Avon Plains Lakes Water Management Plan

REPORT

- Final
- 23 February 2006

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Sinclair Knight Merz
ABN 37 001 024 095
590 Orrong Road, Armadale 3143
PO Box 2500
Malvern VIC 3144 Australia
Tel: +61 3 9248 3100
Fax: +61 3 9248 3400
Web: www.skmconsulting.com

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Executive Summary

Introduction

Three ephemeral lakes lie on the floodplains of the Avon River, approximately 18 km south of the township of Donald, and 30 km north-west of St Arnaud. Overflows from the lakes flow into Lake Batyo Catyo, which is located to the south of Donald. The lakes have their own natural catchment area that is drained by Souths Creek.

Hollands Bank is located approximately 3 km to the south of Hollands Lake. It runs across a natural saddle between the catchments of the Avon River and Souths Creek. The bank currently prevents all but the largest floods from overflowing from the Avon River into Souths Creek. The level of the natural saddle is approximately 138.0 m AHD (or 0.6 m lower than the crest of Hollands Bank), so prior to construction of the bank floods from the Avon River floodplain would have overtopped the saddle more frequently and caused more water to flow into the Avon Plains Lakes system.

The Avon Richardson Floodplain Management Plan was prepared in June 2000. The Plan recommended that Hollands Bank should be retained at its current height to provide flood mitigation for properties downstream of the bank. The Floodplain Management Plan also recommended that options should be investigated for construction of a drain through Hollands Bank to improve management of water in the Avon Plains Lakes and to provide further flood mitigation benefits to downstream properties.

Sinclair Knight Merz was engaged by the North Central Catchment Management Authority in June 2005 to develop a water management plan for the Avon Plains Lakes that enhances the environmental values of the lakes system.

Options Considered

A key consideration in management of water for the Avon Plains Lakes is the management of flood flows from the Avon River catchment to Souths Creek through or over the Hollands Bank area. This report specifically addresses four options for the future management of Hollands Bank:

1) “Do Nothing” or retain Hollands Bank in its current configuration;
2) Install a drainage pipe through Hollands Bank, including a concrete inlet structure with its crest level at 138.0 m AHD (approximately the same level as the natural saddle);
3) Install a drainage pipe through Hollands Bank, including a concrete inlet structure with its crest level at 137.4 m AHD (approximate natural surface level on northern and southern sides of the natural saddle);
4) Removal of Hollands Bank, restoring levels along the saddle to their natural levels of 138.0 m AHD.

Analysis of Flood Flows and Water Management

Installation of pipe drainage through Hollands Bank would provide additional water into Souths Creek during times of flood in the Avon River. The total volume passing through the bank for the pipe inlet at 137.4 m AHD would increase gradually with flood magnitude from around 220 ML at 1 in 2, to around 260 ML at 1 in 20. These volumes would flow through the bank over a period of about 3 to 7 days. The pipe drainage options would have some small flood mitigation benefits downstream of the bank over existing conditions for large floods (with Annual Exceedance Probabilities (AEP) between 1 in 50 and 1 in 100).

Installation of a similar pipe drain but with the inlet set at 138.0 m AHD (or the same as the level of the natural saddle) would prevent flow through the bank for the 1 in 2 AEP event but would allow flows to pass in the 1 in 5 and less frequent floods. Flows through the bank would increase with flood magnitude from around 200 ML at 1 in 5, to around 250 ML at 1 in 20. As with the lower pipe, these volumes would flow through the bank over a typical period of between 3 and 7 days.

Over the period of investigation (1963 to 2004), there would have been 53 separate flood events when flows would have been expected through a pipe drain in Hollands Bank. This extra water would have been supplied during wet periods, when it is expected that the Avon Plains lakes would already be receiving significant runoff from their local catchment area (downstream of Hollands Bank). The extra water supplied through a pipe drainage structure in Hollands Bank would therefore not change the time series of water levels and storage volumes in the lakes. However, the pipe drainage options would increase the mean annual volume of water flushing through the lakes system by between 185 and 265 ML/year or between 18% and 25% of the spills from Walkers Lake under existing conditions.

Removal of Hollands Bank, so that the level of the overflow is restored to a level of 138.0 m AHD would result in considerable increases in flood volumes over the natural saddle for AEP between 1 in 5 and 1 in 100.

Assessment of Influence of Options on Vegetation Communities in the Lakes

A field and desktop assessment was undertaken of the vegetation communities in Hollands, Walkers and Hancocks lakes and Lake Batyo Catyo. The focus of this assessment was on how changes in watering regimes, associated with the options considered for management of Hollands Bank, might influence the vegetation communities in the lakes.

Changes in vegetation community associated with prolonged dry conditions generally involve the expansion of some communities and species at the expense of others. More specifically, the expanding communities are those associated with infrequent flooding and that are more tolerant of dry conditions. Declining communities are those requiring with more frequent inundation. This change in community structure is evident at all lakes.

Vegetation associations or patterns are usually defined by the range of environmental conditions which exist in an ecosystem. If conditions change to the extent that they fall outside the natural environmental tolerances of a particular species occupying the site, then it is likely that these species will decline and will be replaced by species better suited to the changed conditions. In most cases, these are exotic species.

Extended dry periods at the lakes have resulted in a visible shift in floristic diversity and coverage in the lakes. This is indicated by the encroachment of dryland vegetation to the littoral zone and into the main body of the lakes. This has caused an increase in dominance by vegetation that is more tolerant of drier conditions. For example, Chenopod communities are prevalent within the littoral zone and scattered throughout the main body of the lakes.

Dry conditions have caused unfavourable conditions for submerged and emergent vegetation and as a consequence, these species have had little or no opportunity to recharge the seed bank or to renew storage.   This could result in reduced recruitment following a future flood, provided propagules still remain viable.

Changes in water levels have altered the composition, structure and production of the vegetation at the lakes, as vegetation adjusts to falling and rising water levels. Prolonged dry conditions have been responsible for the displacement of aquatic and semi-aquatic vegetation with terrestrial vegetation. Generally, native wetland vegetation is well adapted to patterns of drought and flood and have developed specific mechanisms for their recovery. It is anticipated that water will be supplied to the lakes during wet years and wetland vegetation will re-establish. However, the rate of recovery can vary considerably, being influenced by succession patterns in plants and the viability of the seed, rhizomes and propagules of wetland flora.

River Red Gum (*Eucalyptus camaldulensis*) and Black Box (*Eucalyptus largiflorens*) communities at the lakes have experienced long periods of dry conditions as a consequence of climatic conditions, river regulation and land-forming (particularly the construction of Hollands Bank). For trees that have experienced an extended dry phase, frequent short floods and longer duration floods both reduce water stress and hence results in greater growth (Bacon *et. al* 1993).

Both pipe options propose to deliver longer periods of water inundation at the lakes when compared to existing conditions. The pipe option through Hollands Bank set at 137.4 m AHD would extend the inundation periods and increase water depth at all lakes. This additional inundation time and water depth will provide benefit to the existing vegetation communities by enhancing opportunities for regeneration and establishment and help maintain the health of existing populations. These changes will also benefit waterbird populations (including migratory) by extending breeding periods and improving foraging opportunities.

Under current conditions, the lack of episodic flushing events following flooding may be causing an increase in salinity at the lakes. The proposed pipe option will provide some periodic flushing of the lakes and could provide some salinity mitigation benefits. The extent of this benefit should be investigated and the relative merits of increasing flushing cycles at the lakes should also be explored.

Recommendations

It is recommended that a pipe is installed in Holland’s Bank to allow for a controlled release of flow into the Avon Plains Lakes. It is recommended that:

- Releases through the pipe are controlled to a maximum rate of 50 ML/d by the configuration of the inlet structure;
- The inlet structure is constructed so that flows through the pipe commence at a water level of 137.4 m AHD upstream of Holland’s Bank;
- A drain and associated road crossings are constructed between the pipe outlet and South’s Creek to convey at least 50 ML/d, thereby avoiding additional flooding of properties that are located between Holland’s Bank and South’s Creek; and
- The on-going management and maintenance of Lake Batyo Catyo is addressed to avoid exacerbating flooding downstream of Lake Batyo Catyo. This may involve continued operation and maintenance of the outlet channel from Lake Batyo Catyo to allow for overflows from Walkers Lake to be conveyed through Batyo Catyo without exacerbating downstream flooding.

1. Introduction

Three ephemeral lakes lie on the floodplains of the Avon River, approximately 18 kilometres south of the township of Donald, and 30 kilometres north-west of St Arnaud. Overflows from the lakes flow into Lake Batyo Catyo, which is located to the south of Donald. The lakes have their own natural catchment area that is drained by Souths Creek.

The majority of the land adjacent to the Avon Plains Lakes is privately owned and has been cleared for agriculture. The surrounding land is mainly used for broadacre farming (esp. sheep grazing and dryland cropping).

Hollands Bank is located approximately 3 km to the south of Hollands Lake. It runs across a natural saddle between the catchments of the Avon River and Souths Creek. The bank has a crest level of 138.6 m AHD and it currently prevents all but the largest and least frequent of floods from overflowing from the Avon River into Souths Creek. The level of the natural saddle is approximately 138.0 m AHD (or 0.6 m lower than the crest of Hollands Bank), so prior to construction of the bank floods from the Avon River floodplain would have overtopped the saddle more frequently and caused more water to flow into the Avon Plains Lakes system.

The Avon Richardson Floodplain Management Plan was prepared in June 2000. The Plan recommended that Hollands Bank should be retained at its current height to provide flood mitigation for properties downstream of the bank. The Floodplain Management Plan also recommended that options should be investigated for construction of a drain through Hollands Bank to improve management of water in the Avon Plains Lakes and to provide further flood mitigation benefits to downstream properties.

Sinclair Knight Merz was engaged by the North Central Catchment Management Authority in June 2005 to develop a water management plan for the Avon Plains Lakes that enhances the environmental values of the lakes system. This report summarises the investigations that Sinclair Knight Merz have conducted into management of water within the lakes system.

A key consideration in management of water for the Avon Plains Lakes is the management of flood flows from the Avon River catchment to Souths Creek through or over the Hollands Bank area. This report specifically addresses four options for the future management of Hollands Bank:

5) “Do Nothing” or retain Hollands Bank in its current configuration;
6) Install a drainage pipe through Hollands Bank, including a concrete inlet structure with its crest level at 138.0 m AHD (approximately the same level as the natural saddle);

7) Install a drainage pipe through Hollands Bank, including a concrete inlet structure with its crest level at 137.4 m AHD (approximate natural surface level on northern and southern sides of the natural saddle);
8) Removal of Hollands Bank, restoring levels along the saddle to their natural levels of 138.0 m AHD.

This report considers the hydrological and ecological aspects of water management of the Avon Plains Lakes and options for management of flows through the Hollands Bank area in particular. The report is organised into the following chapters:

- Chapter 2 analyses flood flows in the area, to estimate the frequency, peak and volumes released during floods under each of the four options for Hollands Bank;
- Chapter 3 analyses the water balance for each of the lakes in the Avon Plains Lakes system, providing projections of the volume of water stored in the lakes, water levels in the lakes and flows in and out of each of the lakes under each of the four options for Hollands Bank;
- Chapter 4 assesses the vegetation in and around each of the lakes, providing an assessment of how this vegetation might respond to the watering regimes that would exist under each of the four options for Hollands Bank;
- Chapter 6 provides an overall assessment of the options considered and gives recommendations on the Water Management Plan that should be adopted for the lakes.

A location map of the study area is included on the following page.

2. Analysis of Flood Flows

The Avon Plains Lakes have their own natural catchment area, which is drained by Souths Creek. During large flood events, flows from the floodplain of the Avon River can overtop Hollands Bank and enter the lakes system via Souths Creek.

One of the aims of this study was to estimate the time series of levels within each of the three lakes that would typically be observed under each of the management options for Holland's Bank. Under existing conditions, inflows to the lakes are limited to runoff from the local catchment area of the Avon Plains Lakes, in all but the largest of floods. Observations of local landholders are that Holland's Bank has not been overtopped during at least the last thirty years. It is therefore likely that it would take a flood with an AEP of somewhere between 1 in 20 and 1 in 40 for Holland's Bank to be overtopped.

Flows over and/or through Holland's Bank have been estimated for each of the four options using the RORB rainfall-runoff routing model. RORB (Laurenson and Mein, 1994) is a hydrological model that has been specifically developed for estimation of the magnitude, volume and duration of flooding. A RORB model was developed for the study area as part of the Avon-Richardson Floodplain Management Plan by Egis (2000). The parameters of the RORB model were calibrated by Egis (2000) to the observed flood events in 1981 and 1996. The model included Hollands Bank in its existing configuration, which currently prevents all but the largest floods from overtopping Hollands Bank and flowing into Souths Creek.

The hydraulic response of flow from the area upstream of Holland's Bank along the Duxons Stop Drain during periods of flooding was investigated in order to ensure that the RORB model accurately reflects the flood flows in the area. The results of the hydrological modelling were used to estimate the inflows to the Avon Plains Lakes that result from flow through/over Holland's Bank for the water balance modelling of the lakes.

2.1 RORB modelling

The Egis RORB model covers the entire Avon–Richardson catchment. A small part of the overall model covers the area of interest for this study, which is the area from the Avon River at Wimmera Highway (gauge 415220) to Holland's Bank and either back to the river via Duxons Stop Drain or over Holland's Bank to South's Creek and the lakes downstream. The RORB model was calibrated to streamflow data available at gauge 415220 upstream of the area of interest as well as several sites downstream on the Richardson River. Since there is no additional information available to calibrate the model to, it is difficult to justify any significant changes to the parameters calibrated for the RORB model. A review of the Egis model showed that the RORB model is appropriate for use in this study.

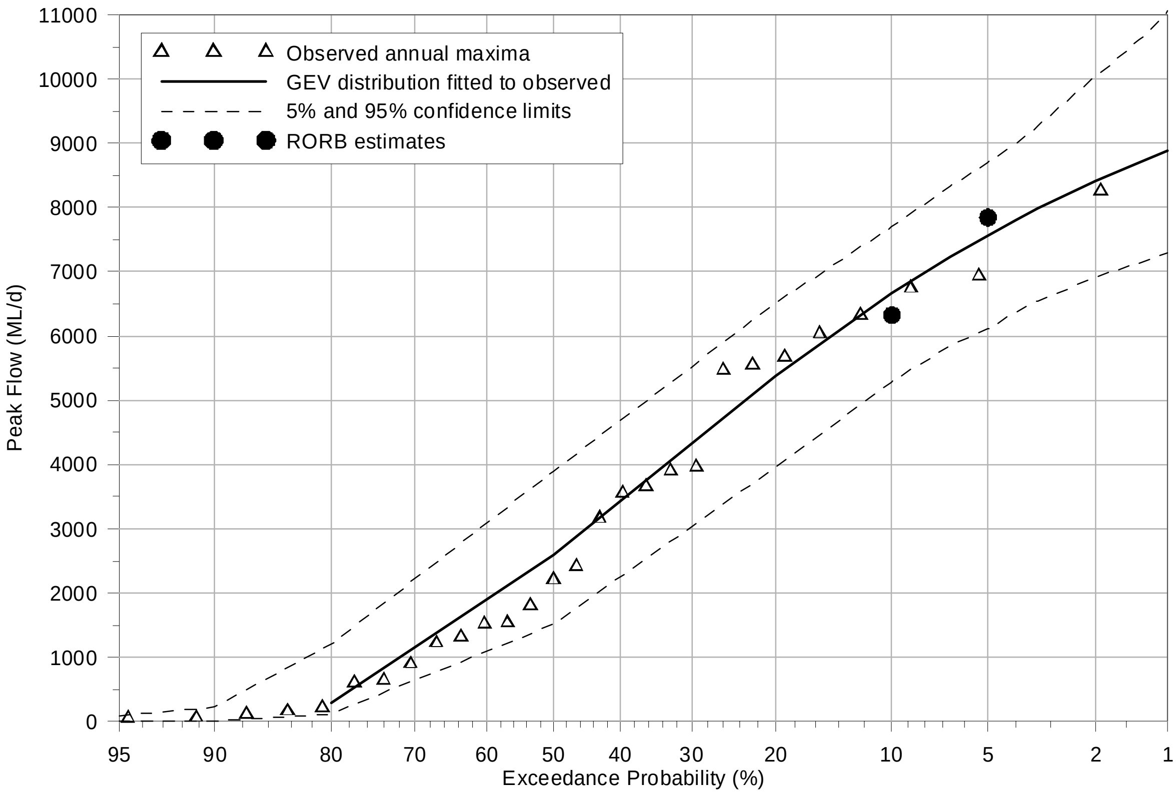
Modifications were performed on the RORB model to correctly represent the flow conditions in the vicinity of Hollands Bank for each of the four options that were considered in this study.

2.1.1 Design Runs

The Egis RORB model was converted to a 'design' model to enable the model to be run for hypothetical 'design' storms rather than just historical storm events. The following modifications were made to the original RORB model:

- The baseflow hydrographs in the model were replaced with constant values for baseflow, using the mean of the baseflow hydrographs from the 1981 storm file in each case.
- A value of K_c equal to 120 was adopted (average of the K_c values run in the Egis model runs of 100 or 140 for different storm events) with an *m* value of 0.9 (as used in the Egis model runs).
- The design model was calibrated to the 1 in 10 and 1 in 20 flows in the Avon River at Wimmera Highway (gauge 415220) in order to determine appropriate design parameters

The design parameters adopted were an initial loss of 19mm and a runoff coefficient of 0.4. Figure 2-1 shows the results of the flood frequency analysis observed annual maxima compared to the estimates from RORB with the adopted model parameter values.



▪ **Figure 2-1 Comparison between frequency analysis of observed annual maxima and RORB estimates for the Avon River at the Wimmera Highway gauge (415220)**

2.1.2 Joint Probability Framework to Estimation of Flood Volumes Through or Over Holland's Bank

Current practice for estimation of design floods is typically based on the "design event" approach, in which all parameters other than rainfall are input as fixed, single values. This concept is illustrated in Figure 2-2 for the case where a distribution of design rainfalls is combined with fixed values of losses, rainfall temporal patterns and spatial patterns. Considerable effort is made to ensure that the single values of the adopted parameters are "AEP-neutral", that is, they are selected with the objective of ensuring that the resulting flood has the same annual exceedance probability as its causative rainfall.

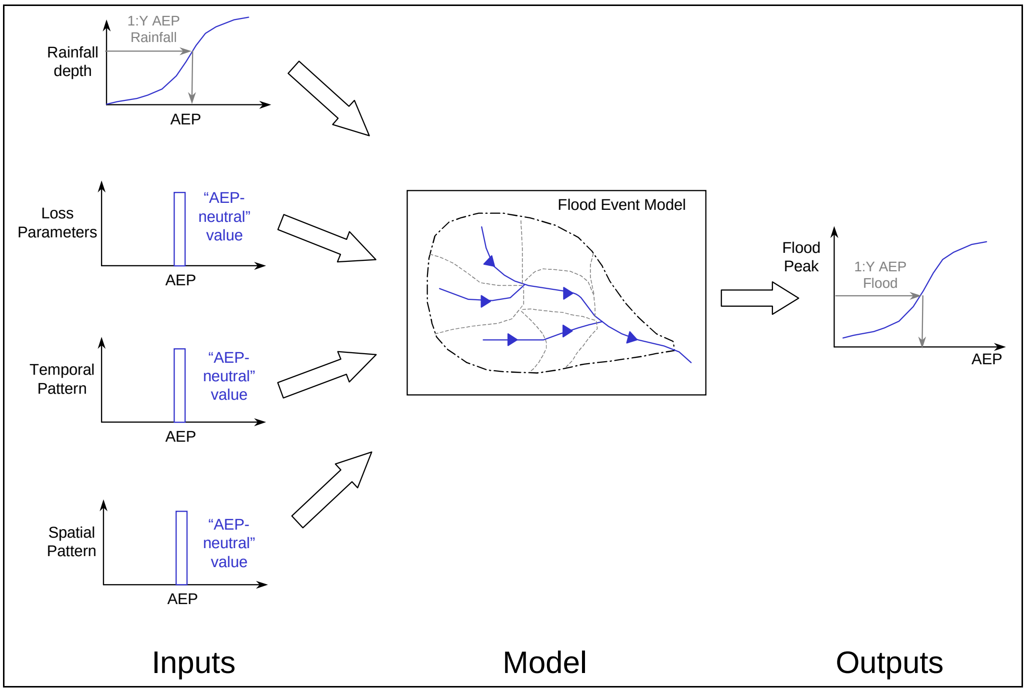


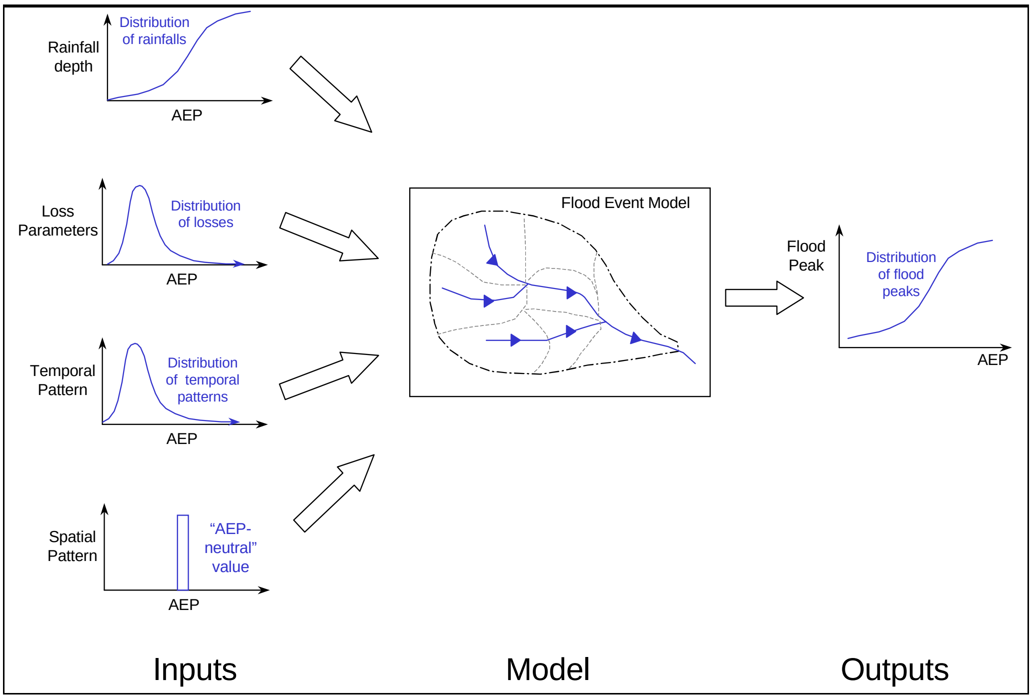
Figure 2-2 Schematic illustration of the design event approach. Moving from left to right, the design event approach selects one value each for rainfall depth, losses, rainfall temporal pattern and spatial pattern; these single values are then applied to the flood event model of the catchment to estimate the flood peak. The inherent assumption in this approach is that the inputs on the left side of the figure can be selected so that the AEP of the flood estimate is the same as the AEP of the rainfall that is used to estimate it.

While this approach represents current practice in Australia (and overseas), it does suffer from the limitations that:

- the AEP-neutrality of some inputs can only be tested on frequent events for which independent estimates are available;
- for more extreme events, the adopted values of AEP-neutral inputs must be conditioned by physical and theoretical reasoning; and,
- the treatment of more complex interactions (such as the seasonal variation of inputs) becomes rapidly more complex and less easy to defend.

Joint probability techniques offer an alternative to the design event method. These techniques recognise that any design flood characteristics (e.g. peak flow) could result from a variety of combinations of flood producing factors, rather than from a single combination. For example, the same peak flood could result from a moderate storm on a saturated basin, or a large storm on a dry basin; in probabilistic terms, a 1 in 20 AEP flood could be the result of a 1 in 10 AEP rainfall on a very wet catchment, or a 1 in 40 AEP rainfall on a dry catchment. Joint probability approaches attempt to mimic "mother nature" in that the influence of all probability distributed inputs are explicitly considered, thereby providing a more realistic representation of the flood generation processes.

The method is easily adapted to focus on only those aspects that are most relevant to the problem. For example as illustrated in Figure 2-3 it is possible to adopt single "AEP-neutral" values for some inputs (in this case the manner in which rainfalls are spatially distributed over the catchment), and full distributions for other more important inputs, such as losses and temporal patterns.

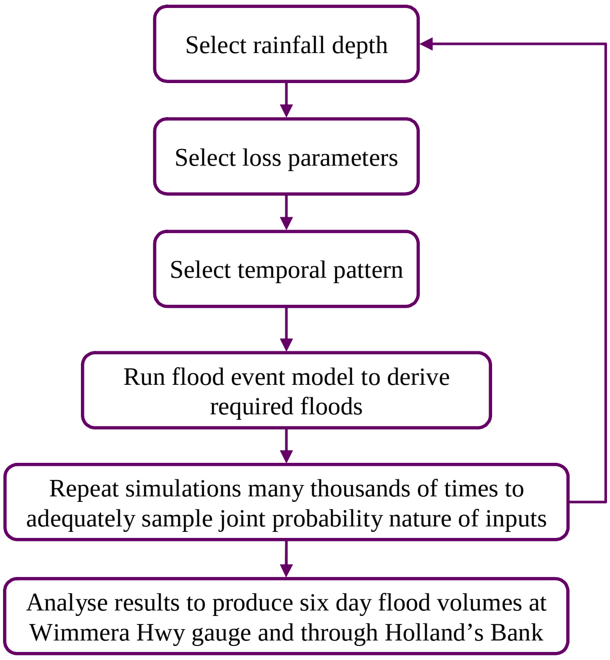


- **Figure 2-3 Schematic illustration of the joint probability approach. Moving from left to right, the joint probability approach selects many times from the distributions of rainfall depth, losses, rainfall temporal pattern and spatial pattern; the values selected from the distributions are then applied many times to the flood event model of the catchment to estimate the distribution of flood peaks. This overcomes some of the limitations of the design event approach and produces a more reliable estimate of the distribution of flood peaks.**

The application of joint probability approaches to flood estimation has received some attention in the scientific literature over the past 20 years, but there have been few practical applications of the technique. More recently, the application of these techniques to extreme events has started to receive more attention (particularly in northern America; Neudorf 1994; Barker *et al.* 1997), but it is only very recently that Monte-Carlo techniques have been used in Australian design practice (Nathan et al. 2002; 2003).

The following sections outline the overall framework adopted, and the nature of the evidence used to characterise the distribution of the inputs.

An overview of the joint probability framework adopted is illustrated in Figure 2-4. In essence the approach involves undertaking numerous model simulations where the model inputs are varied in accordance with that observed in nature. The inputs are sampled from non-parametric distributions that are either based on readily available design information or on the results of recent research.

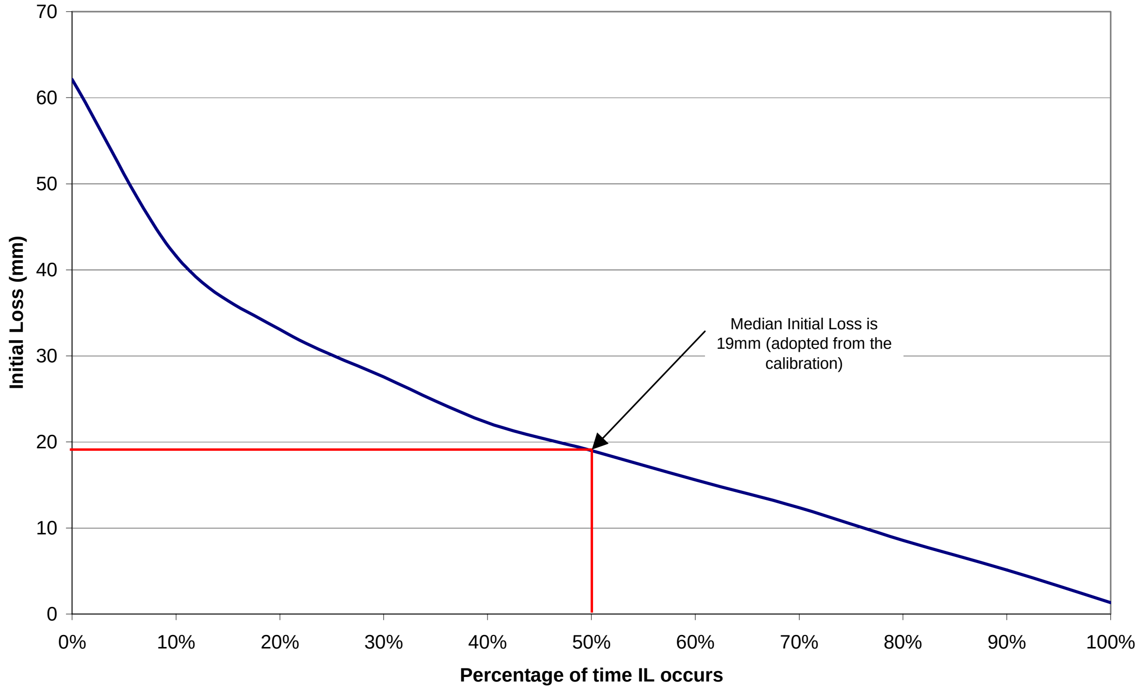


- **Figure 2-4: Overview of adopted joint probability framework**

The following briefly describes the main elements of the approach, and the manner in which they relate to established design information.

- *Select rainfall depth.* Rainfall depths are stochastically sampled from the cumulative distribution of rainfall depths. The relationship between burst depth and annual exceedance probabilities is based directly on the Intensity-Frequency-Duration relationships in Australian Rainfall and Runoff (Pilgrim, 1987) for AEP between 1 in 2 and 1 in 100.
- *Select storm losses:* Storm initial losses are stochastically sampled from a non-parametric distribution that was determined from the analysis of a large number of Victorian catchments (Hill et al., 1997), see Figure 2-5.
- *Select temporal pattern.* Temporal patterns are randomly selected from a sample of temporal patterns relevant to the duration of the storm. The temporal patterns are derived from the six-minute resolution historical record of rainfall at another gauge in the same rainfall temporal pattern region, Tamworth.
- *Monte-Carlo simulation.* Simulations are undertaken using a stratified sampling approach in which the sampling procedure focuses selectively on the probabilistic range of interest. The rainfall frequency curve was divided into 50 intervals uniformly spaced over the standardised

normal probability domain, and 500 simulations were taken within each division. Thus, a total of 25,000 simulations were undertaken to derive the frequency curve corresponding to each storm duration considered.



- **Figure 2-5 Distribution of initial loss values (mm) used in the Monte-Carlo runs, where the median of the distribution is equal to the adopted value of 19mm from the calibration runs.**

The Monte-Carlo runs sampled from different temporal patterns and initial loss values. Thirty temporal patterns were derived for rainfall zone 2 (Murray-Darling Division, AR&R Vol2) using pluviograph data from Tamworth. The loss distribution (Hill et al., 1997) was adopted, such that the median is equal to the adopted fixed initial loss value of 19mm. The results of the Monte-Carlo runs are the best estimate of conditions, given that every combination of temporal pattern (variation in storm intensity over its duration) and initial loss (how wet/dry the catchment is prior to the storm event) is considered.

2.1.3 Model scenarios

The initial RORB model created was for the existing condition, i.e. with Holland's Bank in place. Three model scenarios were also run, one for natural conditions and one for each of the scenarios of a pipe through Holland's Bank. The design RORB model was modified for each of these scenarios, such that the Monte-Carlo results for each could be compared. The differences in the RORB models are summarised in Table 2-1.

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Table 2-1 Summary of the differences between the RORB models for the three scenarios

Scenario	Holland's Pondage starting level (m AHD)	Crest level of inlet structure for pipe (m AHD)	Description
Existing	138.2	n/a	Water level in the pondage starts at the inlet level of Duxons Stop Drain (DS) and all outflows are assumed to occur through DS. Rating curve for DS outflow adopted from Egis RORB model.
Pipe Version 1	138.0	138.0	Hec-Ras model used to model flow through and over Holland's Bank in order to create a rating table for RORB that splits the flow to DS and through/over Holland's Bank. Flow rate through the pipe was limited to a maximum rate of 50 ML/d.
Pipe Version 2	137.4	137.4	Hec-Ras model used to model flow through and over Holland's Bank in order to create a rating table for RORB that splits the flow to DS and through/over Holland's Bank. Flow rate through the pipe was limited to a maximum rate of 50 ML/d.
Natural	138.0	n/a	Water level in the pondage starts at the crest level of the natural saddle and flood overflows are passed over the saddle into Souths Creek. Broad crested weir formula is assumed to estimate the rating for flows over the natural saddle.

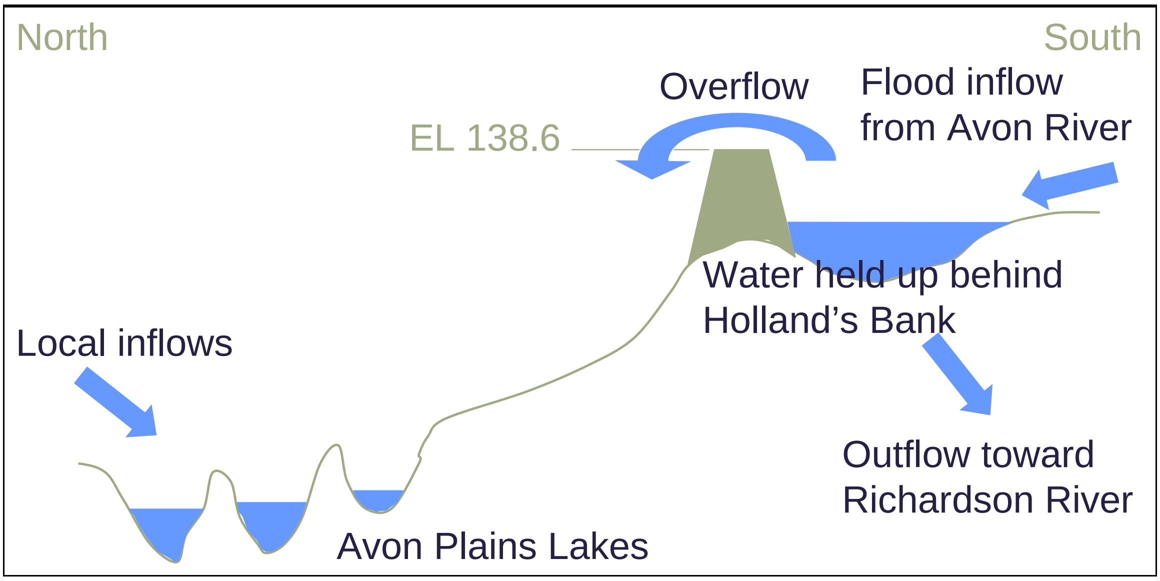
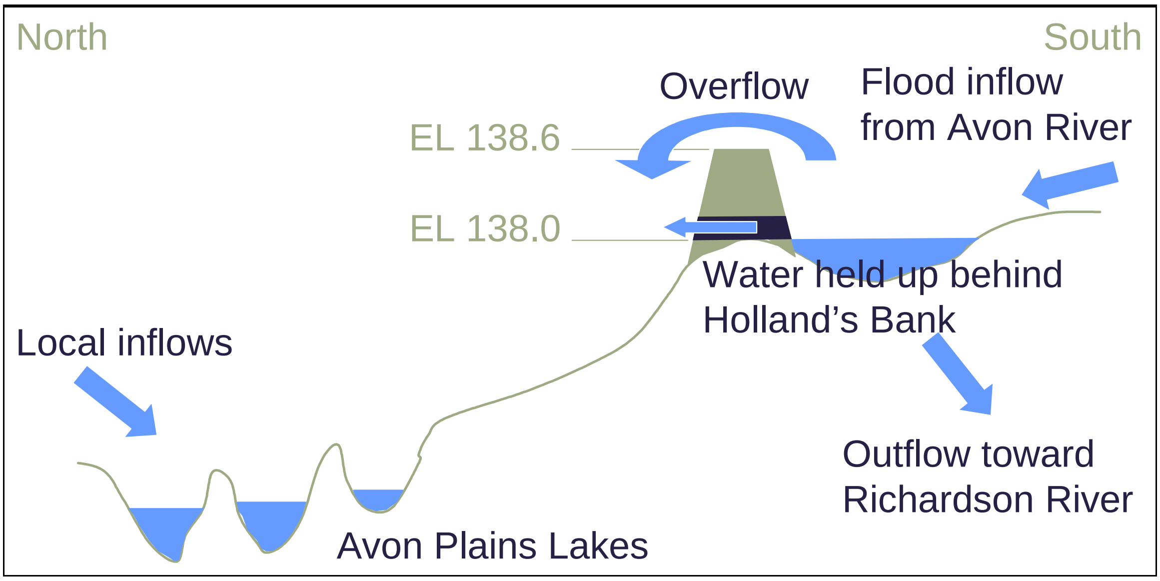
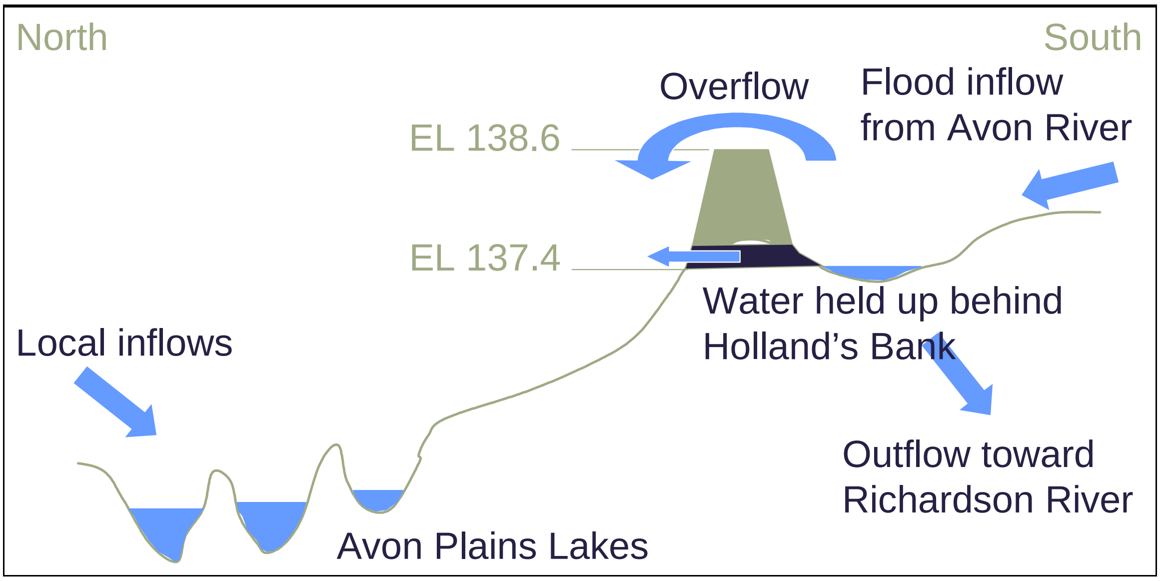


Figure 2-6 Existing Scenario



■ **Figure 2-7 Pipe Version 1 Scenario**



■ **Figure 2-8 Pipe Version 2 Scenario**

2.1.4 Results

The RORB model was run for each of the four scenarios to estimate flood hydrograph volumes at the following locations:

- Avon River at the Wimmera Highway streamflow gauge (415220);
- Inflow to area upstream of Hollands Bank (breakout from the right bank of the Avon River);
- Flow out of area upstream of Hollands Bank through Duxons Stop; and
- Flows through or (in large floods) over Hollands Bank and into Souths Creek.

Flood peaks and hydrographs were extracted from the model for design events with AEP between 1 in 2 and 1 in 100 and rainfall event durations between 6 and 72 hours.

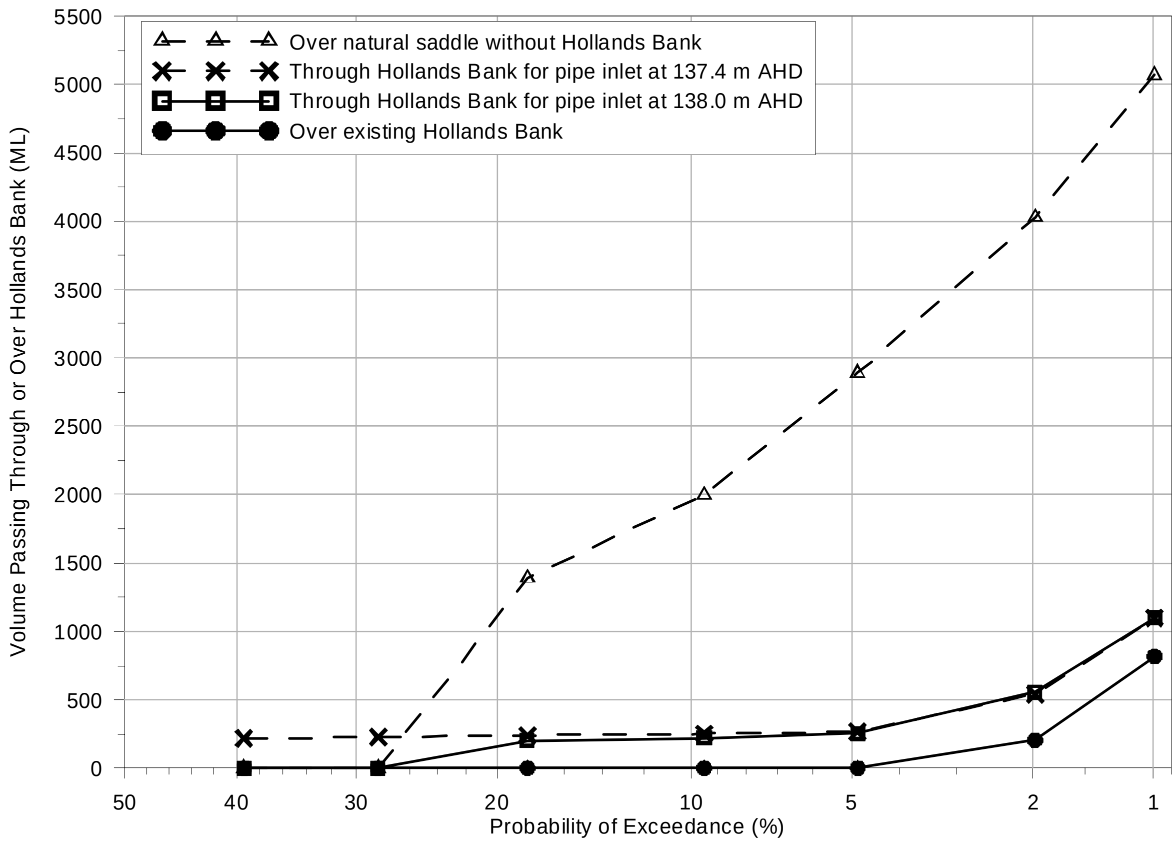
The aim of the RORB modelling was to develop a relationship between flow volumes during floods at the Wimmera Highway gauge and flow volumes through or over Hollands Bank. The analysis therefore concentrated on flood volumes that were estimated at each of the two locations. For all of the locations considered and all scenarios, the 72 hour duration rainfall event produced the largest overall volume of runoff, although in most cases the runoff volume from the 72 hour rainfall event was not appreciably larger than from the 48 hour event. Flood hydrograph volumes were extracted over a model run period of 6 days (144 hours) to capture the runoff volume in the falling limbs of the flood hydrographs over the 72 hour period following the end of the rainfall event.

Figure 2-9 shows the flood volumes passing through or over Hollands Bank in each of the four options considered. Under existing conditions, it would take a flood with an AEP of between 1 in 20 and 1 in 50 for flow to commence over Holland’s Bank.

Both of the pipe drain options would allow for flow volumes to pass through Hollands Bank during flood events. Figure 2-9 shows that the total volume passing through the bank for the pipe inlet at 137.4 m AHD would increase gradually with flood magnitude from around 220 ML at 1 in 2, to around 260 ML at 1 in 20. Flood flows would go over Hollands Bank in the 1 in 50 AEP event.

If the pipe inlet level was increased to 138.0 m AHD then the 1 in 2 AEP event would not cause any flow through the pipe. The total volume passing through the bank would increase gradually from around 200 ML at 1 in 5 to around 250 ML at 1 in 20. Both of the pipe options increase the volume of flood storage behind Hollands Bank, which provides some mitigation for the larger floods.

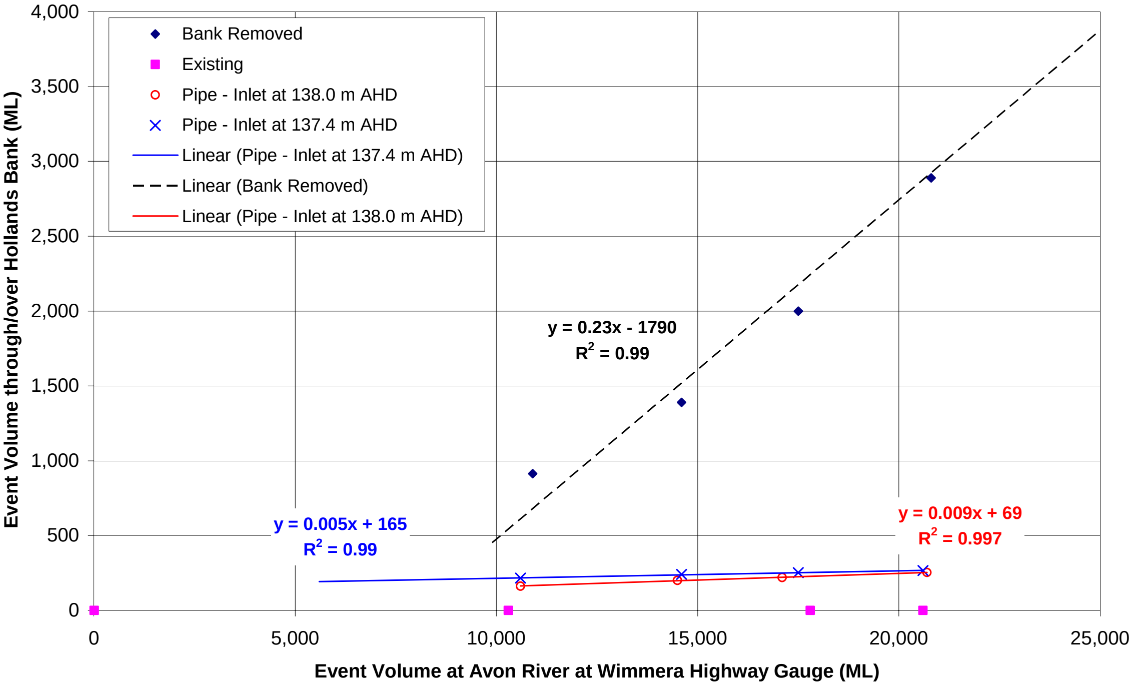
Removal of Hollands Bank would result in considerable increases in flood volumes passing over the natural saddle and into Souths Creek. Figure 2-9 shows that there would be no flow over the saddle for the 1 in 2 event. However the volume passing over the saddle would increase with flood magnitude from 1400 ML in the 1 in 5 event to 2900 ML in the 1 in 20 event.



- **Figure 2-9 Estimates of volumes through/over Holland's Bank estimated from RORB model for each of the four scenarios**

Figure 2-10 shows RORB model estimates of flood hydrograph volumes at the Avon River at Wimmera Highway gauge and flood volumes passing through or over Hollands Bank for each of the four options. Linear relationships were fitted to these RORB estimates for each of the four options considered. The relationships were used to estimate the volume of water passing into Souths Creek in each flood event, given the observed flows in the Avon River at the Wimmera Highway gauge. The time series of flood volumes that were derived in this manner were provided as additional flows into Souths Creek for the water balance modelling in Chapter 3 of this report.

Observed flows have not exceeded 20 000 ML over any six day period in record used for the water balance modelling (1963 to 2004). For the existing case, there were no additional flood flows supplied to Souths Creek over Hollands Bank during this period, which is consistent with the observations of local landholders that the Bank has not overtopped during this time. For both of the pipe drainage options and the bank removed option, there were a total of 53 events over the 40 year period modelled when flows would have been sufficient in the Avon River to provide for additional flood volumes through Hollands Bank and into Souths Creek.



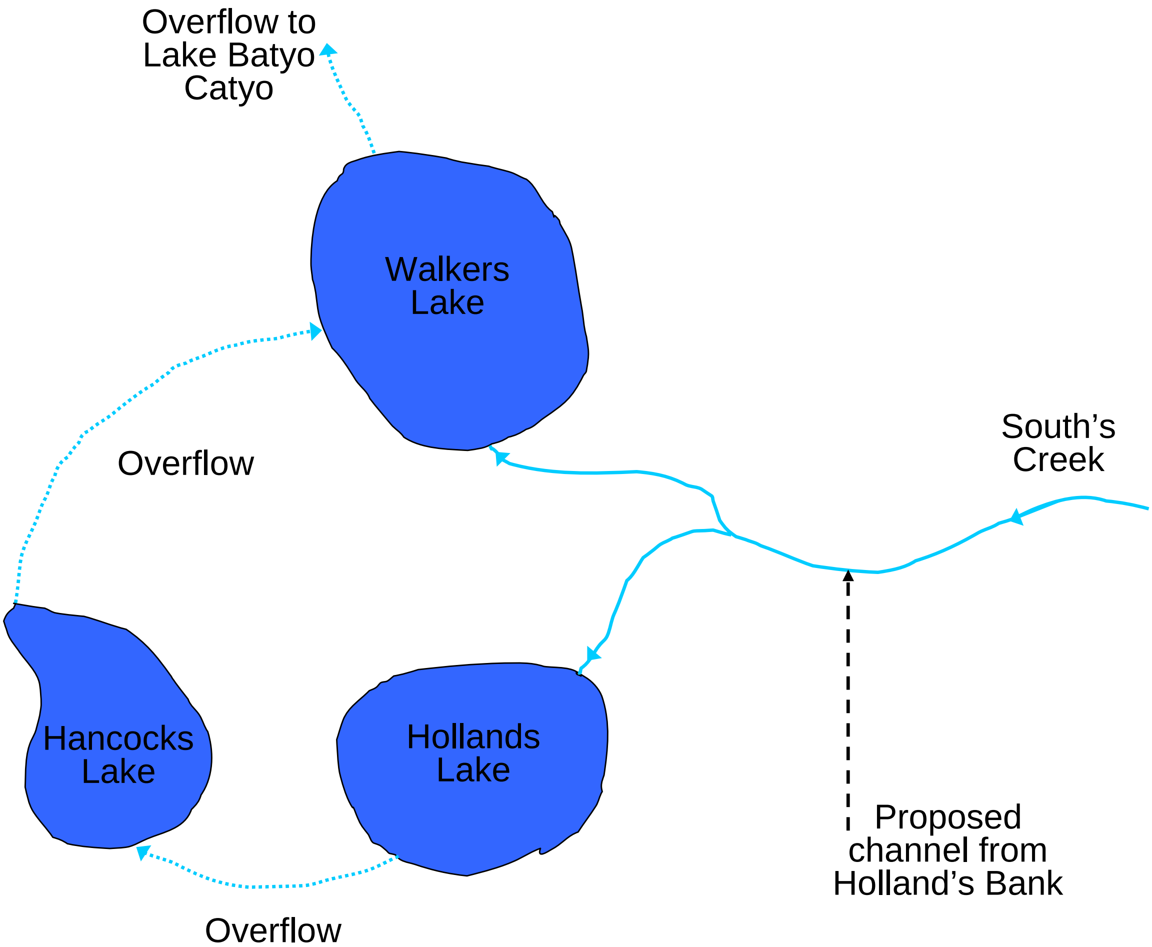
- **Figure 2-10 Relationships between flood event volume for Avon River at Wimmera Highway Gauge and flood event volume through or over Hollands Bank for each of the scenarios modelled. The points show the estimated volumes from the RORB modelling, and linear relationships were fitted for the natural and each of the pipe cases.**

3. Water Balance Modelling

3.1 Water Balance Model Configuration

A water balance model was established of the Avon Plains Lakes system. This model was used to estimate, for each of the four scenarios, daily time series of inflows, outflows, storage levels and storage volumes for each of the lakes. The water balance was constructed using the REALM software because it was well suited to modelling various management options for the Avon Plains Lakes.

Figure 3-1 shows the schematic used to model the water balance of the Avon Plains Lakes in REALM. It can be seen that water from South's Creek can be directed each of the three lakes and that flow over or through Hollands Bank flows into South's Creek before it flows into the lakes. Both Hancocks and Hollands Lake the overflow to Walkers Lake and any overflow from Walkers Lake flows north towards Lake Batyo Catyo.



- **Figure 3-1 REALM water balance model schematic, showing the natural inflow from South's Creek, the proposed additional inflows from flow through Holland's Bank and the flow paths to and between the lakes.**

3.2 Inputs to the water balance model

3.2.1 Evaporation

Average monthly point potential evaporation values (Bureau of Meteorology, 2001) were disaggregated linearly to daily evaporation in each month. A repeating annual series of daily evaporation was adopted for the REALM model as there were no nearby long-term records of evaporation.

3.2.2 Rainfall

Rainfall at St Arnaud (station 79040) over the period 1963-2004 was adopted for the REALM model. The rainfall data set contains periods of missing records and periods of data accumulated over several days. Therefore the data requires two steps of processing: disaggregation of accumulated periods and the infilling of missing data. Accumulated totals were disaggregated using the method that was proposed by Porter and Ladson (1993), which assumes the influence of nearby stations is inversely proportional to their distance from the gauge for which the accumulated data is to be disaggregated (the focal gauge). An infilling procedure was applied that calculates the correlation between the focal gauge and nearby gauges. The gauge with the highest correlation that has data concurrent with the missing period was used for infilling. The hyetograph of the selected nearby station is adjusted by the ratio of the concurrent mean annual rainfalls of the two stations and used to infill the missing period.

3.2.3 Inflows from Souths Creek catchment

Inflows to the lakes from the local catchment area of Souths Creek were estimated by transposing the daily streamflow data from the gauge on the Avon River at Wimmera Highway (gauge 415220). It was expected that the Souths Creek catchment would have a much lower runoff coefficient than the catchment of the Avon River to the Wimmera Highway because the catchment is flatter and mean annual rainfall is lower. It was therefore estimated that, on average, the runoff coefficient of the Souths Creek catchment would be about 1/3 of the upper Avon River catchment. Daily flows were therefore transposed using the following formula:

$$Q_{Souths} = \frac{1}{3} \times \frac{A_{Souths}}{A_{Avon@WimmeraHwy}} Q_{Avon@WimmeraHwy} = \frac{1}{3} \times \frac{185}{596} Q_{Avon@WimmeraHwy}$$

Daily flow series in South's Creek were estimated for the period from July 1963 to June 2004. There is about one year of data missing from November 1972 to October 1973 and since it was not possible to infill this data easily, the REALM model was run over two these two independent periods of record (excluding the missing period).

The inflows estimated from the above formula represent inflows from the local catchment that are available to be directed into the three smaller lakes (Walkers, Hancocks and Hollands lakes). It is recognised that some runoff from the Souths Creek catchment can flow directly into Lake Batyo Catyo without flowing into the three smaller lakes. This flow has not been considered in the current water balance modelling because it does not influence the water levels or storage volumes in the three smaller Avon Plains lakes, which are the focus of this current study.

3.2.4 Regulation of inflows from the Souths Creek catchment

Inflows to the lakes from the local catchment are controlled by regulators on Souths Creek, which are operated by local landholders. Recent practice has been to operate flow regulating structures on Souths Creek so that water is supplied to Walkers Lake first and that once Walkers Lake is full the regulators are operated to fill Hollands and Hancocks lakes. It has been assumed in the REALM modelling that this practice continues, with flows directed to Walkers Lake from Souths Creek until it is full, with later flows directed to Hollands and Hancocks Lakes.

3.2.5 Demands from lakes

The REALM model assumes that there is no demand from the Lakes (ie no water is extracted from the Lakes) and that the only outflow from the Lakes is due to evaporation or overflows. Seepage was considered to be negligible and has not been included in the REALM model. The model also assumes that extractions from the Souths Creek upstream of the lakes are negligible.

3.3 Results and Discussion

All four options under consideration produce very similar time series of storage levels in all three of the Avon Plains lakes. Additional water supplied through Hollands Bank in either of the pipe options or with the bank removed would be supplied during wet years, when it is expected that the lakes would fill under existing conditions anyway.

Figure 3-2 shows the variation in storage volume in each of the three lakes over the modelled period for the existing Hollands Bank.

The modelling has been conducted assuming that available flows in Souths Creek are passed into Walkers Lake first. For all of the options modelled, Walkers Lake would fill in 21 of the 40 years that were modelled. Walkers Lake would only have been completely empty on two occasions: over the summer of 1967/68 and during the majority of the period since late 2000, which is consistent with the memories of local landholders. Figure 3-4 shows that the storage traces would have been very similar for all four options, with the only significant difference coming over the period from July 1999 to late 2000 when additional water supplied through the pipe options and bank removal options would have delayed Walkers Lake completely drying out.

Hollands Lake would receive water from Souths Creek as second priority to supplying Walkers Lake. Figure 3-5 shows that Hollands Lake would have filled in only 13 of the 40 years modelled (for the existing bank configuration) compared with 21 years for Walkers Lake. The model simulations also show that Hollands Lake would have been empty on at least 10 occasions over the last 40 years, including all of the period since late 1998.

Hancocks Lake would receive water from Souths Creek only after Hollands Lake has filled and is therefore the driest of the three lakes. Figure 3-6 shows that Hancocks Lake would only have filled 12 times over the 40 year model period and that it would have been completely dry on at least nine occasions over this same time.

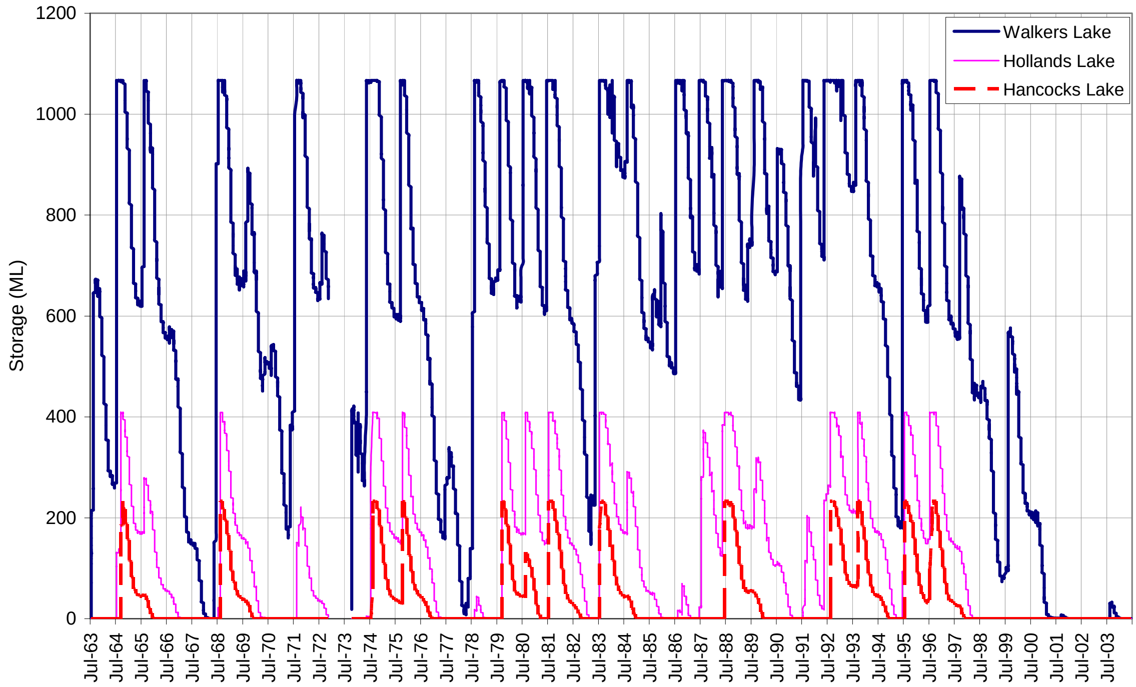
The period since 1997 has been notably dry and the lakes have only stored a substantial volume of water in them once (in 1999) over the last eight years (1997 to 2005). The model estimates that Walkers Lake would have dried out under existing conditions in February 2001, which compares favourably with observations that it emptied most recently in December 2000 (Rob Loats, pers. comm., 2005).

Removal of the bank or installation of a pipe in Hollands Bank would provide additional inflow to the lakes during flood periods, via Souths Creek. Additional inflow would have occurred to the lakes in 53 separate flood events over the 40 year period modelled. However, Figure 3-2 & Figure 3-3 (storage volumes) and Figure 3-4 to Figure 3-6 (lake levels) shows that this additional water would not have significantly modified the time series for the volume (or level) of water stored in the lakes, because it is supplied when the lakes would otherwise have filled.

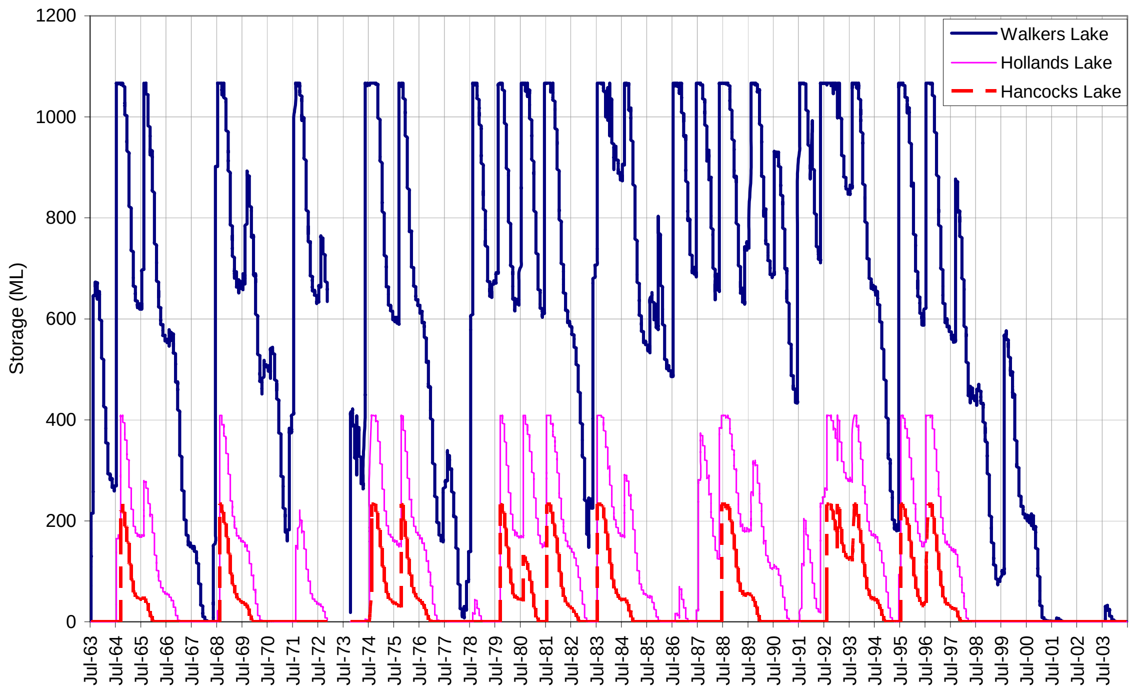
The water balance model shows that the pipe options would have increased the volume of water stored in the lakes over four periods over the 40 year period:

- August 1980 to July 1981, when the pipe options would have put an additional 220 ML into Hancocks Lake, causing the lake to contain an additional 0.4 m of water depth over this period;
- June 1987 to April 1988, when the pipe options would have put an additional 190 ML into Hancocks Lake, causing Hancocks Lake to have up to 1.4 m of water depth over a period when the lake was dry under existing conditions;
- December 1992 to September 1993, when the pipe options would have put an additional 590 ML into Hollands and Hancocks lakes, keeping the water depth in Hollands 0.4 m higher and the water depth in Hancocks 0.5 m higher during this period than was the case under existing conditions; and
- August 1999 to September 2001, when the 137.4 m AHD pipe option would have put an additional 160 ML into Walkers Lake, which would have caused the lake to hold an extra 0.5 m of water over this period and delayed the drying out of the lake by about six months.

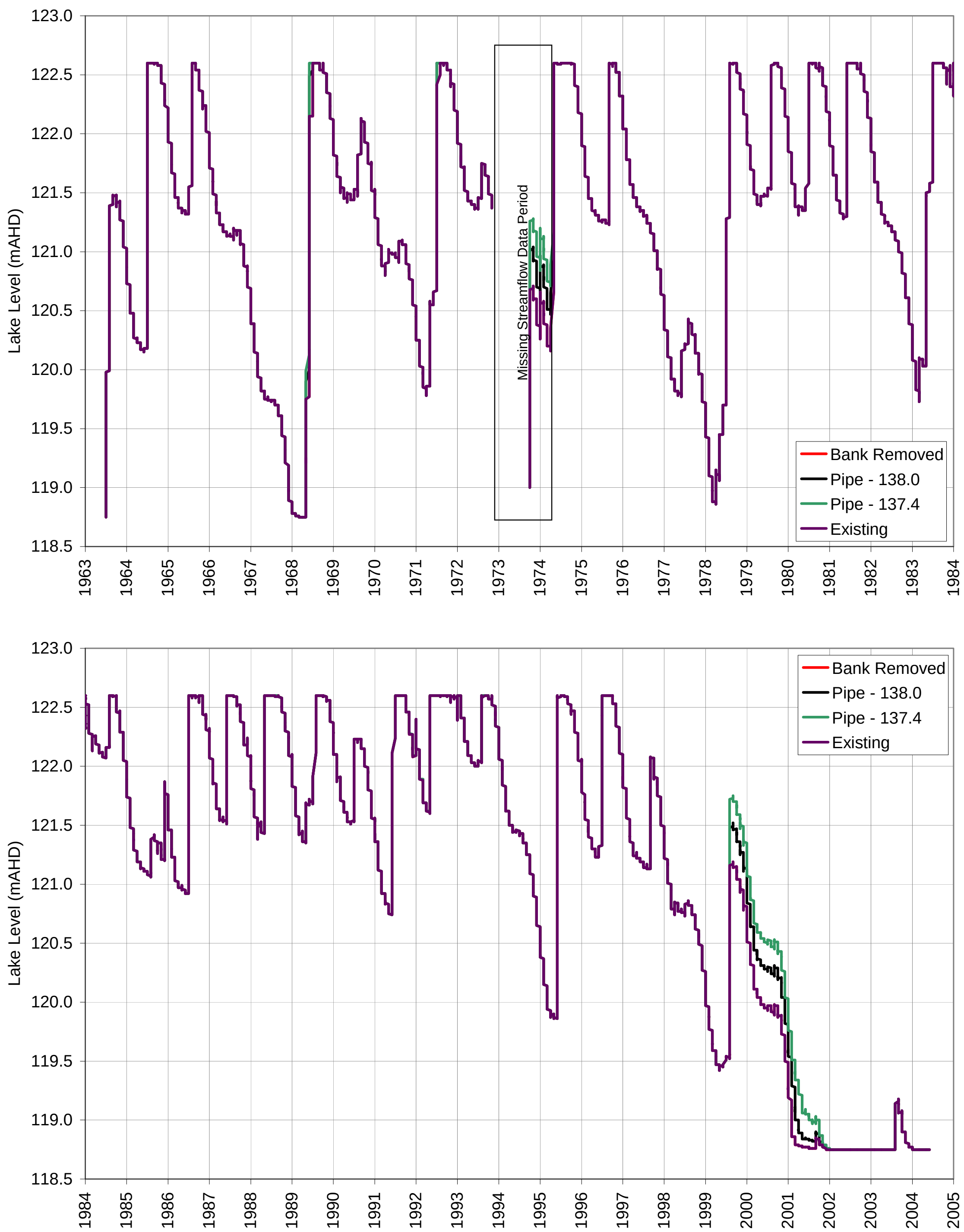
Median lake depths for each month of the year were extracted for existing conditions, as shown in Table 3-1. As discussed above, the median lake depths for each of the pipe options and with the bank removed are virtually identical from those shown for existing conditions. These median lake depths were used to plot the four rings for median seasonal depth on the plots in Appendix B.



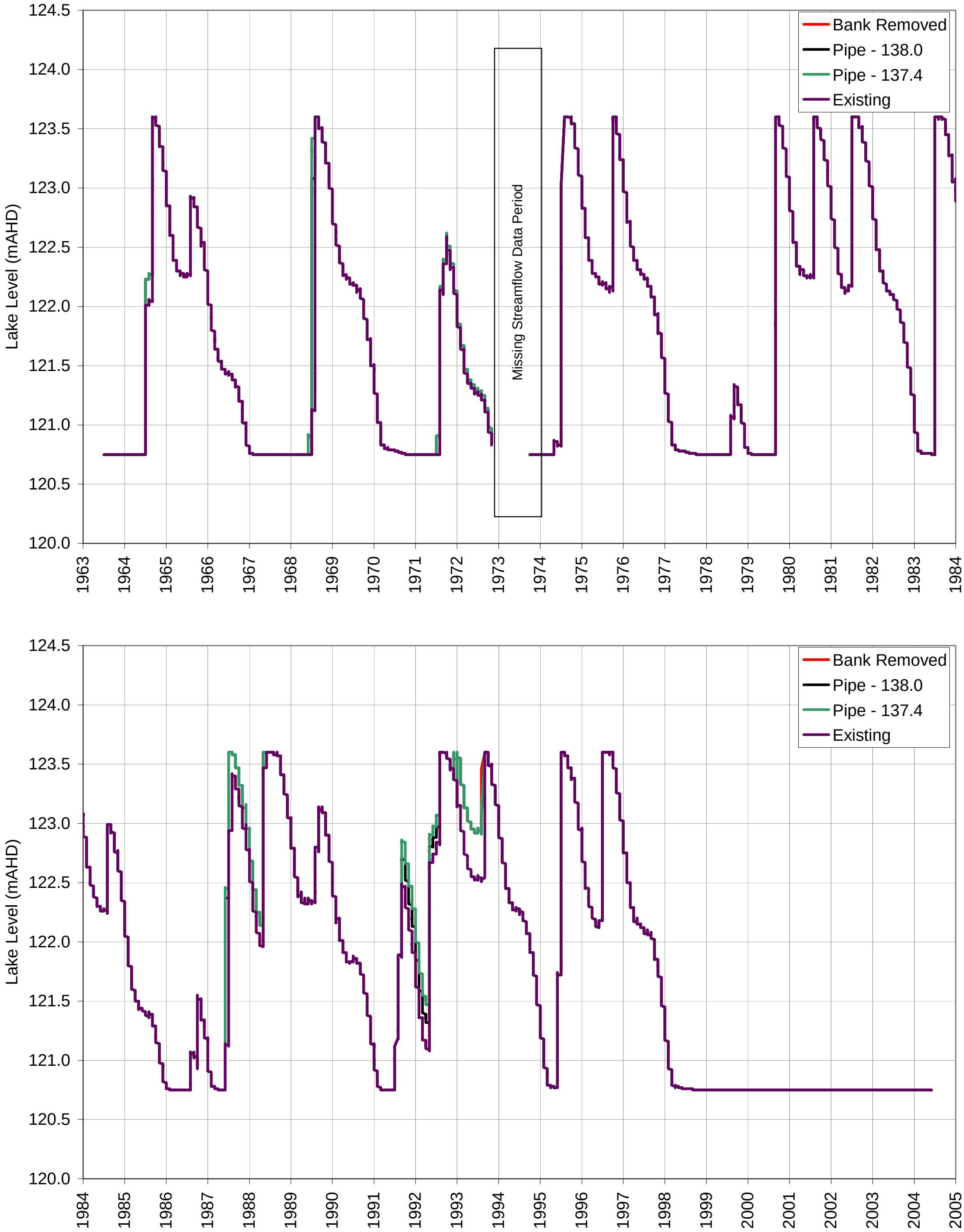
- **Figure 3-2 Water Balance Model Results – Lake Volume for Existing Conditions**



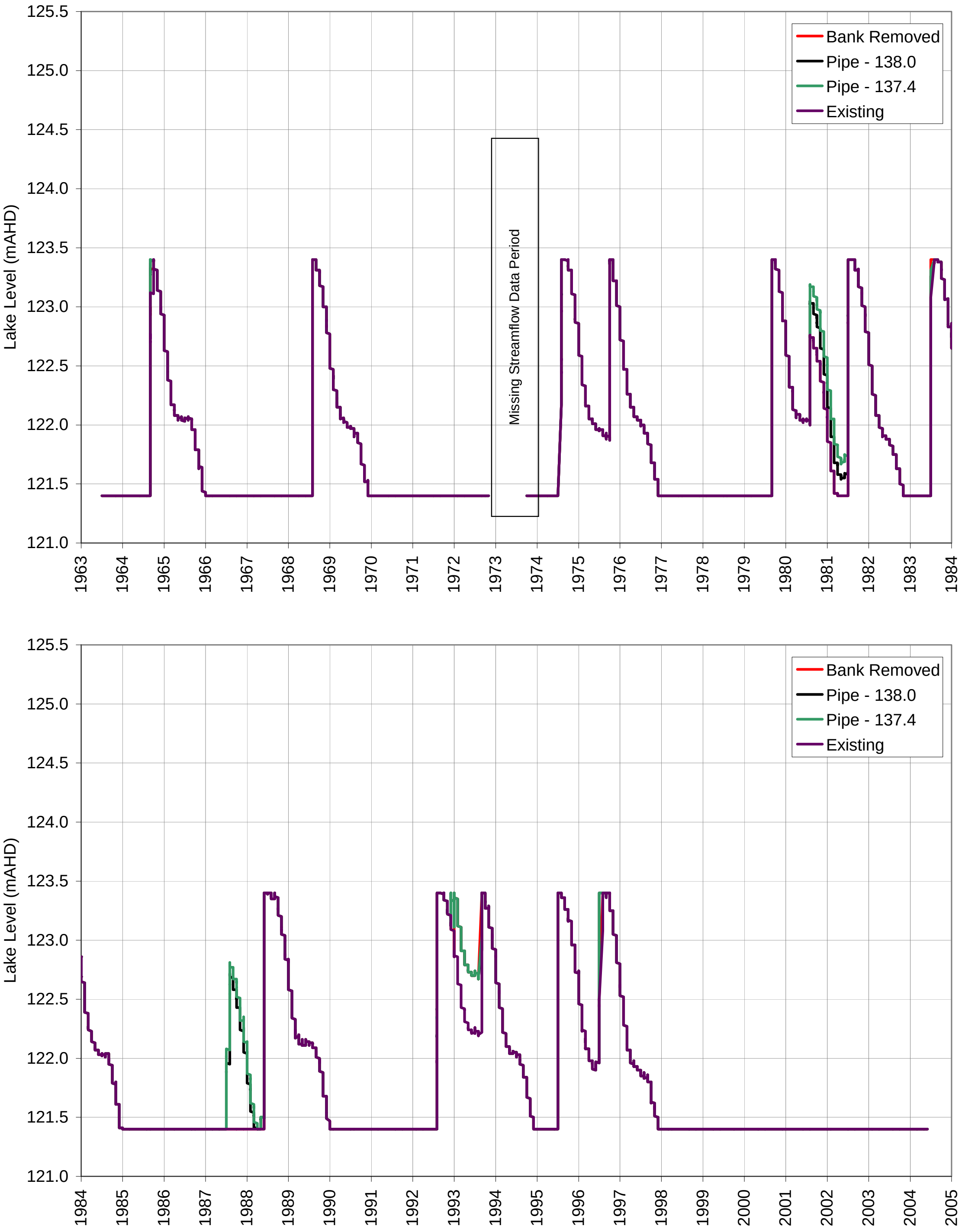
- **Figure 3-3 Water Balance Model Results – Lake Volume for Natural Conditions**



▪ **Figure 3-4 Water Balance Model Results – Walkers Lake Levels for all scenarios**



■ **Figure 3-5 Water Balance Model Results –Hollands Lake Levels for all scenarios**

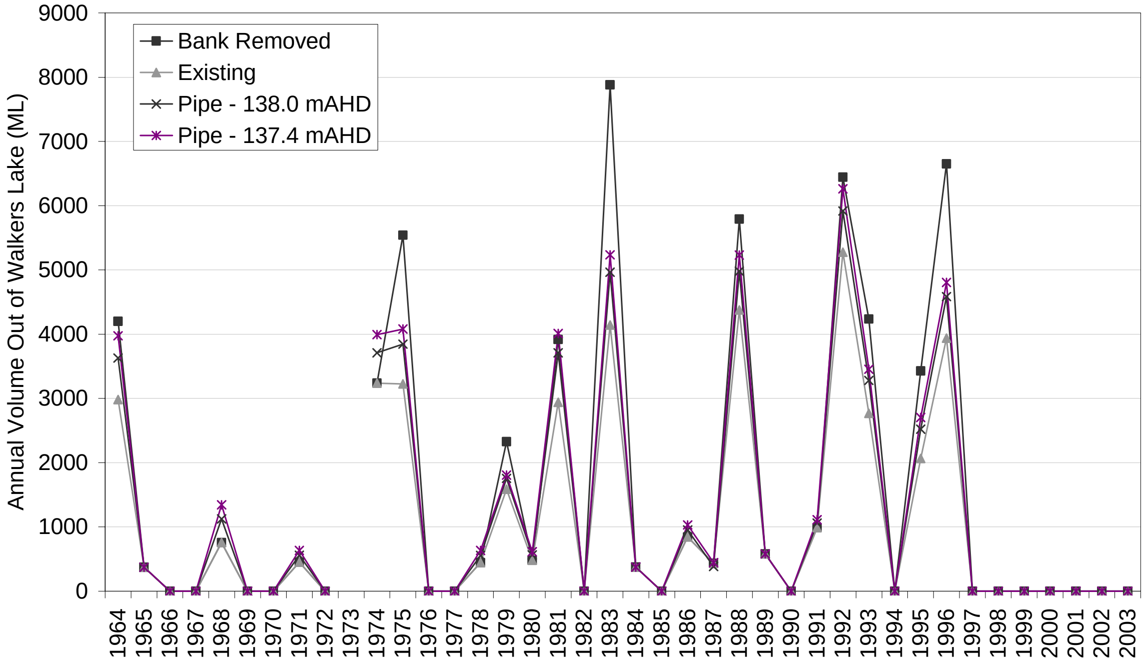


■ **Figure 3-6 Water Balance Model Results –Hancocks Lake Levels for all scenarios**

- **Table 3-1 Median monthly lake depths (in m) for existing conditions.**

Month	Walkers Lake	Hancocks Lake	Hollands Lake
January	3.08	0.00	0.69
February	2.82	0.00	0.41
March	2.63	0.00	0.15
April	2.50	0.00	0.06
May	2.47	0.00	0.05
June	2.51	0.00	0.10
July	2.67	0.00	0.64
August	3.02	0.00	1.26
September	3.79	0.69	1.34
October	3.69	0.21	1.27
November	3.50	0.02	1.09
December	3.35	0.00	0.93

Figure 3-7 shows that either of the pipe options or removal of Hollands Bank would increase the total volume that would flow out of Walkers Lake and into Lake Batyo Catyo in those years when spills occur. Table 3-2 shows that the additional flows supplied during these wet years in either of the pipe options would increase the volume of water flushing through the Avon Plains Lakes system and into Lake Batyo Catyo. The option with the pipe through Hollands Bank with the inlet structure level at 137.4 m AHD, results in an average of an additional 267 ML/year of outflow from the lakes, which is 25% more than in the existing case. With the inlet to the pipe through Hollands Bank set at 138.0 m AHD there is 17% more water flushed through the lakes (183 ML/year on average). If Hollands Bank were removed, there would be an additional 439 ML/year (or 40%) flushed through the lakes than is the case under existing conditions.



- **Figure 3-7 Annual series of outflow volume from Walkers Lake into Lake Batyo Catyo for each of the four options**

- **Table 3-2 Average annual outflow from Walkers Lake to Lake Batyo Catyo over modelling period (1963-2004)**

Option	Average Annual Volume (ML)	Increase in Average Annual Volume over Existing (ML)	% Increase in Average Volume over Existing
Existing	1084	-	-
Pipe with inlet at 138 m AHD	1268	183	17%
Pipe with inlet at 137.4 m AHD	1351	267	25%
Hollands Bank Removed	1523	439	40%

4. Groundwater and Salinity Effects

4.1 Conceptual Hydrogeological Model

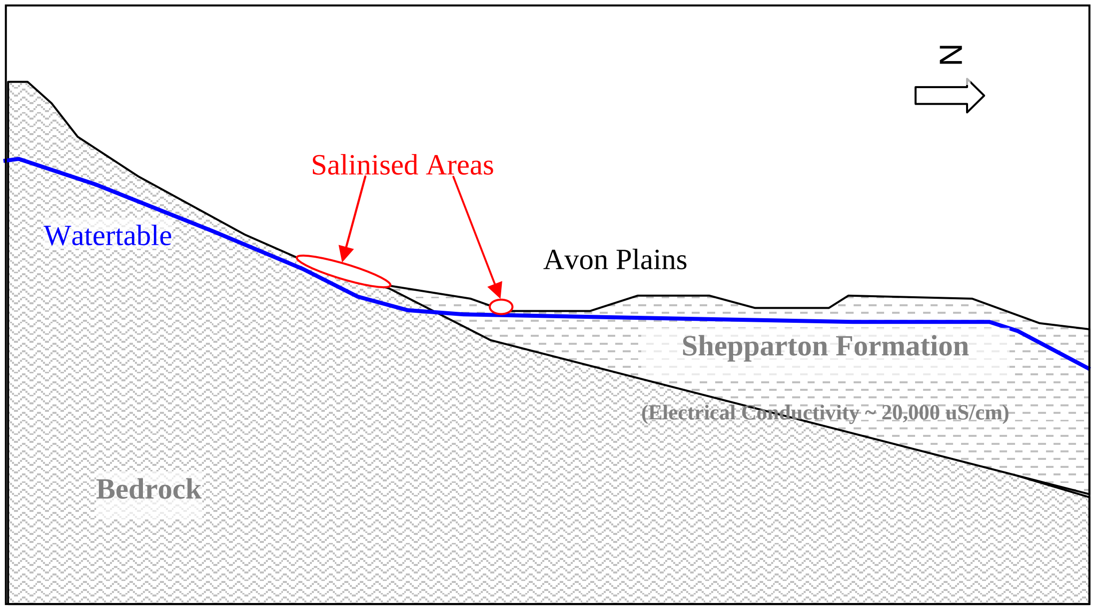
The geology of the Avon Plains lakes area comprises bedrock Cambrian to Ordovician (approximately 500 million years ago) sedimentary rocks with overlying unconsolidated sediments of the Quaternary-aged (2.5 million to 100,000 years ago) Shepparton Formation.

The bedrock is composed of shale, siltstone and sandstone and includes green shales interbedded with turbidite units that have undergone folding and low-grade regional metamorphism. The bedrock is varyingly fractured and is often weathered to considerable depth, this providing good hydraulic connection with the overlying alluvial sediments. The bedrock forms a crescent shaped ridge to the south of the lake system. Weathering depth increases north, down slope from the ridge, with the depth to bedrock becoming deeper to the north. Groundwater flow through the bedrock is predominantly through fractures.

The overlying Shepparton Formation comprises unconsolidated to poorly consolidated clay and silty clay with lenses of coarse sand and gravel. The sand and gravel lenses are often described as "shoestring sands" and have little lateral continuity. During a previous groundwater investigation of the Avon Plains Lakes (Hekmeijer, 2004), the encountered geology consisted of brown and grey clays from the surface to the bedrock. Bedrock was encountered between 20.5 m to 25.5 m below ground level. Permeability testing (slug tests) of the Shepparton Formation clays at the site showed that hydraulic conductivity values were extremely low, ranging between 0.0001 and 0.0059 m/d, with a median value of 0.0004 m/d. Electrical conductivity of the groundwater in the bores in the Shepparton Formation ranged from 10,070 to 27,910 µS/cm.

Time series hydrographs from bores screened in the Shepparton Formation in the vicinity of the lakes are presented in Appendix A (Hekmeijer, 2004). The hydrographs display a recharge-regression trend typical of many sites in northern Victoria. This is usually a rapid rise in groundwater level due to winter and spring rainfall, followed by a slow recession. Superimposed on this is the longer term trend in the area. Prior to 1995 this appeared to be stable, or even upwards, however since 1995 the longer term trend has been downward There has been a general downward trend since 1995 due to below average rainfall, with the depth to watertable at the deepest on record (data ends 2003). Depth to water in the bores varies between approximately 0.5 m and 3.5 m below ground level in wetter periods, to between 3 m and 7 m below ground level in drier periods. The depth to groundwater beneath the lakes is within 1 m of the surface despite below average rainfall since 1997 (NCCMA, 2005).

A conceptual hydrogeological model for the lakes is presented in Figure 4-1.



- **Figure 4-1 Conceptual cross section of hydrogeology of Avon Plains Lakes area**

According to Linke and Ryan (1988) there is a connection between lake level movements in Lake Batyo Catyo and the adjacent watertable. Ponding of water in Lake Batyo Catyo as a result of changed management practices in the in the 1960's resulted in increased soil salinisation in areas adjacent to the lake.

4.2 Salinity Occurrence and Conceptualisation in the Avon Plains Lakes

A major salinised area occurs at the base of the crescent-shaped ridge to the south of the lakes. Hekmeijer (2004) concludes that this area is influenced by the ridge of deeply weathered fractured rock aquifer, with the fractured rock groundwater flow systems providing a direct link between recharge and discharge zone.

Minor saline zones have been mapped on the north-western flanks of Hollands and Walkers Lakes. Evidence of salt scalding was observed to the southeast of the Hollands Lake bed during the compilation of this water management plan. Hekmeijer (2004) concludes that this is due to prior groundwater mounding during times of high lake levels which has not been leached away due to the current low rainfall conditions. Hancocks lake, to the northwest of Hollands lake, is less affected by salinisation than Hollands lakes and Walkers lake is mostly unaffected by salinisation (Hekmeijer, 2004)

4.3 Risks Associated with Flood Management at Hollands Bank

Results from the Realm modelling appear to indicate that extra water would have been supplied through Hollands Bank would be during wet periods, when it is expected that the Avon Plains lakes would already have been filled by runoff from their local catchment area (downstream of Hollands Bank). The extra water supplied through a pipe drainage structure in Hollands Bank would therefore not change the time series of water levels and storage volumes in the lakes.

With no effective change in water levels in the Avon Plains lakes as a result of the increased flow through Hollands Bank, it is unlikely that salinisation of the lakes would be exacerbated as a result of this increased flow through Hollands Bank.

However, the relationship between lake levels and the watertable is currently unknown. Therefore, if Hollands Bank is modified, it is recommended that water levels in surrounding bores are monitored to assess the interactions.

5. Vegetation Assessment

5.1 Background

Hollands Lake, Hancocks Lake and Walkers Lake form part of a wetland chain connecting to Lake Batyo Catyo (2 km north). Historically, these lakes would have been terminal lakes (permanent open freshwater). Although these lakes have been degraded to varying degrees, they have a high conservation value and contain significant habitat characteristics (Egis, 2000). The Avon Plains Lakes are strongly supported by the local community, who are committed to protect and develop the wetlands' ecological and recreational values. Local Landcare Groups such as the Avon Plains and Donald and District Landcare Group are actively involved in revegetation activities, with the aim of reconnecting corridors between the lakes (Avon Plains Landcare Group, homepage).

There are significant environmental, social and also economic benefits of restoring these wetlands to a more natural cycle of wetting and drying. Ecologically, these wetlands are beneficial for a wide variety of flora and fauna, some of which are endangered and internationally important. The Avon Plains Lakes offer important recreational areas for bushwalking, birdwatching and picknicking (Egis, 2000).

The purpose of this chapter is to outline the existing environmental values of Avon Plains Lakes and to determine the dominant vegetation associations and their general water requirements to ensure populations are maintained and to some extent enhanced.

5.2 Tenure and adjacent land use

The majority of the land adjacent to the Avon Plains Lakes is privately owned and has been cleared for agriculture. The surrounding land is principally used for broadacre cropping and grazing.

5.3 Water regime

According to Roberts & Marston (2000), a water regime is the pattern of water, principally water depth (and the lack of water) through time, so includes duration, seasonality and predictability. These are considered measures of 'wetness' but similar measures of 'dryness' are equally important for floodplain wetlands in dry and hot climates. Dryness can be described, or estimated, by measures of soil moisture.

The ecological requirements for wetlands are generally reflected by the requirements of emergent and fringing vegetation. Moreover, the distribution, growth and reproduction of wetland vegetation correlate strongly to the duration, depth and the amount of seasonal inundation periods. Altered water regimes demonstrate the value of water levels, as different species are adapted to specific water levels and inundation periods. Any change to these parameters can result in a shift in vegetation community composition and structure (Roberts & Marston, 2000).

One of the main objectives for assessing the vegetation in the Avon Plains lakes was to describe the water regimes of the identified plant associations including; common emergent plants and the subsequent application of this information to determine the water needs for these species.

Historically, the Avon Plains Lakes would have received floodwater water flows from the Avon River. These flows would have flushed saline water out of the lakes. Currently, these lakes do not receive floodwater flows from the Avon River due to the presence of Hollands Bank, and their salinity appears to be rising. According to DCE (1991), a combination of factors has added to the rise of salinity of the lakes.

5.4 Existing vegetation communities

Information regarding the description of the ecological values of the Avon Plains Lakes is limited to only a few references. The background information presented in this report has been largely confined to Department of Sustainability and Environment (DSE) databases, Departmental reports and consultant reports, local Land Care Group web pages and anecdotal records from local landholders and Government officers.

5.4.1 Threatened flora species recorded at Avon Plains Lakes

Three threatened flora species have been recorded at the Lakes. Limited information is available on the water requirements for these species, however Pale Spike sedge (*Eleocharis pallens*) would be the only species that is critically water dependent. Chariot Wheels (*Maireana cheeli*) and Turnip Copperbur (*Sclerolaena napiformis*) are species which are common on floodplains and would be semi water-dependent. It is anticipated that the current water regime (in average years) for the lakes is satisfactory for these species. Table 4.1 lists the threatened plant species recorded at the lakes and their probability of occurrence.

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Table 5-1Threatened Flora Species Recorded in the study area

Scientific Name	Common Name	Conservation Status	Habitat Requirements	Likelihood of Occurrence
Amyema linophylla subsp. orientale	Buloke Mistletoe	v	Stem parasite, predominately on Buloke (*Casuarina luehmannii*).	**Medium**
Eleocharis pallens	Pale Spike-sedge	k V v	Occurs in shallow water and on the margins of swamps, gilgais, claypans and in lake beds. Can be found in Black Box and Canegrass communities and in open clay soil plains.	**Medium**
Maireana cheelii	Chariot Wheels	v	Mainly found on grey clay soils, in bladder saltbush communities. Never common, with small localised occurrences in scattered localities.	**Medium**
Sclerolaena napiformis	Turnip Copperburr	E e L	Mainly found on clay soils. Limited information on this species, but is probably associated with Black Box communities.	**Low-Medium**
References: Cunningham *et al*. (2003) Walsh and Entwisle (1999).				

5.4.2 Ecological Vegetation Classes (EVC)

Ecological Vegetation Classes (EVCs) are used in Regional Catchment Strategies and their associated Regional Native Vegetation Plans to describe native ecosystems. They are critical in the consistent and targeted application of regulatory and investment processes. EVCs are the basic mapping units used for vegetation and biodiversity planning and conservation management at the regional scale in Victoria

A total of four Ecological Vegetation Classes are recorded at the Lakes, three of these are classified as endangered.

Specific Ecological Vegetation Classes for Avon Plains Lakes are described below.

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- **Lake Batyo Catyo**

According to DSE (2005), Lake Batyo Catyo supports 4 EVC, including: Plains Woodland; Grassy Woodland; Wetland formation; Red Gum Wetland and Floodplain Riparian Woodland. General water requirements for these vegetation types can be seen in Table 5-1.

- **Walkers Lake**

According to DSE, Walkers Lake supports 4 EVC. These include; Plains Woodland; Grassy Woodland; Wetland Formation; and Red Gum Wetland. General water requirements for these vegetation types can be seen in Table 5-1.

- **Hancocks Lake**

According to DSE, Hancocks Lake supports 2 types of EVCs. They are; Plains Woodland and Wetland Formation. General water requirements for these vegetation types can be seen in Table 5-1.

- **Hollands Lake**

According to DSE, Hollands Lake supports 3 types of EVCs. They are; Plains Woodland; Grassy Woodland; and Wetland Formation; general water requirements for these vegetation types can be seen in Table 5-1.

- **Table 5-1 Water requirements for EVC types existing in Avon Plains Lakes**

EVC Type	Status	Dominant overstorey Vegetation	Frequency of inundation	Duration of inundation	Interflood duration	Depth of inundation	Timing/season of inundation
Plains Woodland	Endangered	Yellow Gum, Buloke, Grey Box, Yellow Box	Seasonal saturation, flooding < 1 in 2 years	seasonal short duration, <1 month (30 days)	Late spring-summer-autumn.	Shallow - 0.1m to 0.3m deep	Winter-early spring
Grassy Woodland	Endangered	Grey Box Box, Yellow Gum	Seasonal saturation, flooding < 1 in 2 years	seasonal short duration, <1 month (30 days)	Late spring-summer-autumn.	Shallow - 0.1m to 0.3m deep	Winter-early spring
Wetland Formation	Endangered	Beyond limits for Red Gum, supports herbaceous aquatic vegetation	Annual flooding (most years).	6-10 months duration (180-300 days)	3-5 years in 5 (summer-autumn)	0.6-1.5m deep.	Winter-spring-summer
Red Gum Wetland	Vulnerable	River Red Gum	Seasonal inundation, flooding most years	4-6 months (120-180 days).	Summer-autumn	0.4-1m deep	Winter-spring

Reference: Roberts & Marston (2000)

5.5 Vegetation Field Survey

A field inspection of the Avon Plains Lakes (including Lake Batyo Catyo) was conducted during the 24th-26th August, 2005. The main purpose for the field inspection was to identify the key ecological values of the lakes and to distinguish the existing dominant vegetation communities for each of the lakes.

Mapping of the dominant vegetation associations was carried out as part of the vegetation field survey. Aerial photography (supplied by NCCMA) of the lakes was used to assist the mapping all areas of remnant vegetation. This information can be seen in Appendix B.

A total of 29 vegetation associations were identified for the Lakes (including Lake Batyo Catyo).

The vegetation of the Avon Plains Lakes is dominated by two tree species; Black Box (*E. largiflorens*) and River Red Gum (*E. camaldulensis*) (occurring at Walkers Lakes and Lake Batyo Catyo).

A brief description of the survey results for each lake is described below.

5.5.1 Hancocks Lake

Hancocks Lake is approximately 20 hectares and was found to be disturbed to varying degrees as a result of grazing and contained few ecological values (but would provide significant foraging areas and possibly breeding sites for wetland birds when full). Small to medium Black Box (*E. largiflorens*) with an understorey of Tangled Lignum (*Muehlenbeckia florulenta*) occur on the periphery of the lake. The main body of the lake is dominated by exotic pasture species (currently grazed by domestic stock) (Refer to Appendix B).

Due to the disturbed nature of the site, there were only 2 native vegetation communities identified for the lake. The first was Black Box open woodland, which is located on the higher margins of the lake and the second was a sedgeland of Spiny Sedge (*Cyperus gymnocaulus*) located along the eastern side of the lake (lower margins). While approximately 70% of the lake's vegetation cover is comprised of exotic pasture species, native wetland vegetation cover should re-establish following wet periods, assuming that Submerged and Emergent vegetation seeds, propagules and rhizomes are still viable.

Refer to Figure 5-2 for the breakdown of vegetation associations and approximate percentage cover for Hancocks Lake.

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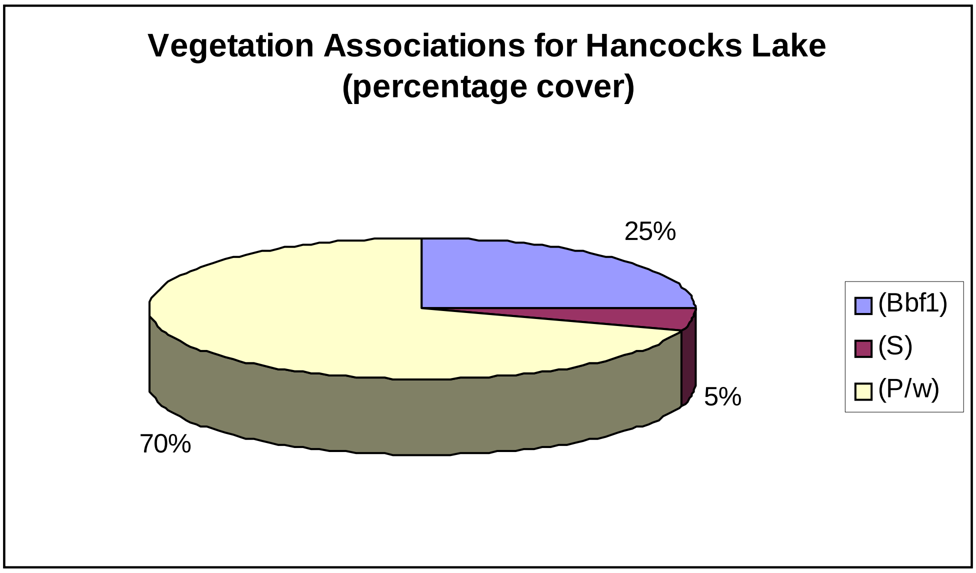


- **Figure 5-2 Vegetation Associations for Hancocks Lake (percentage cover)**

Vegetation Association	Key
Black Box (*E. largiflorens*) open woodland over Tangled Lignum (*Muehlenbeckia florulenta*)	Bbf1
Sedgeland (predominately Spiny Sedge (*Cyperus gymnocaulus*)	S
Pasture/Weed species (main body of wetland)	P/W

- **Figure 5-3 Small-Medium Black Box (E.largiflorens) located on the southern side of Hancocks Lake (looking west)**

5.5.2 Holland's Lake

Holland's Lake is approximately 23 hectares and is also disturbed as a direct result from

grazing. Accumulation of salt from discharging groundwater was also evident throughout the main body of the lake.

A total of 6 native vegetation associations were identified at the lake. The dominant vegetation communities identified at Holland's Lake include Black Box open woodland over a canegrass wetland complex, located on the northern margin of the site Figure 5-6 and a Black Box over a Tangled Lignum/chenopod/sedgeland/grassland complex located on the north-west and southern margins of the lake. Tangled Lignum over sedgeland communities also exist along the eastern and western margins of the Lake. (Refer to Appendix B).

Some parts of the lake's centre were wet, and a number of aquatic species were observed, however the lakes bed was mainly dominated by exotic species and scattered individuals of *Sclerolaena intricata*. The littoral sections and some more elevated parts of the lake supported dense and/or scattered populations of Spiny Sedge (*Cyperus gymnocaulos*)

Old plantings of Sugar Gums are located on the higher margins of the lake Figure 5-5.

Refer to Figure 5-4 for the breakdown of vegetation associations and approximate percentage cover for Holland's Lake.

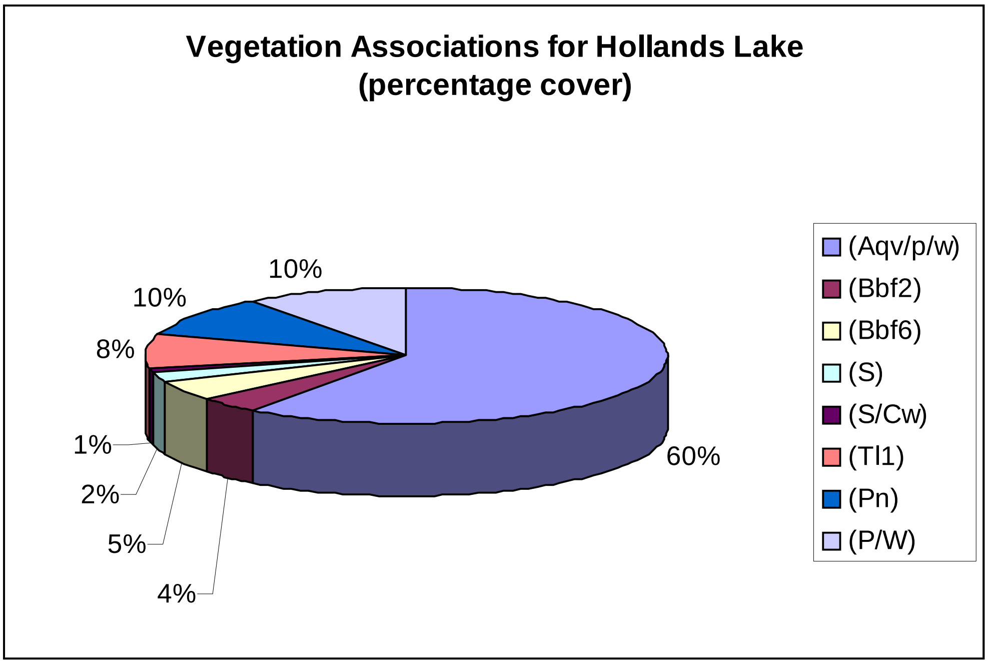


Figure 5-4 Vegetation Associations for Holland's Lake (percentage cover

Vegetation Association	Key
Black Box (*E. largiflorens*) open woodland over Canegrass (*Eragrostis infecunda*) wetland	Bbf2
Black Box (*E. largiflorens*) open woodland over Tangled Lignum (*Muehlenbeckia florulenta*)/ Sedgeland (predominately Spiny Sedge, *Cyperus gymnocaulus*)/Chenopod (predominately *Atriplex semibaccata, Einadia nutans subsp. Nutans*) Grassland (predominately, *Austrodanthonia duttoniana, Austrodanthonia caespitosa, Austrostipa scabra*)	Bbf6
Sedgeland (predominately Spiny Sedge, (*Cyperus gymnocaulus*)	S
Sedgeland (predominately Spiny Sedge, *Cyperus gymnocaulus*)/Canegrass (*Eragrostis infecunda*) wetland	S/Cw
Tangled Lignum (*Muehlenbeckia florulenta*) over Canegrass (*Eragrostis infecunda*) wetland	Tl1
Aquatic vegetation (predominately Dry wetland bed plants)/pasture/weed species (main body of wetland)	Aqv/p/w
Planted natives (Sugar Gum, *Eucalyptus cladocalyx*)	Pn
Pasture/weed species	P/W

- **Figure 5-5 Sugar Gums (*E. cladocalyx*) and Tangled Lignum (*Muehlenbeckia florenta*) over Canegrass (*Eragrostis infecunda*) wetland located on the western periphery of Holland's Lake.**

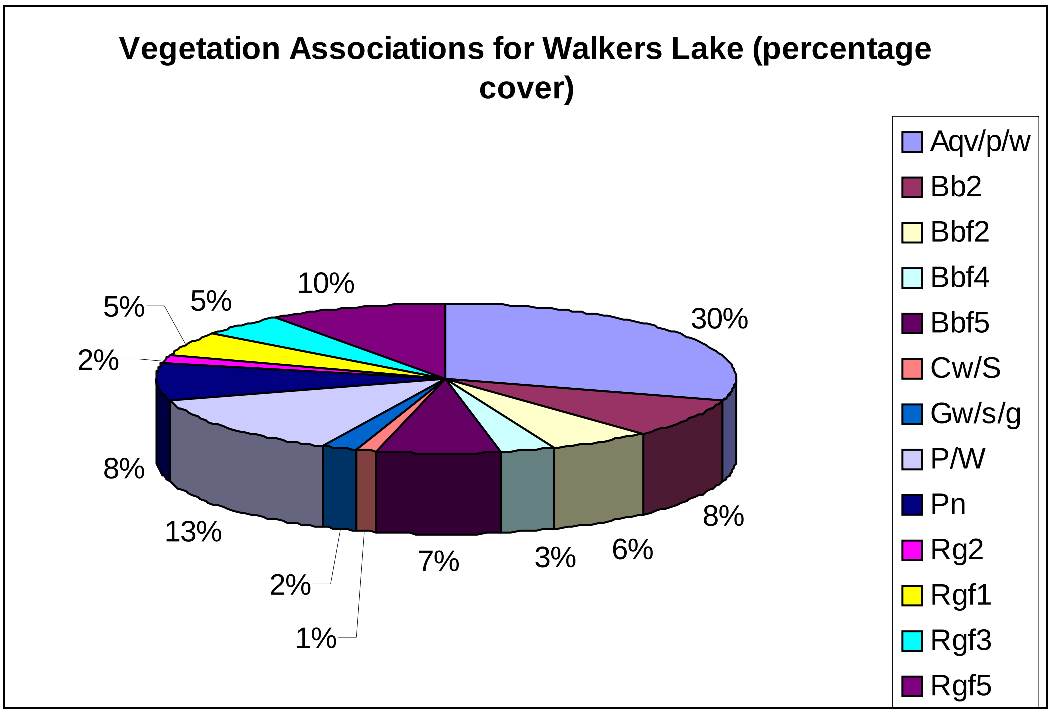
- **Figure 5-6 Black Box (*E. largiflorens*) over (*Eragrostis infecunda*) on the northern margins of Holland's Lake.**

5.5.3 Walkers Lake

Walkers Lake is approximately 35 hectares. Although disturbed to varying degrees, it is more ecologically intact than Hollands and Hancocks Lakes and contains a higher diversity of native vegetation.

A total of 11 native vegetation associations were identified at the Lake. The dominant native vegetation communities identified at Walkers Lake include River Red Gum (*E. camaldulensis*) located on the higher margins of the lake. These stands mainly occur in association with Tangled Lignum (*Muehlenbeckia florulenta*), Canegrass (*Eragrostis infecunda*) and Spiny Sedge (*Cyperus gymnocaulus*). This understorey reflects differences in flooding frequency, soil characteristics and depth of flooding. Black Box (*E.largiflorens*) occurs on higher sites than Red Gum, particularly in the north-west and southern areas of the lake. These stands also occur in association with Tangled Lignum (*Muehlenbeckia florulenta*), Canegrass (*Eragrostis infecunda*), Spiny Sedge (*Cyperus gymnocaulus*), Chenopods (predominately *Atriplex semibaccata, Einadia nutans subsp. Nutans*) and Wallaby Grass (predominately, *Austrodanthonia duttoniana*, *Austrodanthonia caespitosa*, *Austrostipa scabra*) (Refer to Appendix B).
A small stand of Red Gum (*E. camaldulensis*) recruitment occurs on the south-eastern corner of the lake.

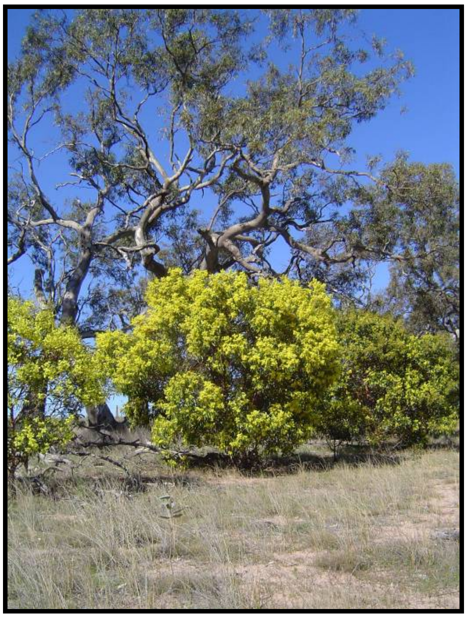
Refer to Figure 5-7 for the breakdown of vegetation associations and approximate percentage cover for Walkers Lake.



▪ **Figure 5-7 Vegetation Associations for Walkers Lake (percentage cover)**

Vegetation Association	Key
Black Box (*E. largiflorens*) open woodland over Sedgeland, (predominately Spiny Sedge, (*Cyperus gymnocaulus*)	Bb2
Black Box (*E. largiflorens*) open woodland over Canegrass (*Eragrostis infecunda*) wetland	Bbf2
Black Box (*E. largiflorens*) open woodland over Tangled Lignum (*Muehlenbeckia florulenta*)/ Sedgeland (predominately Spiny Sedge, *Cyperus gymnocaulus*)	Bbf4
Black Box (*E. largiflorens*) open woodland over Tangled Lignum (*Muehlenbeckia florulenta*)/ Sedgeland (predominately Spiny Sedge, *Cyperus gymnocaulus*)/Chenopod (predominately *Atriplex semibaccata, Einadia nutans subsp. Nutans*)/Grassland	Bbf6
Canegrass (*Eragrostis infecunda*) wetland/ Sedgeland (predominately Spiny Sedge, *Cyperus gymnocaulus*)	C/w/S
Golden Wattle (*Acacia pycnantha*) over Sedgeland (predominately Spiny Sedge, *Cyperus gymnocaulus*)/ Grassland (predominately, *Austrodanthonia duttoniana, Austrodanthonia caespitosa, Austrostipa scabra*)	Gws/G
Red Gum (*E. camaldulensis*) open woodland over Canegrass (*Eragrostis infecunda*) wetland	Rgf1
Red Gum (*E. camaldulensis*) open woodland over Tangled Lignum (*Muehlenbeckia florulenta*)/ Sedgeland (predominately Spiny Sedge, *Cyperus gymnocaulus*)/Chenopod (predominately *Atriplex semibaccata, Einadia nutans subsp. Nutans*)/Herbfield	Rgf5
Red Gum (*E. camaldulensis*) open woodland over Sedgeland (predominately Spiny Sedge, *Cyperus gymnocaulus*)	Rgf3
Red Gum recruitment/regeneration	Rg2
Pasture/weed species	P/W
Planted natives (Sugar Gum, *Eucalyptus cladocalyx*)	Pn
Aquatic vegetation (predominately Dry wetland bed plants)/pasture/weed species (main body of wetland)	Aqv/p/w

- **Figure 5-8 Red Gum (*E. camaldulensis*) open woodland over Canegrass (*Eragrostis infecunda*) wetland located on the northern margins of Walkers Lake (looking west).**



- **Figure 5-9Figure 8. Red Gum (*E. camaldulensis*) over Golden Wattle (*Acacia pycnantha*)/sedgeland/grassland.**

5.5.4 Lake Batyo Catyo

Lake Batyo Catyo is largely used for passive recreation. Although the lake has been disturbed by recreational activities, it still contains significant environmental values. A total of 15 native vegetation associations were identified at the lake (Refer to Appendix B).

The dominant native vegetation communities identified at the lake include River Red Gum (*E. camaldulensis*) which fringes the higher margins of the lake. These stands are usually associated with Canegrass (*Eragrostis infecunda*) Tangled Lignum (*Muehlenbeckia florulenta*) and Spiny Sedge (*Cyperus gymnocaulus*). Black Box (*E.largiflorens*) occurs on higher sites than River Red Gum, particularly in the south-west corner of the lake. These stands mainly occur in association with Tangled Lignum (*Muehlenbeckia florulenta*). Large communities of Canegrass (*Eragrostis infecunda*) and Sedgeland occur on the northern margins of the lake.

5.6 Water requirements for native vegetation.

There is limited information available on the water requirements for wetland vegetation. The most relevant and detailed knowledge on this topic is by Roberts and Marston (2000). This reference was instrumental when assessing the general water needs for the specific vegetation types at the lakes. A summary of this information is shown in Appendix C.

5.7 Threats

There are a number of threats that have impacted on the ecology of the Avon Plains Lakes. The most significant threats to the Avon Plains Lakes include; altered hydrology (the lack of flushing flows), drought, grazing and salinity.

5.8 Vegetation change

Changes in vegetation community associated with prolonged dry conditions generally involve the expansion of some communities and species at the expense of others. More specifically, the expanding communities are those associated with infrequent flooding and more tolerant of dry conditions. Declining communities are those associated with more frequent inundation. This change in community structure is evident at all lakes.

Vegetation associations or patterns are usually defined by the range of environmental conditions which exist in an ecosystem. If conditions change to the extent that they fall outside the natural environmental tolerances of a particular species occupying the site then it is likely that these species will decline and will be replaced by species better suited to the changed conditions. In most cases, these are exotic species.

Extended periods of dry conditions at the lakes have resulted in a visible shift in floral diversity and coverage in the Lakes. This is indicative by the encroachment of dryland vegetation to the littoral zone and into the main body of the lakes. This has caused an increase in dominance by vegetation that is more tolerant of drier conditions. For example, Chenopod communities are prevalent within the littoral zone and scattered throughout the main body of the lakes. This is indicative of the time since the lakes have been inundated.

Dry conditions have caused unfavourable conditions for submerged and emergent vegetation and as a consequence, these species have had little or no opportunity to recharge the seed bank or to renew storage. This could result in reduced vigour when plants regrow, assuming that by the time flooding occurs the propagules are still viable.

From field observations, prolonged water stress and potentially, salinity is causing a decline in the health of trees and woody shrubs at some sites of the lakes. This is indicated by the thinning crowns of Black Box (*E. largiflorens*) and River Red Gum (*E. camaldulensis*), a physiological response by eucalypts to conserve water and adapt to changing environmental conditions.

Signs of soil salinisation occur at the lakes, particularly at Hollands Lake. The long term effects of salinisation may result in the death of original vegetation and a gradual change to communities that are dominated by salt tolerant species. The reduction of periodic flushing in subsequent flooding or filling events may be a key factor for increases in salinity at the lakes. Reduced flushing may have facilitated salt accumulation at the lakes.

6. Conclusions

Installation of pipe drainage through Hollands Bank would provide additional water into Souths Creek during times of flood in the Avon River. The total volume passing through the bank for the pipe inlet at 137.4 m AHD would increase gradually with flood magnitude from around 220 ML at 1 in 2, to around 260 ML at 1 in 20. These volumes would be flow through the bank over a period of between about 3 and 7 days.

Over the period of investigation (1963 to 2004), there would have been 53 separate flood events when flows would have been expected through a pipe drain in Hollands Bank. This extra water would have been supplied during wet periods, when it is expected that the Avon Plains lakes would already be receiving significant runoff from their local catchment area (downstream of Hollands Bank). The extra water supplied through a pipe drainage structure in Hollands Bank would therefore not change the time series of water levels and storage volumes in the lakes. However, the pipe drainage options would increase the mean annual volume of water flushing through the lakes system by between 185 and 265 ML/year or between 18% and 25% of the spills from Walkers Lake under existing conditions.

Removal of Hollands Bank would result in considerable increases in flood volumes over the natural saddle for AEP between 1 in 5 and 1 in 100, which would make this an undesirable option. By contrast the controlled flow of 50 ML/d in either of the pipe drainage options would have some small flood mitigation benefits downstream of the bank over existing conditions for large floods (with AEP between 1 in 50 and 1 in 100).

Changes in water levels have altered the composition, structure and production of the vegetation at the lakes, as vegetation adjusts to falling and rising water levels. Prolonged dry conditions have been responsible for the displacement of aquatic and semi-aquatic vegetation with terrestrial vegetation. Generally, native wetland vegetation is well adapted to patterns of drought and flood and have developed specific mechanisms for their recovery. It is anticipated that water will be supplied to the lakes during wet years and wetland vegetation will re-establish. However, the rate of recovery can vary considerably, being influenced by succession patterns in plants and the viability of the seed, rhizomes and propagules of wetland flora.

River Red Gum (*Eucalyptus camaldulensis*) and Black Box (*Eucalyptus largiflorens*) communities at the lakes have experienced long periods of dry conditions as a consequence of climatic conditions, river regulation and land-forming (particularly the construction of Hollands Bank). For trees that have experienced an extended dry phase, frequent short floods and longer duration floods both reduce water stress and hence results in greater growth (Bacon *et. al* 1993).

Both pipe options propose to deliver longer periods of water inundation at the lakes when compared to existing conditions. The pipe option through Hollands Bank set at 137.4 m AHD would extend the inundation periods and increase water depth at all lakes. This additional inundation time and water depth will provide benefit to the existing vegetation communities by enhancing opportunities for regeneration and establishment and help maintain the health of existing populations. These changes will also benefit waterbird populations (including migratory) by extending breeding periods and improving foraging opportunities.

Under current conditions, the lack of episodic flushing events following flooding may be causing an increase in salinity at the lakes. The proposed pipe option will provide some periodic flushing of the lakes and could provide some salinity mitigation benefits. The extent of this benefit should be investigated and the relative merits of increasing flushing cycles at the lakes should also be explored.

7. Recommendations

It is recommended that a pipe is installed in Holland’s Bank to allow for a controlled release of flow into the Avon Plains Lakes. It is recommended that:

- Releases through the pipe are controlled to a maximum rate of 50 ML/d by the configuration of the inlet structure;
- The inlet structure is constructed so that flows through the pipe commence at a water level of 137.4 m AHD upstream of Holland’s Bank;
- A drain and associated road crossings are constructed between the pipe outlet and South’s Creek to convey at least 50 ML/d, thereby avoiding additional flooding of properties that are between Holland’s Bank and South’s Creek; and
- The on-going management and maintenance of Lake Batyo Catyo is addressed to avoid exacerbating flooding downstream of Lake Batyo Catyo. This would involve continued operation and maintenance of the outlet channel from Lake Batyo Catyo to allow for overflows from Walkers Lake to be conveyed through Batyo Catyo without exacerbating downstream flooding.

8. References

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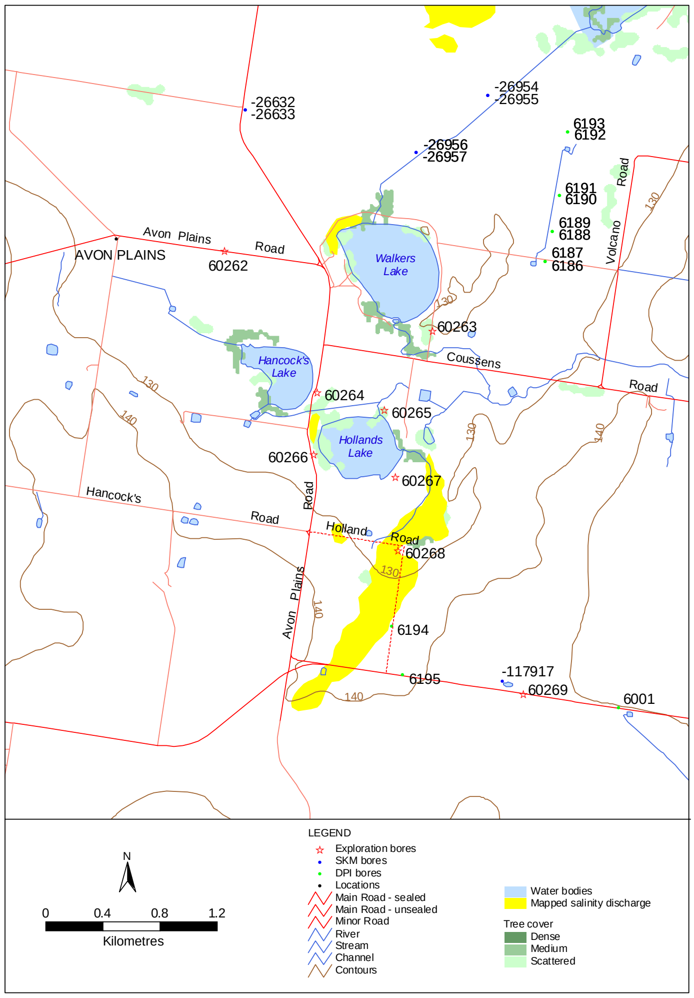
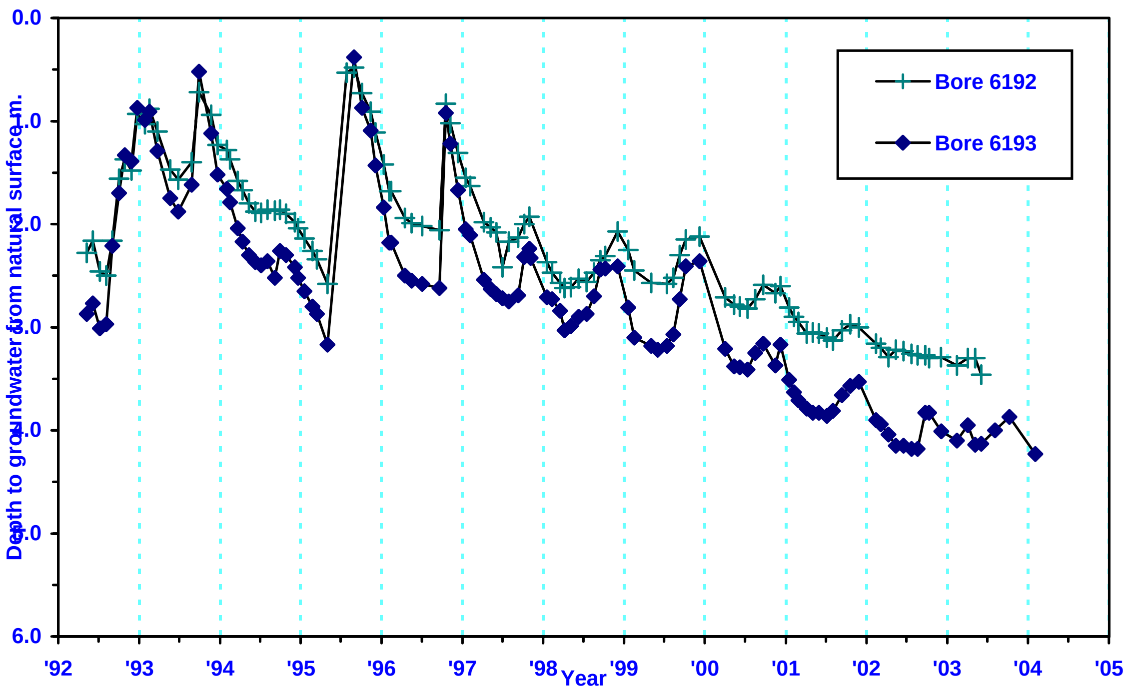
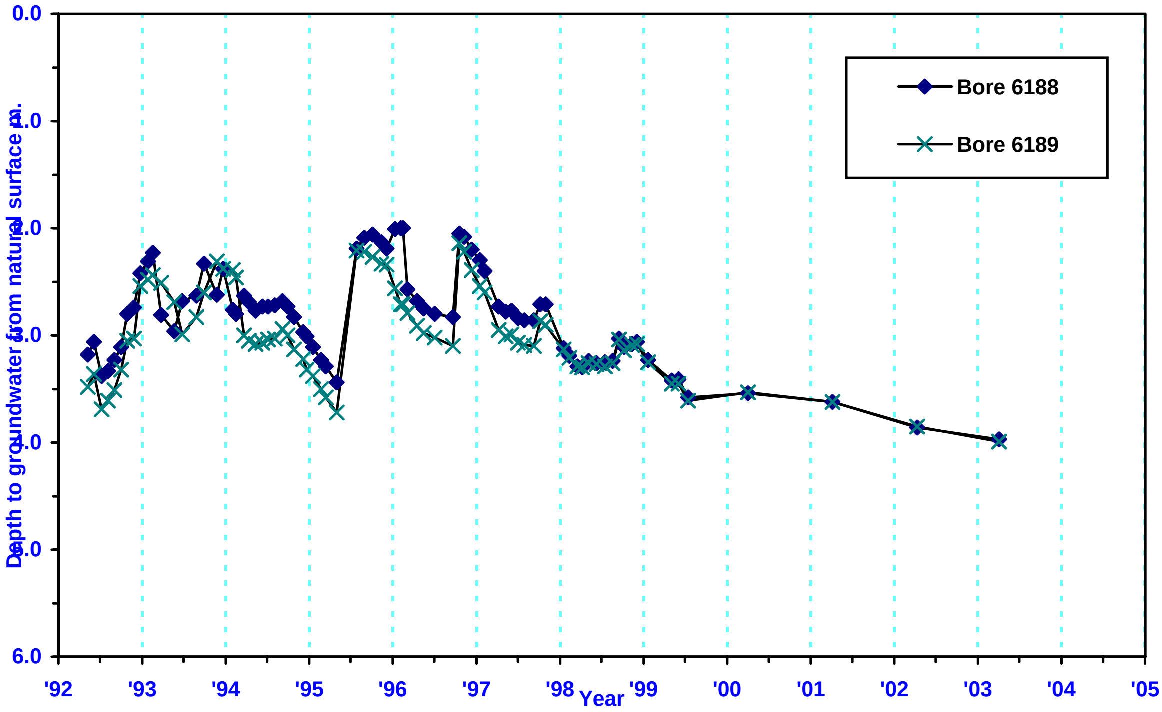
Appendix A Hydrographs from Groundwater Monitoring Bores in the Vicinity of Avon Plains Lakes

- **Bore Location Plan**

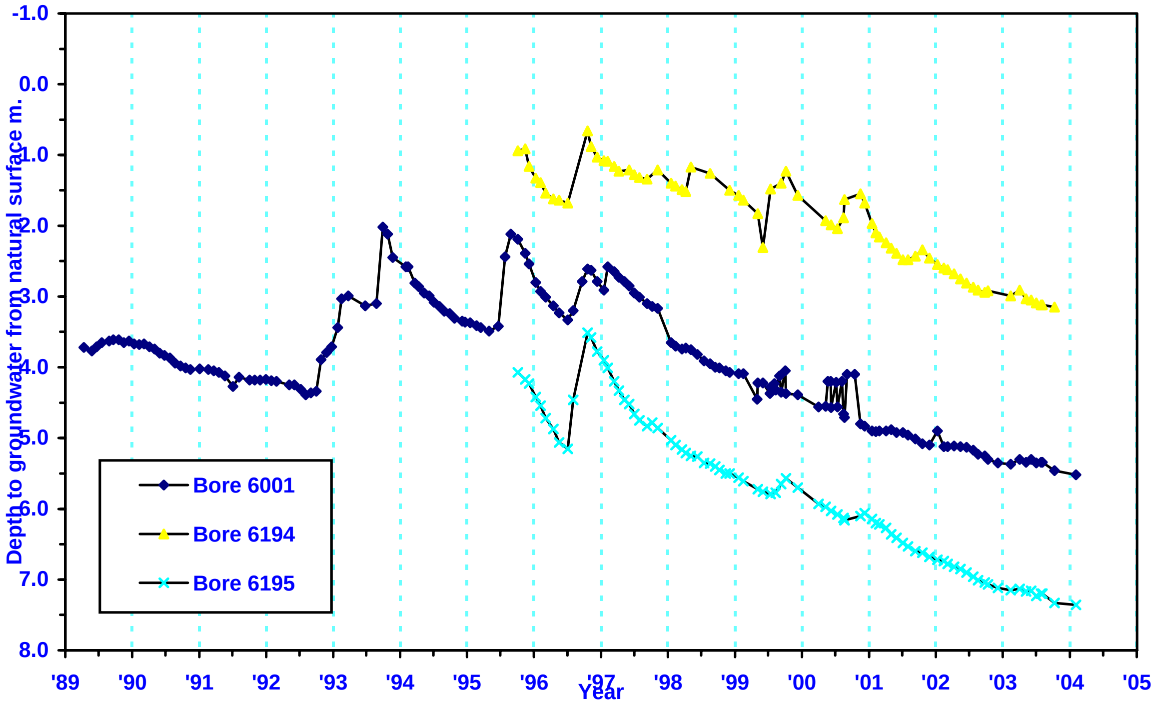




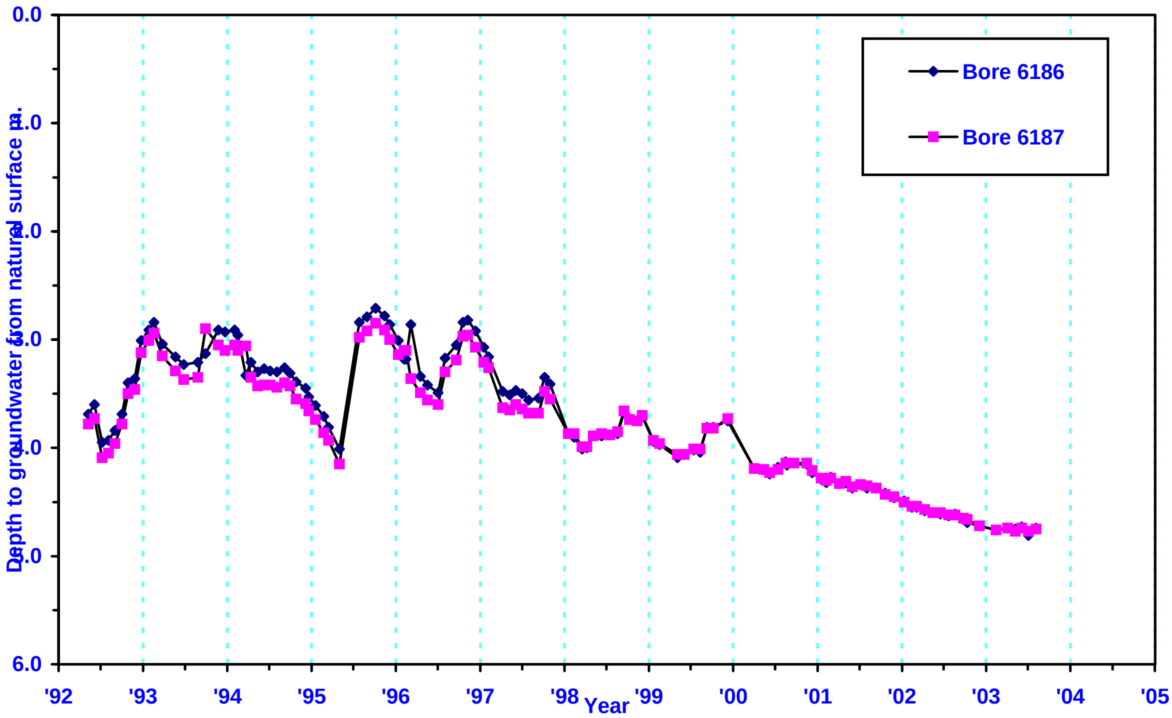
- **Figure A-1 Groundwater bore hydrographs for bores 6192 and 6193**



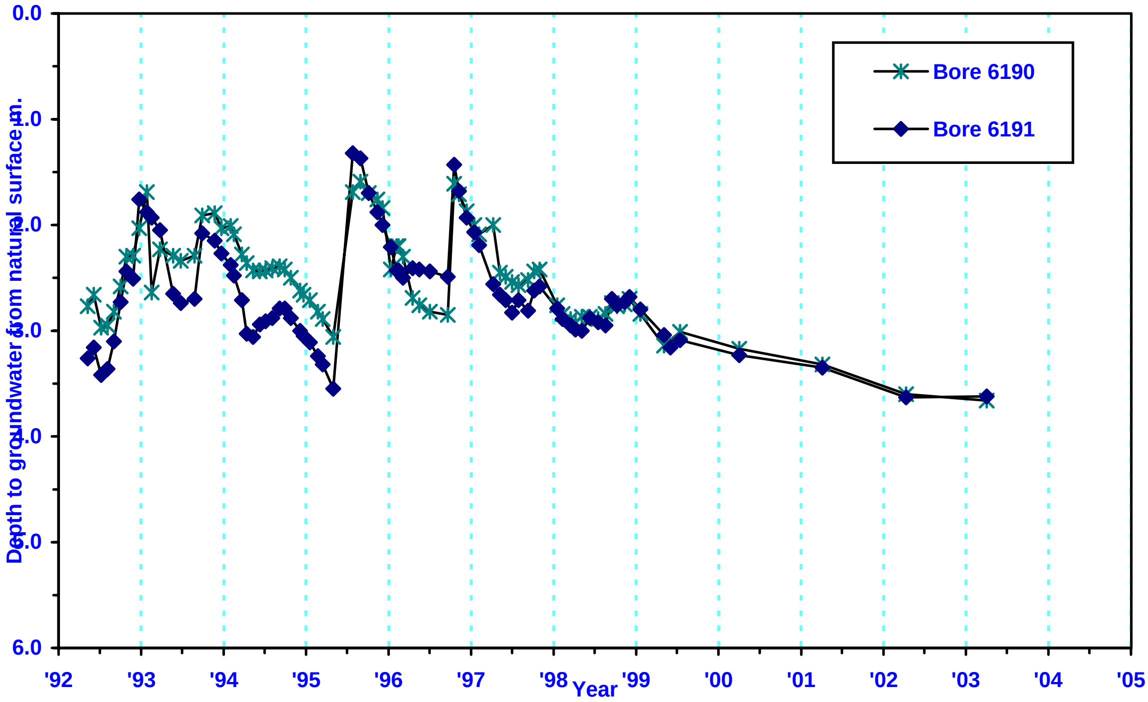
- **Figure A-2 Groundwater bore hydrographs for bores 6198 and 6189**



▪ **Figure A-3 Groundwater bore hydrographs for bores 6001, 6194 and 6195**

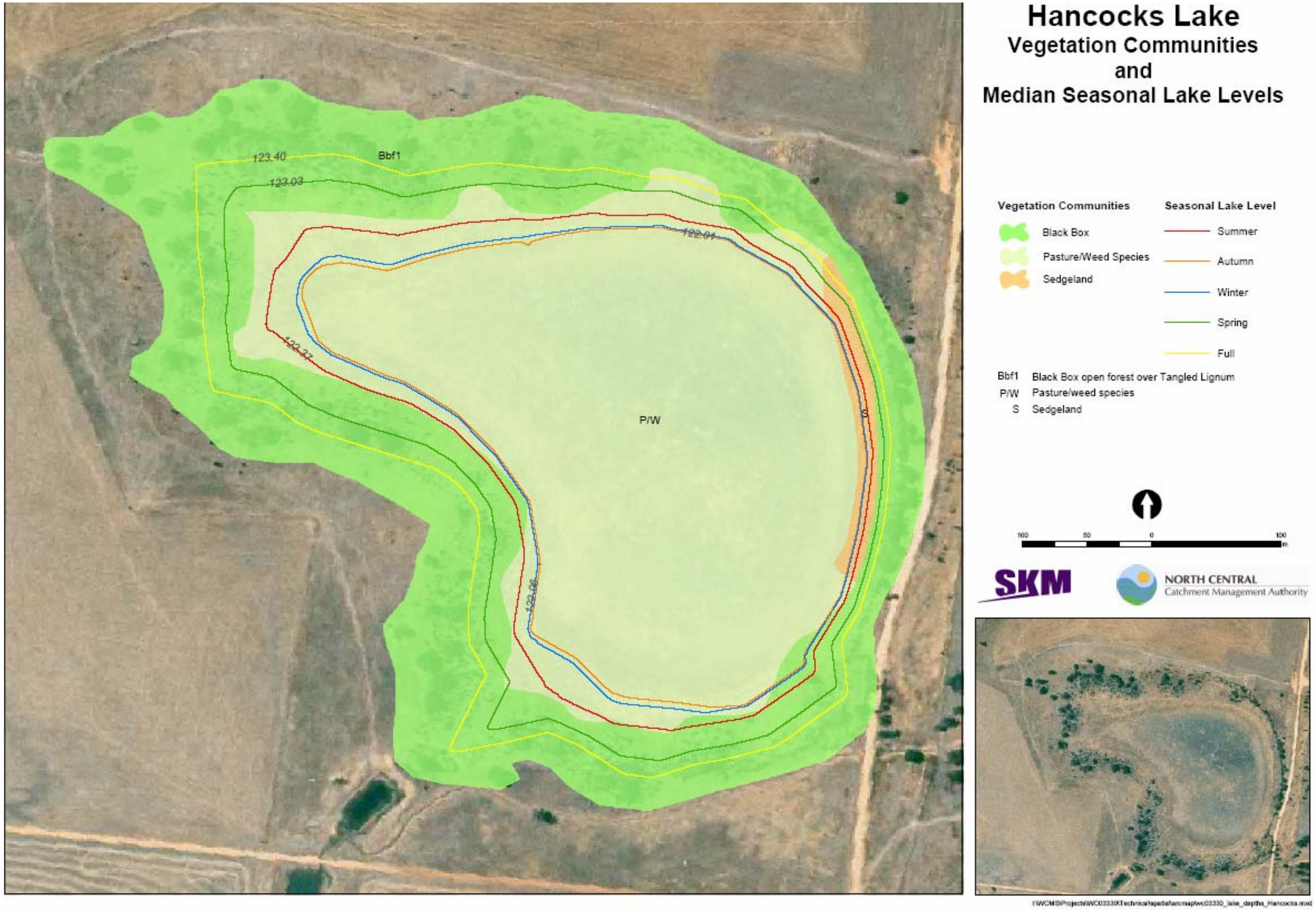


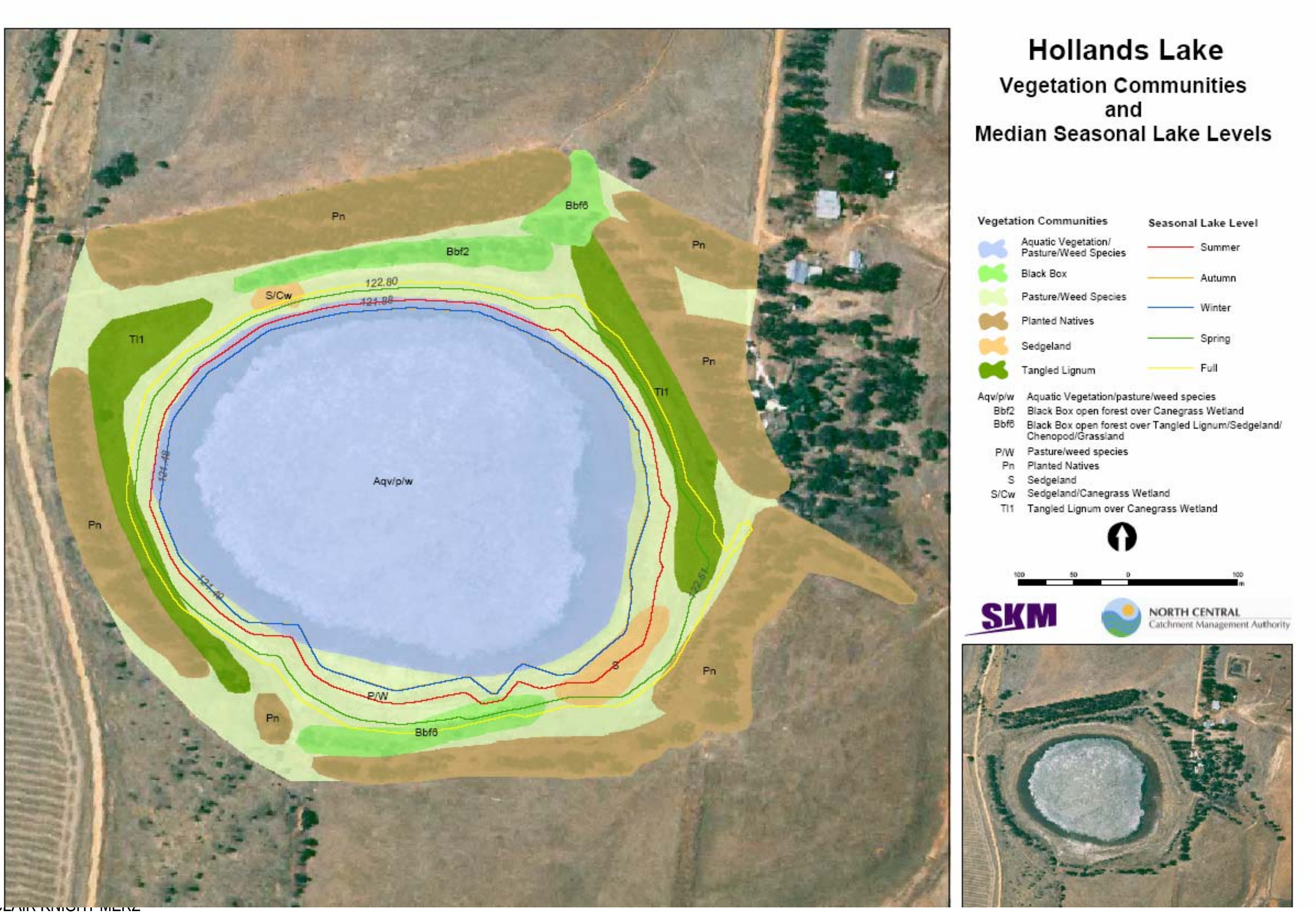
▪ **Figure A-4 Groundwater bore hydrographs for bores 6186 and 6187**

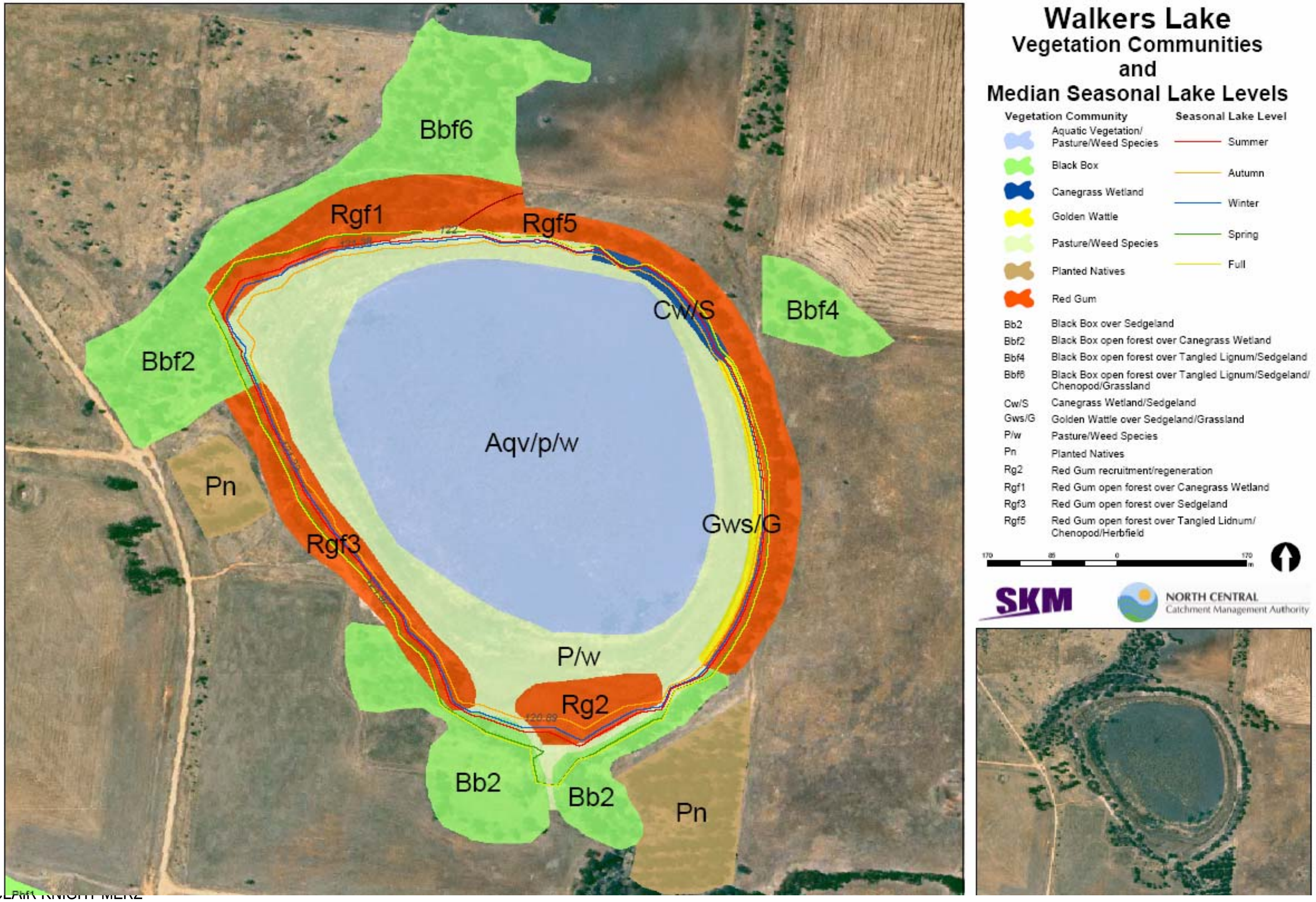


▪ **Figure A-5 Groundwater bore hydrographs for bores 6190 and 6191**

Appendix B Maps of Vegetation Communities


Hancocks Lake
Vegetation Communities
and
Median Seasonal Lake Levels
Vegetation Communities
Black Box
Pasture/Weed Species
Sedgeland
Seasonal Lake Level
Summer
Autumn
Winter
Spring
Full
Bbf1 Black Box open forest over Tangled Lignum
P/W Pasture/weed species
S Sedgeland
123.40
123.03
Bbf1
122.61
122.37
P/W
122.06
S
SKM
NORTH CENTRAL
Catchment Management Authority


Hollands Lake
Vegetation Communities
and
Median Seasonal Lake Levels
Vegetation Communities
Aquatic Vegetation/ Pasture/Weed Species
Black Box
Pasture/Weed Species
Planted Natives
Sedgeland
Tangled Lignum
Seasonal Lake Level
Summer
Autumn
Winter
Spring
Full
Aqv/p/w Aquatic Vegetation/pasture/weed species
Bbf2 Black Box open forest over Canegrass Wetland
Bbf6 Black Box open forest over Tangled Lignum/Sedgeland/ Chenopod/Grassland
P/W Pasture/weed species
Pn Planted Natives
S Sedgeland
S/Cw Sedgeland/Canegrass Wetland
Tl1 Tangled Lignum over Canegrass Wetland
SKM
NORTH CENTRAL
Catchment Management Authority
Pn
Bbf6
Bbf2
S/Cw
122.80
121.88
Tl1
Aqv/p/w
P/W
Bbf6
S


Walkers Lake
Vegetation Communities
and
Median Seasonal Lake Levels
Vegetation Community
Aquatic Vegetation/ Pasture/Weed Species
Black Box
Canegrass Wetland
Golden Wattle
Pasture/Weed Species
Planted Natives
Red Gum
Seasonal Lake Level
Summer
Autumn
Winter
Spring
Full
Bb2 Black Box over Sedgeland
Bbf2 Black Box open forest over Canegrass Wetland
Bbf4 Black Box open forest over Tangled Lignum/Sedgeland
Bbf6 Black Box open forest over Tangled Lignum/Sedgeland/ Chenopod/Grassland
Cw/S Canegrass Wetland/Sedgeland
Gws/G Golden Wattle over Sedgeland/Grassland
P/w Pasture/Weed Species
Pn Planted Natives
Rg2 Red Gum recruitment/regeneration
Rgf1 Red Gum open forest over Canegrass Wetland
Rgf3 Red Gum open forest over Sedgeland
Rgf5 Red Gum open forest over Tangled Lidnum/ Chenopod/Herbfield
SKM
NORTH CENTRAL
Catchment Management Authority
Bbf6
Rgf1
Rgf5
Bbf2
Cw/S
Bbf4
Aqv/p/w
Pn
Gws/G
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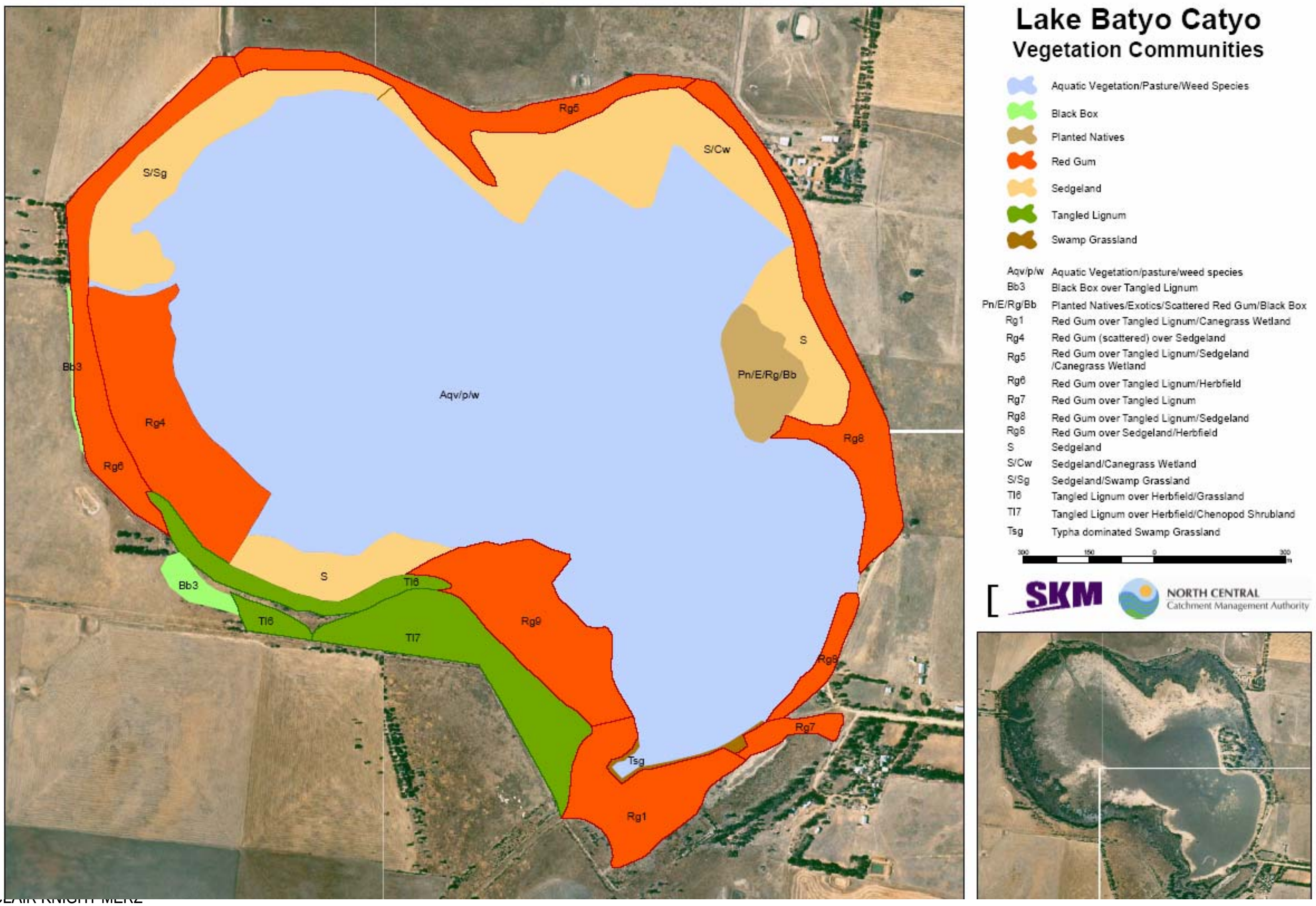
Rg2
Bb2
Bb2
Pn


Lake Batyo Catyo
Vegetation Communities
Aquatic Vegetation/Pasture/Weed Species
Black Box
Planted Natives
Red Gum
Sedgeland
Tangled Lignum
Swamp Grassland
Aqv/p/w Aquatic Vegetation/pasture/weed species
Bb3 Black Box over Tangled Lignum
Pn/E/Rg/Bb Planted Natives/Exotics/Scattered Red Gum/Black Box
Rg1 Red Gum over Tangled Lignum/Canegrass Wetland
Rg4 Red Gum (scattered) over Sedgeland
Rg5 Red Gum over Tangled Lignum/Sedgeland /Canegrass Wetland
Rg6 Red Gum over Tangled Lignum/Herbfield
Rg7 Red Gum over Tangled Lignum
Rg8 Red Gum over Tangled Lignum/Sedgeland
Rg8 Red Gum over Sedgeland/Herbfield
S Sedgeland
S/Cw Sedgeland/Canegrass Wetland
S/Sg Sedgeland/Swamp Grassland
Tl6 Tangled Lignum over Herbfield/Grassland
Tl7 Tangled Lignum over Herbfield/Chenopod Shrubland
Tsg Typha dominated Swamp Grassland
SKM
NORTH CENTRAL
Catchment Management Authority
Aqv/p/w
S/Sg
Rg5
S/Cw
Bb3
Rg4
Rg6
S
Pn/E/Rg/Bb
Rg8
Tl6
Tl7
Rg9
Tsg
Rg1
Rg7

Appendix C General water requirements for wetland vegetation for the Avon Plains Lakes

Vegetation Type	Flooding frequency	Ponding duration	Preferred season	Notes
River Red Gum (*E. camaldulensis*)	Annual-most years – 1-2-3 years	4-6 months	Winter-Spring	Continuous flooding not lasting more than 24 months and/or 24 months without flooding. Flood frequency and duration may need to be reduced according to groundwater levels. Complete drying between flood cycles is needed (or as much as possible, to ensure cracking for soil aeration and deep recharge).
Black Box (*E. largiflorens*)	Seasonal saturation – 1 in 3-5 years (average)	4-2 months	Season may not be important (in adult trees), but Winter-Spring flooding may be beneficial.	Can tolerate infrequent flooding such as 1 in 7-10 years, providing there is no reduction in flood duration. Continuous flooding of 4+ months may be beneficial initially, but will have a cumulative adverse effect (loss of vigour as soil oxygen gradually becomes depleted).
Tangled Lignum (*Muehlenbeckia florenta*)	Seasonal saturation – 1 in 2-8 years.	6-12 months	Season may not be important.	Continuously wet should be avoided. Complete drying is required to allow adequate soil aeration, soil water recharge and to preserve crack habitat for small native mammals and herpetofauna.
Canegrass (*Eragrostis infecunda*)	Annual-most years	3-9 months	Spring-Summer	Optimum conditions for flowering are shallow (<50cm) for 6 months (range 3-9 months).
Spiny Sedge (*Cyperus gymnocaulos*)				Insufficient information to provide definitive recommendations.
Common Spike Sedge (*Eleocharis acuta*)	Annual-most years	8 months (optimum) but tolerates 3-10 months flooding	Spring-Summer	Shallow depths, typically 10cm in Spring-Summer Information for water regime maintenance for this genus is insufficient to provide accurate recommendations.

Vegetation Type	Flooding frequency	Ponding duration	Preferred season	Notes
Cumbungi (*Typha domingensis*)	Annual-most years (1 in 1-2).	7-9 months (ideally) but 6-12 months also. If short duration, then should cover winter-spring-early summer.		Rhizome can survive without flooding (1-2 years) – if well established. Depth range variable, from 5cm to 1.5 m. Flooding can be pulsed, providing ground remains saturated between pulses. Inter-flood interval in mid summer of 1-2 weeks.
Charophytes	Annual	4 months (typically 25 cm deep-but varies between species).		Charophytes may be annuals or perennials. They are dependant on being flooded in order to grow and to reproduce. Being relatively short, they can grow and survive in water that is relatively shallow (eg 5-50cm) provided shallowness is not the result of drawdown and conductivity increasing through evaporation. They are generally tolerant of changes in water level, provided the changes do not expose them, as this will result in rapid desiccation and death.
Ribbonweed (*Vallisneria sp*)	Annual	At least 8 months if flooded in late winter, longer if flooded earlier.		Drawdown in spring or summer will mean peak canopy biomass is not reached, and if this recurs, then vigour may be negatively affected. Turbidity reduced light penetrating the water, and if water is deep, plant growth will cease.
Herb and Forb Communities	Annual	Species differ in time required after an autumn flood to reach maximum biomass.	Spring-Summer	Species richness is higher after spring flood than after a comparable length summer flood; and is higher in shallow (<30cm) water than water more than 30cm deep. Species richness is higher under a seasonally fluctuating water regime than under a permanent and stable water regime, and both spring and summer flooding result in species richness that is higher than stable water level conditions. Species richness declines through time when water levels are stable but no decline evident when water levels fluctuate.

Reference: Roberts and Marston, October, 2000. CSIRO. Water Regime of Wetland & Floodplain Plants in the Murray-Darling Basin – A Source Book of Ecological Knowledge.