therefore need to be stocked. We also don’t think many of these species, for example Murray Cod and Golden Perch, would establish self-sustaining populations in the weir pool and would therefore require ongoing stocking. While stocking may be easy to secure for the weir pool, it does rely on resources from an outside organisation (most likely Fisheries Victoria) and therefore cannot be guaranteed to occur at this stage even if water was provided.

Growling Grass Frogs are federally protected under the EPBC Act and their presence at the weir pool was significant, particularly as they have disappeared from many areas around the state. However, surveys conducted as part of this assessment failed to detect Growling Grass Frogs in the landscape surrounding the weir pool. While we cannot be certain that there are not populations nearby, our survey was conducted using a protocol that means that we are 95% confident that Growling Grass Frogs are not present at any of the surveyed sites.

Growling Grass Frog populations probably cannot persist in a landscape for more than a year of two without successful recruitment and so it is unsurprising that we did not detect them at the weir pool. It is possible that populations are located further away, but Growling Grass Frogs cannot disperse long distances to colonise new habitats or re-colonise habitats and therefore suitable source populations would need to be within one or two kilometres of the weir pool in order for recolonisation to occur. Widespread drying means that there are unlikely to be any source populations close to the Rich Avon Weir Pool and therefore providing environmental water to the weir pool may not facilitate the return of a self-sustaining population of Growling Grass Frogs.

Water quality in the weir pool is also a major risk. It is our assessment that one of the major factors that made the weir pool such high quality habitat for a range of aquatic biota was the good water quality, which would have been at least partly because so much water was transferred to Lake Batyo Catyo. This transfer would have resulted in regular flushing of the water in the weir pool, without which, water quality may have deteriorated. It would not be possible to mimic this flushing with environmental water (given the volumes required) and therefore there is a risk that water quality in the weir pool may become unsuitable for a range of aquatic species and for the associated vegetation.

Another point counting against the feasibility of this option is the volume of environmental water required to keep the weir pool at the previous operational level. Based on the ‘best case’ estimates of evaporation and seepage, we think that approximately 500 ML might be required each year to compensate for losses, and this could be as high as 3,650 ML per year if the ‘worst case’ seepage and evaporation estimates are adopted. This is a large volume of environmental water. To put this in perspective, the entire environmental entitlement to mitigate impacts to all the off-stream wetlands associated with the decommissioning of the old Stock and Domestic Supply was 1000 ML a year. Based on our estimates, keeping the weir pool full would require at least half of that entitlement and that is assuming that the weir pool was filled by a natural event.

The feasibility of providing environmental water to the weir pool is also reduced due to the reliability of the environmental water allocation. Environmental water to maintain permanent habitats will only be needed in dry periods when the environmental allocation will be minimal. The large volume of water needed to maintain permanent water in the weir pool and competing demands for environmental water during dry periods means that it is almost certain that the weir pool will completely dry during severe dry periods.

Another major risk associated with keeping water within the weir pool is related to the condition of the weir. It was clear during the field assessments that the weir had cracking in the base and to the side of the radial gates. Ongoing costs of maintaining the weir need to be factored into considerations of feasibility.

The cost of connecting the weir pool to the Wimmera-Mallee Pipeline is also high (currently estimated at $292,000) which needs to be considered in any assessment of feasibility.

In summary, the fish species that made the weir pool highly valued during its operation would not have been present naturally and we are not confident that Growling Grass Frogs would re-establish at the weir pool. Those species that may benefit (e.g. frogs, turtles, birds) are common and also would likely not have been more abundant in this section of the river than the rest of the system prior to the construction of the weir. In contrast, not providing environmental water may result in a change in the vegetation communities that have developed along the banks and terraces of the weir pool and in time the section is likely to revert to communities associated with ephemeral rivers. On balance, it is our assessment that it is not worth the significant investment in environmental water that we estimate would be required to maintain the weir pool at the previous operational level purely based on environmental grounds.

10.2 Scenario 2: Provide sufficient environmental water to fill the weir pool to 50% of the previous operational level between natural filling events

The second environmental watering scenario was designed to use less water than the first scenario, but to provide refuges for aquatic biota between natural filling events. The major benefits of this scenario are that it would provide some aquatic habitat between natural filling events, with primarily common species (frogs, turtles, birds, macroinvertebrates, terrestrial mammals) benefited.

Another benefit of this water regime is to maintain water dependent vegetation communities at the weir pool. These communities have only developed because of the historic inundation of the weir pool and removing this inundation would result in a change in the vegetation communities.

The major risks identified for the first scenario are repeated for Scenario 2. Primarily that recreationally valuable fish species would need to be stocked and we are not confident that Growling Grass Frogs would re-establish at the weir pool.

Even though less water is required than Scenario 1, as there are no deep pools, the volume of water needed to fill the entire length of the weir pool to an adequate depth is prohibitive. Maintaining the weir pool at a volume of 300 ML between natural filling events could require approximately 240 ML a year if no natural events occur (under the ‘best case’ scenario). This is approximately a quarter of the volume of water of the entitlement available for the Wimmera-Mallee wetlands. Under a high loss scenario, volumes of up to 2,200 ML over a year could be required.

While this scenario would likely benefit a range of common species (frogs, birds, terrestrial mammals) and water dependent vegetation communities, based on our assessment of benefit and risk, we do not believe this scenario represents a worthwhile investment of environmental water.

10.3 Scenario 3: Do not provide environmental water but retain the weir

The third environmental water scenario retains the weir but does not provide environmental water. The weir pool naturally fills completely on average approximately once every two years and to a volume greater than 300 ML on average approximately three out of four years (see Section 9.1 and 9.2). Filling occurs generally in winter and the weir pool is likely to hold water for over a year, but is almost certain to dry completely over time, particularly in dry climate conditions. As the weir gates are closed, essentially the weir pool is currently being managed as per Scenario 3.

This scenario would benefit the riparian vegetation although it is likely that in time the section is likely to revert to communities associated with ephemeral rivers. The weir pool may also support populations of common frog species and turtles when the weir pool is inundated (provided some individuals can find refuges when the weir pool was not full). During inundation events, the weir pool would also attract a range of mammal and bird species. As the weir pool could hold water for significant periods through natural inflows in wet periods, it could therefore be stocked with fish, however, this would require additional investment from outside agencies such as the Fisheries Victoria.

A critical factor determining the feasibility of this scenario is how long the weir pool would stay inundated following filling. As outlined, there is some uncertainty between the ‘best case’ and ‘worst case’ inundation duration. We therefore recommend that monitoring is undertaken next time the weir pool fills to understand how long the weir pool will remain full, which will provide important insight into how feasible this scenario is. It is important that surface water and groundwater levels are monitored to properly quantify seepage and evaporation from the weir pool.

Assuming the ‘best case’ scenario, the weir pool would retain some water for up to 22 months if no natural events occurred to top up the weir pool. During at least half of this time the weir pool would be an aesthetically pleasing place for recreation but would not return the weir pool to being a high value fishery (unless it is stocked) or hunting location. Despite this, provided that the weir structure was deemed safe, this scenario could provide benefits to a range of common species as well as provide some social value during the time that the weir pool was full. Furthermore, as there are few deep natural pools left in the system, very little water will be retained elsewhere in the system between natural events. This scenario also provides some ecological benefit as it will maintain some water in the system for up to a couple of years after large flow events.

10.4 Scenario 4: Do not provide environmental water and remove or decommission the weir

The fourth scenario involves removing or decommissioning the weir and allowing all natural flows to pass downstream. The passing of the flow could be achieved by opening the weir gates, removing the weir entirely or reinstating the natural path of the river. It should be noted that opening the weir gates completely will still see some volume of water pooled in the weir as the sill level is higher than the bed level; therefore not all flows would pass downstream.

This scenario returns the system to closer to its natural flow hydrology (notwithstanding the influence of upstream diverters and farm dams). However, as there are no deeper pools upstream of the weir, the inundation regime is not natural (i.e. this section of the river would have had deep pools that held water for a period after events).

While many of the values that were previously supported by the weir pool (i.e. fish, water dependent vegetation communities) would not benefit from this scenario, these species and communities would not have been present historically. Under this scenario, over time the area of the weir pool would resemble much of the rest of the system. We would expect contraction and probable loss of the highly water-dependent Sedgy Riverine Forest and Riverine Swamp Forest communities. There would also likely be a loss of some regenerating River Red Gums (i.e. thinning of existing stands, not contraction of area) that have become established while the weir pool was full. Larger River Red Gums, however, will mostly be unaffected as they will have developed deep tap roots able to access groundwater.

One of the major risks of removing or decommissioning the weir is the fate of the sediment currently in the weir pool. It is possible that this sediment could become mobilised under high flows and deposit downstream. The mobilised sediment could infill downstream deep pools, as has happened upstream of the weir. Additional studies are would be needed to properly evaluate the risk of flushing sediment downstream, especially because the weir has acted as a sediment trap for more than 100 years and probably limited infilling of natural pools in downstream reaches.

The Rich-Avon Weir does not perform any flood protection function for the township of Donald (Donald Flood and Drainage Management Plan 2014). Therefore, removing the weir is unlikely to increase flood risk.

The major benefits of this scenario are that it will return the species and communities in the area to a state that is not reliant on environmental water. The scenario may also lead to benefits downstream, which only rarely received flows when the weir pool was operational. Downstream benefits are beyond the scope of this study. It is our assessment that this scenario is a feasible management option for the weir pool into the future but is less beneficial than Scenario 3 which maintains water in the landscape for extended periods.

10.5 Scenario 5: Provide water to keep deep refuge pools full (excavate deep pools)

The final scenario considers the ecological consequences if deep refuges were present in the area of the weir pool, which would have likely been the case in this part of the river prior to the weir's construction. As outlined above, a large amount of sediment has deposited in the channel and therefore excavation works would be required to reinstate deep refuge pools.

As with the other scenarios considered, it was not deemed feasible to provide a relatively large volume of environmental water that would primarily be to support species and communities that would not have naturally occurred in the system or that may not re-establish even if water was provided. Having said that, deep refuge pools may provide ecological benefits for a range of species even in the absence of environmental water. Frogs and turtles may be supported between natural high flow events and fish populations may be maintained provided they are present (which would likely require stocking).

Balanced against this benefit, however, are concerns about water quality, particularly salinity. Furthermore, it is likely that the deep pools would need to be frequently maintained and excavated as they are likely to fill up over time as sediment deposits in the channel. Other potential risks include intercepting groundwater during the pool excavation (which would make the water in these pools very saline) and breaking the relatively impermeable bed of the river, which may cause rapid draining.

Therefore, while it is not feasible to provide environmental water, it may be feasible to re-establish deep pools in the channel (regardless of whether the weir structure is retained or decommisioned). Additional work is needed to investigate potential risks associated with this scenario to determine if it is feasible. It may be possible to conduct a trial, where a small deep refuge pool is excavated, prior to full implementation.

10.6 Summary of feasibility assessment

A summary of the details, benefits and risks of each scenario are provided in Table 10-1. Also provided is a summary of the assessment of feasibility for each option.

Table 10-1 Summary of the consequences of the different environmental watering scenarios.

Scenario	Hydrology	Volume of e-water required	Major benefits	Major risks	Feasibility
1. Provide environmental water to keep the weir pool at or near the previous operational level	When full, water depth in the centre of the channel would be between 2 and 3 m.	Daily losses of approximately 1.43 ML/day ('best case'). Approximately 500 ML a year ('best case'), or up to 3.650 ML a year ('worst case') if high seepage occurs.	- Support water dependent vegetation - Habitat for fish and frogs - Benefit common species (frogs, turtles, birds, terrestrial mammals) - Social value (but not as high as when operational)	- Fish will need to be stocked - Growling Grass Frogs unlikely to re-establish - Vegetation communities unlikely to be sustainable without watering - Water quality may degrade without flushing flow	**Not feasible** - High volume of water required to support marginal environmental value - Environmental water unlikely to be available when needed in very dry years. - Weir structure may require maintenance
2. Provide environmental water to keep the weir pool at or near 50% of the previous operational level between natural filling events	The water depth in the centre of the channel would be approximately 1.5 m. The weir pool fills naturally to greater than 300 ML on average approximately three out of four years.	Daily losses of approximately 0.67 ML/day ('best case'). Approximately 240 ML a year ('best case'), or up to 2,200 ML a year ('worst case') if high seepage occurs.	- Support water dependent vegetation - Some habitat for fish and frogs - Benefit common species (frogs, turtles, birds, terrestrial mammals) - Social value (but not as high as when operational)	- Fish will need to be stocked - Growling Grass Frogs unlikely to re-establish - Vegetation communities unlikely to be sustainable without watering - Water quality may degrade without flushing flow	**Not feasible** - Relatively high volume of water required to support marginal environmental value - Environmental water unlikely to be available when needed in very dry years - Delivery infrastructure may not be suitable - Weir structure may require maintenance
3. Do not provide environmental water but retain the weir	The weir pool fills completely naturally on average 1 in 2 years and to greater than 300 ML 3 in 4 years. Filling generally in winter. Could hold water up to 22 months ('best case' estimate). Would dry completely occasionally.	N/A	- Support riparian vegetation but over time community would change - Benefit common species (frogs, turtles, birds, terrestrial mammals) - Some social value when the weir pool is full in winter/spring	- Not provide habitat for fish - Growling Grass Frogs unlikely to re-establish - Some retraction of water dependent vegetation communities.	**Feasible** - Doesn't require environmental water for marginal environmental value - Major cost being the weir structure may require maintenance - Some social value
4. Do not provide environmental water and remove or decommission the weir	Flow in the river is flashy and it frequently doesn't flow (only 2% of flows exceed 300ML/day, and the stream ceases to flow 77% of the time).	N/A	- Communities return to a sustainable state not reliant on environmental water	- Overall decline in aquatic habitat - Area unlikely to support more species than the rest of the system	**Potentially feasible** - Doesn't require environmental water, but will provide less aquatic habitat than Scenario 3 - Risk of sediment transfer
5. Ecological consequences if deep refuge pools were present in the weir pool	Deep pools may provide important refuge habitat for aquatic biota, especially fish, turtles, macroinvertebrates and possibly frogs.	Similar to Scenario 2	- Support water dependent vegetation - Some habitat for fish and frogs - Benefit common species (frogs, turtles, birds, terrestrial mammals)	- Water quality may degrade in pools - Designed to support species that may not re-establish regardless of intervention - Pools would need to be re-excavated regularly	**Potentially feasible** - Costly to support species that may not re-establish regardless of intervention - More detailed assessment required to determine feasibility

11. Next steps and recommendations for management of the weir pool

The results of the feabiltilty assessment were presented to a community reference group on 9 December 2015. The following section summarises the results of that discussion including required next steps.

The main finding of this assessment, and agreed by the community group, is that although it likely reduces the weir pool's value as a community asset compared to when it was operational, it is not feasibile to provide environmental water to support the environmental values of the weir pool. We are not confident that even if a high volume of environmental water was provided to the weir pool that the significant ecological values that were supported during its operation (primarily fish species and Growling Grass Frogs) would re-establish. The riparian vegetation communities that would be supported would not have occurred in the area historically and are not sustainable without frequent watering.

The absence of deep holes in this section of the river (due to sedimentation) means that the volume of water required to provide habitat in the flat bottomed channel is large and represents a significant proportion of the entire entitlement established following the construction of the Wimmera-Mallee Pipeline. The volume required is also likely to increase over time with mean annual runoff in the rivers in the Wimmera Basin expected to fall by 19% under the 2030 climate change scenario (50th percentile median) and by 32% in 2060.

The feasibility of providing environmental water to the weir pool is also reduced due to the reliability of the environmental water allocation. Water would be required during dry periods when the environmental allocation will be minimal and when there is a The large volume of water needed to maintain permanent water in the weir pool and competing demands for environmental water during dry periods means that it is almost certain that the weir pool will completely dry during severe dry periods.

11.1 Feasible management options

Discussion as part of the community consultation considered further the management scenarios assessed as feasible as they did not require environmental water. The first feasible option is to return the river to closer to its historic flow state by allowing flows to pass downstream by decommissioning the weir or opening the gates. Over time the biotic communities would adapt to a state that is not dependent on environmental water and eventually the area around the weir pool would resemble the rest of the riparian corridor.

The second feasible option is to maintain the weir and retain water in the weir pool following natural events. Our 'best case' estimate of inundation duration means the weir pool may hold some water for up to 22 months following filling without additional inflows (the inundation duration would need to be confirmed by in field monitoring). Based on the 'best case' estimate, in comparatively wet periods (the 1990s in Figure 11-1) the weir pool would not fall below half full and would only dry in severe droughts.

Provided that the weir pool retained water near our 'best case' estimate, this option would mean that the weir pool would still attract higher biodiversity that then rest of the river, likely benefitting frogs, turtles, birds, mammals and the surrounding riparian vegetation. Furthermore, when inundated, the weir pool would be a community asset (albeit not as high value as during its operation) and could potentially be stocked with fish.

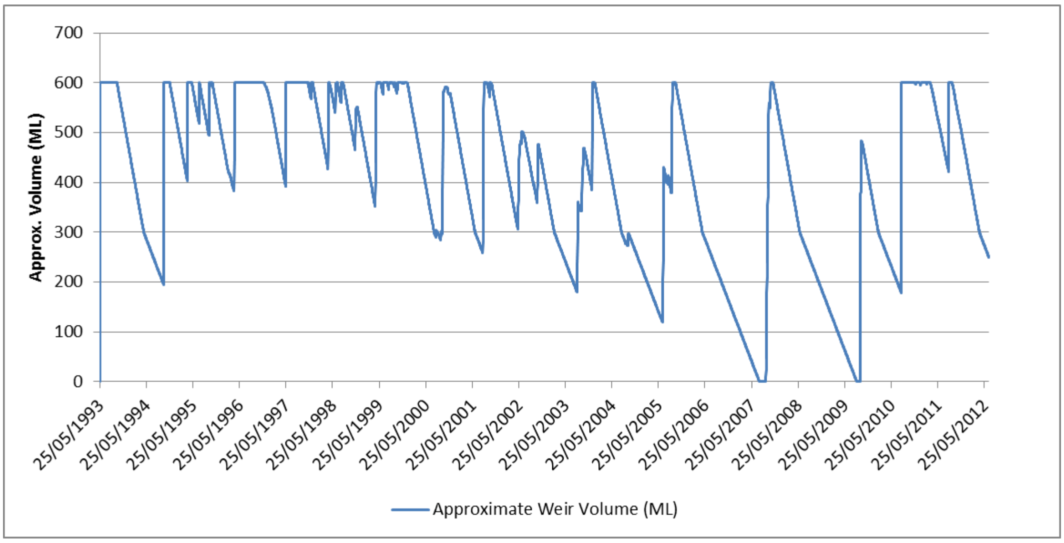


Figure 11-1 Approximate weir volume based on historical streamflow (excluding channel transfers) and average losses based on the 'best case' loss scenario.

While both these options are feasible, there are two main factors which are critical in determing which one should be adopted:

1. What is the condition of the weir structure? How much would it cost to repair and to operate into the future?

2. If the weir is decommissioned or opened, what is the risk to the river downstream of the weir from any mobilised sediment? Can the sediment be removed, or the risk mitigated in some other way?

Additional work to understand these factors is therefore critical before a final decision can be made as to how the weir pool will be managed in the future. Provided that the weir can be operated safely and that funds are available, leaving the weir in place and allowing the weir pool to fill and empty has ecological and social benefits not dependent on the provision of high volumes of environmental water and therefore the cost may be justified.

The community reference group expressed a strong desire that the weir structure not be left to deteriorate. If it is to be kept in place to retain water then the maintenance and management responsibilities should be clearly determined. If the weir is to be removed, the community reference group would prefer the entire weir is removed (including the concrete structure).

A final recommendation to come out of the community reference group consultative process was to explore the option of excavating some pools to try and recreate natural features that could fill during natural events and hold water after natural events. There is no suggestion to use environmental water to maintain those pools, however, the community reference group suggested pools in this area, provided they held water following natural events, would be highly valued by the community. Theses pools would provide a pleasant place to camp and, if they held water long enough, could be stocked in some instances with fish for take. Many of the risks highlighted in Scenario 5 (see Section 9.5) may occur, namely that the excavated pools may rapidly fill with sediment, they may intercept groundwater or increase seepage from the weir pool in general. However, as such a scenario may provide high social value and some ecological benefit then additional work to assess the costs and potential risks may be warranted. A small trial could be completed with one or two small pools excavated in the downstream part of the weir pool to determine if they hold water and and support environmental values. The community reference group suggested a pool up to about 400 m long at downstream end of weir pool would be a good place for a trial.

11.2 Additional recommendations for management of the weir pool

A number of other management recommendations were discussed by the community reference group.

Regardless of the fate of the weir structure, we recommend that the riparian zone is fenced from stock access. We have noted that as the vegetation changes in response to reduced water availability, there is a risk of weeds colonising the available areas and this has been observed on the northern banks east of the Stawell-Donald road where grazing sheep were observed. In contrast, to the west of the road in areas where this has been done, the vegetation is in excellent condition. Although if the weir pool remains empty we may see die off of some small trees, the large River Red Gums would be able to access deeper groundwater are likely to be resilient to this change. Some weed monitoring and management may also be of benefit during the adaptation phase to encourage regeneration of native species.

It was recommended that if the weir was removed and the flow hydrology of the river was returned to a more natural state, that other options should be considered to restore the natural flow regime in the rest of the catchment. In particular, it was suggested by the community reference group that modifactions could be made to Hollands Bank to restore the natural flow regime down the Avon River and through Lakes Batyo Catyo, Walkers and Hancocks. While this is outside the scope of the current study, it may need to be considered as part of the management of the catchment as a whole.

12. References

Brambuk National Park and Cultural Centre (2015) About Brambuk. Published online: http://www.brambuk.com.au/about.htm. Brambuk National Park and Cultural Centre, Accessed, January 13th, 2014.

Clark, I. D. (1990) Aboriginal Language and Clans: An Historical Atlas of Western and Central Victoria, 1800-1900. Monash Publications in Geography no. 37.

Clark, I. D. (1995) Scars on the Landscape. A Register of Massacre sites in Western Victoria 1803-1859, Aboriginal Studies Press.

Cogger, H. (2000) Reptiles and amphibians of Australia. CSIRO Publishing, Victoria.

CSIRO (2015) Atlas of Australian Acid Sulfate Soils. Commonwealth Scientific and Industrial Research Organisation. http://www.clw.csiro.au/acidsulfatesoils/atlas.html, accessed September 24th 2015.

DEPI (2014) A guide to the inland angling waters of Victoria. Published online: http://www.depi.vic.gov.au/fishing-and-hunting/fishing-guides/inland-angling-guide/wimmera/wimmera-angling-waters#richardson. Department of Environment and Primary Industries, accessed July 4th 2014.

DEWHA. (2009) EPBC Act Policy Statement 3.14 - Nationally Threatened Species and Ecological Communities - Significant Impact Guidelines for the Vulnerable Growling Grass Frog (Litoria raniformis) - February 2009. Commonwealth Department of Environment, Water, Heritage and the Arts, Canberra.

Donald Flood and Drainage Management Plan (2014) Report prepared for the North Central CMA, Midland Highway, Huntly, 2014.

DSE (2008) Climate change in the Wimmera. Department of Sustainability and Environment.

DSE (2011) Guidelines for the development of a water supply demand strategy. Department of Sustainability and Environment. August 2011.

Egis Consulting Australia (2000) Water Quality Improvement Plan - Final Report, Report to Grampians Water.

EPA and Wimmera CMA. (2008) The Health of Streams in the Wimmera Basin. Report by EPA Victoria and Wimmera CMA.

Evans, R. (2012) Mallee Salinity Workshop May 30, 2012: Chapter 1 - Geology and hydrogeology. Paper by SKM (Ray Evans) for the Mallee CMA.

GWMWater (2010) DRAFT: Lake Batyo Catyo and Rich-Avon Weir Pool Management Plan. Draft report by Grampians Wimmera Mallee Water, August 2010.

Halliwell, J. (1998) Avon Richardson Water Quality Issues Paper. Water EcoScience.

Heard, G., Scroggie, M. And Clemann, N. (2010) Guideline for managing the endangered Growling Grass Frog in urbanising landscapes. Arthur Rylah Institute for Environmental Research Technical Report Series No. 208.Department of Sustainability and Environment, Heidelberg, Victoria.

Heard, G.W.,Scroggie, M.P., Clemann, N. and D. S. L. Ramsey (2014). Wetland characteristics influence disease risk for a threatened amphibian. Ecological Applications 24:650–662.

Koehler, S.L., Gilmore, DC & Newell, D.A. in press, 'Translocation of the threatened Growling Grass Frog *Litoria raniformis:* a case study', Australian Zoologist. http://dx.doi.org/10.7882/AZ.2014.043

Muller, B. (2002) Landform mapping and recharge estimations from Horsham to Dimboola. Report by Briony Muller and Mark Hocking for Agriculture Victoria – Bendigo Centre for Land Protection Research.

Murray Darling Basin Authority (2015) About the Basin. Published online: http://www.mdba.gov.au/about-basin/how-river-runs/wimmera-avoca. Murray Darling Basin Authority, accessed January 12th 2015.

McIlvena, B. (2007) 'Muddy water', on the Avon and Richardson. The Mail Times, Monday February 26, 2007.

North Central CMA (2014) Campaspe River Environmental Water Management Plan. North Central Catchment Management Authority, Huntly.

NSW DIPNR (Undated) NSW Water Bug Survey Buglopedia Factsheets. NSW Department of Infrastructure, Planning and Natural Resources.

Pannell, D. and Ridley, A. (2005) SIF3 Tour of North Central Region, 13-15 December 2005. Report by David Pannell (Univ. of WA; CRC Salinity) & Anna Ridley (DPI Victoria; CRC Salinity).

Pyke, G.H. (2002) A review of the biology of the southern bell frog *Litoria raniformis* (Anura: Hylidae). Aust Zool 32:32–48

Pizzey, G. and Knight, F. (2012) The Field Guide to the Birds of Australia - Ninth Edition, HarperCollins, Sydney

SKM (2005a) Avon-Richardson Catchment Background Issues. Report by Sinclair Knight Merz for the Wimmera CMA.

SKM (2005b) Avon-Richardson Catchment Environmental Flow Recommendations. Report by Sinclair Knight Merz for the Wimmera CMA.

SKM (2005c) Environmental flow recommendations; Mt William Creek, Avon-Richardson and Upper Avoca Catchments: Hydrology. Final. Sinclair Knight Merz for Wimmera Catchment Management Authority. SKM ref: WC03257

SKM (2014) VEFMAP - Vegetation monitoring in the Loddon and Campaspe Rivers. Report for the North Central CMA.

Smith, M.A. and Green, D.M. (2005) Dispersal and the metapopulation paradigm in amphibian ecology and conservation: are all amphibian populations metapopulations? Ecography, 28, 110-128.

State of Victoria (2015a) Victorian Water Register Bulk Entitlements. Published online: http://waterregister.vic.gov.au/water-entitlements/bulk-entitlements#bulkEntDiv, accessed September 2015.

State of Victoria (2015b) Victorian Water Register Entitlement Statistics Water License Statistics. Published online: http://waterregister.vic.gov.au/water-entitlements/entitlement-statistics#licenceTable, accessed September 2015.

Van Dyck, S. and Strahan, R. (2008) The mammals of Australia, Sydney: New Holland Publishers

VBA (2014) Victorian Biodiversity Atlas. Department of Environment and Primary Industries, accessed July 4th 2014.

Wassens, S. (2011) Frogs in Floodplain wetland biota in the Murray-Darling Basin: Water and habitat requirements. (eds. Rogers, K. and T. J. Ralph). CSIRO Publishing, Collingwood, Australia.

Waterwatch (2015) Water quality data from the Richardson River, Rich-Avon, near Donald Stawell Rd, south bank. 1996-2013.

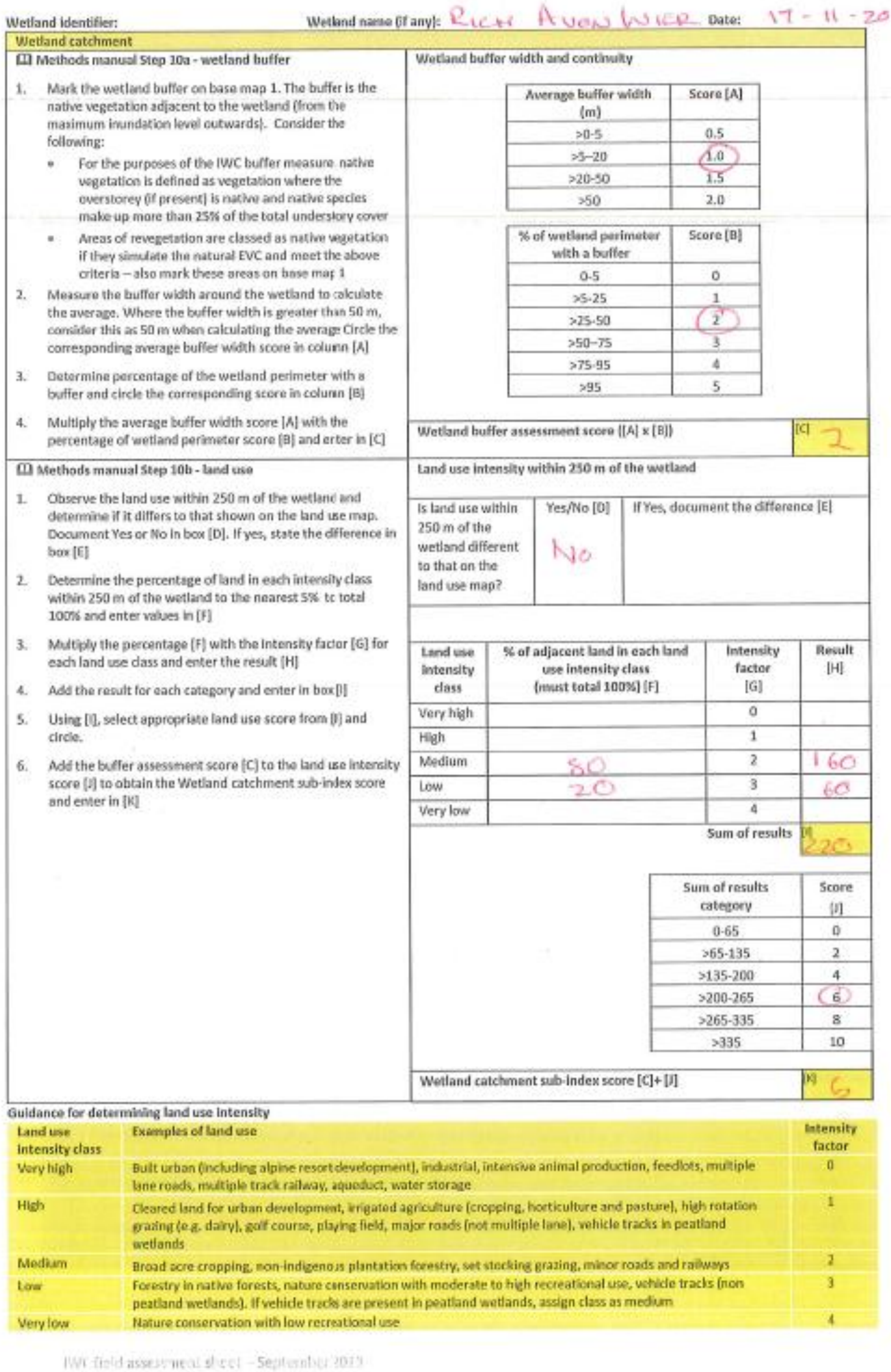
Wimmera CMA. (2005). Wimmera Regional Salinity Action Plan: 2005 – 2010.

Appendix A. Flora species list

Species Name	Common Name	Introduced	Listed
Acaena echinata	Sheep's Burr	*	
Allocasuarina luehmannii	Buloke		FFG
Alternanthera denticulata s.s.	Lesser Joyweed		
Anthosachne sabra s.s.	Common Wheat-grass		
Arctotheca calendula	Cape weed	*	
Asperula conferta	Common Woodruff		
Aster subulatus	Aster-weed	*	
Atriplex semibaccata	Berry Saltbush		
Austrostipa sabra subsp. falcata	Rough Spear-grass		
Brachyscome paludicola	Woodland Swamp-daisy		
Bromus diandrus	Great Brome	*	
Bromus hordeaceus subsp. hordeaceus	Soft Brome	*	
Bromus rubens	Red Brome	*	
Carex bichenoviana	Plains Sedge		
Carex tereticaulis	Poong'ort		
Centipeda cunninghamii	Common Sneezeweed		
Chloris truncata	Windmill Grass		
Chrysocephalum semipapposum	Clustered Everlasting		
Cirsium vulgare	Spear Thistle	*	
Cotula coronopifolia	Water Buttons	*	
Cynodon dactylon var. dactylon	Couch	*	
Cyperus gymnocaulos	Spiny Flat-sedge		
Cyperus spp.	Flat Sedge		
Dianella sp. aff. longifolia (Riverina)	Pale Flax-lily		V*
Duda floribunda	Tangled Lignum		
Enchylaena tomentosa var. tomentosa	Ruby Saltbush		
Eragrostis infecunda	Southern Cane-grass		
Eucalyptus camaldulensis	River Red-gum		
Eucalyptus largiflorens	Black Box		
Euphorbia drummondii spp. agg.	Flat Spurge		
Goodenia heteromera	Spreading Goodenia		
Goodenia spp.	Goodenia		
Hakea tephrosperma	Hooked Needlewood		
Haloragis aspera	Rough Raspwort		
Helichrysum luteoalbum	Jersey Cudweed		
Helminthotheca echioides	Ox-tongue	*	
Hordeum spp.	Barley Grass	*	
Juncus spp.	Rush		
Lachnagrostis filiformis s.s.	Common Blown-grass		
Lactuca serriola	Prickly Lettuce	*	
Lepidium africanum	Common Peppercress	*	
Lolium rigidum	Wimmera Rye-grass	*	
Lophopyrum ponticum	Tall Wheat-grass	*	
Oxalis perennans	Grassland Wood-sorrel		
Panicum effusum	Hairy Panic		
Phalaris aquatica	Toowoomba Canary-grass	*	
Phalaris minor	Lesser Canary-grass	*	
Phyla canescens	Fog-fruit	*	
Plantago lanceolata	Ribwort	*	
Polygonum aviculare s.s.	Hogweed	*	
Polypogon monspeliensis	Annual Beard-grass	*	

Species Name	Common Name	Introduced	Listed
Ptilotus macrocephalus	Feather Heads		
Rumex brownii	Slender Dock		
Rytidosperma caespitosum	Common Wallaby-grass		
Rytidosperma duttonianum	Brown-back Wallaby-grass		
Rytidosperma setaceum	Bristly Wallaby-grass		
Sclerolaena muricata	Black Roly-poly		
Senecio quadridentatus	Cotton Fireweed		
Sida corrugata	Variable Sida		
Sonchus asper s.l.	Rough Sow-thistle	*	
Teucrium racemosum s.s.	Grey Germander		
Themeda triandra	Kangaroo Grass		
Trifolium arvense var. arvense	Hare's-foot Clover	*	
Typha spp.	Bulrush		
Vittadinia cuneata	Fuzzy New Holland Daisy		
Vittadinia gracilis	Woolly New Holland Daisy		
Wahlenbergia gracilenta s.l.	Annual Bluebell		
Walwhalleya proluta	Rigid Panic		

Appendix B. Index of Wetland Condition Assessment



Wetland identifier: **Wetland name (if any):** Rich Avon Weir **Date:** 17 - 11 - 2014

Wetland catchment

Methods manual Step 10a - wetland buffer

1. Mark the wetland buffer on base map 1. The buffer is the native vegetation adjacent to the wetland (from the maximum inundation level outwards). Consider the following:
    - For the purposes of the IWC buffer measure native vegetation is defined as vegetation where the overstorey (if present) is native and native species make up more than 25% of the total understory cover
    - Areas of revegetation are classed as native vegetation if they simulate the natural EVC and meet the above criteria – also mark these areas on base map 1
2. Measure the buffer width around the wetland to calculate the average. Where the buffer width is greater than 50 m, consider this as 50 m when calculating the average Circle the corresponding average buffer width score in column [A]
3. Determine percentage of the wetland perimeter with a buffer and circle the corresponding score in column [B]
4. Multiply the average buffer width score [A] with the percentage of wetland perimeter score [B] and enter in [C]

Wetland buffer width and continuity

Average buffer width (m)	Score [A]
>0-5	0.5
>5–20	[✓ 1.0]
>20-50	1.5
>50	2.0

% of wetland perimeter with a buffer	Score [B]
0-5	0
>5-25	1
>25-50	[✓ 2]
>50–75	3
>75-95	4
>95	5

Wetland buffer assessment score ([A] x [B]) [C] 2

Methods manual Step 10b - land use

1. Observe the land use within 250 m of the wetland and determine if it differs to that shown on the land use map. Document Yes or No in box [D]. If yes, state the difference in box [E]
2. Determine the percentage of land in each intensity class within 250 m of the wetland to the nearest 5% to total 100% and enter values in [F]
3. Multiply the percentage [F] with the intensity factor [G] for each land use class and enter the result [H]
4. Add the result for each category and enter in box [I]
5. Using [I], select appropriate land use score from [J] and circle.
6. Add the buffer assessment score [C] to the land use intensity score [J] to obtain the Wetland catchment sub-index score and enter in [K]

Land use intensity within 250 m of the wetland

Is land use within 250 m of the wetland different to that on the land use map?	Yes/No [D]	If Yes, document the difference [E]
	No	

Land use intensity class	% of adjacent land in each land use intensity class (must total 100%) [F]	Intensity factor [G]	Result [H]
Very high		0	
High		1	
Medium	80	2	160
Low	20	3	60
Very low		4	
		Sum of results	[I] 220

Sum of results category	Score [J]
0-65	0
>65-135	2
>135-200	4
>200-265	[✓ 6]
>265-335	8
>335	10

Wetland catchment sub-index score [C]+ [J] [K] 6

Guidance for determining land use intensity

Land use intensity class	Examples of land use	Intensity factor
Very high	Built urban (including alpine resort development), industrial, intensive animal production, feedlots, multiple lane roads, multiple track railway, aqueduct, water storage	0
High	Cleared land for urban development, irrigated agriculture (cropping, horticulture and pasture), high rotation grazing (e.g. dairy), golf course, playing field, major roads (not multiple lane), vehicle tracks in peatland wetlands	1
Medium	Broad acre cropping, non-indigenous plantation forestry, set stocking grazing, minor roads and railways	2
Low	Forestry in native forests, nature conservation with moderate to high recreational use, vehicle tracks (non peatland wetlands). If vehicle tracks are present in peatland wetlands, assign class as medium	3
Very low	Nature conservation with low recreational use	4

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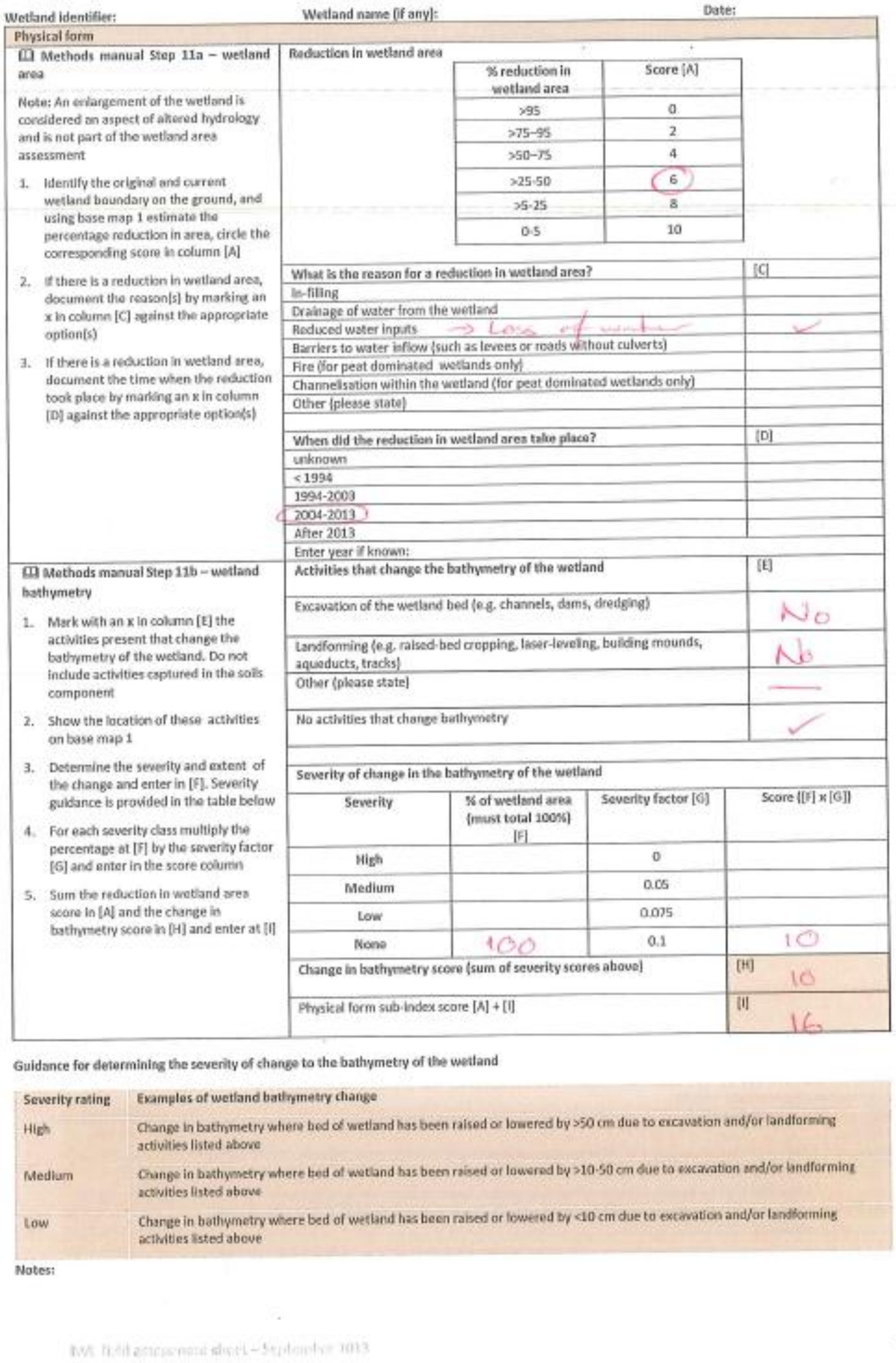

Wetland identifier: **Wetland name (if any):** Date:

Physical form

Methods manual Step 11a – wetland area

Note: An enlargement of the wetland is considered an aspect of altered hydrology and is not part of the wetland area assessment

1. Identify the original and current wetland boundary on the ground, and using base map 1 estimate the percentage reduction in area, circle the corresponding score in column [A]
2. If there is a reduction in wetland area, document the reason(s) by marking an x in column [C] against the appropriate option(s)
3. If there is a reduction in wetland area, document the time when the reduction took place by marking an x in column [D] against the appropriate option(s)

Reduction in wetland area

% reduction in wetland area	Score [A]
>95	0
>75–95	2
>50–75	4
>25-50	[✓ 6]
>5-25	8
0-5	10

What is the reason for a reduction in wetland area?	[C]
In-filling	
Drainage of water from the wetland	
Reduced water inputs → Loss of water	✓
Barriers to water inflow (such as levees or roads without culverts)	
Fire (for peat dominated wetlands only)	
Channelisation within the wetland (for peat dominated wetlands only)	
Other (please state)	

When did the reduction in wetland area take place?	[D]
unknown	
< 1994	
1994-2003	
[✓ 2004-2013]	
After 2013	
Enter year if known:	

Methods manual Step 11b – wetland bathymetry

1. Mark with an x in column [E] the activities present that change the bathymetry of the wetland. Do not include activities captured in the soils component
2. Show the location of these activities on base map 1
3. Determine the severity and extent of the change and enter in [F]. Severity guidance is provided in the table below
4. For each severity class multiply the percentage at [F] by the severity factor [G] and enter in the score column
5. Sum the reduction in wetland area score in [A] and the change in bathymetry score in [H] and enter at [I]

Activities that change the bathymetry of the wetland	[E]
Excavation of the wetland bed (e.g. channels, dams, dredging)	No
Landforming (e.g. raised-bed cropping, laser-leveling, building mounds, aqueducts, tracks)	No
Other (please state)	—
No activities that change bathymetry	✓

Severity of change in the bathymetry of the wetland

Severity	% of wetland area (must total 100%) [F]	Severity factor [G]	Score ([F] x [G])
High		0	
Medium		0.05	
Low		0.075	
None	100	0.1	10
Change in bathymetry score (sum of severity scores above)			[H] 10
Physical form sub-index score [A] + [I]			[I] 16

Guidance for determining the severity of change to the bathymetry of the wetland

Severity rating	Examples of wetland bathymetry change
High	Change in bathymetry where bed of wetland has been raised or lowered by >50 cm due to excavation and/or landforming activities listed above
Medium	Change in bathymetry where bed of wetland has been raised or lowered by >10-50 cm due to excavation and/or landforming activities listed above
Low	Change in bathymetry where bed of wetland has been raised or lowered by <10 cm due to excavation and/or landforming activities listed above

Notes:

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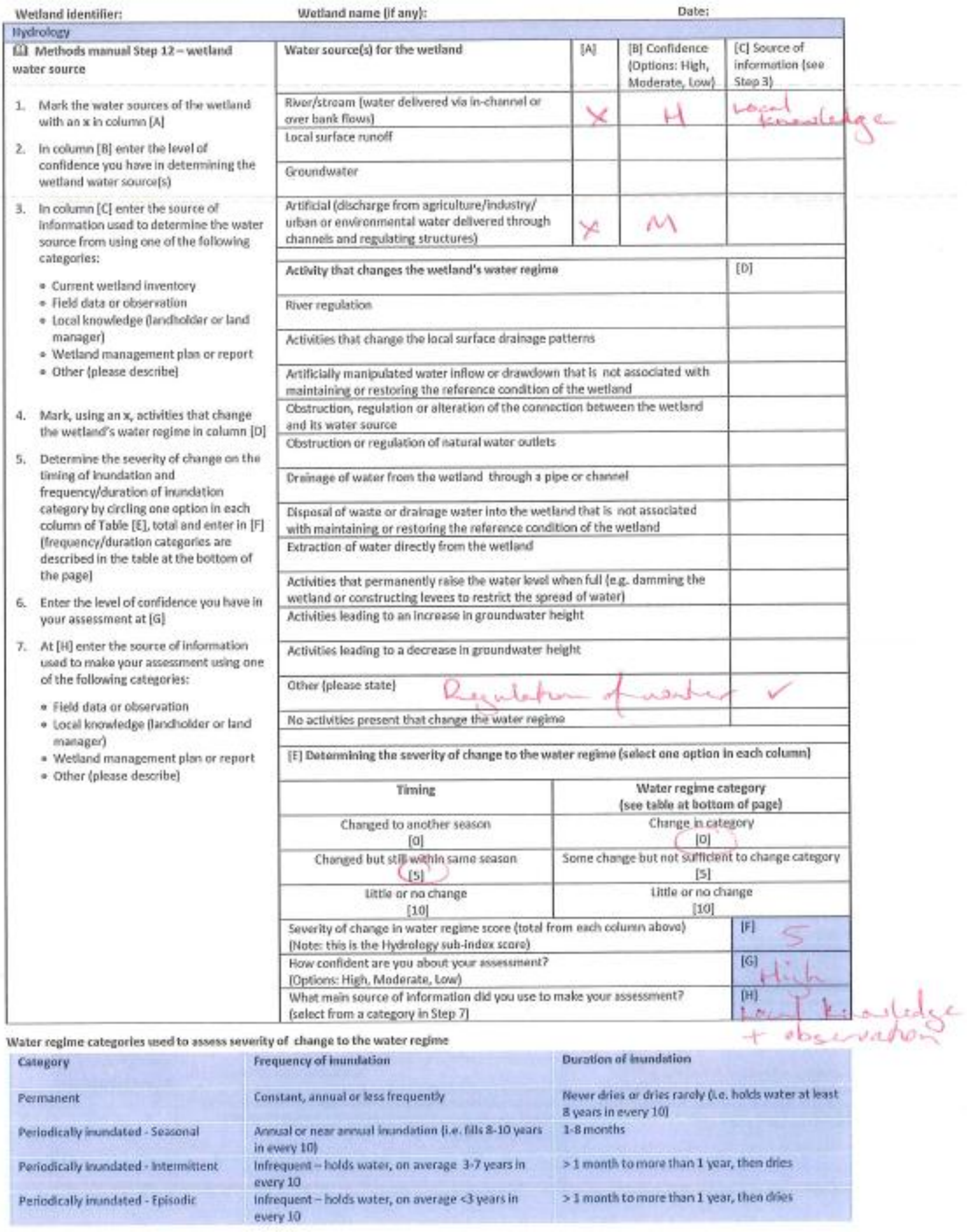

Wetland identifier: **Wetland name (if any):** **Date:**

Hydrology

Methods manual Step 12 – wetland water source

1. Mark the water sources of the wetland with an x in column [A]
2. In column [B] enter the level of confidence you have in determining the wetland water source(s)
3. In column [C] enter the source of information used to determine the water source from using one of the following categories:
   - Current wetland inventory
   - Field data or observation
   - Local knowledge (landholder or land manager)
   - Wetland management plan or report
   - Other (please describe)
4. Mark, using an x, activities that change the wetland's water regime in column [D]
5. Determine the severity of change on the timing of inundation and frequency/duration of inundation category by circling one option in each column of Table [E], total and enter in [F] (frequency/duration categories are described in the table at the bottom of the page)
6. Enter the level of confidence you have in your assessment at [G]
7. At [H] enter the source of information used to make your assessment using one of the following categories:
   - Field data or observation
   - Local knowledge (landholder or land manager)
   - Wetland management plan or report
   - Other (please describe)

Water source(s) for the wetland	[A]	[B] Confidence (Options: High, Moderate, Low)	[C] Source of information (see Step 3)
River/stream (water delivered via in-channel or over bank flows)	X	H	Local knowledge
Local surface runoff			
Groundwater			
Artificial (discharge from agriculture/industry/urban or environmental water delivered through channels and regulating structures)	X	M	

Activity that changes the wetland's water regime	[D]
River regulation	
Activities that change the local surface drainage patterns	
Artificially manipulated water inflow or drawdown that is not associated with maintaining or restoring the reference condition of the wetland	
Obstruction, regulation or alteration of the connection between the wetland and its water source	
Obstruction or regulation of natural water outlets	
Drainage of water from the wetland through a pipe or channel	
Disposal of waste or drainage water into the wetland that is not associated with maintaining or restoring the reference condition of the wetland	
Extraction of water directly from the wetland	
Activities that permanently raise the water level when full (e.g. damming the wetland or constructing levees to restrict the spread of water)	
Activities leading to an increase in groundwater height	
Activities leading to a decrease in groundwater height	
Other (please state) Regulation of water	✓
No activities present that change the water regime	

[E] Determining the severity of change to the water regime (select one option in each column)

Timing	**Water regime category (see table at bottom of page)**
Changed to another season [0]	[✓ Change in category [0]]
[✓ Changed but still within same season [5]]	Some change but not sufficient to change category [5]
Little or no change [10]	Little or no change [10]

Severity of change in water regime score (total from each column above) (Note: this is the Hydrology sub-index score)	[F] 5
How confident are you about your assessment? (Options: High, Moderate, Low)	[G] High
What main source of information did you use to make your assessment? (select from a category in Step 7)	[H] Local knowledge + observation

Water regime categories used to assess severity of change to the water regime

Category	**Frequency of inundation**	**Duration of inundation**
Permanent	Constant, annual or less frequently	Never dries or dries rarely (i.e. holds water at least 8 years in every 10)
Periodically inundated - Seasonal	Annual or near annual inundation (i.e. fills 8-10 years in every 10)	1-8 months
Periodically inundated - Intermittent	Infrequent – holds water, on average 3-7 years in every 10	> 1 month to more than 1 year, then dries
Periodically inundated - Episodic	Infrequent – holds water, on average <3 years in every 10	> 1 month to more than 1 year, then dries

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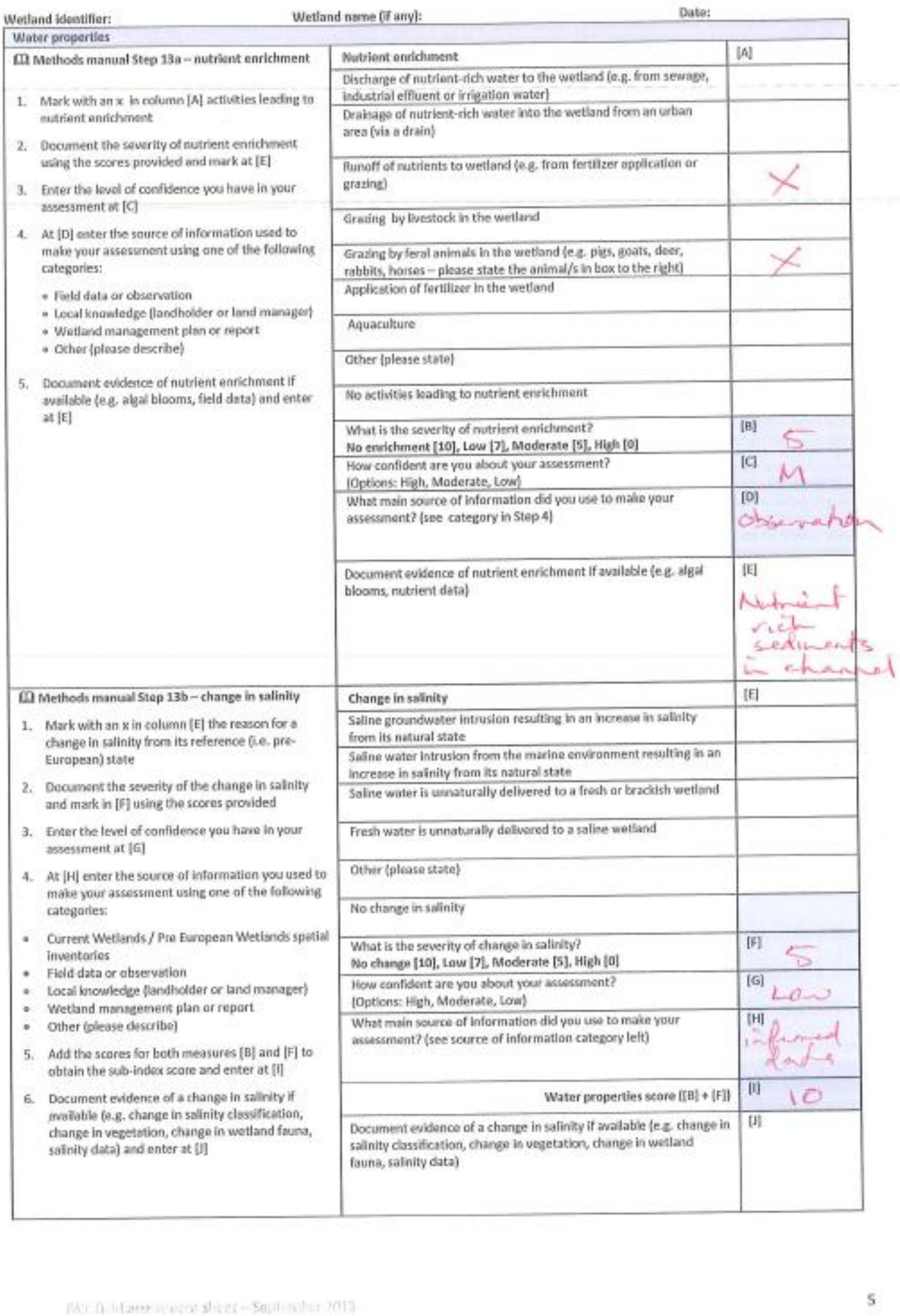


Wetland identifier: **Wetland name (if any):** **Date:**

Water properties

📖 Methods manual Step 13a – nutrient enrichment

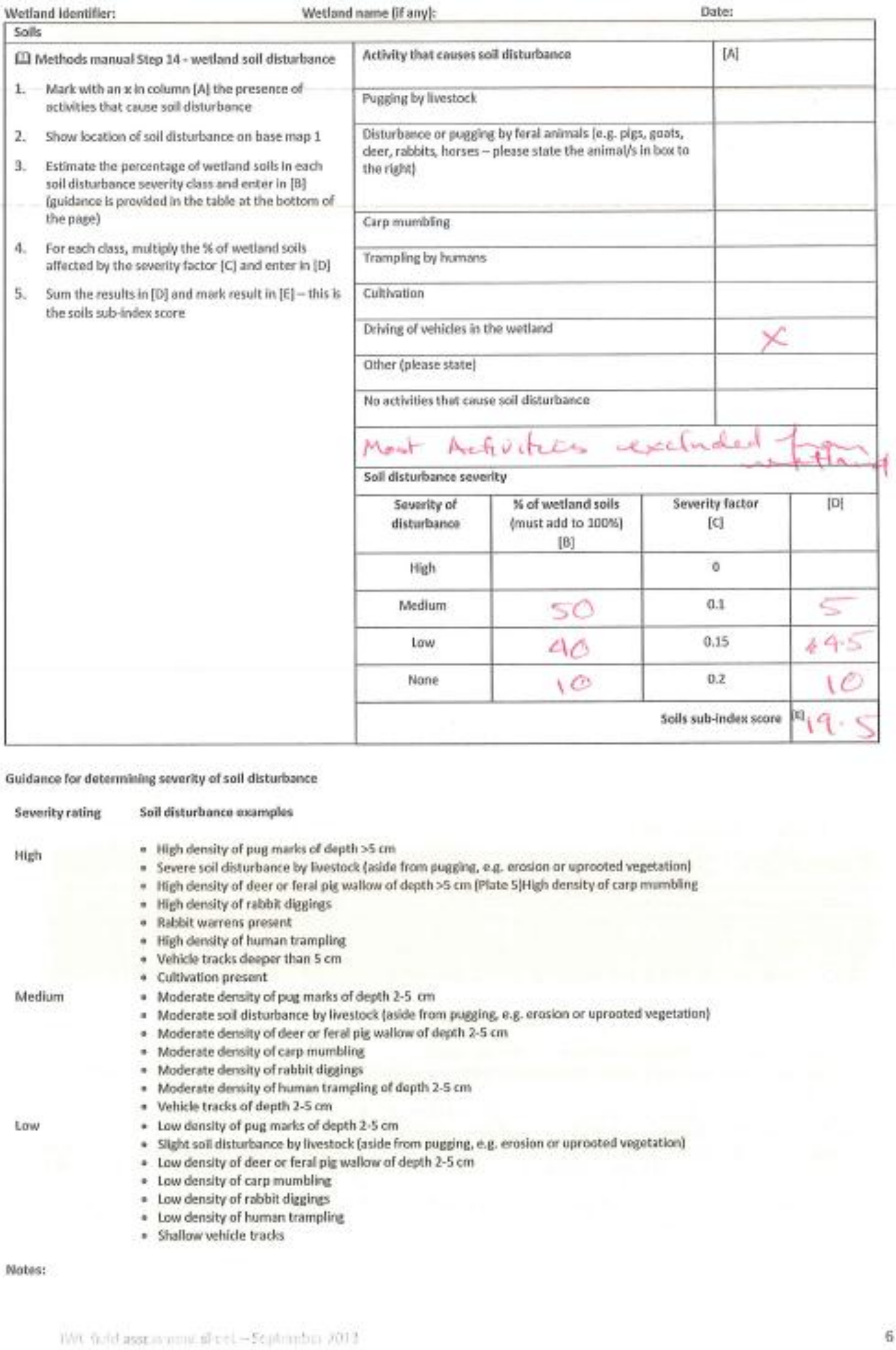
1. Mark with an x in column [A] activities leading to nutrient enrichment
2. Document the severity of nutrient enrichment using the scores provided and mark at [E]
3. Enter the level of confidence you have in your assessment at [C]
4. At [D] enter the source of information used to make your assessment using one of the following categories:
   - Field data or observation
   - Local knowledge (landholder or land manager)
   - Wetland management plan or report
   - Other (please describe)
5. Document evidence of nutrient enrichment if available (e.g. algal blooms, field data) and enter at [E]

Nutrient enrichment	[A]
Discharge of nutrient-rich water to the wetland (e.g. from sewage, industrial effluent or irrigation water)	
Drainage of nutrient-rich water into the wetland from an urban area (via a drain)	
Runoff of nutrients to wetland (e.g. from fertilizer application or grazing)	X
Grazing by livestock in the wetland	
Grazing by feral animals in the wetland (e.g. pigs, goats, deer, rabbits, horses – please state the animal/s in box to the right)	X
Application of fertilizer in the wetland	
Aquaculture	
Other (please state)	
No activities leading to nutrient enrichment	
What is the severity of nutrient enrichment? **No enrichment [10], Low [7], Moderate [5], High [0]**	[B] 5
How confident are you about your assessment? (Options: High, Moderate, Low)	[C] M
What main source of information did you use to make your assessment? (see category in Step 4)	[D] observation
Document evidence of nutrient enrichment if available (e.g. algal blooms, nutrient data)	[E] Nutrient rich sediments in channel

📖 Methods manual Step 13b – change in salinity

1. Mark with an x in column [E] the reason for a change in salinity from its reference (i.e. pre-European) state
2. Document the severity of the change in salinity and mark in [F] using the scores provided
3. Enter the level of confidence you have in your assessment at [G]
4. At [H] enter the source of information you used to make your assessment using one of the following categories:
   - Current Wetlands / Pre European Wetlands spatial inventories
   - Field data or observation
   - Local knowledge (landholder or land manager)
   - Wetland management plan or report
   - Other (please describe)
5. Add the scores for both measures [B] and [F] to obtain the sub-index score and enter at [I]
6. Document evidence of a change in salinity if available (e.g. change in salinity classification, change in vegetation, change in wetland fauna, salinity data) and enter at [J]

Change in salinity	[E]
Saline groundwater intrusion resulting in an increase in salinity from its natural state	
Saline water intrusion from the marine environment resulting in an increase in salinity from its natural state	
Saline water is unnaturally delivered to a fresh or brackish wetland	
Fresh water is unnaturally delivered to a saline wetland	
Other (please state)	
No change in salinity	
What is the severity of change in salinity? **No change [10], Low [7], Moderate [5], High [0]**	[F] 5
How confident are you about your assessment? (Options: High, Moderate, Low)	[G] Low
What main source of information did you use to make your assessment? (see source of information category left)	[H] informed data
Water properties score ([B] + [F])	[I] 10
Document evidence of a change in salinity if available (e.g. change in salinity classification, change in vegetation, change in wetland fauna, salinity data)	[J]



Wetland identifier: **Wetland name (if any):** **Date:**

Soils

📖 **Methods manual Step 14 - wetland soil disturbance**

1. Mark with an x in column [A] the presence of activities that cause soil disturbance
2. Show location of soil disturbance on base map 1
3. Estimate the percentage of wetland soils in each soil disturbance severity class and enter in [B] (guidance is provided in the table at the bottom of the page)
4. For each class, multiply the % of wetland soils affected by the severity factor [C] and enter in [D]
5. Sum the results in [D] and mark result in [E] – this is the soils sub-index score

Activity that causes soil disturbance	[A]
Pugging by livestock	
Disturbance or pugging by feral animals (e.g. pigs, goats, deer, rabbits, horses – please state the animal/s in box to the right)	
Carp mumbling	
Trampling by humans	
Cultivation	
Driving of vehicles in the wetland	x
Other (please state)	
No activities that cause soil disturbance	

Most Activities excluded from wetland

Soil disturbance severity

Severity of disturbance	**% of wetland soils (must add to 100%)** [B]	**Severity factor** [C]	[D]
High		0	
Medium	50	0.1	5
Low	40	0.15	4.5
None	10	0.2	10
		Soils sub-index score	[E] 19.5

Guidance for determining severity of soil disturbance

Severity rating	**Soil disturbance examples**
High	• High density of pug marks of depth >5 cm • Severe soil disturbance by livestock (aside from pugging, e.g. erosion or uprooted vegetation) • High density of deer or feral pig wallow of depth >5 cm (Plate 5)High density of carp mumbling • High density of rabbit diggings • Rabbit warrens present • High density of human trampling • Vehicle tracks deeper than 5 cm • Cultivation present
Medium	• Moderate density of pug marks of depth 2-5 cm • Moderate soil disturbance by livestock (aside from pugging, e.g. erosion or uprooted vegetation) • Moderate density of deer or feral pig wallow of depth 2-5 cm • Moderate density of carp mumbling • Moderate density of rabbit diggings • Moderate density of human trampling of depth 2-5 cm • Vehicle tracks of depth 2-5 cm
Low	• Low density of pug marks of depth 2-5 cm • Slight soil disturbance by livestock (aside from pugging, e.g. erosion or uprooted vegetation) • Low density of deer or feral pig wallow of depth 2-5 cm • Low density of carp mumbling • Low density of rabbit diggings • Low density of human trampling • Shallow vehicle tracks

Notes:

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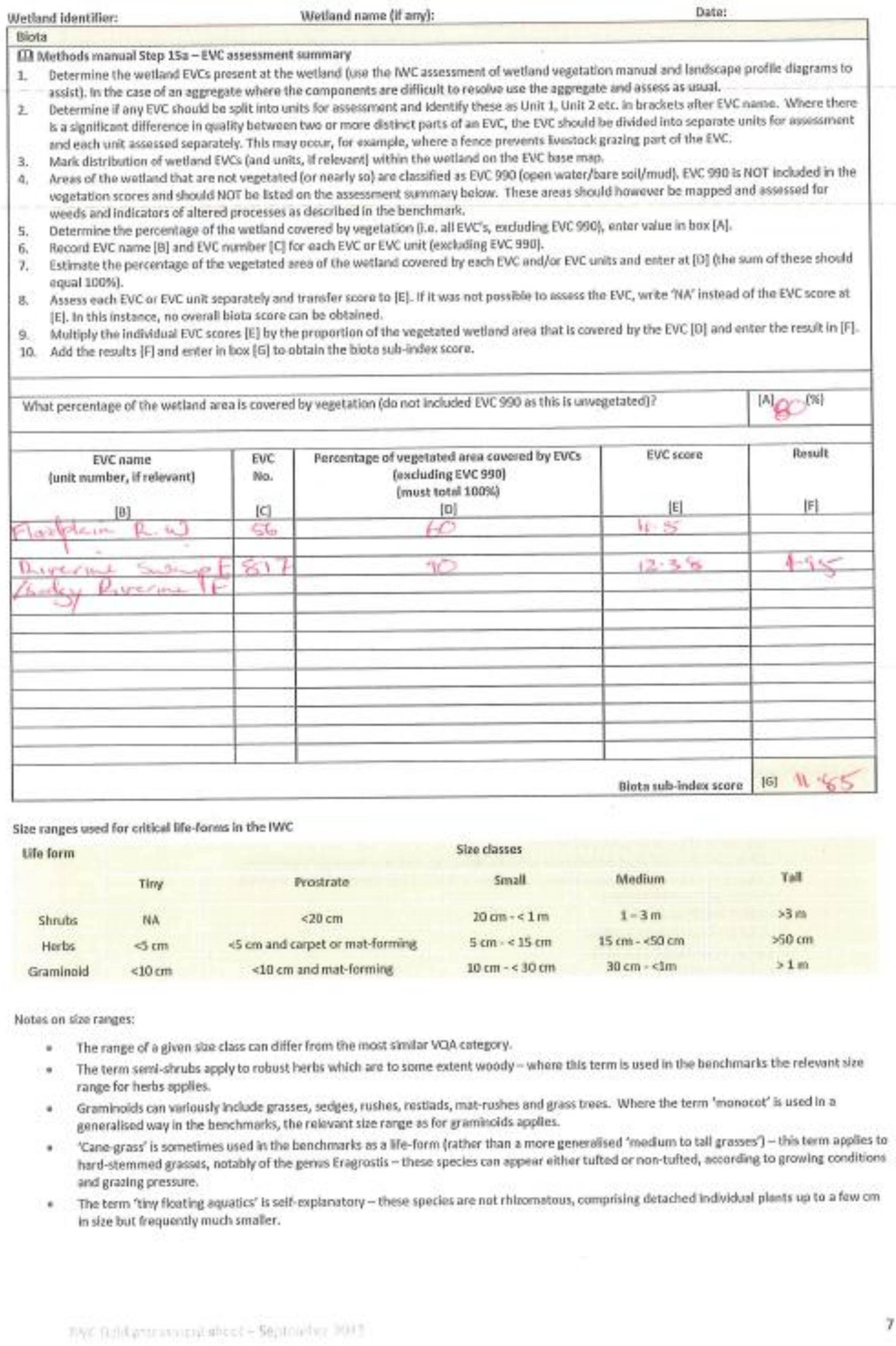

Wetland identifier: **Wetland name (if any):** **Date:**

Biota

Methods manual Step 15a – EVC assessment summary

1. Determine the wetland EVCs present at the wetland (use the IWC assessment of wetland vegetation manual and landscape profile diagrams to assist). In the case of an aggregate where the components are difficult to resolve use the aggregate and assess as usual.
2. Determine if any EVC should be split into units for assessment and identify these as Unit 1, Unit 2 etc. in brackets after EVC name. Where there is a significant difference in quality between two or more distinct parts of an EVC, the EVC should be divided into separate units for assessment and each unit assessed separately. This may occur, for example, where a fence prevents livestock grazing part of the EVC.
3. Mark distribution of wetland EVCs (and units, if relevant) within the wetland on the EVC base map.
4. Areas of the wetland that are not vegetated (or nearly so) are classified as EVC 990 (open water/bare soil/mud). EVC 990 is NOT included in the vegetation scores and should NOT be listed on the assessment summary below. These areas should however be mapped and assessed for weeds and indicators of altered processes as described in the benchmark.
5. Determine the percentage of the wetland covered by vegetation (i.e. all EVC's, excluding EVC 990), enter value in box [A].
6. Record EVC name [B] and EVC number [C] for each EVC or EVC unit (excluding EVC 990).
7. Estimate the percentage of the vegetated area of the wetland covered by each EVC and/or EVC units and enter at [D] (the sum of these should equal 100%).
8. Assess each EVC or EVC unit separately and transfer score to [E]. If it was not possible to assess the EVC, write 'NA' instead of the EVC score at [E]. In this instance, no overall biota score can be obtained.
9. Multiply the individual EVC scores [E] by the proportion of the vegetated wetland area that is covered by the EVC [D] and enter the result in [F].
10. Add the results [F] and enter in box [G] to obtain the biota sub-index score.

What percentage of the wetland area is covered by vegetation (do not included EVC 990 as this is unvegetated)? [A] 80 (%)

EVC name (unit number, if relevant) [B]	EVC No. [C]	Percentage of vegetated area covered by EVCs (excluding EVC 990) (must total 100%) [D]	EVC score [E]	Result [F]
Floodplain R. W	56	60	11.5	
Riverine Swamp F	817	40	12.38	4.95
Sedgy Riverine F				
			Biota sub-index score	[G] 11.65

Size ranges used for critical life-forms in the IWC

Life form	Size classes				
	Tiny	Prostrate	Small	Medium	Tall
Shrubs	NA	<20 cm	20 cm - < 1 m	1 - 3 m	>3 m
Herbs	<5 cm	<5 cm and carpet or mat-forming	5 cm - < 15 cm	15 cm - <50 cm	>50 cm
Graminoid	<10 cm	<10 cm and mat-forming	10 cm - < 30 cm	30 cm - <1m	> 1 m

Notes on size ranges:

- The range of a given size class can differ from the most similar VQA category.
- The term semi-shrubs apply to robust herbs which are to some extent woody – where this term is used in the benchmarks the relevant size range for herbs applies.
- Graminoids can variously include grasses, sedges, rushes, restiads, mat-rushes and grass trees. Where the term 'monocot' is used in a generalised way in the benchmarks, the relevant size range as for graminoids applies.
- 'Cane-grass' is sometimes used in the benchmarks as a life-form (rather than a more generalised 'medium to tall grasses') – this term applies to hard-stemmed grasses, notably of the genus Eragrostis – these species can appear either tufted or non-tufted, according to growing conditions and grazing pressure.
- The term 'tiny floating aquatics' is self-explanatory – these species are not rhizomatous, comprising detached individual plants up to a few cm in size but frequently much smaller.

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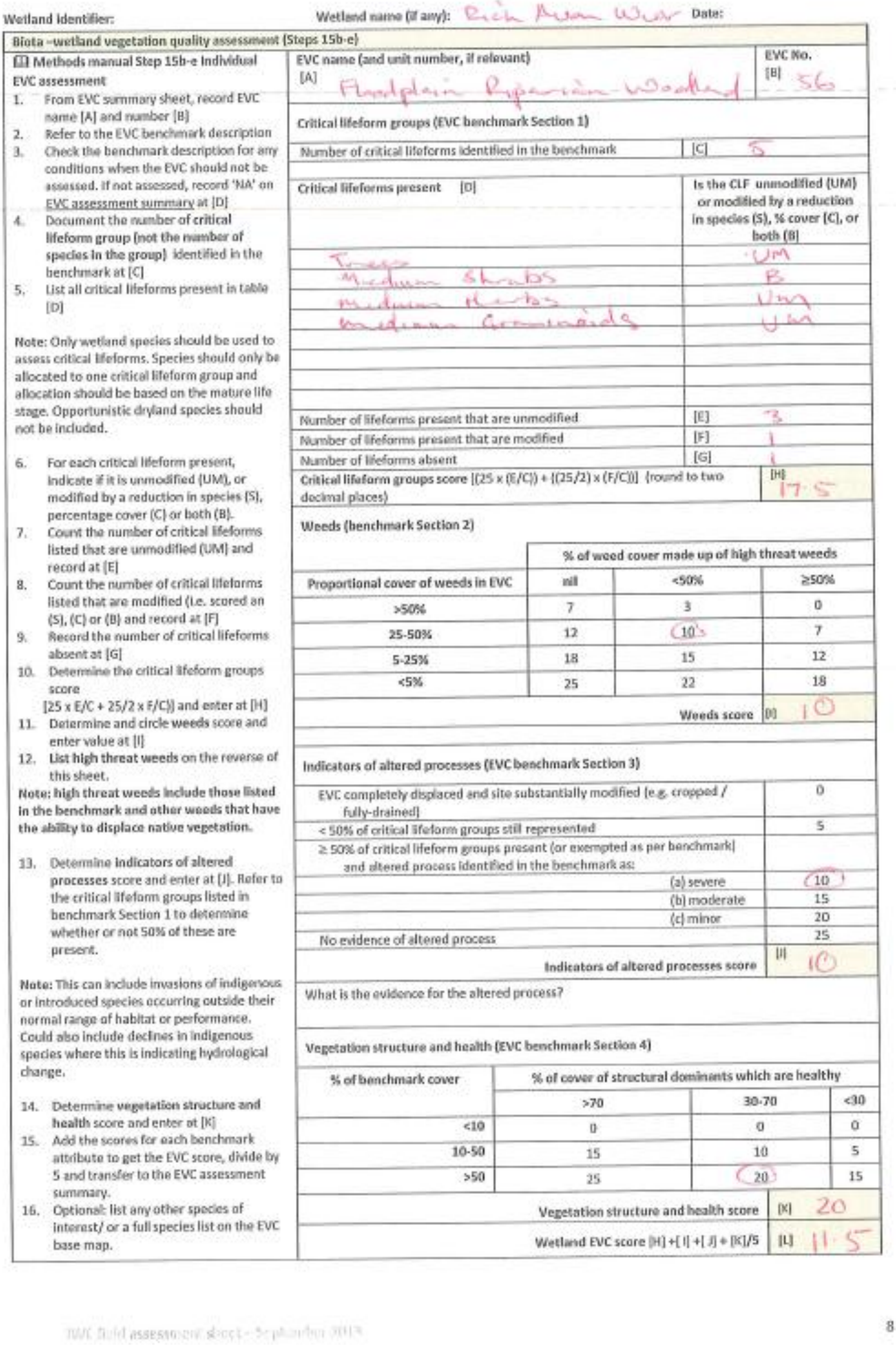

Wetland identifier:

Wetland name (if any): Rich Avon Weir **Date:**

Biota –wetland vegetation quality assessment (Steps 15b-e)

Methods manual Step 15b-e Individual EVC assessment

1. From EVC summary sheet, record EVC name [A] and number [B]
2. Refer to the EVC benchmark description
3. Check the benchmark description for any conditions when the EVC should not be assessed. If not assessed, record 'NA' on EVC assessment summary at [D]
4. Document the number of **critical lifeform group (not the number of species in the group)** identified in the benchmark at [C]
5. List all critical lifeforms present in table [D]

Note: Only wetland species should be used to assess critical lifeforms. Species should only be allocated to one critical lifeform group and allocation should be based on the mature life stage. Opportunistic dryland species should not be included.

6. For each critical lifeform present, indicate if it is unmodified (UM), or modified by a reduction in species (S), percentage cover (C) or both (B).
7. Count the number of critical lifeforms listed that are unmodified (UM) and record at [E]
8. Count the number of critical lifeforms listed that are modified (i.e. scored an (S), (C) or (B) and record at [F]
9. Record the number of critical lifeforms absent at [G]
10. Determine the critical lifeform groups score [25 x E/C + 25/2 x F/C)] and enter at [H]
11. Determine and circle **weeds** score and enter value at [I]
12. **List high threat weeds** on the reverse of this sheet.

Note: high threat weeds include those listed in the benchmark and other weeds that have the ability to displace native vegetation.

13. Determine **indicators of altered processes** score and enter at [J]. Refer to the critical lifeform groups listed in benchmark Section 1 to determine whether or not 50% of these are present.

Note: This can include invasions of indigenous or introduced species occurring outside their normal range of habitat or performance. Could also include declines in indigenous species where this is indicating hydrological change.

14. Determine **vegetation structure and health** score and enter at [K]
15. Add the scores for each benchmark attribute to get the EVC score, divide by 5 and transfer to the EVC assessment summary.
16. Optional: list any other species of interest/ or a full species list on the EVC base map.

EVC name (and unit number, if relevant) [A] Floodplain Riparian Woodland	**EVC No.** [B] 56

Critical lifeform groups (EVC benchmark Section 1)

Number of critical lifeforms identified in the benchmark	[C]	5

Critical lifeforms present [D]	**Is the CLF unmodified (UM) or modified by a reduction in species (S), % cover (C), or both (B)**
Trees	UM
Medium Shrubs	B
Medium Herbs	UM
Medium Graminoids	UM

Number of lifeforms present that are unmodified	[E]	3
Number of lifeforms present that are modified	[F]	1
Number of lifeforms absent	[G]	1
Critical lifeform groups score [(25 x (E/C)) + ((25/2) x (F/C))] (round to two decimal places)	[H] 17.5	

Weeds (benchmark Section 2)

	% of weed cover made up of high threat weeds		
Proportional cover of weeds in EVC	**nil**	**<50%**	**≥50%**
>50%	7	3	0
25-50%	12	[✓ 10]	7
5-25%	18	15	12
<5%	25	22	18
		Weeds score	[I] 10

Indicators of altered processes (EVC benchmark Section 3)

EVC completely displaced and site substantially modified (e.g. cropped / fully-drained)	0
< 50% of critical lifeform groups still represented	5
≥ 50% of critical lifeform groups present (or exempted as per benchmark) and altered process identified in the benchmark as:	
(a) severe	[✓ 10]
(b) moderate	15
(c) minor	20
No evidence of altered process	25
Indicators of altered processes score	[J] 10

What is the evidence for the altered process?

Vegetation structure and health (EVC benchmark Section 4)

% of benchmark cover	**% of cover of structural dominants which are healthy**		
	>70	30-70	<30
<10	0	0	0
10-50	15	10	5
>50	25	[✓ 20]	15

Vegetation structure and health score	[K] 20
Wetland EVC score [H] +[I] +[J] + [K]/5	[L] 11.5