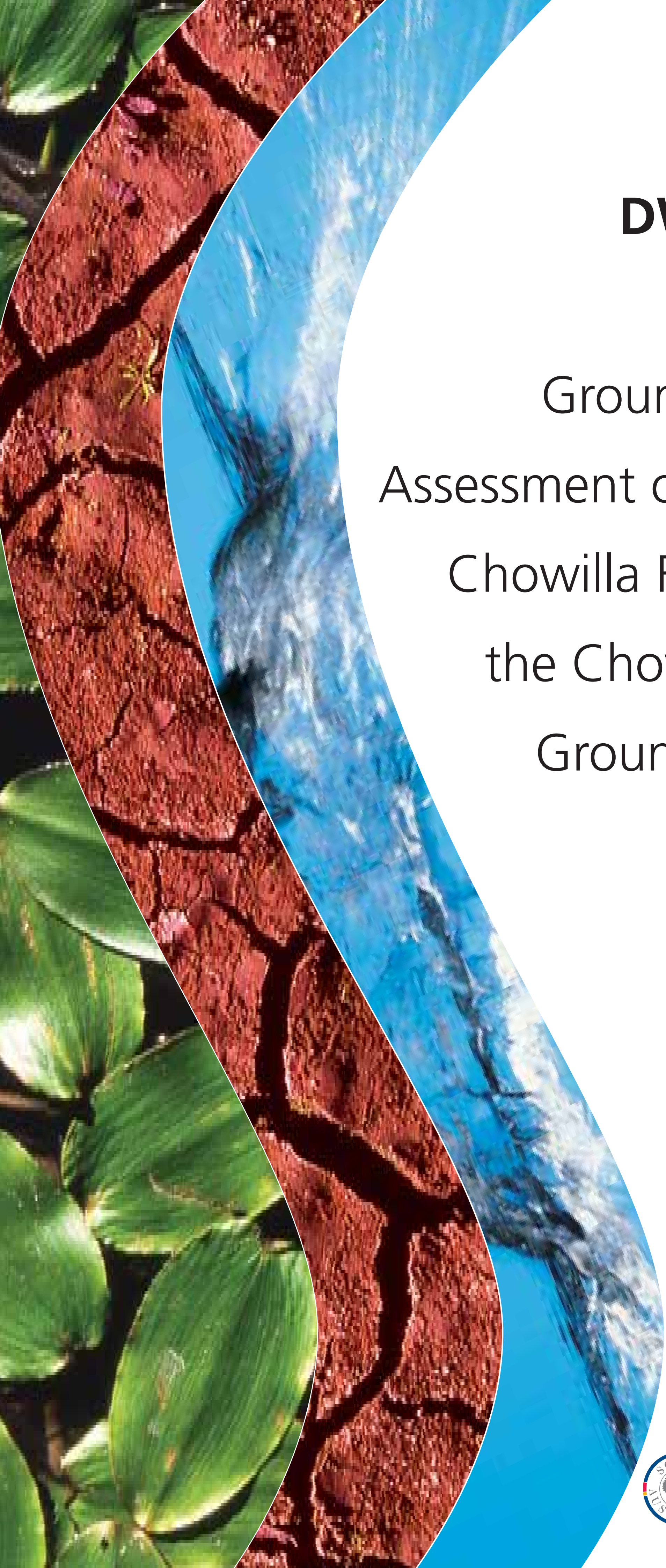

DWLBC REPORT

Groundwater Impact Assessment of the Proposed Chowilla Regulator using the Chowilla Numerical Groundwater Model: Report 1

2007/28

Government of South Australia
Department of Water, Land and Biodiversity Conservation

Groundwater Impact Assessment of the Proposed Chowilla Regulator using the Chowilla Numerical Groundwater Model: Report 1

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Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation

December 2007

Report DWLBC 2007/28

Government of South Australia
Department of Water, Land and Biodiversity Conservation

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FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Rob Freeman
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

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EXECUTIVE SUMMARY

This report describes the application of the DWLBC Chowilla numerical groundwater model to simulate the aquifer hydraulic response to natural flooding, and predict the impacts of a flow regulator proposed to be constructed for environmental purposes on the Chowilla floodplain adjacent the River Murray, South Australia.

Model scenarios allow calculation of salt load accession to the anabranch creeks (which ultimately enter the River Murray), and prediction of regional groundwater level change resulting from:

- Natural flooding.
- Flooding induced by the proposed regulator.
- Operation of a proposed groundwater management scheme (GMS).
- Operation of both the regulator and GMS.

The model indicates natural river flow over the past 30 years (1977–2007) generated an average salt load accession to the River Murray of 112 t/d from Chowilla. Assuming operation of the regulator nine times over the past 30 years, the model indicates an average salt load accession of 140 t/d to the river. When constant operation of a GMS is coupled with the regulator, the average salt load accession to the river is 89 t/d.

The model indicates that the mean change (rise) in groundwater level resulting from frequent operation of the regulator ranges up to 1 m through out the inundation area.

Further scenarios, including altering the operating regime of the regulator, are expected to be completed in 2007–08, and this work will be documented in a subsequent report.

1. INTRODUCTION

The Chowilla floodplain is one of six significant ecological assets identified within the Murray Darling Basin by the Murray Darling Basin Ministerial Council. As such, Chowilla is a priority site for the delivery of environmental flows using water made available through the Murray Darling Basin Commission (MDBC) Living Murray Initiative First Step decision. It is also a priority site for investment in structural and operational change through the MDBC Environmental Works and Measures Program.

The Chowilla floodplain is well recognised as a discharge point for regional saline groundwater. Significant volumes of saline groundwater are both intercepted by anabranch creeks and/or stored in floodplain sediments. This salt is ultimately mobilised and transported to the River Murray during and following large floods. Salt load accession to the river following large flood events can exceed 1000 t/d (Sharley et al 1995) while those during low flow periods (i.e. current conditions) are ~30–40 t/d.

Like the majority of the lower Murray floodplains, much of the biota of the Chowilla floodplain is under stress resulting from the combined effects of salt accumulation and lack of flooding. In order to combat these threats, proposals have been developed for a groundwater management scheme (GMS) and flow management infrastructure. The presently preferred flow management infrastructure consists of a regulator in the Chowilla Creek that would enable the water level in the anabranch creek system to be temporarily raised and large areas of the floodplain to be inundated, even under low river (non-flooding) flow conditions.

The impacts of operation of the proposed regulator (hereafter referred to as regulator) need to be considered in terms of water use, vegetation response, groundwater response, and increased salt load accession to the River Murray. This report forms a component of a detailed assessment to inform and enable further progress of this infrastructure proposal.

The project methodology involves using a series of models to provide a quantitative estimate of salt load accession and in-river EC impact resulting from the operation of the regulator. Surface water (hydrodynamic) modelling provides flood inundation zones and creek levels for use in the numerical groundwater model. A potential recharge map is combined with the hydrodynamic model output to generate recharge zones for the groundwater model, which is used to generate salt load (in t/d) for input to BIGMOD[1]. The groundwater model also generates groundwater levels for the unconfined aquifer, for use in the Commonwealth Scientific and Industrial Research Organisations (CSIRO) Weighted INDex of Salinisation (WINDS) model, which predicts salt accumulation and vegetation response to operation of the regulator.

Full details of the Knowledge and Information Division (KID) component of the project are given in the project proposal in Appendix A. Groundwater modelling tasks that have not been completed will most likely be documented in a subsequent report. WINDS and BIGMOD modelling, completed by the CSIRO and KID respectively, will either be reported separately or included within future volumes to this report.

[1] BIGMOD is the MDBC's basin scale hydrological model which models the salinity impact measured at Morgan or other 'end of valley' key locations, due to specific scenarios or intervention occurring within the Basin.

1.1 HISTORY OF THE CHOWILLA GROUNDWATER MODEL

In 2004, DWLBC developed a numerical groundwater flow model capable of simulating the regional aquifer system underlying the Chowilla floodplain (Fig. 1). At that time, all model structures and boundaries were defined and hydraulic parameters were estimated during calibration. The model is comprehensively documented in Yan et al, (2004). The model was used to simulate the regional aquifer system under low river flow conditions and did not include the impact of any flooding.

In 2005–06, the model was used for the first time by DWLBC to simulate the aquifer hydraulic response to natural flooding and flooding induced by the regulator. During the project it was assumed that the regulator was operated on an annual basis over a ten-year period (Overton et al, 2005). This assessment indicated that operation of the regulator induced an increased salt load accession (above that of the same flood magnitude under natural conditions) of up to ~400 t/d immediately after flooding, and an average increase of ~75 t/d over the ten year period.

The current assessment covers a longer period (30 years), with a broader range of flow variability, and is based on a more realistic operating strategy involving an average regulator usage frequency of once every three years. In the current modelling project, the groundwater model is used to simulate the aquifer hydraulic response to historic flood events and flooding induced by the regulator, using a simplified version of the River Murray flow hydrograph of the past 30 years (Fig. 2). The fundamental model parameters and conditions have not changed since model development in 2004, other than to apply the conditions necessary to simulate flooding. This report details the changes made to the model and specific information concerning the scenarios run in relation to the operation of the regulator and GMS.

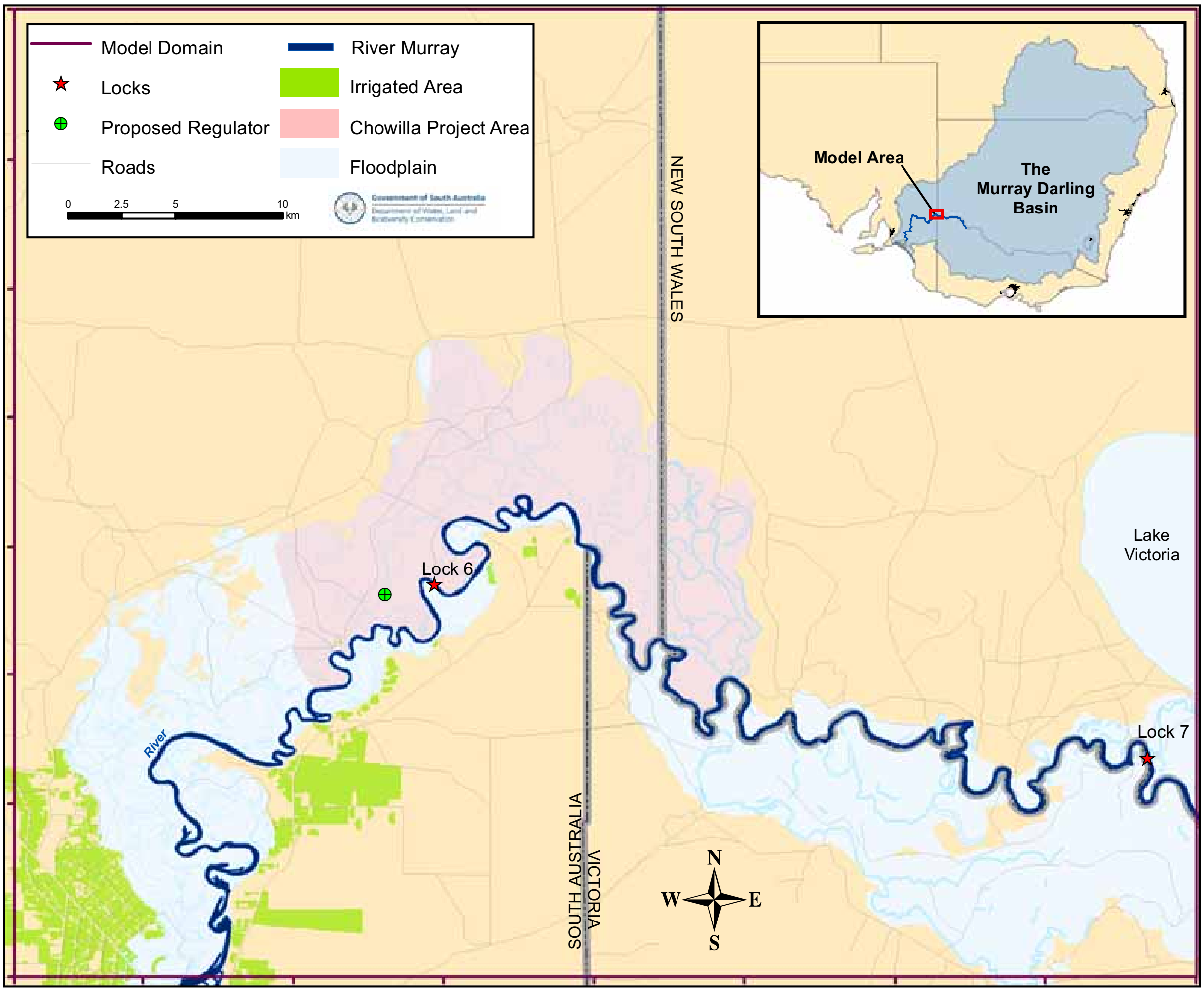


Figure 1. Chowilla model domain and site map

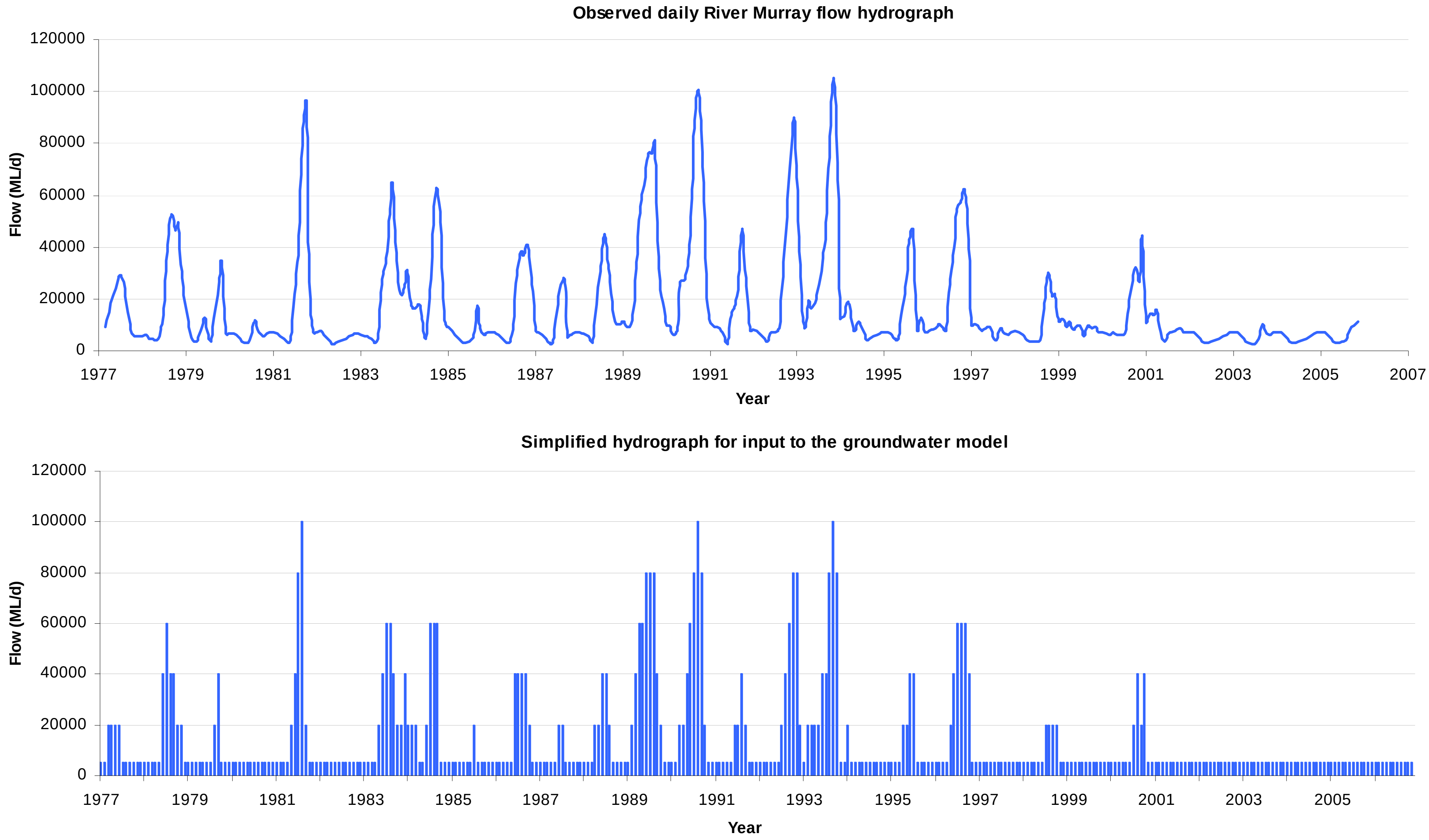


Figure 2. Observed and simplified River Murray flow hydrograph at Lock 6 (ML/d)

2. MODELLING OBJECTIVES

The primary objective of this modelling project was to use the existing Chowilla groundwater model to simulate the aquifer hydraulic response to natural flooding events using a simplified version of the River Murray flow hydrograph of the past 30 years. The modelled groundwater flux and an average observed groundwater salinity is used to calculate salt load accession to the anabranch creeks (which ultimately enter the River Murray) that match historical salt loads generated by flooding. After calibration, the model was used to predict the aquifer hydraulic response to various management options, including the regulator and GMS.

Four key scenarios were requested by the Infrastructure and Business Division (IBD) (Table 1). Scenario1 (natural flow) serves as a history-matching scenario (calibration) and as a reference point for comparison with the other scenarios.

Table 1. Scenario name and description

No.	Name	Description
1	Natural Flow	Designed to simulate the aquifer hydraulic response to the simplified River Murray flow hydrograph of the past 30 years, from 1977–2007
2A	Natural Flow with GMS*	Designed to examine the aquifer hydraulic response to operating the GMS
2B	Natural Flow with Regulator	Designed to examine the aquifer hydraulic response to operating the regulator, with an average operating frequency of once every three years
2C	Natural Flow with Regulator and GMS	Designed to examine the aquifer hydraulic response to operating the GMS in conjunction with the regulator

* Groundwater Management Scheme

3. MODEL INPUTS

3.1 SCENARIO 1 — NATURAL FLOW

3.1.1 RIVER MURRAY FLOW HYDROGRAPH

The past 30 year observed River Murray flow hydrograph from Lock6 forms the basis for simulating flood events using the groundwater model. This hydrograph was simplified into 30 day time steps and 20 000 ML/d flow magnitude divisions (Fig. 2 and App. B) to enable application in the groundwater model. IBD and KID agreed upon the simplified hydrograph and time steps as a suitable input, prior to the commencement of the modelling project. All model scenarios were run over the same 30 year period 1977–2007. River flow of 5000 ML/d is assumed between flood events.

3.1.2 THE ANABRANCH CREEK SYSTEM (RIVER CELLS)

River cells simulate the anabranch creek system on the Chowilla floodplain, which have been simplified into 24 groups. The results of hydrodynamic modelling, conducted by KID (2006–07), were used to determine the creek levels for the different river flows, as specified by the hydrograph (Fig. 2). Figure 3 shows the location of the river cell groups, and Table 2 gives the river cell parameters and creek levels applicable at each flow.

3.1.3 RECHARGE ZONES AND RATES

The extent of inundation during flooding was predicted using the hydrodynamic model. Figure 4 shows the modelled inundation for river flows of 40 000, 60 000, 80 000 and 100 000 ML/d. It is both predicted and observed that no overbank flooding occurs at flows of 20 000 ML/d and less.

CSIRO (Overton et al 2005) divided the floodplain into three potential recharge zones with recharge rates of between 0.5–2 mm/d (Fig. 5).

A recharge zone with a negative rate (-1 mm/d) was applied in the zone adjacent the River Murray where red gums (eucalypts) and other deep-rooted trees are believed to use the lower salinity groundwater (Fig. 6).

The recharge applied in the groundwater model combined the two information layers, flood inundation extent and potential recharge.

In order to achieve consistency between the model scenarios, a single complex recharge distribution plan consisting of 23 zones (Fig. 6) was generated. This plan allows the recharge conditions for all model runs, including natural flooding and regulator induced flooding, to be simulated.

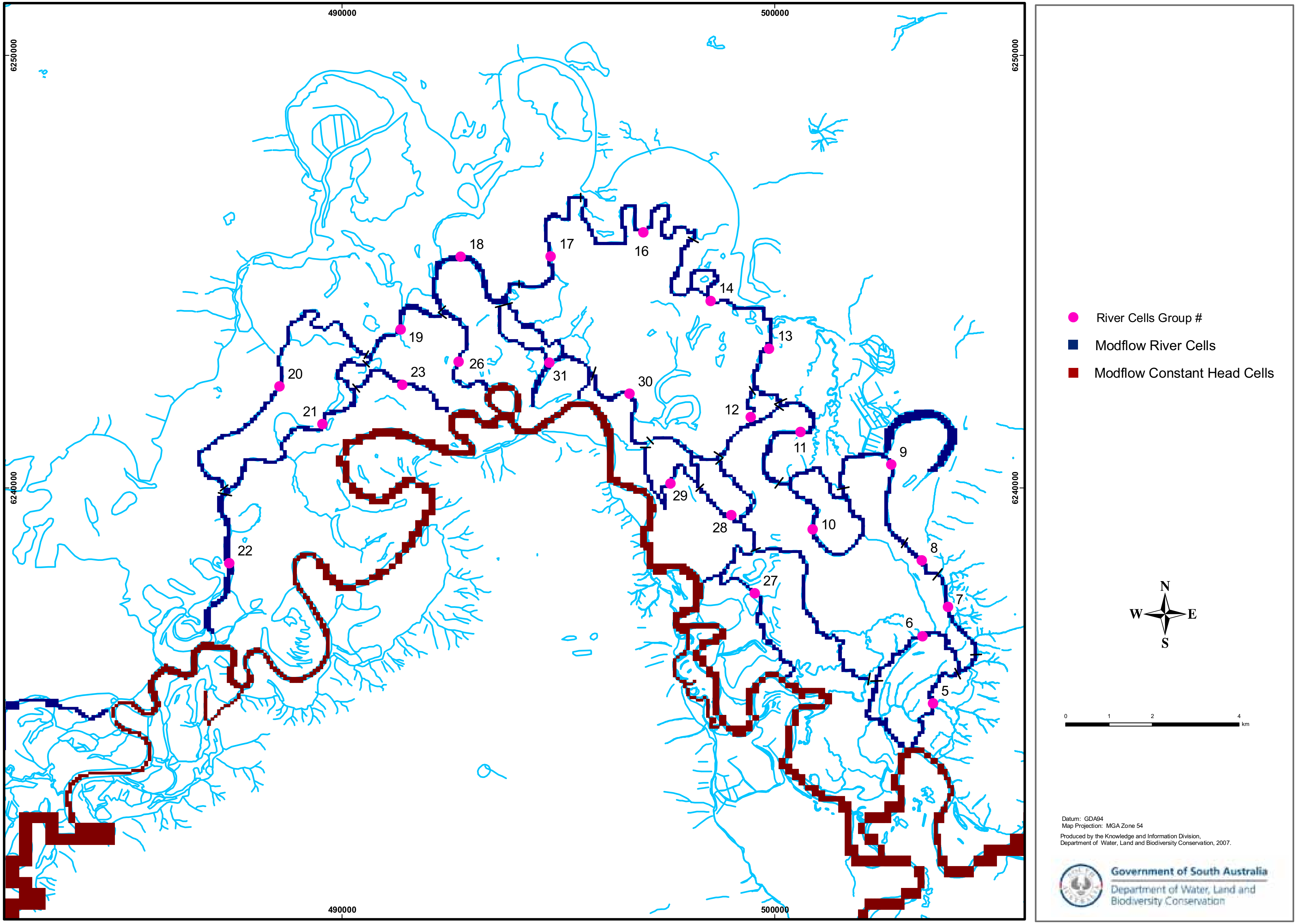


Figure 3. Model boundary conditions used to simulate the River Murray and anabranch creek system in Chowilla

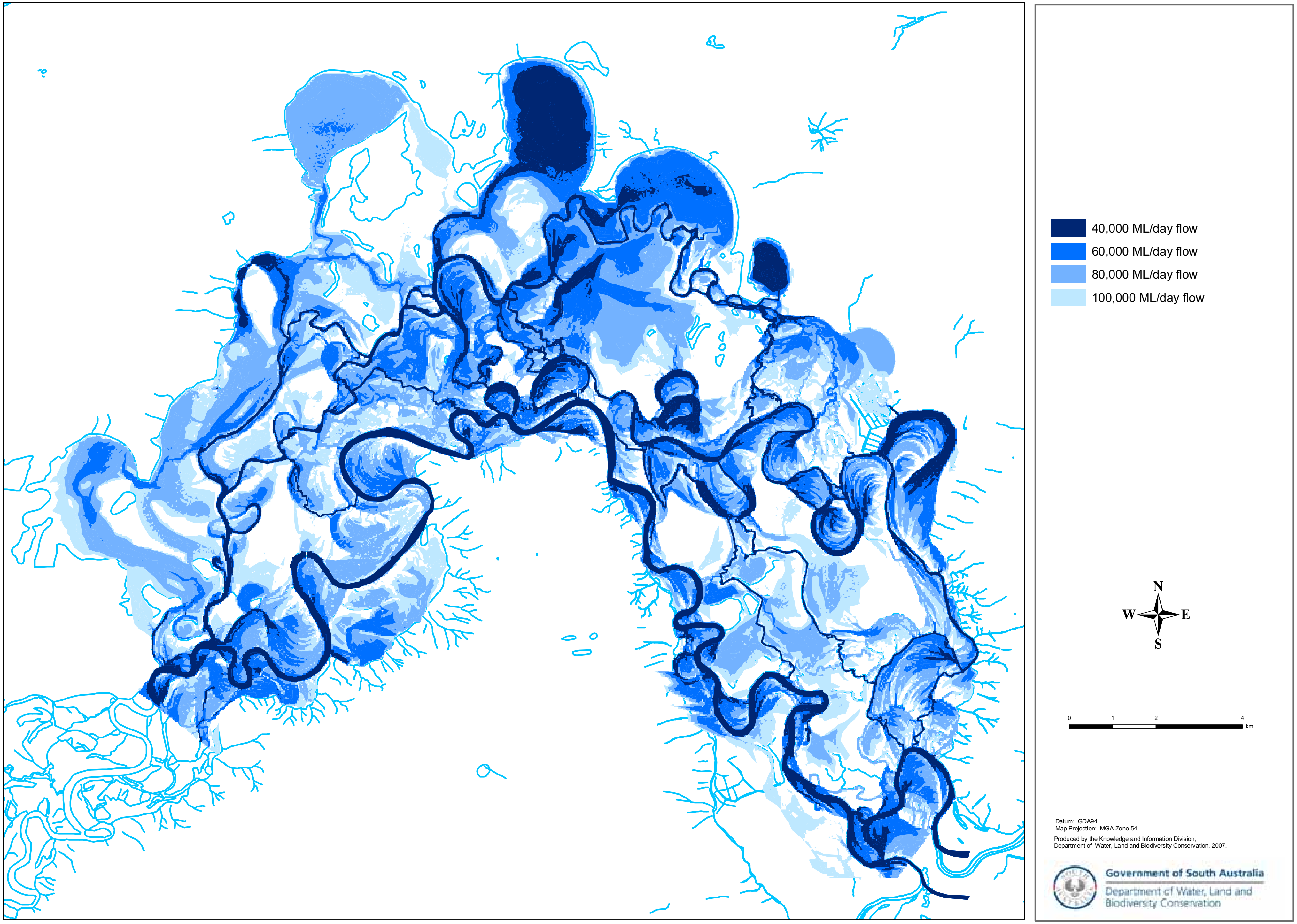


Figure 4. Natural Flood scenario inundation zones

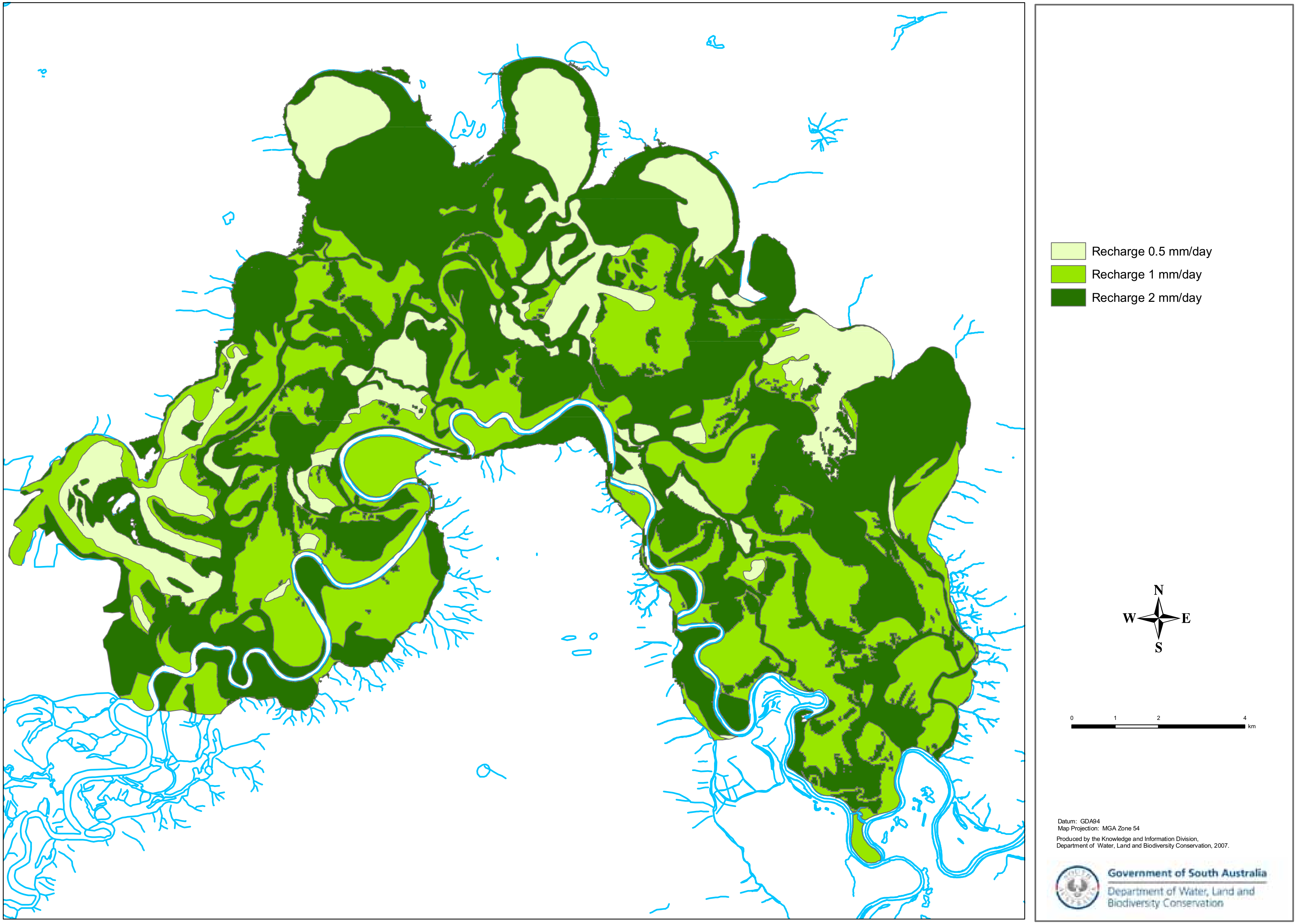


Figure 5. Potential recharge zones

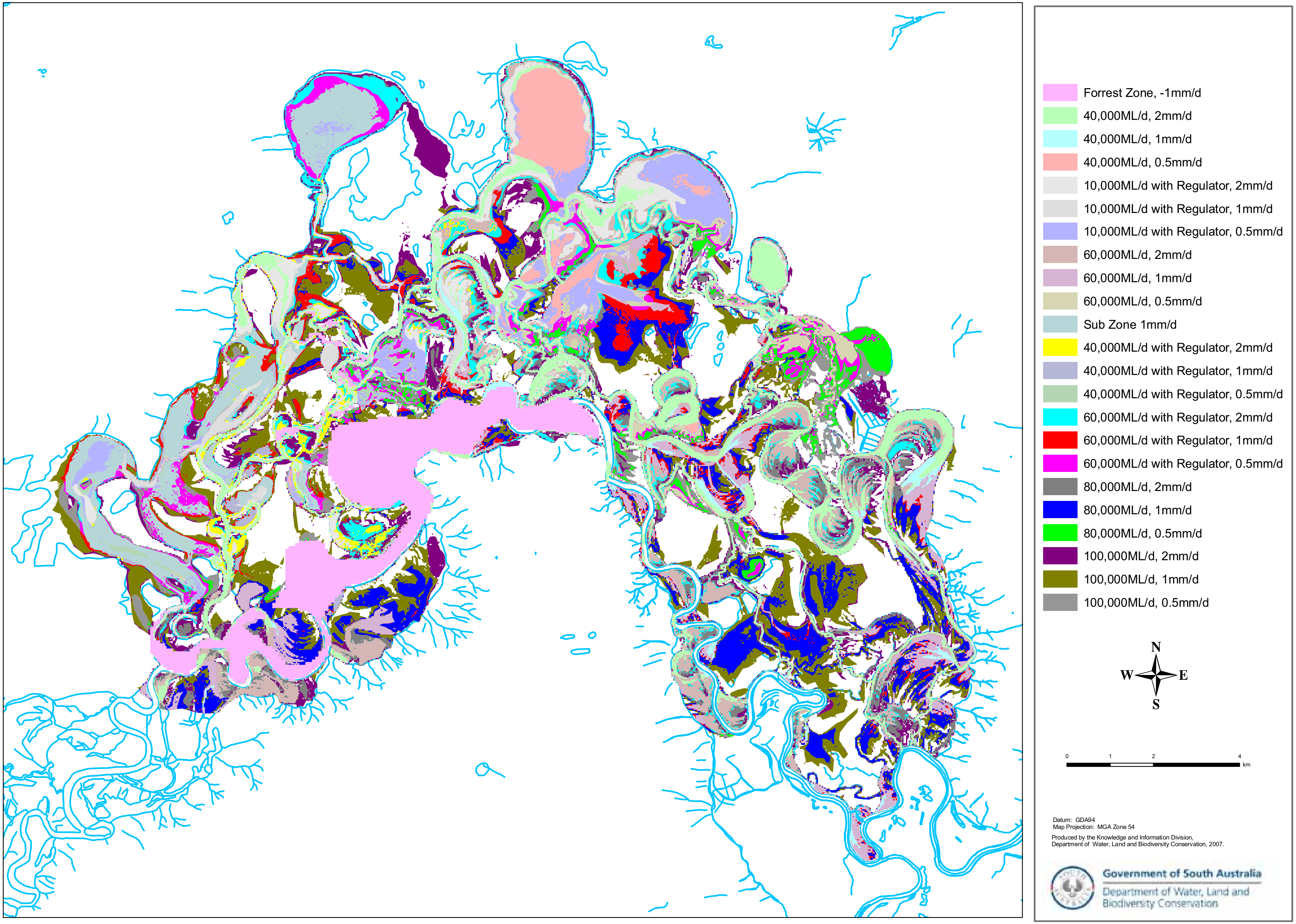


Figure 6. Model recharge zones

Table 2. River cell parameters and creek levels for different river flow magnitudes

MODFLOW River Cell Group #	**Creek Level (m AHD) @ River Murray Flow** (ML/d)						**River Cell Parameters**	
	5000	*20 000*	*40 000*	*60 000*	*80 000*	*100 000*	*Bed Elev (m AHD)*	*Conductance (m^2/d)*
5	19.14	19.90	20.71	21.62	22.24	22.58	18.0	10
6	18.97	19.89	20.66	21.51	22.13	22.46	18.0	10
7	18.25	19.89	20.61	21.38	21.94	22.28	18.0	10
8	18.29	19.89	20.57	21.31	21.86	22.19	17.7	10
9	18.21	19.88	20.49	21.18	21.74	22.03	17.0	10
10	18.10	19.40	20.40	21.03	21.57	21.87	17.8	10
11	17.99	18.90	19.97	20.76	21.32	21.64	17.0	10
12	17.68	18.89	19.92	20.66	21.23	21.57	16.5	10
13	17.82	18.84	19.77	20.50	21.09	21.50	16.1	50
14	17.65	18.00	19.64	20.41	21.02	21.40	16.1	50
16	17.41	17.99	19.49	20.24	20.87	21.22	16.0	10
17	16.70	17.99	19.33	20.18	20.85	21.20	16.0	5
18	16.74	17.91	19.21	20.11	20.79	21.14	14.3	100
19	16.66	17.86	19.12	20.01	20.66	21.02	12.0	50
20	16.66	17.86	18.89	19.48	20.08	20.59	14.5	5
21	16.61	17.46	18.59	19.53	20.29	20.75	13.5	5
22	16.63	17.07	18.17	19.04	19.77	20.29	13.3	5
23	17.66	18.51	19.11	19.95	20.64	21.00	15.0	5
26	16.58	17.89	19.17	20.10	20.79	21.13	15.0	5
27	18.26	19.77	20.35	21.14	21.68	21.98	18.0	5
28	17.84	19.77	20.22	20.84	21.29	21.60	17.4	5
29	19.47	19.68	20.12	20.76	21.24	21.55	17.5	5
30	17.44	18.63	19.79	20.53	21.14	21.48	16.8	5
31	17.06	18.71	19.60	20.37	20.92	21.24	15.0	5

3.1.4 EVAPOTRANSPIRATION RATES AND ZONES

The model evapotranspiration zones have been modified slightly from those applied during the development of the model in 2004. The distribution and values (rate and extinction depth) are shown in Figure 7. Evapotranspiration values have been increased in some localised areas in order to better match observed groundwater levels.

3.2 SCENARIO 2A — NATURAL FLOW WITH GMS

The GMS applied in this model scenario refers to a combination of 20 salt interception production wells and 18 environmental scheme production wells, as reported in Yan et al 2004. The GMS was developed prior to the regulator proposal. The two scheme components were designed to meet different objectives. Salt interception production wells were designed

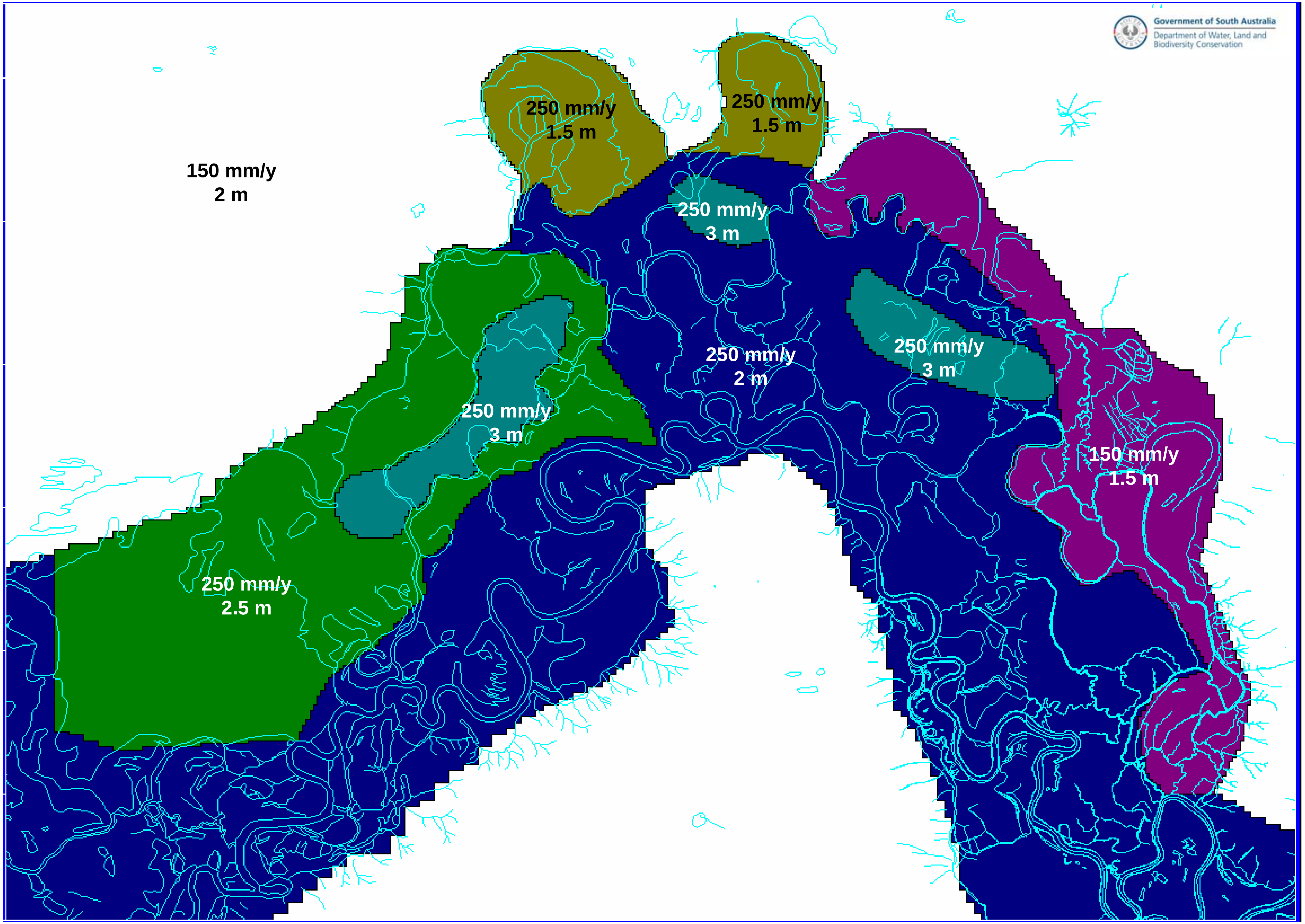


Figure 7. Model evapotranspiration zones (rate (mm/y) and extinction depth (m))

to reduce the hydraulic gradient towards the anabranch creeks to zero. This is achieved when the groundwater level at the mid-point between production wells is reduced to river pool level. Environmental production wells were designed to achieve drawdown of 1.5–2 m in targeted areas (identified by DEH and CSIRO) to provide benefits for vegetation.

The GMS production wells pump continuously from the Monoman Formation, commencing at 5.5 L/s and reducing to a minimum of 3 L/s after five years. The distribution of the production wells is shown in Figure 8.

3.3 SCENARIO 2B — NATURAL FLOW WITH REGULATOR

3.3.1 RIVER MURRAY FLOW HYDROGRAPH

Scenario 2B is based on the simplified River Murray flow hydrograph of the past 30 years with the inclusion of nine regulator operating events (Fig. 9 and App. B). The timing of operating events was provided by IBD and the regulator is assumed to be operating at its maximum level (19.87 m AHD).

For modelling purposes, use of the regulator was considered at three different river flows, 10 000, 40 000 and 60 000 ML/d. Hydrodynamic modelling results (provided by KID in 2006–07) were used to determine inundation zones (Fig. 10) and creek levels (Table 3) for each of the three flow conditions.

A modelling assumption was made that regulator operation during river flows of 5000–20 000 ML/d would adopt 10 000 ML/d flow conditions.

3.3.2 THE RIVER MURRAY (CONSTANT HEAD CELLS)

Constant Head Cells were used to simulate the River Murray (Fig. 3). The cells above Lock 6 vary temporally between 19.25 m AHD at normal river pool level, to 19.87 m AHD when the regulator is in operation.

3.4 SCENARIO 2C – NATURAL FLOW WITH REGULATOR AND GMS

Scenario 2C combines the conditions of Scenario 2A and Scenario 2B (detailed above), i.e. regulator and GMS.

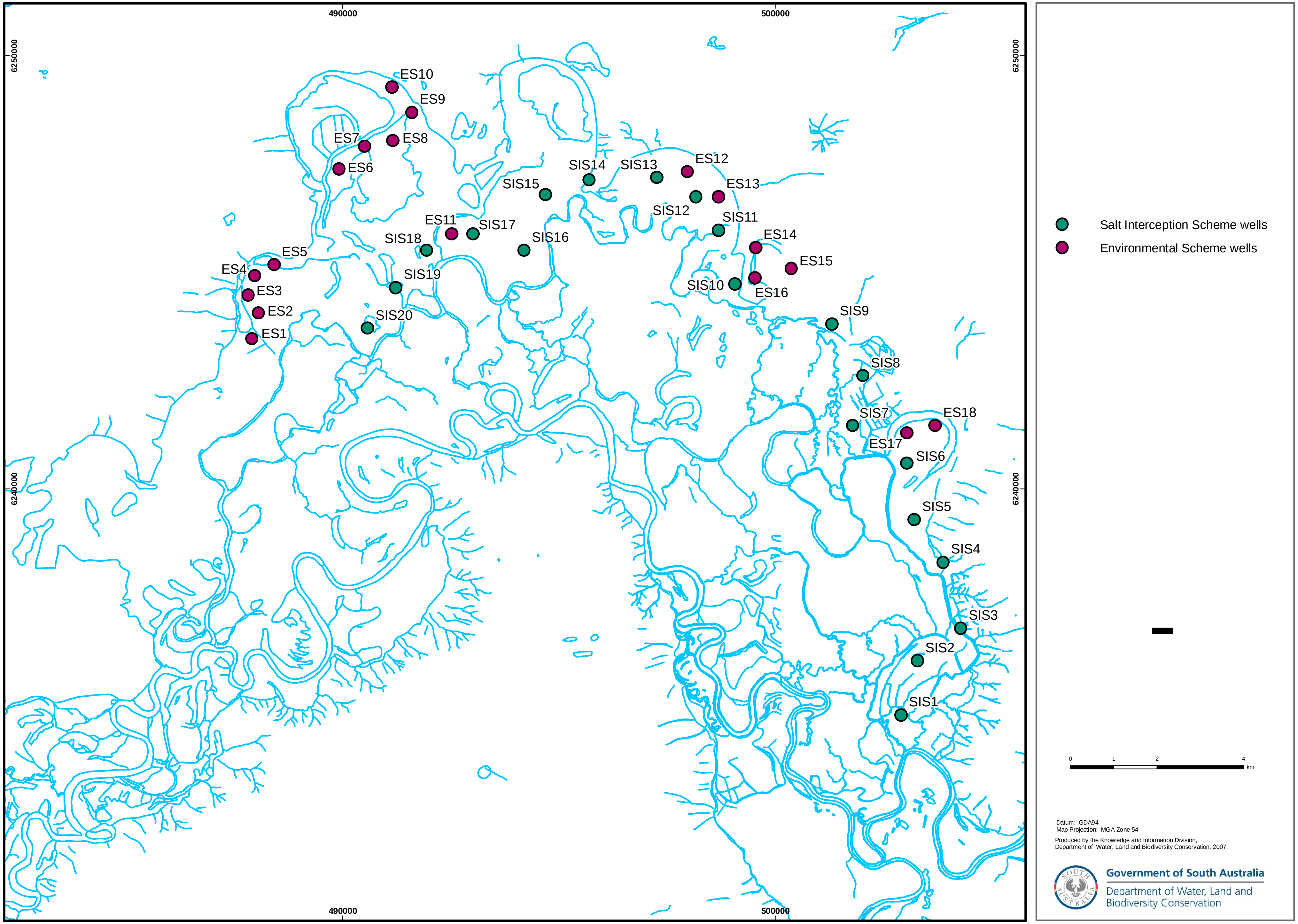


Figure 8. Groundwater management scheme

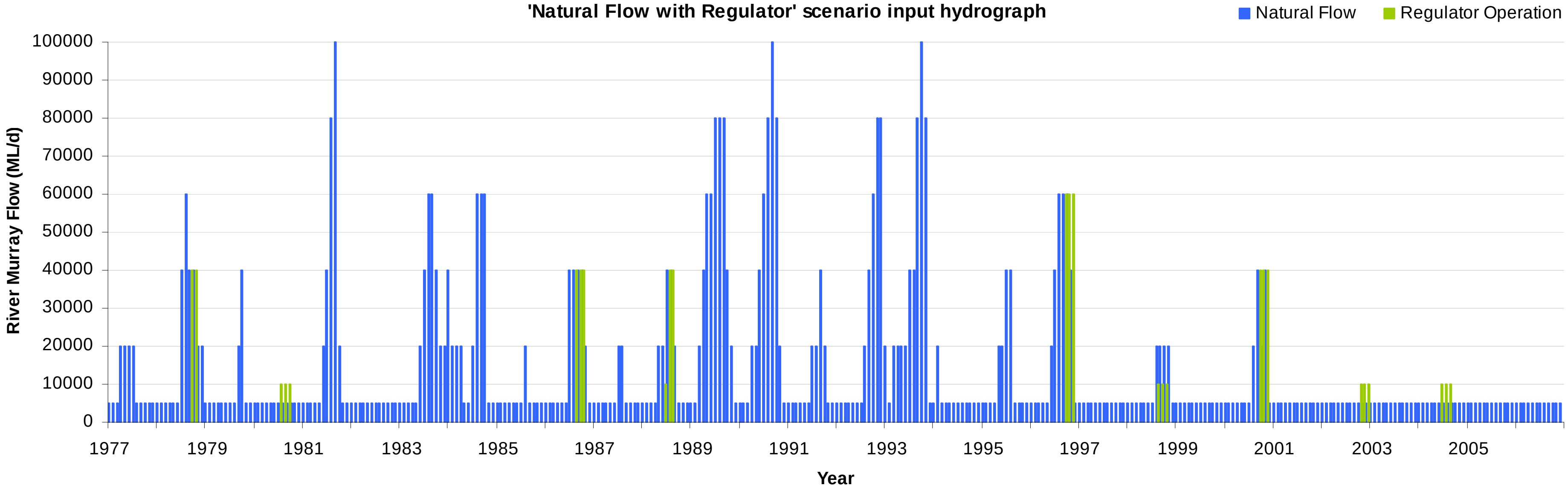


Figure 9. Natural flow with regulator scenario river flow input hydrograph

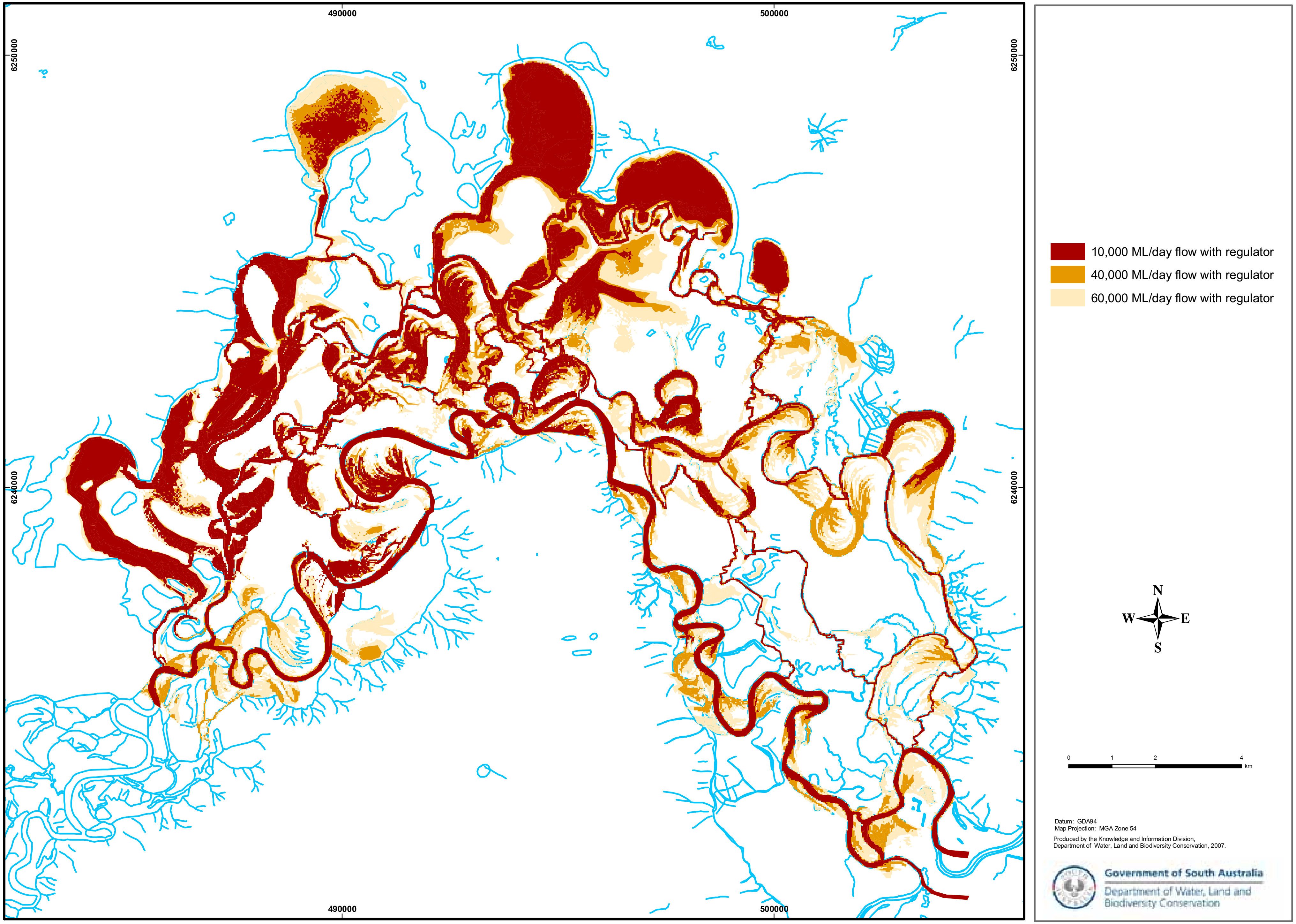


Figure 10. Natural flood with regulator scenario inundation zones

Table 3. Creek levels at various river flows with regulator operating at maximum level of 19.87 m AHD

MODFLOW River Cell Group #	**Creek Level (m AHD) @ River Murray Flow With Regulator Operating at 19.87 m AHD** (ML/d)		
	10 000	*40 000*	*60 000*
5	19.99	20.96	21.71
6	19.98	20.91	21.60
7	19.98	20.85	21.47
8	19.98	20.81	21.41
9	19.97	20.71	21.30
10	19.97	20.61	21.16
11	19.91	20.44	20.94
12	19.91	20.40	20.87
13	19.91	20.32	20.74
14	19.90	20.27	20.68
16	19.89	20.20	20.58
17	19.89	20.18	20.56
18	19.89	20.15	20.51
19	19.89	20.11	20.44
20	19.88	19.93	20.12
21	19.88	19.98	20.22
22	19.88	19.88	20.03
23	19.89	20.10	20.41
26	19.89	20.14	20.51
27	19.96	20.68	21.27
28	19.95	20.53	20.99
29	19.94	20.48	20.93
30	19.91	20.34	20.78
31	19.90	20.26	20.64

4. MODEL CALIBRATION

During the development of the groundwater model in 2004, all model boundary conditions and hydraulic parameters were estimated during calibration. The model and subsequent calibration were based on low river flow conditions and did not include any flooding.

The current model has been calibrated by the following methods:

- Matching modelled and observed groundwater level data at 2003.
- Matching model derived salt loads with observed salt loads over the 30 year period.

Calibration of groundwater levels has only been undertaken for 2003. It should be noted that 2003 represents a relatively dry period of prolonged low river flow. While historic groundwater level monitoring data exists, none is available through periods of flooding.

4.1 QUALITATIVE COMPARISON OF GROUNDWATER LEVELS

Qualitative comparison, between the modelled and observed groundwater level contours for 2003 (Fig. 11) indicates the modelled distribution 'closely' represents the shape and form of the observed distribution in some areas, and 'reasonably' represents it in others.

4.2 NORMALISED ROOT MEAN SQUARED (RMS) ERROR

The normalised root mean squared between modelled and observed groundwater levels was calculated using data from 2003. The calculation (Fig. 12) indicates a normalised root mean squared value of ~5%. This value is less than the 10% recommended by MDBC Groundwater Modelling Guidelines (MDBC, 2001).

4.3 SALT LOAD

The MODFLOW model is a groundwater flux model and produces output in terms of groundwater fluxes entering the anabranch creeks. The salt load accession to the anabranch creeks (which ultimately enter the River Murray) are derived for each scenario by multiplying the modelled groundwater flux and the average groundwater salinity of 25 000 mg/L (App. B).

For calibration purposes, the model derived in-river salt load has been compared to the observed salt load (as calculated by B Porter DWLBC) for the period 1977–2003 using daily in-stream flow and salinity readings from gauging stations positioned in the River Murray above and below the Chowilla Creek confluence (Fig. 13). The match between the model derived and observed salt loads is acceptable. The magnitude of the salt load peaks match well in some years but are over estimated in others. The model derived salt load closely matches the observed salt load during periods of low river flow. It should be noted that the simplified River Murray flow hydrograph used as model input (Fig. 13) dictates the timing and magnitude of the salt load peaks.

Model derived and observed cumulative salt load over the past 30 year period are shown in Figure 14, and indicate a close match, however there is a under-estimation after the relatively dry period ~1995.

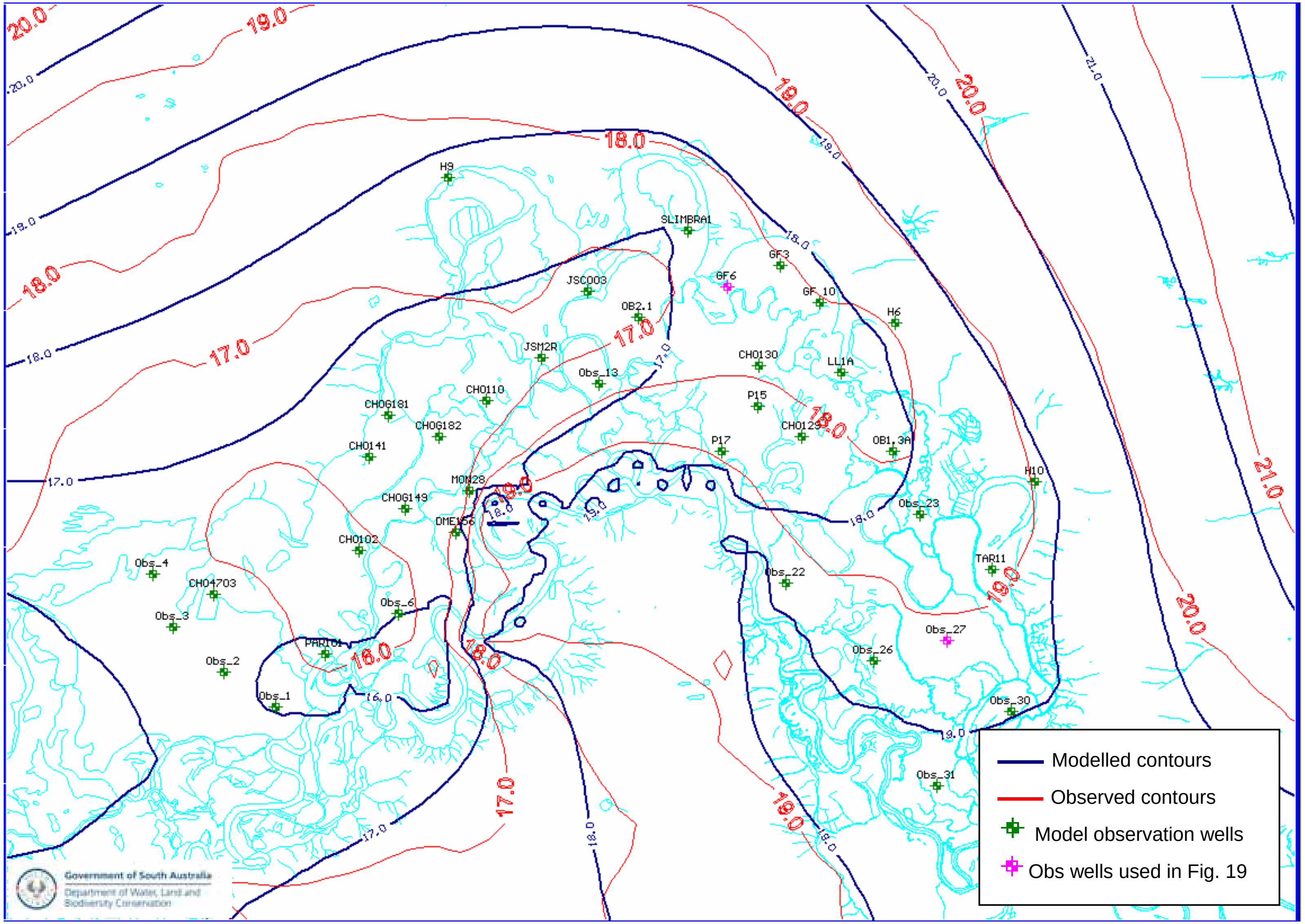


Figure 11. Modelled and observed groundwater level contours (m AHD) in 2003

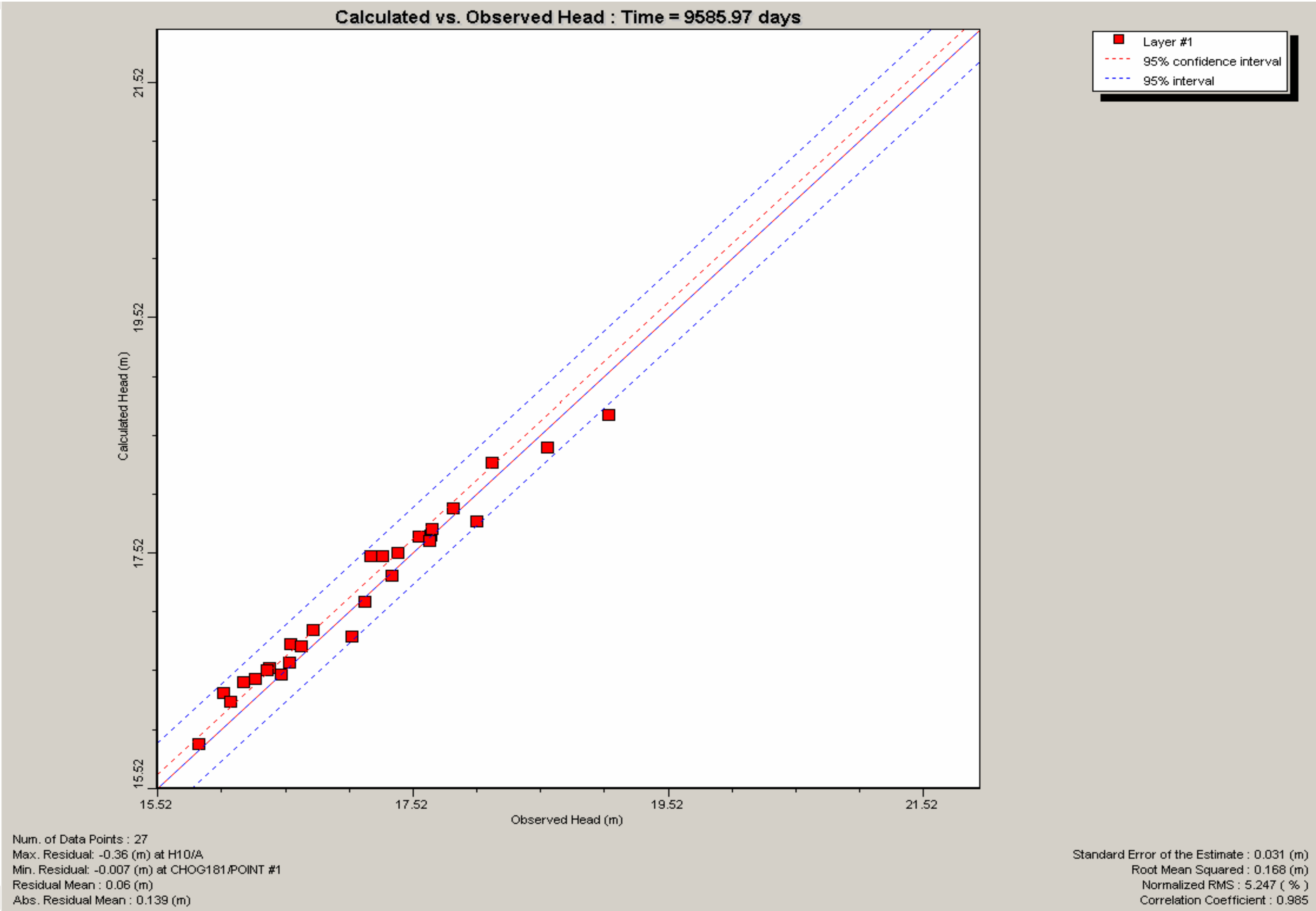
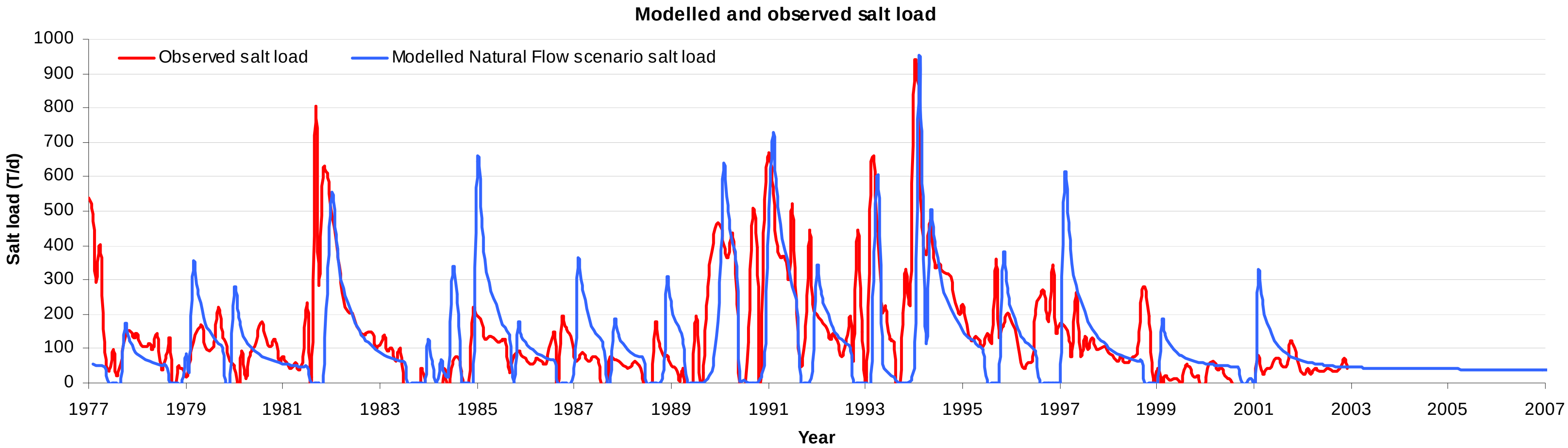


Figure 12. Modelled vs observed groundwater level (2003)



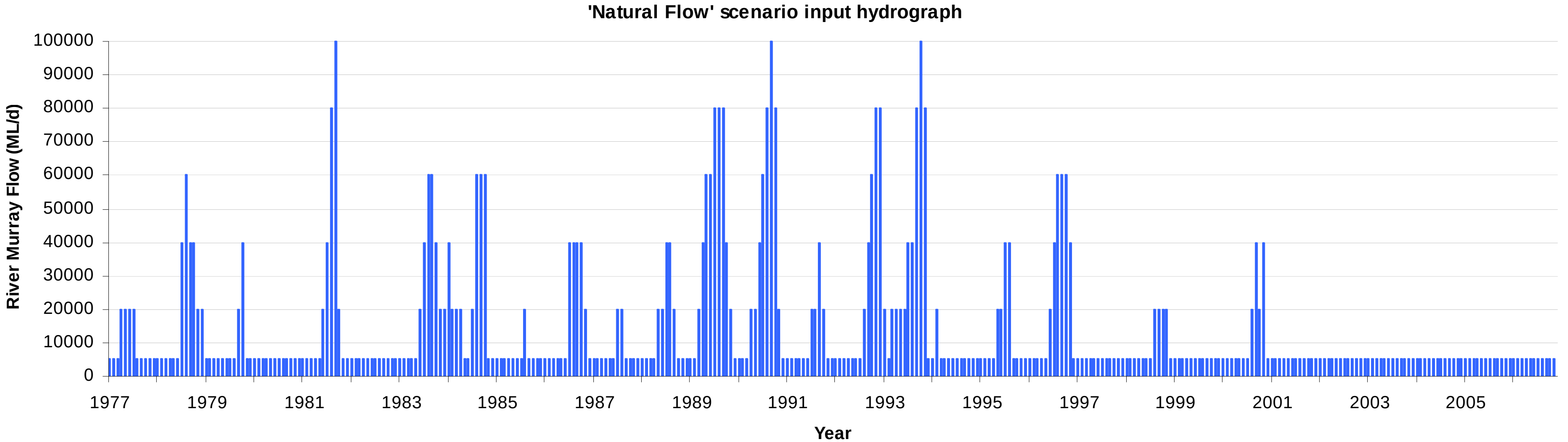


Figure 13. Modelled and observed salt load and the natural flow scenario river flow input hydrograph (ML/d)

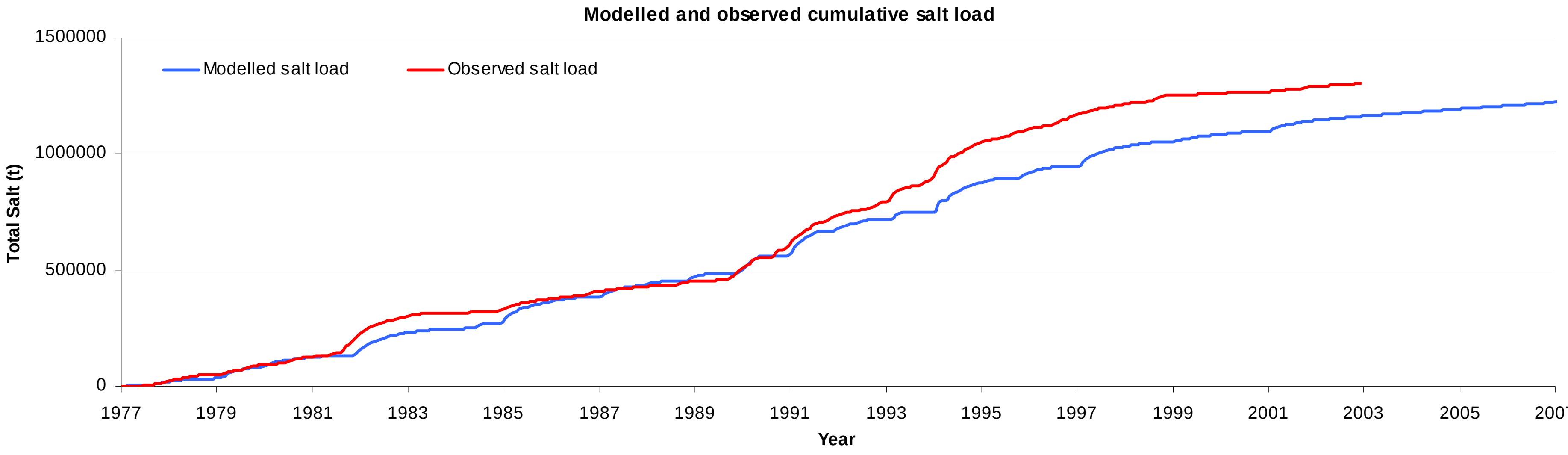


Figure 14. Modelled and observed cumulative salt load (tonnes) over the 30 year simulation period

5. MODEL RESULTS

5.1 SALT LOAD

The salt load accession to the anabranch creeks are derived for each scenario by multiplying the modelled groundwater flux and the average groundwater salinity of 25 000 mg/L.

5.1.1 SCENARIO 1 – NATURAL FLOW

The model derived salt load for Scenario 1 is shown in Figure 13 and is used as a comparison in Figures 16–18. The highest salt load (~950 t/d) occurs in 1994 in response to the 100 000 ML/d flow, which eventually reduces to ~45 t/d after a prolonged period of low river flow.

The average salt load over the 30 year period for the Natural Flow scenario is 112 t/d (Fig. 15).

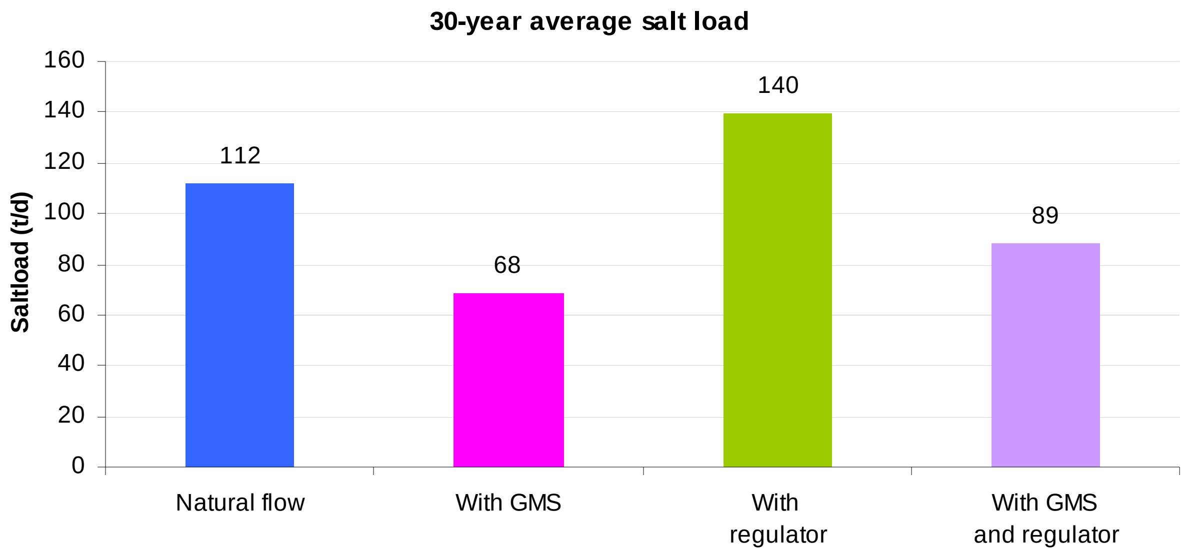


Figure 15. Average salt load for the 30-year period for all scenarios

5.1.2 SCENARIO 2A – NATURAL FLOW WITH GMS

The model derived salt load for Scenario 2A compared to Scenario 1 is shown in Figure 16, and indicates the GMS reduces the salt load both during and between floods.

The results indicate that constant operation of the GMS over the 30 year period would result in an average salt load of 68 t/d, a decrease of 44 t/d in comparison with the natural flow scenario (see Fig. 15).

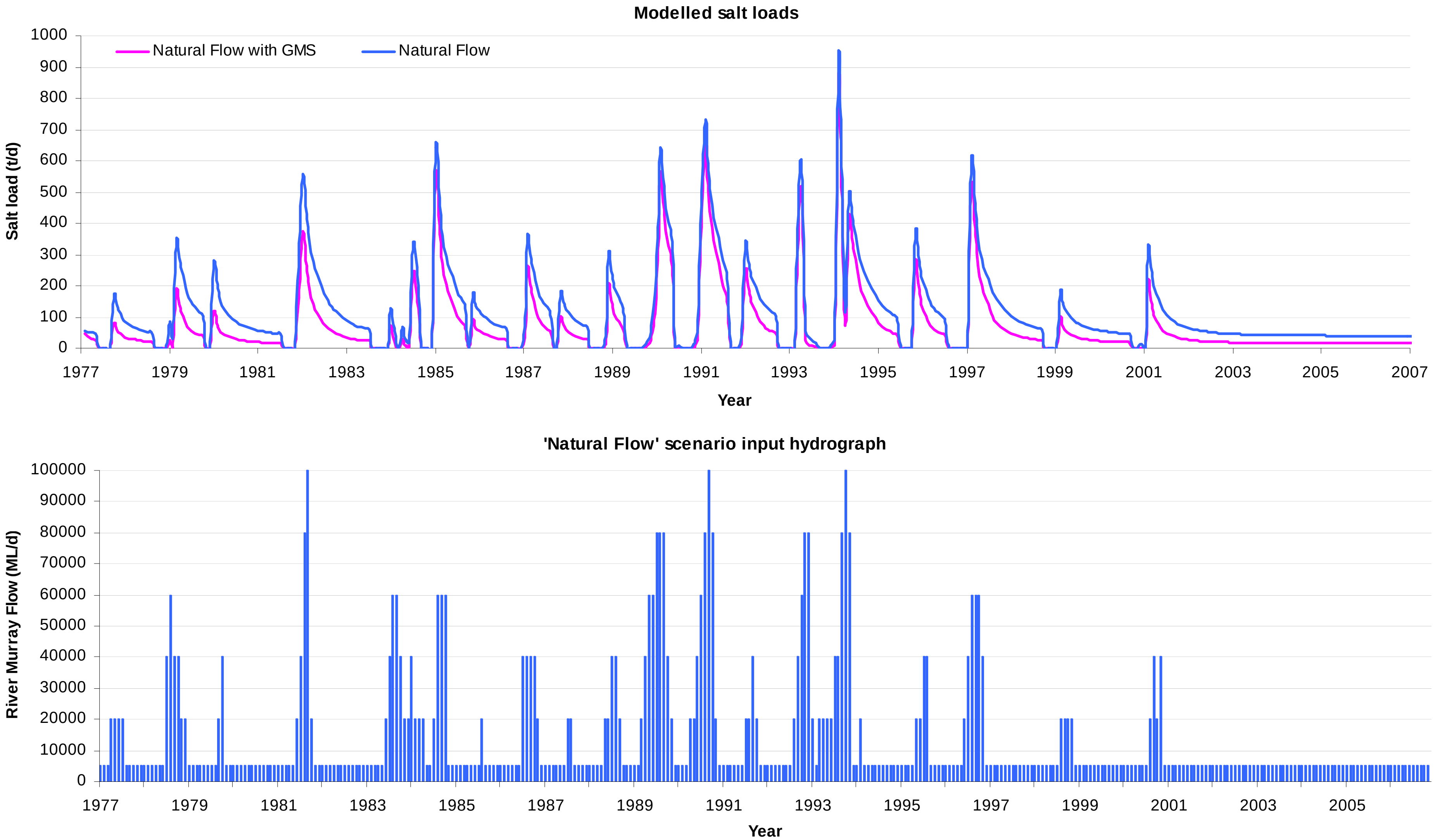
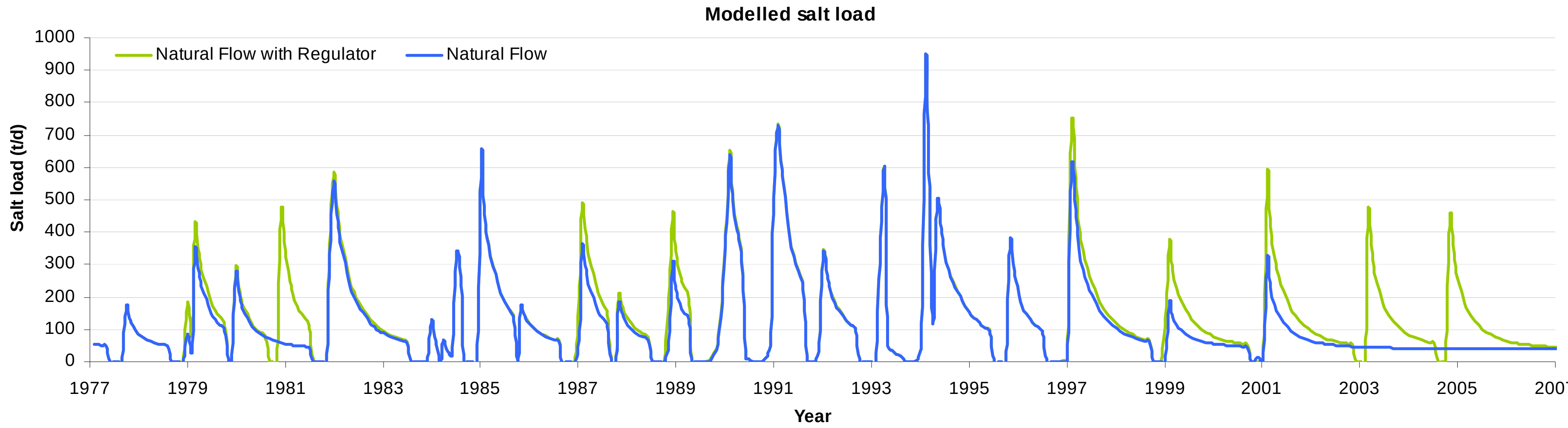


Figure 16. Comparison natural flow with GMS and natural flow salt loads (t/d) and the river flow input hydrograph (ML/d)



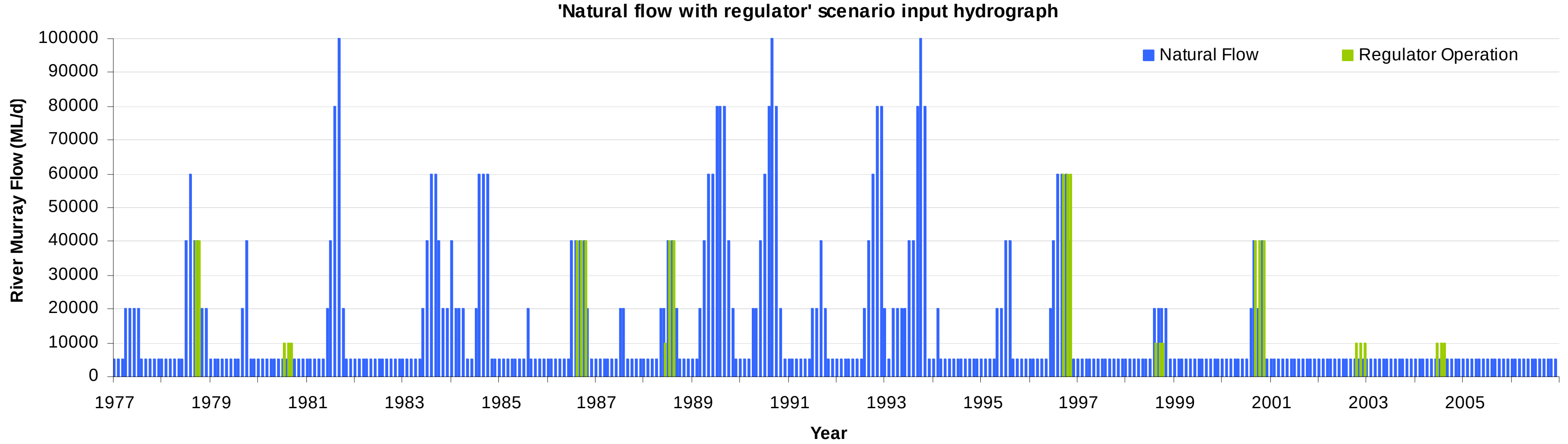
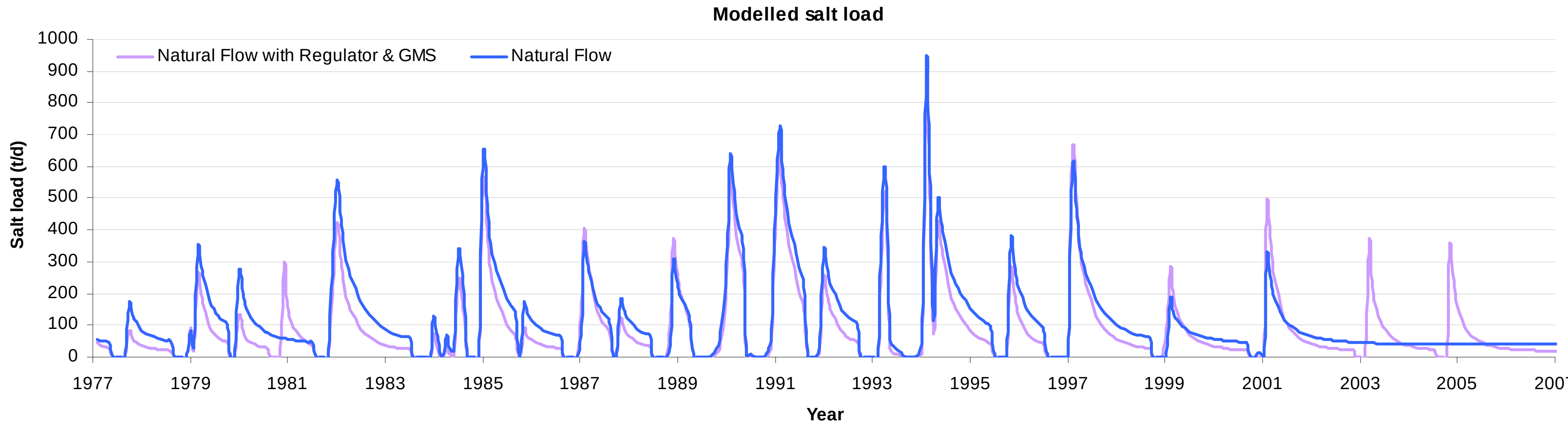


Figure 17. Comparison natural flow with regulator and natural flow salt loads (t/d) and the natural flow with regulator scenario river flow input hydrograph (ML/d)



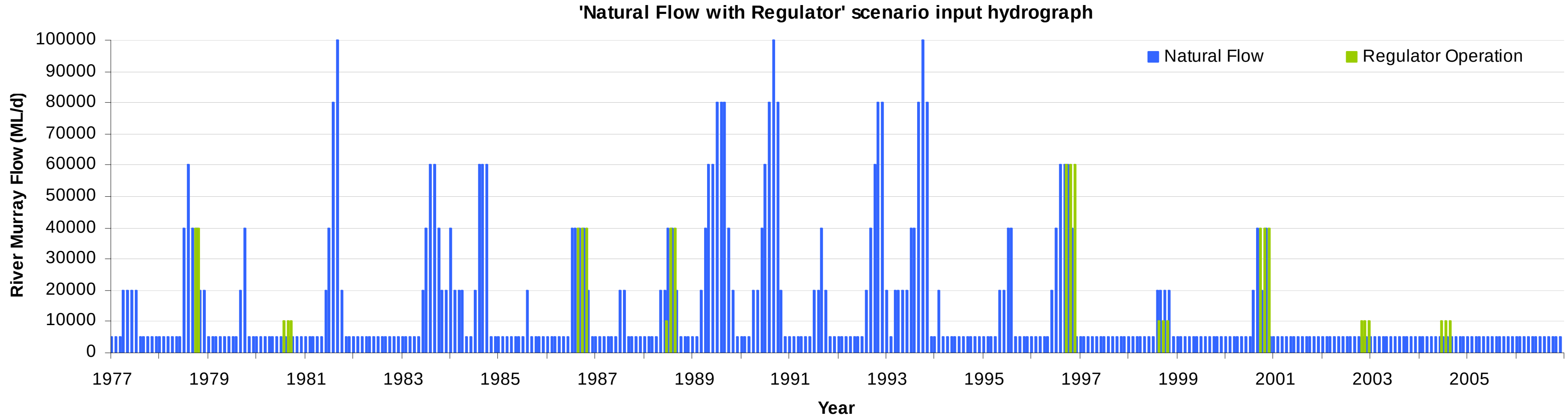


Figure 18. Comparison natural flow with regulator and GMS and natural flow salt loads (t/d) and the natural flow with regulator scenario river flow input hydrograph (ML/d)

5.1.3 SCENARIO 2B – NATURAL FLOW WITH REGULATOR

The model derived salt load for Scenario 2B compared to Scenario 1 is shown in Figure 17 and indicates the regulator increases the salt load during and following operation.

The results indicate that operating the regulator nine times over the 30 year period would result in an average[2] salt load of 140 t/d, an increase of 28 t/d in comparison with the natural flow scenario (see Fig. 15).

5.1.4 SCENARIO 2C – NATURAL FLOW WITH REGULATOR AND GMS

The model derived salt load for Scenario 2C compared to Scenario 1 is shown in Figure 18. The results indicate that operating the regulator nine times, combined with constant operation of the GMS, over the 30 year period would result in an average salt load of 89 t/d, a decrease of 23 t/d in comparison with the Natural Flow scenario (see Fig. 15).

5.2 OUTPUT FOR WINDS MODELLING

After a meeting with interstate stakeholders held in Buronga, Victoria on 8 May 2007, it was agreed that DWLBC would provide CSIRO with the modelled average and maximum groundwater level change (rise) resulting from operation of the regulator, for use in the WINDS model.

The WINDS model requires groundwater level change as a spatial distribution for model input. The regulator event in 2004 was selected to provide the worst-case impact of the regulator as there is no natural flooding during this period, but there is recurring operation of the regulator (Fig. 9).

The groundwater model produces groundwater level distributions for each time step, making it difficult to determine the most appropriate time step to represent the average or maximum groundwater level change (associated with operation of the regulator). This is due to the temporally variable response of the aquifer system, as a function of distance from anabranch creeks and inundation zones. The magnitude, shape and delay of the response varies with proximity to the creeks and inundation zones (Fig. 19). This figure illustrates why output at a single time step cannot capture the mean or maximum groundwater level change.

The mean and maximum groundwater level change spatial distributions were calculated using 11 different groundwater level distributions for the time steps in Figure 19.

The maximum and mean modelled groundwater level change resulting from operation of the regulator are shown in Figures 20 and 21 respectively, and these were provided to CSIRO for input into the WINDS model.

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[2] This means an average salt load in t/d calculated over the entire 30-year period.

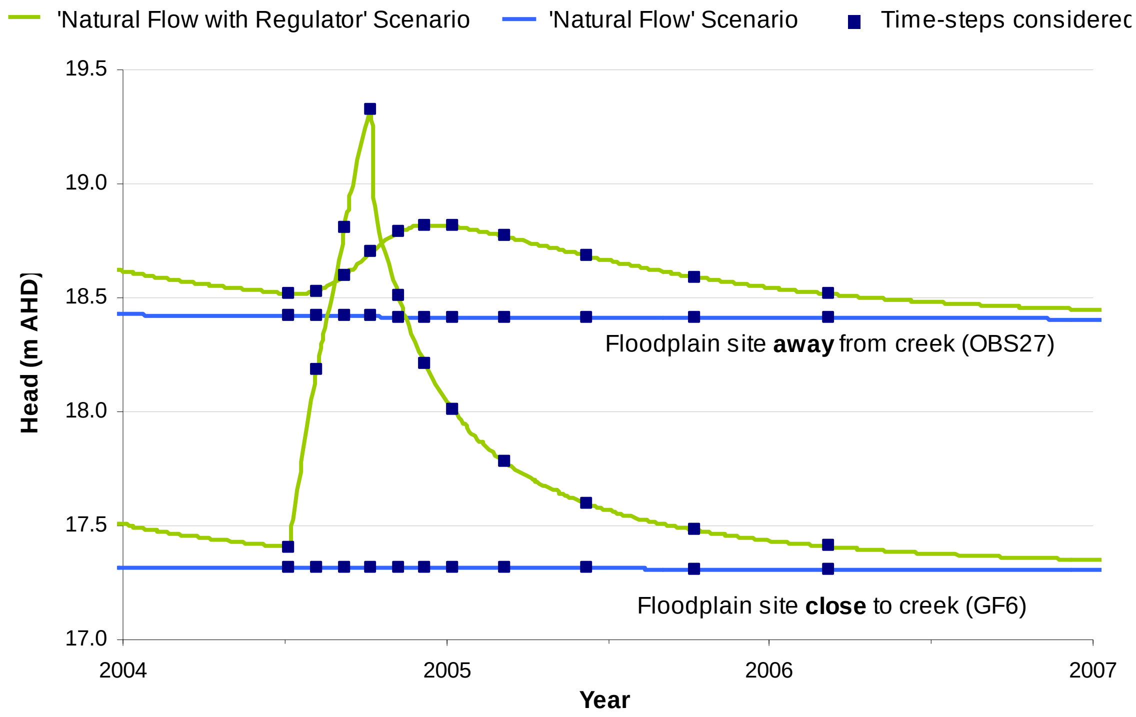

Figure 19. Example of varying groundwater level change resulting from operation of the regulator

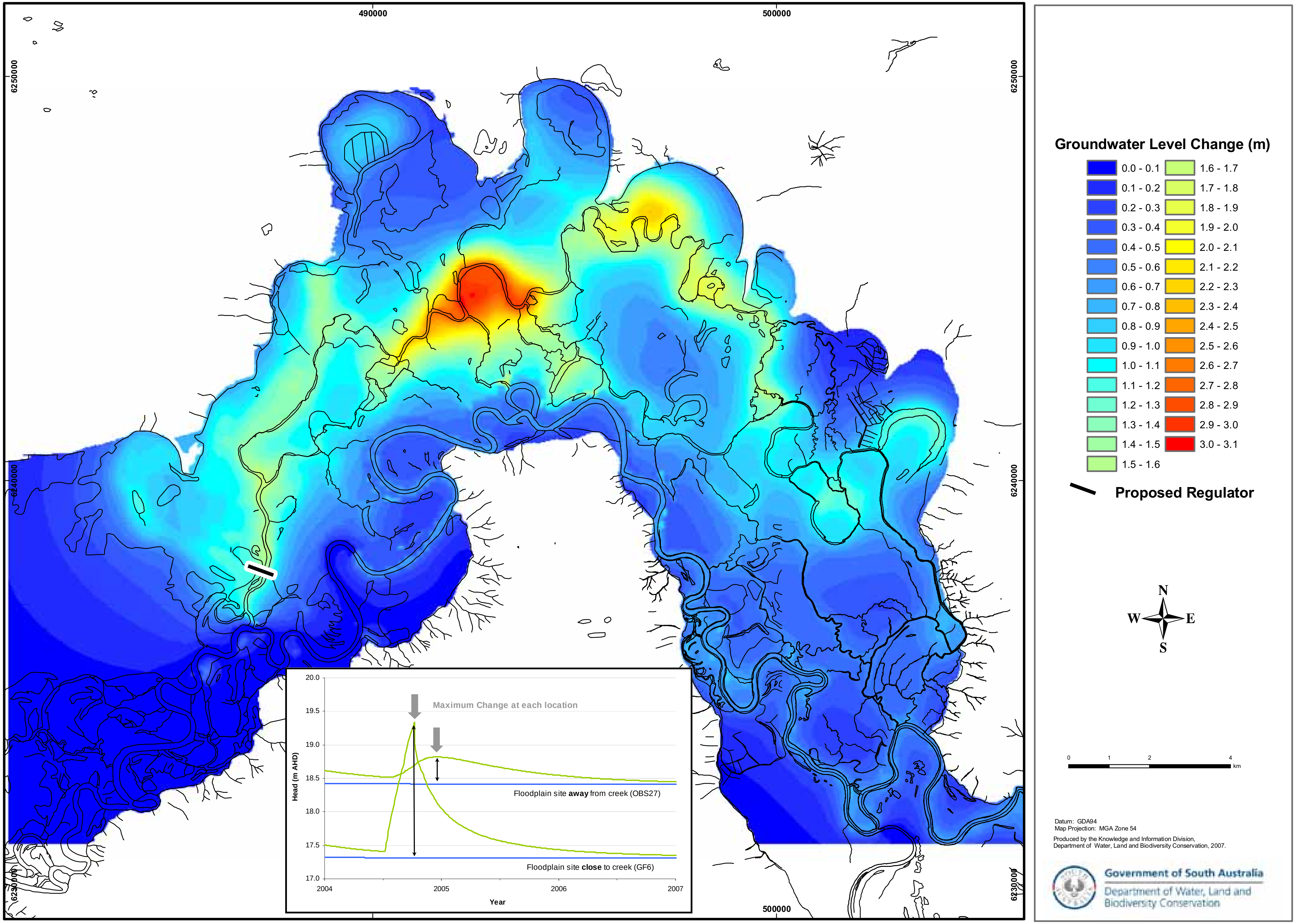

Figure 20. Maximum groundwater level change

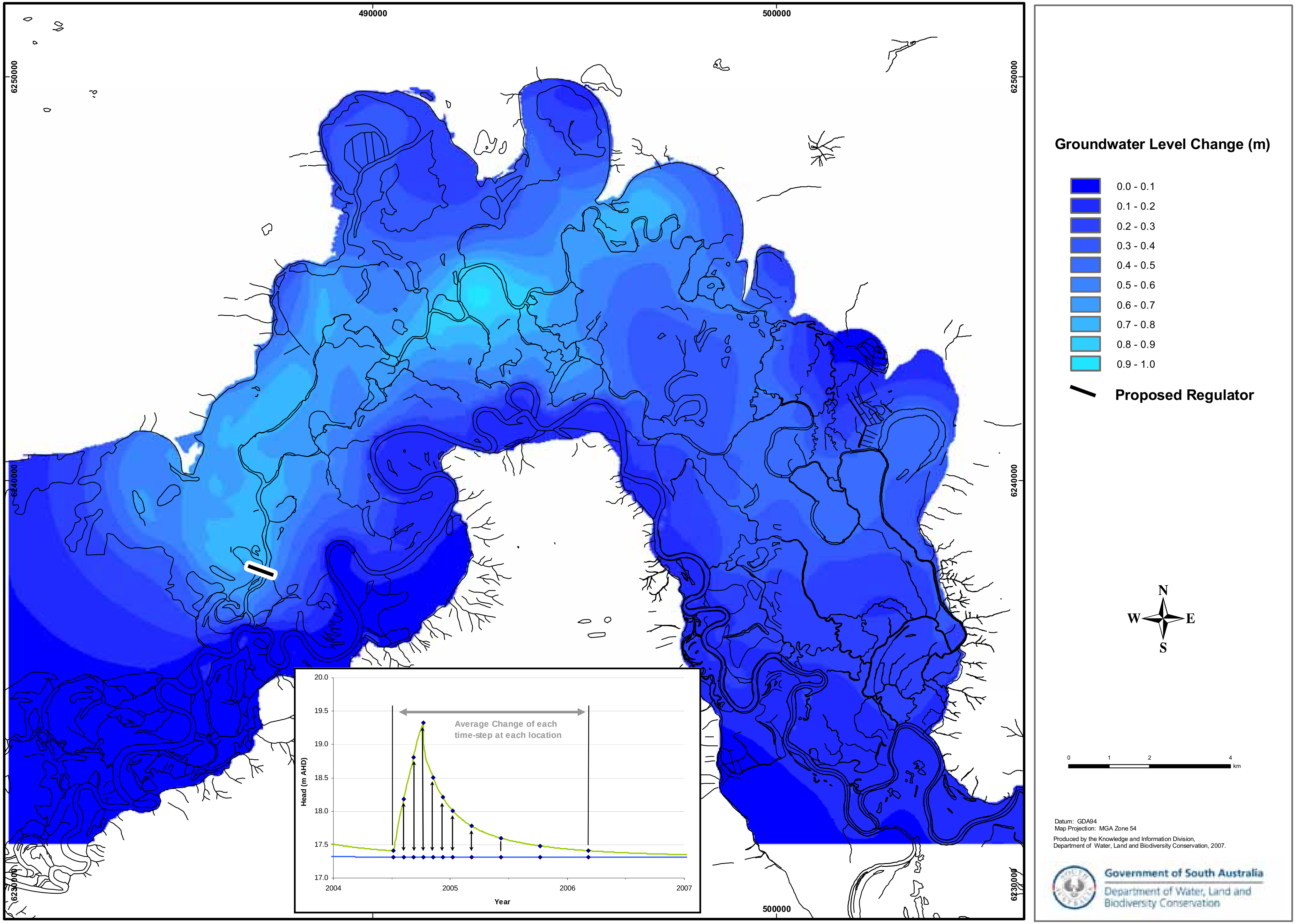

Figure 21. Mean groundwater level change

6. MODEL UNCERTAINTY/LIMITATIONS

The following factors are considered to be the most important in terms of model accuracy and uncertainty in the results.

6.1 HYDRODYNAMIC MODEL INPUT

The accuracy of the hydrodynamic (surface water) model is fundamental to the groundwater model as it provides flood inundation zones and creek level. Although the hydrodynamic model is calibrated against observed floods, there is always some uncertainty inherent in model results. However, this input data represents the best currently available data.

6.2 HYDROGRAPH SIMPLIFICATION

The River Murray flow hydrograph of the past 30 years has been simplified into 30 day time steps and 20 000 ML/d flow magnitude divisions for application in the groundwater model (Fig. 2). Real flood hydrographs are highly variable and this natural complexity cannot be modelled due to the limitations of the modelling package and computer processing capacity. The simplification of the hydrograph, into 30 day time steps and 20 000 ML/d flow magnitude divisions, means that all floods arrive and pass instantaneously. This will have implications in terms of model derived salt load and should be examined further with sensitivity testing.

6.3 SALT PROCESSES

The MODFLOW model is a groundwater flux model and produces output in terms of groundwater fluxes entering the anabranch creeks. The salt load accession to the anabranch creeks (which ultimately enter the River Murray) are derived for each scenario by multiplying the modelled groundwater flux and the average groundwater salinity of 25 000 mg/L.

Complex salt processes not considered in the model include:

- Variations in groundwater salinity (both spatially and temporally).
- Reduction in groundwater salinity following flooding.
- Unsaturated zone salt storage and soil processes.
- Surface salt wash-off during floods.

These processes are fundamental to the highly complex movement of salt through the floodplain landscape but are beyond current modelling capabilities.

6.4 LIMITED DATA FOR CALIBRATION

There is high confidence in modelled groundwater levels during periods of prolonged low river flow since the normalised root mean squared for the 2003 calibration is within the MDBC Groundwater Modelling Guidelines limit of ten percent. This calibration result has been derived from the low river flow condition.

No calibration has been undertaken during periods of flooding, as no reliable groundwater level data exists at these times.

The model derived salt load provides confidence in the groundwater model, as it indicates an acceptable match to observed values.

7. CONCLUSIONS AND RECOMMENDATIONS

The numerical groundwater model was used to simulate the aquifer hydraulic response to natural flooding and flooding induced by the regulator using a simplified version of the River Murray flow hydrograph of the past 30 years. The model simulates changes in groundwater level and quantifies groundwater flux to the anabranch creek system of the Chowilla floodplain, and ultimately allows calculation of the salt load accession to the River Murray. A number of scenarios involving various management options have been developed in order to predict their likely impact on the aquifer system, and anabranch creeks.

Figure 15 and Table 4 indicate the 30 year average salt load accession to the anabranch creek system for all scenarios.

Table 4. 30 year average salt load accession to the anabranch creek system for the scenarios

No.	Name	30 year average salt load (t/d)
1	Natural Flow	112
2A	Natural Flow with GMS	68
2B	Natural Flow with Regulator	140
2C	Natural Flow with Regulator and GMS	89

7.1 RECOMMENDED WORK

7.1.1 REVISED RIVER FLOW HYDROGRAPH

Flow conditions in the River Murray have changed in the past 30 years due to additional diversions, and changes in flow management. At the Buronga meeting of 8 May 2007, it was recommended that a revised river flow hydrograph be developed to replace the simplified version of the River Murray flow hydrograph of the past 30 years. The new hydrograph should be developed as the basis for future predictive scenarios.

At the meeting, it was agreed that the revised river flow hydrograph would be developed by the MDBC using current diversion and management regimes, with a conservative prediction of future climatic conditions. The hydrograph would align with the benchmark period (1975–2000) identified in the Basin Salinity Management Strategy protocol, and potentially allow in-river EC impacts to be included on the salinity register.

7.1.2 SENSITIVITY TEST – SLOW AND RAPID REGULATOR RECESSION

Scenario2B (natural flow with regulator) provides some indication of the salt load accession induced by the use of the regulator operating at the maximum level (19.87 m AHD). The peak salt load indicated in this scenario may cause some concern in terms of in-river EC impacts. It is recommended that sensitivity testing be conducted, which will involve examining the salt load response resulting from altering the time period taken to lower the pool level held behind the regulator. The model results may assist with optimising regulator operating schedules and provide an increased level of confidence in the previous modelling results.

APPENDICES

A. PROJECT PROPOSAL

ASSESSMENT OF SALINITY IMPACTS AND WATER USE RESULTING FROM FLOW MANAGEMENT ON THE CHOWILLA FLOODPLAIN — JANUARY 2007

1. INTRODUCTION

This proposal has been prepared by DWLBC Knowledge and Information Division (KID) in response to a brief issued by Strategic Policy Division (SPD) Environmental Flows Program.

2. APPRECIATION OF THE BRIEF

2.1 Background

The Chowilla floodplain is one of six Significant Ecological Assets identified within the Murray Darling Basin by the Murray Darling Basin Ministerial Council. As such, Chowilla is a priority site for the delivery of environmental flows using water made available through the MDBC Living Murray Initiative First Step decision. It is also a priority site for investment in structural and operational change through the MDBC Environmental Works and Measures Program.

In addition to its ecological importance the Chowilla floodplain is well recognised as a discharge point for the regional saline aquifer and significant volumes of salt are intercepted by anabranch creeks and/or stored in floodplain soils. The salt entering Chowilla is ultimately mobilised and transported to the River Murray during and following large floods. Salt load accessions following large flood events can exceed 1000 tonnes per day while salt loads during low flow periods (i.e. current conditions) are only 30–40 tonnes per day.

Like the majority of the lower Murray floodplain, much of the Chowilla area is under stress from the combined effects of salt accumulation and lack of flooding. To combat these threats plans have been developed to construct a groundwater interception scheme and flow management infrastructure. The preferred flow management infrastructure consists of a regulator in the Chowilla Creek that would enable the water level in the anabranch to be raised and large areas of the floodplain to be inundated, even under low flow conditions.

The impacts of the operation of such a regulator need to be considered in terms of salinity impact and water use. Initial estimates have been completed for both of these impacts (CSIRO 2005) but both were based on a simplistic operating regime and over a limited period of time. A more detailed and realistic assessment is now required to inform the further progress of this proposal.

2.2 Project scope

The major purpose of this project is to quantitatively assess the impacts of flooding large areas of the Chowilla floodplain in terms of water use and resultant salinity impact. As the impacts of the flow management activities may need to be reported under Schedule C of the MDB Agreement it will be important to quantify the difference between the do nothing and flow management scenarios. The outputs from this project will further inform the development of flow management strategies and proposals for investment in infrastructure. The standard flow management regime to be assessed as part of objective 1 will be provided in the form of a 30-year hydrograph with periods the regulator is in operation clearly identified.

2.3 Project Objectives

The project objectives, reproduced from the brief, are following. By agreement with the client objective 2B has been removed from the scope of the project.

Objective 1. Determine the salinity impacts of flow management compared to the do nothing scenario in terms of:

A. EC and salt load change at Morgan over the MDBC Benchmark period.

B. EC and salt load (tones/day) change (peak and average) immediately down stream associated with managed flow events.

C. Potential EC and salt load change in the Ral Ral system following managed flow events.

Objective 2. Quantify changes in in-stream salinity (as per 1A-C) for variations of the specified operating regime. Variations to be assessed will include:

A. Increase or decreased duration of flooding.

B. Increased or decreased frequency of flooding.

C. Release/recession rate of water back into the Chowilla Creek.

D. Provision of dilution flows in the main channel.

Objective 3. Determine the water volume usage associated with all flow management regimes in terms of:

A. Volume used for specified events.

B. Volumes used assuming varied frequency and duration of events (as per objective 2).

Objective 4. Estimate the long-term consequences of frequent flooding on the freshening of the groundwater aquifer and the resultant post flood salt loads.

Objective 5. Assess the influence of the management strategies on the performance of the proposed “no regrets” SIS in terms of.

A. EC benefit.

B. Post flood accession reduction.

3. METHODOLOGY

KID propose to achieve the project objectives through a combination of hydraulic, groundwater, and hydrologic modelling, utilising models that are available or will shortly be available. These are:

- A groundwater model on the MODFLOW platform, developed in the course of previous studies in the region.
- A hydraulic (surface water) model on the MIKE Flood platform, developed by consultants DHI Water and Environment as part of a related project.
- The Murray Darling Basin Commission's daily hydrologic (river-operations) model MSM-BigMod.

The methodology proposed for the modelling work is illustrated conceptually in Figure 3.1. For a set of flood events and management actions to be supplied by the client, the hydraulic (surface water) model will be used to map the spatial and temporal extent of floodplain inundation. The hydraulic model will also be used to report the floodplain water use associated with each of these management actions. The inundation extent(s) predicted by the hydraulic model will be used as input to the groundwater model, in conjunction with updated groundwater recharge zone maps being developed by CSIRO at present. The groundwater model will predict the magnitude of salt accessions from the floodplain.

Salt accessions predicted by the groundwater model will be added to MSM-BigMod and MSM-BigMod run to assess changes in River salinity immediately downstream of Chowilla, in the Ral Ral Creek anabranch, and at Morgan.

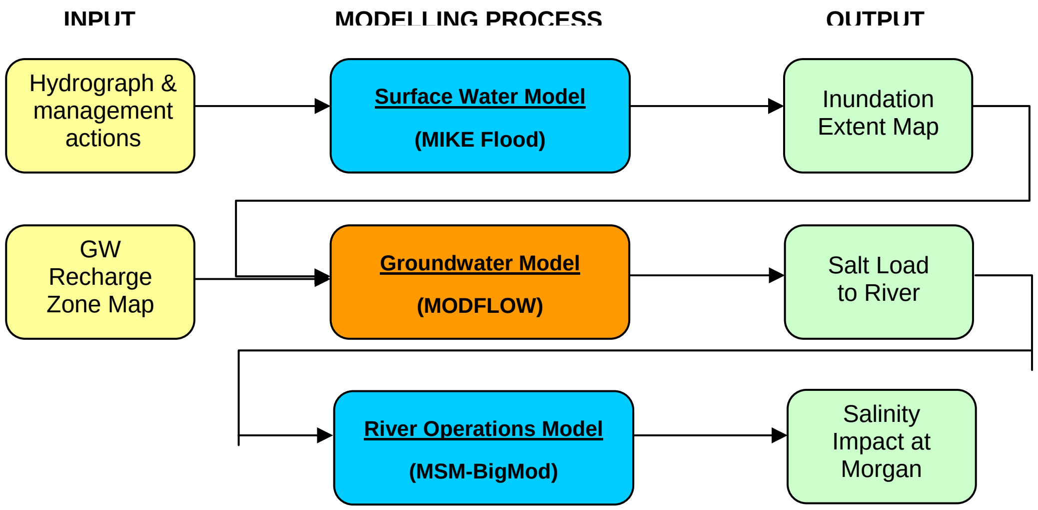

Figure 3.1 Proposed methodology for modelling work

The modelling effort will be constrained primarily by:

- run-times for the hydraulic model (at best ~30 times real-time),
- the time-step for MODFLOW runs, which experience suggests cannot be reduced below one month for reliable runs.

KID propose modelling only a limited number of scenarios selected to best address the project objectives within the modelling and time constraints. These scenarios are described in Table 3.1 below. Scenario five involves the use of the (computationally) resource intensive MT3D model. The time period over which the MT3D model can be run will be limited to the maximum which available computer resources reliably allow, which can only be determined once work commences.

Table 3.1 Proposed modelling scenarios

Scenario Number		Satisfies objective	Scenario Title	Scenario Description	Scenario Time Frame	Model Runs: *MIKE Flood*	*MODFLOW*	*MSM-BigMod*
1		1, 2, 3, 5	Base Case	Present conditions. No SIS and no weir.	30 y	✓	✓	✓
2	a	2A, 3, 5	Chowilla SIS	With Chowilla SIS but no weir.	30 y		✓	✓
	b		Chowilla Weir	With Chowilla Weir but no SIS.	30 y		✓	✓
	c		Chowilla SIS + Weir	With Chowilla Weir and SIS.	30 y	✓	✓	✓
	d		Increased flood duration	With Chowilla Weir, duration of flood peaks prolonged (doubled).	30 y		✓	✓
3	a	2C, 3	'Slow' recession	Chowilla Weir at full level initially and then lowered 'slowly' (eg 1 m per month).	One event	✓	✓	✓
	b			Sensitivity test. As for 3a with reduced MODFLOW timestep if possible.	One event		✓	✓
	c		'Rapid' recession	Chowilla Weir at full level initially an then lowered 'rapidly'(eg completely in 1 month).	One event	✓	✓	✓
4	a	2D	Dilution flows	Chowilla Weir and additional 2k Ml/d dilution flow (temporal distribution to be determined).	30 y			✓
	b			Chowilla Weir and additional 5k Ml/d dilution flow (temporal distribution to be determined).	30 y			✓
	c			Chowilla Weir and additional 10k Ml/d dilution flow (temporal distribution to be determined).	30 y			✓
5		4	Aquifer freshening	Consequences of frequent flooding on aquifer salinity using MT3D.	TBA		✓	

3.1 Project Tasks

Details of the tasks to be undertaken are following. An indicative Gantt chart is in Appendix A.

3.1.1 Task 0 – Project Management

Purpose: Administer, coordinate, organise and supervise the project.

Input: Project brief, project proposal, client agreement.

Description:

- Administer and direct the project.
- Monitor work progress and costs against schedule and budget.
- Liaise with client.

Responsibility: Nicholas Souter.

Outputs: Timely completion of project and reporting to the client's satisfaction.

3.1.2 Task 1 – Hydraulic Modelling (MIKE Flood)

Task 1.1 Run hydraulic model base case

Purpose: Provide the inundation maps for the scenarios without Chowilla Weir (including the 'do nothing' scenario).

Input: Hydrograph provided by client.

Description: Run the hydraulic model over the 30-year period to determine the spatial and temporal extent of inundation with no Chowilla Weir.

Responsibility: DHI Water and Environment.

Outputs:

- Inundation maps for Scenarios 1 and 2a.
- Water use for Scenarios 1 and 2a.

Task 1.2: Run hydraulic model with Chowilla Weir

Purpose: **Provide the inundation maps for the scenarios with Chowilla Weir.**

Input:

- Hydrograph provided by client.
- Proposed weir operating rules provided by client.

Description: Run the hydraulic model over the 30-year period to determine the spatial and temporal extent of inundation with Chowilla Weir.

Responsibility: DHI Water and Environment.

Outputs:

- Inundation maps for Scenarios 2b, 2c, 2d and 4.
- Water use for Scenarios 2b, 2c, 2d and 4.

Task 1.3: Run hydraulic model for a 'slow' recession event

Purpose: Provide the inundation maps for a 'slow' recession of Chowilla Weir.

Input:

Description: Run the hydraulic model with the Chowilla weir initially at full level and then slowly draw down at the rate of 1m per month.

Responsibility: DHI Water and Environment

Outputs: Inundation maps for Scenarios 3a and 3b.

Task 1.4: Run hydraulic model for a 'rapid' recession' event

Purpose: Provide the inundation maps for a 'slow' recession of Chowilla Weir.

Input: Choice of event to be agreed with client.

Description: Run the hydraulic model with the Chowilla weir initially at full level and then fully draw down in one month.

Responsibility: DHI Water and Environment.

Outputs: Inundation maps for Scenario 3c.

3.1.3 Task 2 – Groundwater Modelling (MODFLOW)

Task 2.1: Run groundwater model base case

Purpose: Estimate the salt-load for the scenarios without SIS or Chowilla Weir.

Input:

- Inundation map from Task 1.1.
- Groundwater recharge maps.

Description: Run the groundwater model over the 30-year period to predict the salt load with no SIS and no Chowilla Weir.

Responsibility: Wei Yan

Outputs: Salt-load for Scenario 1.

Task 2.2: Run groundwater model with SIS

Purpose: Estimate the salt-load for the scenario with SIS and without Chowilla Weir.

Input:

- Inundation map from Task 1.1.
- Groundwater recharge maps.

Description: Run the groundwater model over the 30-year period to predict the salt load with SIS and no Chowilla Weir.

Responsibility: Wei Yan

Outputs: Salt-load for Scenario 2a.

Task 2.3: Run groundwater model with Chowilla Weir

Purpose: Estimate the salt-load for the scenario with Chowilla Weir and without SIS.

Input:
- Inundation map from Task 1.2.
- Groundwater recharge maps.

Description: Run the groundwater model over the 30-year period to predict the salt load with Chowilla Weir and without SIS.

Responsibility: Wei Yan

Outputs: Salt-load for Scenario 2b.

Task 2.4: Run groundwater model with Chowilla Weir and SIS

Purpose: Estimate the salt-load for the scenario with Chowilla Weir and SIS.

Input:
- Inundation map from Task 1.2.
- Groundwater recharge maps.

Description: Run the groundwater model over the 30-year period to predict the salt load with Chowilla Weir and SIS.

Responsibility: Wei Yan

Outputs: Salt-load for Scenario 2c.

Task 2.5: Run groundwater model with increased flood duration

Purpose: Estimate the salt-load from increasing flood duration.

Input:
- Inundation map from Task 1.2.
- Groundwater recharge maps.

Description: Run the groundwater model over the 30-year period to predict the salt load from prolonging (doubling) duration of flood peaks.

Responsibility: Wei Yan

Outputs: Salt-load for Scenario 2d.

Task 2.6: Run groundwater model for a ‘slow’ recession event

Purpose: Estimate the salt load from a ‘slow’ flood recession.

Input:
- Inundation map from Task 1.3.

- Groundwater recharge maps.

Description: Run the groundwater model for one event to predict the salt load from a ‘slow’ draw down of Chowilla Weir.

Responsibility: Wei Yan

Outputs: Salt-load for Scenario 2a.

Task 2.7: Test sensitivity of MODFLOW model to time-step

Purpose: Test the sensitivity of the MODFLOW model to the one-month time-step.

Input:
- Inundation map from Task 1.3.
- Groundwater recharge maps.

Description: Test the sensitivity of the MODFLOW model to the one-month time-step by running one event with a reduced (½ month) time-step.

Responsibility: Wei Yan

Outputs: Comment on sensitivity of salt load estimates to the MODFLOW time-step.

Task 2.8: Run groundwater model for a ‘rapid’ recession event

Purpose: Estimate the salt load from a ‘rapid’ flood recession.

Input:
- Inundation map from Task 1.3.
- Groundwater recharge maps.

Description: Run the groundwater model for one event to predict the salt load from a ‘rapid’ draw down of Chowilla Weir.

Responsibility: Wei Yan

Outputs: Salt-load for Scenario 2c.

Task 2.9: Run groundwater model with MT3D to investigate aquifer freshening

Purpose: Investigate whether aquifer freshening results from frequent flooding.

Input: Groundwater recharge maps.

Description: Run the groundwater model and MT3D over a 10-year period to investigate the effect of frequent flooding on aquifer salinity.

Responsibility: Wei Yan

Outputs: Comment on the consequences for aquifer salinity resulting from frequent flooding (Scenario 5).

3.1.4 Task 3 – Hydrologic Modelling (MSM-BigMod)

Task 3.1: Dilution flows

Purpose: Investigate the effects of providing additional dilution flows on River salinity resulting from Chowilla salt accessions.

Input: Salt load estimates from Task 2.3.

Description: Run MSM-BigMod over the 30-year period with salt load estimated with Chowilla Weir and additional dilution flows of 2k, 5k and 10k Ml/day respectively.

Responsibility: Theresa Heneker

Outputs: Salinity impacts for Scenario 4.

Task 3.2: Salinity impacts for remaining scenarios

Purpose: Quantify the impacts on River salinity resulting from Chowilla salt accessions for the range of management actions tested.

Input: Salt load estimates from Tasks1, 2 and 3.

Description: Run MSM-BigMod over the 30-year period with salt load estimates from Scenarios 1, 2 and 3.

Responsibility: Theresa Heneker

Outputs: Salinity impacts for Scenarios 1, 2 and 3.

3.1.5 Task 4 – Project Reporting

Purpose: Communicate findings from the modelling effort to the client.

Input: Results of modelling from Tasks 1, 2 and 3.

Description:

- Description of the methodology and scenarios tested.
- Collation and analysis of model results from scenario tests.
- Discussion of limitations and confidence in modelled results, with recommendations for further work.
- Consolidation of the above into a single report.

Responsibility: Mark Alcorn and Theresa Heneker

Outputs: Report of project findings. 10 hard-copies and pdf format.

4. PROJECT PERSONNEL

A brief description of key personnel and their responsibilities follows.

Nicholas Souter –Program Manager, River Murray Assessments (A/PSO4)
- Project direction.
- Client liaison.

Todd Hodgkin – Senior Hydro-geologist (PSO4)
- Provision of senior hydro-geological advice.

Wei Yan – Senior Hydro-geologist (PSO3)
- Groundwater (MODFLOW) model runs.

Theresa Heneker – Senior Engineering Hydrologist (PSO3)
- MSM-BigMod model runs.
- Project reporting.

DHI Water and Environment
- Surface water (MIKE Flood) model runs.

Mark Alcorn – Hydrologist (PSO1)
- Surface water (MIKE Flood) model runs.
- MSM-BigMod model runs.
- Project reporting.

Lazslo Katona – GIS Analyst (ASO5)
- GIS analysis and support.
- Data manipulations for model inputs and outputs.
- Preparation of maps and figures for reporting.

Brenton Howe – Hydro-geologist (PSO1)
- Groundwater modelling support.

B. MODEL INPUTS AND OUTPUTS

		Model input		Modelled and calculated output							
Day	Year	Simplified 30 year River Murray flow hydrograph (ML/d)	Assumed flow during regulator operation (ML/d)	Scenario 1. Natural flow		Scenario 2A. Natural flow with GMS		Scenario 2B. Natural flow with regulator		Scenario 2C. Natural flow with regulator and GMS	
				Modelled flux (m^3/d)	*Salt load (t/d)*	*Modelled flux (m^3/d)*	*Salt load (t/d)*	*Modelled flux (m^3/d)*	*Salt load (t/d)*	*Modelled flux (m^3/d)*	*Salt load (t/d)*
31	1977.08	5 000		2 216	**55**	1 801	**45**	2 216	**55**	1 801	**45**
59	1977.16	5 000		2 081	**52**	1 462	**37**	2 081	**52**	1 462	**37**
90	1977.25	5 000		1 978	**49**	1 231	**31**	1 978	**49**	1 231	**31**
120	1977.33	20 000		1 901	**48**	1 098	**27**	1 901	**48**	1 098	**27**
151	1977.41	20 000		4	**0**	1	**0**	4	**0**	1	**0**
181	1977.50	20 000		13	**0**	2	**0**	13	**0**	2	**0**
212	1977.58	20 000		22	**1**	2	**0**	22	**1**	2	**0**
243	1977.67	5 000		30	**1**	2	**0**	30	**1**	2	**0**
273	1977.75	5 000		6 769	**169**	3 272	**82**	6 769	**169**	3 272	**82**
304	1977.83	5 000		4 883	**122**	2 109	**53**	4 883	**122**	2 109	**53**
334	1977.92	5 000		3 975	**99**	1 660	**41**	3 975	**99**	1 660	**41**
365	1978.00	5 000		3 390	**85**	1 394	**35**	3 390	**85**	1 394	**35**
396	1978.08	5 000		2 989	**75**	1 218	**30**	2 989	**75**	1 218	**30**
424	1978.16	5 000		2 728	**68**	1 107	**28**	2 728	**68**	1 107	**28**
455	1978.25	5 000		2 505	**63**	1 015	**25**	2 505	**63**	1 015	**25**
485	1978.33	5 000		2 338	**58**	943	**24**	2 338	**58**	943	**24**
516	1978.41	5 000		2 200	**55**	883	**22**	2 200	**55**	883	**22**
546	1978.50	5 000		2 095	**52**	836	**21**	2 095	**52**	836	**21**
577	1978.58	40 000		2 006	**50**	796	**20**	2 006	**50**	796	**20**
608	1978.67	60 000		0	**0**	0	**0**	0	**0**	0	**0**
638	1978.75	40 000	40 000	0	**0**	0	**0**	0	**0**	0	**0**
669	1978.83	40 000	40 000	0	**0**	0	**0**	0	**0**	0	**0**
699	1978.92	20 000		0	**0**	0	**0**	3	**0**	0	**0**
730	1979.00	20 000		3 339	**83**	1 015	**25**	7 421	**186**	3 718	**93**
761	1979.08	5 000		1 309	**33**	145	**4**	3 228	**81**	903	**23**
789	1979.16	5 000		13 861	**347**	7 544	**189**	16 871	**422**	10 505	**263**
820	1979.25	5 000		10 400	**260**	4 829	**121**	12 763	**319**	6 791	**170**
850	1979.33	5 000		8 430	**211**	3 570	**89**	10 353	**259**	4 947	**124**
881	1979.41	5 000		7 028	**176**	2 787	**70**	8 615	**215**	3 778	**94**
911	1979.50	5 000		6 020	**151**	2 284	**57**	7 356	**184**	3 018	**75**
942	1979.58	5 000		5 211	**130**	1 927	**48**	6 341	**159**	2 462	**62**
973	1979.67	5 000		4 571	**114**	1 659	**41**	5 530	**138**	2 069	**52**
1 003	1979.75	20 000		4 072	**102**	1 459	**36**	4 889	**122**	1 783	**45**
1 034	1979.83	40 000		10	**0**	1	**0**	12	**0**	2	**0**
1 064	1979.92	5 000		0	**0**	0	**0**	0	**0**	0	**0**
1 095	1980.00	5 000		10 966	**274**	4 759	**119**	11 551	**289**	5 272	**132**
1 126	1980.08	5 000		7 575	**189**	2 737	**68**	8 074	**202**	3 044	**76**
1 155	1980.16	5 000		6 023	**151**	2 086	**52**	6 455	**161**	2 302	**58**
1 186	1980.25	5 000		4 992	**125**	1 702	**43**	5 364	**134**	1 862	**47**
1 216	1980.33	5 000		4 303	**108**	1 457	**36**	4 625	**116**	1 580	**40**
1 247	1980.42	5 000		3 779	**94**	1 283	**32**	4 054	**101**	1 376	**34**
1 277	1980.50	5 000		3 392	**85**	1 159	**29**	3 624	**91**	1 234	**31**
1 308	1980.58	5 000	10 000	3 078	**77**	1 057	**26**	3 274	**82**	1 120	**28**
1 339	1980.67	5 000	10 000	2 832	**71**	975	**24**	0	**0**	0	**0**

Day	Year	Model input: Simplified 30 year River Murray flow hydrograph (ML/d)	Model input: Assumed flow during regulator operation (ML/d)	Scenario 1. Natural flow: Modelled flux (m^3/d)	Scenario 1. Natural flow: Salt load (t/d)	Scenario 2A. Natural flow with GMS: Modelled flux (m^3/d)	Scenario 2A. Natural flow with GMS: Salt load (t/d)	Scenario 2B. Natural flow with regulator: Modelled flux (m^3/d)	Scenario 2B. Natural flow with regulator: Salt load (t/d)	Scenario 2C. Natural flow with regulator and GMS: Modelled flux (m^3/d)	Scenario 2C. Natural flow with regulator and GMS: Salt load (t/d)
1 369	1980.75	5 000	10 000	2 640	**66**	909	**23**	0	**0**	0	**0**
1 400	1980.84	5 000		2 476	**62**	855	**21**	0	**0**	0	**0**
1 430	1980.92	5 000		2 344	**59**	810	**20**	18 752	**469**	11 725	**293**
1 461	1981.00	5 000		2 233	**56**	772	**19**	12 895	**322**	6 448	**161**
1 492	1981.09	5 000		2 140	**53**	739	**18**	9 944	**249**	4 329	**108**
1 520	1981.16	5 000		2 067	**52**	714	**18**	8 238	**206**	3 318	**83**
1 551	1981.25	5 000		1 998	**50**	690	**17**	6 905	**173**	2 616	**65**
1 581	1981.33	5 000		1 941	**49**	670	**17**	5 944	**149**	2 147	**54**
1 612	1981.42	5 000		1 890	**47**	653	**16**	5 172	**129**	1 797	**45**
1 642	1981.50	20 000		1 848	**46**	639	**16**	4 577	**114**	1 555	**39**
1 673	1981.58	40 000		5	**0**	1	**0**	12	**0**	2	**0**
1 704	1981.67	80 000		0	**0**	0	**0**	0	**0**	0	**0**
1 734	1981.75	100 000		0	**0**	0	**0**	0	**0**	0	**0**
1 765	1981.84	20 000		0	**0**	0	**0**	0	**0**	0	**0**
1 795	1981.92	5 000		11 852	**296**	6 522	**163**	13 075	**327**	7 994	**200**
1 826	1982.00	5 000		22 286	**557**	15 013	**375**	23 461	**587**	16 869	**422**
1 857	1982.09	5 000		16 576	**414**	9 921	**248**	17 585	**440**	11 453	**286**
1 885	1982.16	5 000		13 434	**336**	7 414	**185**	14 321	**358**	8 677	**217**
1 916	1982.25	5 000		11 026	**276**	5 657	**141**	11 798	**295**	6 644	**166**
1 946	1982.33	5 000		9 317	**233**	4 494	**112**	9 994	**250**	5 283	**132**
1 977	1982.42	5 000		7 963	**199**	3 625	**91**	8 560	**214**	4 251	**106**
2 007	1982.50	5 000		6 923	**173**	3 004	**75**	7 455	**186**	3 514	**88**
2 038	1982.58	5 000		6 052	**151**	2 524	**63**	6 528	**163**	2 938	**73**
2 069	1982.67	5 000		5 337	**133**	2 160	**54**	5 765	**144**	2 497	**62**
2 099	1982.75	5 000		4 763	**119**	1 892	**47**	5 148	**129**	2 163	**54**
2 130	1982.84	5 000		4 267	**107**	1 679	**42**	4 614	**115**	1 892	**47**
2 160	1982.92	5 000		3 864	**97**	1 515	**38**	4 176	**104**	1 683	**42**
2 191	1983.00	5 000		3 514	**88**	1 379	**34**	3 792	**95**	1 513	**38**
2 222	1983.09	5 000		3 225	**81**	1 265	**32**	3 468	**87**	1 378	**34**
2 250	1983.16	5 000		3 006	**75**	1 181	**30**	3 222	**81**	1 276	**32**
2 281	1983.25	5 000		2 803	**70**	1 105	**28**	2 991	**75**	1 184	**30**
2 311	1983.33	5 000		2 639	**66**	1 043	**26**	2 802	**70**	1 109	**28**
2 342	1983.42	5 000		2 497	**62**	989	**25**	2 639	**66**	1 046	**26**
2 372	1983.50	20 000		2 381	**60**	945	**24**	2 506	**63**	995	**25**
2 403	1983.58	40 000		6	**0**	1	**0**	6	**0**	1	**0**
2 434	1983.67	60 000		0	**0**	0	**0**	0	**0**	0	**0**
2 464	1983.75	60 000		0	**0**	0	**0**	0	**0**	0	**0**
2 495	1983.84	40 000		0	**0**	0	**0**	0	**0**	0	**0**
2 525	1983.92	20 000		4	**0**	1	**0**	5	**0**	1	**0**
2 556	1984.00	20 000		5 167	**129**	2 890	**72**	5 223	**131**	3 009	**75**
2 587	1984.09	40 000		2 168	**54**	817	**20**	2 202	**55**	864	**22**
2 616	1984.17	20 000		0	**0**	0	**0**	0	**0**	0	**0**
2 647	1984.25	20 000		2 751	**69**	1 258	**31**	2 786	**70**	1 308	**33**
2 677	1984.33	20 000		1 192	**30**	368	**9**	1 206	**30**	388	**10**
2 708	1984.42	5 000		667	**17**	130	**3**	676	**17**	142	**4**
2 738	1984.50	5 000		13 451	**336**	9 636	**241**	13 528	**338**	9 795	**245**
2 769	1984.59	20 000		10 398	**260**	6 689	**167**	10 469	**262**	6 819	**170**

Day	Year	Model input: Simplified 30 year River Murray flow hydrograph (ML/d)	Model input: Assumed flow during regulator operation (ML/d)	Scenario 1. Natural flow: Modelled flux (m³/d)	Scenario 1. Natural flow: Salt load (t/d)	Scenario 2A. Natural flow with GMS: Modelled flux (m³/d)	Scenario 2A. Natural flow with GMS: Salt load (t/d)	Scenario 2B. Natural flow with regulator: Modelled flux (m³/d)	Scenario 2B. Natural flow with regulator: Salt load (t/d)	Scenario 2C. Natural flow with regulator and GMS: Modelled flux (m³/d)	Scenario 2C. Natural flow with regulator and GMS: Salt load (t/d)
2 800	1984.67	60 000		59	**1**	5	**0**	60	**2**	5	**0**
2 830	1984.75	60 000		0	**0**	0	**0**	0	**0**	0	**0**
2 861	1984.84	60 000		0	**0**	0	**0**	0	**0**	0	**0**
2 891	1984.92	5 000		13	**0**	0	**0**	15	**0**	0	**0**
2 922	1985.01	5 000		25 696	**642**	22 252	**556**	25 751	**644**	22 361	**559**
2 953	1985.09	5 000		18 182	**455**	14 715	**368**	18 234	**456**	14 817	**370**
2 981	1985.17	5 000		14 469	**362**	10 970	**274**	14 519	**363**	11 066	**277**
3 012	1985.25	5 000		11 758	**294**	8 248	**206**	11 805	**295**	8 330	**208**
3 042	1985.33	5 000		9 887	**247**	6 427	**161**	9 932	**248**	6 497	**162**
3 073	1985.42	5 000		8 429	**211**	5 056	**126**	8 473	**212**	5 114	**128**
3 103	1985.50	5 000		7 322	**183**	4 077	**102**	7 364	**184**	4 122	**103**
3 134	1985.59	5 000		6 402	**160**	3 344	**84**	6 441	**161**	3 379	**84**
3 165	1985.67	20 000		5 651	**141**	2 810	**70**	5 689	**142**	2 836	**71**
3 195	1985.75	5 000		15	**0**	2	**0**	15	**0**	2	**0**
3 226	1985.84	5 000		6 901	**173**	3 617	**90**	6 937	**173**	3 656	**91**
3 256	1985.92	5 000		5 493	**137**	2 629	**66**	5 526	**138**	2 654	**66**
3 287	1986.01	5 000		4 688	**117**	2 154	**54**	4 719	**118**	2 174	**54**
3 318	1986.09	5 000		4 129	**103**	1 852	**46**	4 159	**104**	1 869	**47**
3 346	1986.17	5 000		3 743	**94**	1 651	**41**	3 771	**94**	1 666	**42**
3 377	1986.25	5 000		3 404	**85**	1 480	**37**	3 430	**86**	1 492	**37**
3 407	1986.33	5 000		3 145	**79**	1 349	**34**	3 169	**79**	1 360	**34**
3 438	1986.42	5 000		2 927	**73**	1 244	**31**	2 949	**74**	1 253	**31**
3 468	1986.50	5 000		2 752	**69**	1 161	**29**	2 773	**69**	1 169	**29**
3 499	1986.59	40 000		2 600	**65**	1 091	**27**	2 619	**65**	1 098	**27**
3 530	1986.67	40 000	40 000	0	**0**	0	**0**	0	**0**	0	**0**
3 560	1986.75	40 000	40 000	0	**0**	0	**0**	0	**0**	0	**0**
3 591	1986.84	40 000	40 000	0	**0**	0	**0**	0	**0**	0	**0**
3 621	1986.92	20 000		0	**0**	0	**0**	16	**0**	0	**0**
3 652	1987.01	5 000		2 703	**68**	1 330	**33**	7 873	**197**	5 645	**141**
3 683	1987.09	5 000		14 270	**357**	10 457	**261**	19 539	**488**	15 971	**399**
3 711	1987.17	5 000		10 880	**272**	7 122	**178**	15 009	**375**	11 437	**286**
3 742	1987.25	5 000		8 684	**217**	5 122	**128**	11 973	**299**	8 395	**210**
3 772	1987.33	5 000		7 254	**181**	3 930	**98**	9 963	**249**	6 456	**161**
3 803	1987.42	5 000		6 176	**154**	3 137	**78**	8 436	**211**	5 045	**126**
3 833	1987.50	5 000		5 379	**134**	2 610	**65**	7 296	**182**	4 067	**102**
3 864	1987.59	20 000		4 729	**118**	2 215	**55**	6 360	**159**	3 326	**83**
3 895	1987.67	20 000		13	**0**	2	**0**	18	**0**	2	**0**
3 925	1987.75	5 000		29	**1**	2	**0**	38	**1**	3	**0**
3 956	1987.84	5 000		7 204	**180**	3 873	**97**	8 262	**207**	4 792	**120**
3 986	1987.92	5 000		5 507	**138**	2 639	**66**	6 423	**161**	3 314	**83**
4 017	1988.01	5 000		4 574	**114**	2 089	**52**	5 367	**134**	2 590	**65**
4 048	1988.09	5 000		3 967	**99**	1 765	**44**	4 649	**116**	2 149	**54**
4 077	1988.17	5 000		3 557	**89**	1 557	**39**	4 143	**104**	1 862	**47**
4 108	1988.25	5 000		3 224	**81**	1 395	**35**	3 720	**93**	1 637	**41**
4 138	1988.34	5 000		2 975	**74**	1 275	**32**	3 395	**85**	1 470	**37**
4 169	1988.42	20 000		2 769	**69**	1 177	**29**	3 125	**78**	1 336	**33**
4 199	1988.50	20 000	10 000	6	**0**	1	**0**	7	**0**	1	**0**

Day	Year	Model input: Simplified 30 year River Murray flow hydrograph (ML/d)	Model input: Assumed flow during regulator operation (ML/d)	Scenario 1. Natural flow: *Modelled flux (m^3/d)*	Scenario 1. Natural flow: *Salt load (t/d)*	Scenario 2A. Natural flow with GMS: *Modelled flux (m^3/d)*	Scenario 2A. Natural flow with GMS: *Salt load (t/d)*	Scenario 2B. Natural flow with regulator: *Modelled flux (m^3/d)*	Scenario 2B. Natural flow with regulator: *Salt load (t/d)*	Scenario 2C. Natural flow with regulator and GMS: *Modelled flux (m^3/d)*	Scenario 2C. Natural flow with regulator and GMS: *Salt load (t/d)*
4 230	1988.59	40 000	40 000	18	**0**	2	**0**	0	**0**	0	**0**
4 261	1988.67	40 000	40 000	0	**0**	0	**0**	0	**0**	0	**0**
4 291	1988.76	20 000		0	**0**	0	**0**	0	**0**	0	**0**
4 322	1988.84	5 000		1 519	**38**	498	**12**	6 544	**164**	4 473	**112**
4 352	1988.92	5 000		12 179	**304**	8 215	**205**	18 297	**457**	14 677	**367**
4 383	1989.01	5 000		8 924	**223**	5 203	**130**	13 628	**341**	10 012	**250**
4 414	1989.09	5 000		7 124	**178**	3 749	**94**	10 894	**272**	7 310	**183**
4 442	1989.17	5 000		6 033	**151**	2 990	**75**	9 190	**230**	5 704	**143**
4 473	1989.25	20 000		5 156	**129**	2 442	**61**	7 795	**195**	4 472	**112**
4 503	1989.34	40 000		14	**0**	2	**0**	27	**1**	3	**0**
4 534	1989.42	60 000		0	**0**	0	**0**	0	**0**	0	**0**
4 564	1989.50	60 000		0	**0**	0	**0**	0	**0**	0	**0**
4 595	1989.59	80 000		0	**0**	0	**0**	0	**0**	0	**0**
4 626	1989.67	80 000		43	**1**	0	**0**	104	**3**	0	**0**
4 656	1989.76	80 000		542	**14**	94	**2**	678	**17**	188	**5**
4 687	1989.84	40 000		1 427	**36**	623	**16**	1 614	**40**	795	**20**
4 717	1989.92	20 000		5 473	**137**	2 975	**74**	6 005	**150**	3 434	**86**
4 748	1990.01	5 000		14 052	**351**	11 184	**280**	14 595	**365**	11 827	**296**
4 779	1990.09	5 000		25 462	**637**	22 473	**562**	25 938	**648**	23 066	**577**
4 807	1990.17	5 000		20 044	**501**	16 976	**424**	20 468	**512**	17 509	**438**
4 838	1990.25	5 000		16 200	**405**	13 056	**326**	16 578	**414**	13 533	**338**
4 868	1990.34	20 000		13 554	**339**	10 342	**259**	13 894	**347**	10 772	**269**
4 899	1990.42	20 000		302	**8**	58	**1**	355	**9**	84	**2**
4 929	1990.50	40 000		317	**8**	47	**1**	354	**9**	65	**2**
4 960	1990.59	60 000		0	**0**	0	**0**	0	**0**	0	**0**
4 991	1990.67	80 000		0	**0**	0	**0**	0	**0**	0	**0**
5 021	1990.76	100 000		15	**0**	0	**0**	20	**0**	0	**0**
5 052	1990.84	80 000		561	**14**	107	**3**	585	**15**	116	**3**
5 082	1990.92	20 000		1 983	**50**	1 037	**26**	2 026	**51**	1 077	**27**
5 113	1991.01	5 000		20 097	**502**	17 309	**433**	20 234	**506**	17 477	**437**
5 144	1991.09	5 000		29 204	**730**	26 438	**661**	29 327	**733**	26 592	**665**
5 172	1991.17	5 000		22 865	**572**	20 009	**500**	22 979	**574**	20 154	**504**
5 203	1991.25	5 000		18 412	**460**	15 458	**386**	18 519	**463**	15 594	**390**
5 233	1991.34	5 000		15 371	**384**	12 335	**308**	15 471	**387**	12 462	**312**
5 264	1991.42	5 000		13 008	**325**	9 898	**247**	13 102	**328**	10 016	**250**
5 294	1991.50	5 000		11 222	**281**	8 082	**202**	11 311	**283**	8 185	**205**
5 325	1991.59	20 000		9 745	**244**	6 605	**165**	9 830	**246**	6 697	**167**
5 356	1991.67	20 000		47	**1**	7	**0**	50	**1**	10	**0**
5 386	1991.76	40 000		84	**2**	8	**0**	88	**2**	10	**0**
5 417	1991.84	20 000		0	**0**	0	**0**	0	**0**	0	**0**
5 447	1991.92	5 000		1 311	**33**	496	**12**	1 332	**33**	511	**13**
5 478	1992.01	5 000		13 411	**335**	10 033	**251**	13 476	**337**	10 115	**253**
5 509	1992.09	5 000		10 282	**257**	6 927	**173**	10 344	**259**	6 997	**175**
5 538	1992.17	5 000		8 565	**214**	5 298	**132**	8 624	**216**	5 353	**134**
5 569	1992.26	5 000		7 292	**182**	4 165	**104**	7 349	**184**	4 207	**105**
5 599	1992.34	5 000		6 369	**159**	3 411	**85**	6 423	**161**	3 445	**86**
5 630	1992.42	5 000		5 620	**140**	2 858	**71**	5 672	**142**	2 886	**72**

Day	Year	Model input: Simplified 30 year River Murray flow hydrograph (ML/d)	Model input: Assumed flow during regulator operation (ML/d)	Scenario 1. Natural flow: Modelled flux (m^3/d)	Scenario 1. Natural flow: Salt load (t/d)	Scenario 2A. Natural flow with GMS: Modelled flux (m^3/d)	Scenario 2A. Natural flow with GMS: Salt load (t/d)	Scenario 2B. Natural flow with regulator: Modelled flux (m^3/d)	Scenario 2B. Natural flow with regulator: Salt load (t/d)	Scenario 2C. Natural flow with regulator and GMS: Modelled flux (m^3/d)	Scenario 2C. Natural flow with regulator and GMS: Salt load (t/d)
5 660	1992.51	5 000		5 034	126	2 463	62	5 085	127	2 487	62
5 691	1992.59	5 000		4 536	113	2 146	54	4 584	115	2 167	54
5 722	1992.68	20 000		4 118	103	1 894	47	4 165	104	1 913	48
5 752	1992.76	40 000		9	0	1	0	10	0	1	0
5 783	1992.84	60 000		0	0	0	0	0	0	0	0
5 813	1992.93	80 000		0	0	0	0	0	0	0	0
5 844	1993.01	80 000		0	0	0	0	0	0	0	0
5 875	1993.10	20 000		70	2	0	0	73	2	0	0
5 903	1993.17	5 000		13 613	340	10 722	268	13 646	341	10 759	269
5 934	1993.26	20 000		23 840	596	20 653	516	23 875	597	20 686	517
5 964	1993.34	20 000		2 262	57	1 016	25	2 278	57	1 028	26
5 995	1993.42	20 000		1 462	37	533	13	1 474	37	539	13
6 025	1993.51	20 000		958	24	283	7	969	24	288	7
6 056	1993.59	40 000		635	16	149	4	643	16	153	4
6 087	1993.68	40 000		0	0	0	0	0	0	0	0
6 117	1993.76	80 000		0	0	0	0	0	0	0	0
6 148	1993.84	100 000		0	0	0	0	0	0	0	0
6 178	1993.93	80 000		251	6	27	1	255	6	28	1
6 209	1994.01	5 000		1 615	40	760	19	1 623	41	767	19
6 240	1994.10	5 000		37 046	926	34 310	858	37 069	927	34 325	858
6 268	1994.17	20 000		27 283	682	24 502	613	27 305	683	24 517	613
6 299	1994.26	5 000		4 655	116	2 971	74	4 669	117	2 984	75
6 329	1994.34	5 000		19 802	495	16 847	421	19 823	496	16 863	422
6 360	1994.42	5 000		15 864	397	12 834	321	15 885	397	12 849	321
6 390	1994.51	5 000		13 315	333	10 218	255	13 336	333	10 232	256
6 421	1994.59	5 000		11 350	284	8 218	205	11 371	284	8 230	206
6 452	1994.68	5 000		9 820	245	6 690	167	9 840	246	6 700	168
6 482	1994.76	5 000		8 625	216	5 522	138	8 645	216	5 530	138
6 513	1994.84	5 000		7 610	190	4 565	114	7 630	191	4 568	114
6 543	1994.93	5 000		6 792	170	3 840	96	6 812	170	3 840	96
6 574	1995.01	5 000		6 079	152	3 251	81	6 099	152	3 249	81
6 605	1995.10	5 000		5 476	137	2 795	70	5 495	137	2 792	70
6 633	1995.17	5 000		5 008	125	2 466	62	5 027	126	2 465	62
6 664	1995.26	5 000		4 562	114	2 173	54	4 581	115	2 174	54
6 694	1995.34	5 000		4 190	105	1 944	49	4 208	105	1 945	49
6 725	1995.42	20 000		3 858	96	1 746	44	3 876	97	1 748	44
6 755	1995.51	20 000		9	0	1	0	9	0	1	0
6 786	1995.59	40 000		23	1	2	0	23	1	2	0
6 817	1995.68	40 000		0	0	0	0	0	0	0	0
6 847	1995.76	5 000		0	0	0	0	0	0	0	0
6 878	1995.84	5 000		14 937	373	11 240	281	14 955	374	11 241	281
6 908	1995.93	5 000		10 571	264	6 924	173	10 588	265	6 924	173
6 939	1996.01	5 000		8 287	207	4 811	120	8 303	208	4 811	120
6 970	1996.10	5 000		6 854	171	3 635	91	6 870	172	3 634	91
6 999	1996.18	5 000		5 905	148	2 952	74	5 921	148	2 949	74
7 030	1996.26	5 000		5 142	129	2 457	61	5 158	129	2 455	61
7 060	1996.34	5 000		4 569	114	2 111	53	4 584	115	2 112	53

Day	Year	Model input: Simplified 30 year River Murray flow hydrograph (ML/d)	Model input: Assumed flow during regulator operation (ML/d)	Scenario 1. Natural flow: Modelled flux (m^3/d)	Scenario 1. Natural flow: Salt load (t/d)	Scenario 2A. Natural flow with GMS: Modelled flux (m^3/d)	Scenario 2A. Natural flow with GMS: Salt load (t/d)	Scenario 2B. Natural flow with regulator: Modelled flux (m^3/d)	Scenario 2B. Natural flow with regulator: Salt load (t/d)	Scenario 2C. Natural flow with regulator and GMS: Modelled flux (m^3/d)	Scenario 2C. Natural flow with regulator and GMS: Salt load (t/d)
7 091	1996.43	5 000		4 097	102	1 843	46	4 112	103	1 846	46
7 121	1996.51	20 000		3 725	93	1 643	41	3 739	93	1 646	41
7 152	1996.59	40 000		10	0	1	0	10	0	1	0
7 183	1996.68	60 000		0	0	0	0	0	0	0	0
7 213	1996.76	60 000	60 000	0	0	0	0	0	0	0	0
7 244	1996.85	60 000	60 000	0	0	0	0	0	0	0	0
7 274	1996.93	40 000	60 000	13	0	0	0	130	3	0	0
7 305	1997.01	5 000		141	4	53	1	431	11	61	2
7 336	1997.10	5 000		23 982	600	20 694	517	29 322	733	26 162	654
7 364	1997.18	5 000		17 758	444	14 447	361	21 538	538	18 345	459
7 395	1997.26	5 000		13 892	347	10 544	264	16 741	419	13 495	337
7 425	1997.34	5 000		11 426	286	8 058	201	13 698	342	10 406	260
7 456	1997.43	5 000		9 594	240	6 268	157	11 443	286	8 124	203
7 486	1997.51	5 000		8 250	206	4 998	125	9 791	245	6 494	162
7 517	1997.59	5 000		7 157	179	4 018	100	8 458	211	5 218	130
7 548	1997.68	5 000		6 280	157	3 309	83	7 391	185	4 251	106
7 578	1997.76	5 000		5 585	140	2 801	70	6 546	164	3 539	88
7 609	1997.85	5 000		4 988	125	2 406	60	5 821	146	2 978	74
7 639	1997.93	5 000		4 506	113	2 104	53	5 231	131	2 567	64
7 670	1998.01	5 000		4 089	102	1 860	46	4 718	118	2 232	56
7 701	1998.10	5 000		3 736	93	1 666	42	4 284	107	1 963	49
7 729	1998.18	5 000		3 467	87	1 521	38	3 948	99	1 766	44
7 760	1998.26	5 000		3 217	80	1 388	35	3 630	91	1 584	40
7 790	1998.34	5 000		3 016	75	1 284	32	3 369	84	1 441	36
7 821	1998.43	5 000		2 841	71	1 197	30	3 139	78	1 322	33
7 851	1998.51	5 000		2 697	67	1 128	28	2 952	74	1 231	31
7 882	1998.59	5 000		2 570	64	1 068	27	2 786	70	1 153	29
7 913	1998.68	20 000	10 000	2 462	62	1 018	25	2 647	66	1 088	27
7 943	1998.76	20 000	10 000	6	0	1	0	0	0	0	0
7 974	1998.85	20 000	10 000	18	0	1	0	0	0	0	0
8 004	1998.93	20 000		29	1	2	0	0	0	0	0
8 035	1999.01	5 000		38	1	2	0	4 354	109	2 572	64
8 066	1999.10	5 000		7 306	183	3 967	99	14 940	374	11 267	282
8 094	1999.18	5 000		5 547	139	2 646	66	11 369	284	7 734	193
8 125	1999.26	5 000		4 525	113	2 020	50	9 078	227	5 547	139
8 155	1999.34	5 000		3 909	98	1 689	42	7 600	190	4 267	107
8 186	1999.43	5 000		3 465	87	1 470	37	6 490	162	3 387	85
8 216	1999.51	5 000		3 149	79	1 320	33	5 669	142	2 788	70
8 247	1999.59	5 000		2 902	73	1 206	30	4 998	125	2 343	59
8 278	1999.68	5 000		2 708	68	1 117	28	4 459	111	2 016	50
8 308	1999.76	5 000		2 556	64	1 050	26	4 032	101	1 771	44
8 339	1999.85	5 000		2 426	61	995	25	3 666	92	1 572	39
8 369	1999.93	5 000		2 322	58	951	24	3 371	84	1 420	35
8 400	2000.01	5 000		2 233	56	914	23	3 118	78	1 296	32
8 431	2000.10	5 000		2 158	54	882	22	2 909	73	1 200	30
8 460	2000.18	5 000		2 098	52	856	21	2 745	69	1 126	28
8 491	2000.26	5 000		2 043	51	833	21	2 597	65	1 060	27

Day	Year	Model input		Modelled and calculated output							
		Simplified 30 year River Murray flow hydrograph (ML/d)	Assumed flow during regulator operation (ML/d)	Scenario 1. Natural flow		Scenario 2A. Natural flow with GMS		Scenario 2B. Natural flow with regulator		Scenario 2C. Natural flow with regulator and GMS	
				Modelled flux (m^3/d)	*Salt load (t/d)*	*Modelled flux (m^3/d)*	*Salt load (t/d)*	*Modelled flux (m^3/d)*	*Salt load (t/d)*	*Modelled flux (m^3/d)*	*Salt load (t/d)*
8 521	2000.35	5 000		1 998	**50**	813	**20**	2 477	**62**	1 008	**25**
8 552	2000.43	5 000		1 957	**49**	796	**20**	2 373	**59**	964	**24**
8 582	2000.51	5 000		1 922	**48**	781	**20**	2 288	**57**	928	**23**
8 613	2000.60	5 000		1 891	**47**	768	**19**	2 214	**55**	896	**22**
8 644	2000.68	20 000		1 864	**47**	756	**19**	2 149	**54**	869	**22**
8 674	2000.76	40 000	40 000	5	**0**	1	**0**	5	**0**	1	**0**
8 705	2000.85	20 000	40 000	0	**0**	0	**0**	0	**0**	0	**0**
8 735	2000.93	40 000	40 000	554	**14**	15	**0**	0	**0**	0	**0**
8 766	2001.02	5 000		0	**0**	0	**0**	1	**0**	0	**0**
8 797	2001.10	5 000		12 867	**322**	8 675	**217**	23 281	**582**	19 552	**489**
8 825	2001.18	5 000		9 110	**228**	5 167	**129**	16 707	**418**	13 009	**325**
8 856	2001.26	5 000		7 024	**176**	3 513	**88**	12 845	**321**	9 160	**229**
8 886	2001.35	5 000		5 781	**145**	2 702	**68**	10 467	**262**	6 845	**171**
8 917	2001.43	5 000		4 899	**122**	2 200	**55**	8 742	**219**	5 249	**131**
8 947	2001.51	5 000		4 279	**107**	1 872	**47**	7 495	**187**	4 182	**105**
8 978	2001.60	5 000		3 791	**95**	1 630	**41**	6 492	**162**	3 390	**85**
9 009	2001.68	5 000		3 413	**85**	1 454	**36**	5 693	**142**	2 818	**70**
9 039	2001.76	5 000		3 124	**78**	1 321	**33**	5 063	**127**	2 407	**60**
9 070	2001.85	5 000		2 888	**72**	1 213	**30**	4 526	**113**	2 077	**52**
9 100	2001.93	5 000		2 703	**68**	1 129	**28**	4 095	**102**	1 826	**46**
9 131	2002.02	5 000		2 545	**64**	1 060	**27**	3 723	**93**	1 621	**41**
9 162	2002.10	5 000		2 415	**60**	1 004	**25**	3 411	**85**	1 458	**36**
9 190	2002.18	5 000		2 316	**58**	962	**24**	3 174	**79**	1 341	**34**
9 221	2002.26	5 000		2 225	**56**	923	**23**	2 954	**74**	1 238	**31**
9 251	2002.35	5 000		2 149	**54**	890	**22**	2 777	**69**	1 156	**29**
9 282	2002.43	5 000		2 083	**52**	861	**22**	2 622	**66**	1 086	**27**
9 312	2002.51	5 000		2 029	**51**	838	**21**	2 498	**62**	1 030	**26**
9 343	2002.60	5 000		1 980	**50**	816	**20**	2 390	**60**	982	**25**
9 374	2002.68	5 000		1 938	**48**	798	**20**	2 298	**57**	942	**24**
9 404	2002.76	5 000		1 903	**48**	782	**20**	2 223	**56**	909	**23**
9 435	2002.85	5 000	10 000	1 871	**47**	768	**19**	2 155	**54**	880	**22**
9 465	2002.93	5 000	10 000	1 843	**46**	756	**19**	0	**0**	0	**0**
9 496	2003.02	5 000	10 000	1 819	**45**	745	**19**	0	**0**	0	**0**
9 527	2003.10	5 000		1 797	**45**	736	**18**	0	**0**	0	**0**
9 555	2003.18	5 000		1 780	**45**	728	**18**	18 734	**468**	14 837	**371**
9 586	2003.26	5 000		1 763	**44**	721	**18**	12 667	**317**	8 862	**222**
9 616	2003.35	5 000		1 748	**44**	715	**18**	9 778	**244**	6 072	**152**
9 647	2003.43	5 000		1 735	**43**	709	**18**	7 930	**198**	4 448	**111**
9 677	2003.51	5 000		1 723	**43**	704	**18**	6 696	**167**	3 468	**87**
9 708	2003.60	5 000		1 712	**43**	699	**17**	5 753	**144**	2 787	**70**
9 739	2003.68	5 000		1 703	**43**	695	**17**	5 028	**126**	2 320	**58**
9 769	2003.76	5 000		1 694	**42**	691	**17**	4 471	**112**	1 996	**50**
9 800	2003.85	5 000		1 685	**42**	688	**17**	4 005	**100**	1 741	**44**
9 830	2003.93	5 000		1 678	**42**	685	**17**	3 636	**91**	1 547	**39**
9 861	2004.02	5 000		1 671	**42**	682	**17**	3 321	**83**	1 388	**35**
9 892	2004.10	5 000		1 664	**42**	680	**17**	3 062	**77**	1 266	**32**
9 921	2004.18	5 000		1 659	**41**	678	**17**	2 860	**72**	1 177	**29**

Day	Year	Model input: Simplified 30 year River Murray flow hydrograph (ML/d)	Model input: Assumed flow during regulator operation (ML/d)	Scenario 1. Natural flow: *Modelled flux (m^3/d)*	Scenario 1. Natural flow: *Salt load (t/d)*	Scenario 2A. Natural flow with GMS: *Modelled flux (m^3/d)*	Scenario 2A. Natural flow with GMS: *Salt load (t/d)*	Scenario 2B. Natural flow with regulator: *Modelled flux (m^3/d)*	Scenario 2B. Natural flow with regulator: *Salt load (t/d)*	Scenario 2C. Natural flow with regulator and GMS: *Modelled flux (m^3/d)*	Scenario 2C. Natural flow with regulator and GMS: *Salt load (t/d)*
9 952	2004.27	5 000		1 653	**41**	676	**17**	2 682	**67**	1 101	**28**
9 982	2004.35	5 000		1 648	**41**	674	**17**	2 538	**63**	1 039	**26**
10 013	2004.43	5 000		1 643	**41**	672	**17**	2 413	**60**	986	**25**
10 043	2004.52	5 000	10 000	1 639	**41**	671	**17**	2 314	**58**	944	**24**
10 074	2004.60	5 000	10 000	1 635	**41**	669	**17**	0	**0**	0	**0**
10 105	2004.68	5 000	10 000	1 631	**41**	668	**17**	0	**0**	0	**0**
10 135	2004.77	5 000		1 627	**41**	667	**17**	0	**0**	0	**0**
10 166	2004.85	5 000		1 624	**41**	665	**17**	18 026	**451**	14 174	**354**
10 196	2004.93	5 000		1 621	**41**	664	**17**	12 528	**313**	8 759	**219**
10 227	2005.02	5 000		1 618	**40**	663	**17**	9 651	**241**	5 986	**150**
10 258	2005.10	5 000		1 615	**40**	663	**17**	7 860	**197**	4 416	**110**
10 286	2005.18	5 000		1 612	**40**	662	**17**	6 722	**168**	3 509	**88**
10 317	2005.27	5 000		1 610	**40**	661	**17**	5 778	**144**	2 820	**70**
10 347	2005.35	5 000		1 607	**40**	660	**17**	5 072	**127**	2 357	**59**
10 378	2005.43	5 000		1 605	**40**	660	**16**	4 491	**112**	2 016	**50**
10 408	2005.52	5 000		1 603	**40**	659	**16**	4 036	**101**	1 765	**44**
10 439	2005.60	5 000		1 601	**40**	658	**16**	3 652	**91**	1 560	**39**
10 470	2005.68	5 000		1 599	**40**	658	**16**	3 334	**83**	1 399	**35**
10 500	2005.77	5 000		1 597	**40**	657	**16**	3 081	**77**	1 277	**32**
10 531	2005.85	5 000		1 596	**40**	657	**16**	2 863	**72**	1 179	**29**
10 561	2005.93	5 000		1 594	**40**	656	**16**	2 689	**67**	1 105	**28**
10 592	2006.02	5 000		1 592	**40**	656	**16**	2 538	**63**	1 040	**26**
10 623	2006.10	5 000		1 591	**40**	656	**16**	2 412	**60**	986	**25**
10 651	2006.18	5 000		1 590	**40**	655	**16**	2 317	**58**	946	**24**
10 682	2006.27	5 000		1 588	**40**	655	**16**	2 229	**56**	910	**23**
10 712	2006.35	5 000		1 587	**40**	654	**16**	2 157	**54**	881	**22**
10 743	2006.43	5 000		1 586	**40**	654	**16**	2 093	**52**	854	**21**
10 773	2006.52	5 000		1 585	**40**	654	**16**	2 039	**51**	832	**21**
10 804	2006.60	5 000		1 583	**40**	654	**16**	1 990	**50**	812	**20**
10 835	2006.68	5 000		1 582	**40**	653	**16**	1 948	**49**	795	**20**
10 865	2006.77	5 000		1 581	**40**	653	**16**	1 912	**48**	780	**20**
10 896	2006.85	5 000		1 580	**40**	653	**16**	1 880	**47**	767	**19**
10 926	2006.93	5 000		1 579	**39**	652	**16**	1 852	**46**	755	**19**
Average					**112**		**68**		**140**		**89**

Groundwater Salinity used for salt load calculation

25 000 TDS mg/L

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	µg	10^{-6} g	mass
microlitre	µL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	365 or 366 days	time interval

~	approximately equal to
EC	electrical conductivity (µS/cm)
TDS	total dissolved solids (mg/L)

GLOSSARY

Anabranch — A branch of a river that leaves the main channel.

Aquifer — An underground layer of rock or sediment that holds water and allows water to percolate through.

Aquifer, confined — Aquifer in which the upper surface is impervious and the water is held at greater than atmospheric pressure. Water in a penetrating well will rise above the surface of the aquifer.

Aquifer, unconfined — Aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure.

Aquitard — A layer in the geological profile that separates two aquifers and restricts the flow between them.

Basin — The area drained by a major river and its tributaries.

Benchmark condition — Points of reference from which change can be measured.

Biota — All of the organisms at a particular locality.

CSIRO — Commonwealth Scientific and Industrial Research Organisation.

DEH — Department for Environment and Heritage (Government of South Australia).

DWLBC — Department of Water, Land and Biodiversity Conservation (Government of South Australia).

EC — Electrical conductivity**.** 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C. Commonly used to indicate the salinity of water.

Evapotranspiration — The total loss of water as a result of transpiration from plants and evaporation from land, and surface water bodies.

Floodplain — Of a watercourse means: (a) the floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under Part 7 of the *Water Resources Act 1997*; or (b) where paragraph (a) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the *Development Act 1993*, or (c) where neither paragraph (a) nor paragraph (b) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse.

GMS — Groundwater Management Scheme. A well field designed and operated to lower the groundwater table.

Groundwater — *See underground water.*

Hydrogeology — The study of groundwater, which includes its occurrence, recharge and discharge processes, and the properties of aquifers. *(See hydrology.)*

Impact — A change in the chemical, physical, or biological quality or condition of a water body caused by external sources.

Infrastructure — Artificial lakes; dams or reservoirs; embankments, walls, channels or other works; buildings or structures; or pipes, machinery or other equipment.

Model — A conceptual or mathematical means of understanding elements of the real world which allows for predictions of outcomes given certain conditions. Examples include estimating storm runoff, assessing the impacts of dams or predicting ecological response to environmental change.

Monitoring — (1) The repeated measurement of parameters to assess the current status and changes over time of the parameters measured. (2) Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, animals, and other living things.

Natural resources — Soil; water resources; geological features and landscapes; native vegetation, native animals and other native organisms; ecosystems.

Obswell — Observation Well Network.

Permeability — A measure of the ease with which water flows through an aquifer or aquitard. The unit is m^2/d.

Potentiometric head — The potentiometric head or surface is the level to which water rises in a well due to water pressure in the aquifer; the unit is metres (m).

Recharge — The infiltration of water into an aquifer from the surface (rainfall, streamflow, irrigation etc.).

Recharge area — The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. *(See artificial recharge, natural recharge.)*

Regulator — A permanent in stream structure that can be used to control surface water flow.

Specific storage (S_s) — Specific storativity. The amount of stored water realised from a unit volume of aquifer per unit decline in head. It is dimensionless.

Specific yield (S_y) — The volume ratio of water that drains by gravity, to that of total volume of the porous medium. It is dimensionless.

Surface water — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir.

TDS —Total Dissolved Solids; the unit is milligrams per litre (mg/L).

Underground water (groundwater) — Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground.

Well — (a) an opening in the ground excavated for the purpose of obtaining access to underground water; (b) an opening in the ground excavated for some other purpose but that gives access to underground water; (c) a natural opening in the ground that gives access to underground water.

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