RPS Aquaterra

RIX'S CREEK MINE
FINAL VOID MANAGEMENT PLAN





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	Name	Position	Signature	Date
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Modeller	David Garces	Project Hydrogeologist		19/01/2012
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TABLE OF CONTENTS

TABLES

FIGURES (compiled at end of report)

APPENDICES

1. INTRODUCTION

1.1 Project Overview

RPS Aquaterra Pty Ltd was commissioned by Bloomfield Collieries Pty Ltd to provide a Final Void Management Plan (FVMP) for the Rix's Creek Coal Project (RCCP) to fulfil development consent condition 16C.

The main requirements of the FVMP (under condition 16C) are outlined as follows:

i) *Incorporate design criteria and specifications for the final void based on verified groundwater modelling predictions and a re-assessment of post-mining groundwater equilibration*;

ii) *Assess the potential interactions between creeks on the site and the final void; and*

iii) *Describe what actions and measures would be implemented to;*

- *minimise any potential adverse impacts associated with the final void; and*
- *manage and monitor the potential impacts of the final void.*

In order to address the requirements outlined above and to develop the FVMP, predictive groundwater modelling was undertaken to forecast the long-term impacts to local and regional groundwater flows, residual pit voids, spoil dump storage and long term salinity levels. The modelling has incorporated the use of groundwater data obtained from a groundwater monitoring program developed in 2010, with data used from May 2010 to April 2011. The monitoring program is ongoing.

This FVMP is designed to present a detailed summary of the potential groundwater-related impacts resulting from the RCCP as at 2016, the final approved year of mining under the current consent. The predicted 2016 landform configuration has been utilised to represent conditions at mine closure.

1.2 Technical Considerations

Some of the key issues that have been considered during the development of the FVMP include:

- the potential for open cut mines to form local sinks into which groundwater will flow;
- evaporation from residual pit void lakes (Pit 3 at 2016) leading to increased salinity which can impact on downstream groundwater (and surface water) flows;
- the potential for enhanced recharge in areas of backfill around Rix's Creek to elevate groundwater levels and thereby promote saline groundwater seepages into the Creek system; and
- the potential for groundwater seepages towards the Camberwell open cut mine located immediately north of Pit 1.

1.3 Report Objectives

This report has been structured to address the individual components of consent condition 16C. The sections of the report that address the individual requirements of the consent condition are summarised in Table 1.1.

Table 1.1: Consent Requirements Relevant to Report Section

Component of Consent Condition	Relevant Section of Report
Incorporate design criteria and specifications for the final void based on verified groundwater modelling predictions and a re-assessment of post-mining groundwater equilibration;	Section 2.6 and 3.3.1
Assess the potential interactions between creeks on the site and the final void	Section 3.2, 3.4.1 and 3.5
Describe what actions and measures would be implemented to: • minimise any potential adverse impacts associated with the final void; and • manage and monitor the potential impacts of the final void.	 Section 4 Section 4

2. RCCP SITE OVERVIEW

2.1 Site Description and Conceptual Model

The RCCP lease (1432) is located approximately 1.5km north of Singleton in the Hunter Valley region of New South Wales. The lease covers an area of 18.46km^2. Land elevation ranges from 160mAHD (Australian Height Datum) in the north-west and north-east, to topographical lows in the centre of the lease (60mAHD), where the existing open cut pits are situated (Figure 1).

The RCCP is confined within a geological basin-like north-south trending syncline (Figure 2), and hosts the Permian coal reserves which are part of the Whittingham Coal Measures. The syncline is approximately 8km long by 3km wide and is bounded by the Camberwell and Darlington Anticlines. The syncline is asymmetrical, the western limb generally dipping at a steeper angle than the eastern limb (RPS Aquaterra 2010).

The main aquifer unit relevant to the RCCP is a hard rock system hosted in the Permian coal measures. The groundwater flow within the aquifer is predominantly confined to the cleat fractures in the coal seams. The coal seams themselves form the main aquifer units within the hard rock system. The hydraulic conductivity (permeability) of the coal seams is generally low (0.01 to 0.05m/d) (RPS Aquaterra 2010).

The natural topography at the western end of the mine exhibits gentle undulations which direct natural surface drainage towards Rix's Creek. The creek is an ephemeral stream which runs in a north-east to south-west direction through the mine and connects to the Hunter River towards the south.

Runoff from undisturbed areas is directed away from mining operations through diversion banks, which direct runoff into natural water courses or into a number of clean water dams. Clean water dams overflow into natural drainage systems.

The major coal seams identified in the Rix's Creek syncline are (in descending stratigraphic order):

- the Lemington Seam;
- the Pikes Gully Seam;
- the Liddell Seam;
- the Barrett Seam; and
- the Hebden Seam.

The target coal seams are dispersed as several splits, separated by interburden sediments which comprise alternating sandstone, siltstone, conglomerate, mudstone and shale, as well as occasional minor coal seams. Interburden between the Barrett and Upper Hebden seams increases to in excess of 20m in the northern and western regions, rendering the Upper Hebden seam uneconomical to mine (RPS Aquaterra 2010). Sub-cropping to the east and west of the mine area are the Pikes Gully, Arties, Upper to Lower Liddell, Barrett and Hebden seams.

The unconsolidated regolith in the area comprises clay-bound and silt-bound sands and gravels. Minor alluvium, associated with Rix's Creek, exists to the south of the mine lease. The creek is ephemeral (no groundwater contribution), and as such there are no GDE's associated with the creek (Aquaterra 2010).

2.2 Conceptual Hydrogeological Model

A series of conceptualised sections have been developed to show the main hydrogeological processes and interactions occurring around the RCCP site before (Figure 3), during and post-mining (Figure 4) and post mining (Figure 5) as a result of the anticipated mine configuration at 2016. The nature of groundwater drawdown localised around the mine voids is illustrated in Figure 4. Localised changes in hydraulic gradients, groundwater flows, evaporative lose are also conceptually represented. The effects following the cessation of mining and a period of subsequent groundwater recovery are represented in Figure 5. These conceptualisations also represents Camberwell Pit and Pit 3 as active (and not backfilled) and are acting as groundwater sinks, thereby controlling groundwater flow and artificially suppressing the groundwater levels in Pit 1 below pre-mining levels.

The key ideas behind the conceptualisation have been used in developing the major facets of the numerical model.

2.3 Climate

The Hunter Valley region has a moderate climate, comparable to a Mediterranean climate with hot summers and mild winters. The RCCP area has a summer dominated rainfall pattern with the majority of rainfall occurring over the November to March period. The mean annual rainfall recorded at Singleton is 649 mm/year (Bureau of Meteorology station number 061397) based on data from 2002 to 2011. Evaporation data is not available for this meteorological station, however the *Climatic Atlas of Australia - Evaporation* (BOM 2001) suggests that the annual average potential evaporation is around 1300mm/yr for the region.

2.4 Pre Mining Site Conditions

Pre-mining land use within the RCCP mine lease area was predominantly agriculture - grazing and dairying. Further details of pre-mining land use are outlined in the Rixs Creek Coal Mine Environmental Impact Statement (Croft and Associates, undated).

Due to historical mining activity that has occurred in the area, the pre-mining groundwater conditions are not known. This includes the relationship between groundwater levels and Rix's Creek itself. Monitoring results captured from the monitoring program (RPS Aquaterra 2011) indicate that the Permian strata has been impacted by mining activity.

2.5 Early Open Cut Mining Operations (pre 1990 and 1990 – 2016)

Historically, underground mining activities have occurred to the east of the existing southern open cut around the area occupied by Pit 1 (refer to Figure 1).

Open cut mining at Rix's Creek began in 1990. Extraction has occurred via a multi seam bench open cut operation, which mines up to nine coal seams and associated splits. In 1992 the mining operation was focused to the north of the underground workings in Pit 1 (North Pit) into the Liddell and Arties seams and to the south of the highway in Pit 2 (now the tailings emplacement area) into the Barrett and Hebden Seams, as part of Stage 2 (refer to Figure 1).

The Camberwell open cut mine is located immediately north of Pit 1 and is mining down to the Barrett seam.

2.6 Operations from 2011 - 2016

Mine progression in to Stage 3 and Stage 4 allowed for continued operation in Pit 1 (North Pit) and Pit 2 (Tailings Dam), with the beginning of mining in Pit 3 (West Pit) in to the Liddell seams. Pits 1 and 3 are planned to be mined down to the Liddell and Barrett seams respectively. The mining of Pit 1 is scheduled to finish in 2015. Pit 2 has been fully mined out and developed into an approved tailings emplacement area and is anticipated to be at full capacity by 2014 and then subsequently drained, capped and rehabilitated by 2016.

Pits 1 and 3 are being mined down to the bottom of the Liddell and Barrett seams, respectively. The elevations of the Upper Liddell and Barrett coal seams along with the geological cross sections are presented in Figure 3.

A summary of pit status as at 2016, including mining activity and projected time frames is summarised below in Table 2.1.

Table 2.1: Pit Status Summary

Mining Area	Seam Mined	Extraction / Infill Completion	Status at 2016
Pit 1 (North Pit)	Lower Liddel	1.85 mill ROM coal remaining from end of 2011. Extraction anticipated to be completed in 2014	Receiving overburden from west pit (8 million BCM per year). Pit projected to be partially unfilled with overburden by mid 2016
Pit 2 (Tailings Dam)	Barrett Seam	Infilling completed in 2014	Infilled, capped and rehabilitated
Pit 3 (West Pit)	Barrett Seam	Extraction to continue at a rate of 1.26 mill ROM coal and 10.5 mill BCM	Open void to Barrett Seam

2.7 Projected 2016 Configuration

The projected landform as at 2016 is shown on Figure 6. The proposed mine schedule (refer to Table 2.1) indicates that the long term management of both Pit 1 (North Pit) and Pit 2 (tailings emplacements area) will involve re-instatement or partial infilling of the pit voids to levels above groundwater level. The progressive infilling of voids (in preference to leaving voids open) is often regarded as the most effective and (where possible) the preferred means of minimising the long term effects of mining activity post closure.

2.8 Mine Schedule Simulation

Based on the configuration supplied for the 2016 final landform and the Pit status summary an hypothetical mining schedule was developed. The simulated schedule was generated using pro-rata based extraction volumes and by dividing the observed changes from 2011-16 in to 5 equal increments to represent mining activity annually. Figure 7 highlights graphically the hypothetical mining schedules running up to October 2016.

3. PREDICTIVE MODELLING SUMMARY

A full description of the stages involved in the predictive model development and calibration has been attached to this report as Appendix A. This section is intended to summarise the rationale behind the modelling and also summarise the most pertinent predictions.

3.1 Model Rationale

Development of the model was based on the following key considerations;

- the closed geometry of the investigated domain and the premise that RCCP sits inside a basin-like structure and therefore regional impacts will likely be confined to within that structure;
- the development of practical waste rock infill configurations using the projected mine development schedule (at 2016) and the projected pit shell designs associated with Pit 1 (North Pit) and Pit 2 (Tailings Emplacement area) and Pit 3 (West Pit);
- the physical properties of the porous medium (e.g. it's homogeneity, isotropy) and options involving the use of waste rock infill to maintain groundwater throughflows and water quality, to support the closure planning process;
- the generation of post mining recovery predictions to evaluate potential impacts to sensitive receptors (Rix's Creek) and other significant operations in the area, specifically Camberwell open cut to the north, and
- the ability of the model to be adapted for increasing complexity at a later date so that re-calibration (history match) and re-evaluation (against new data with subsequent parameter adjustments) can be undertaken to validate its predictive capacity.

The predictive model was calibrated against observations recorded from the groundwater monitoring network spanning a timeframe of approximately 18 months (Aquaterra 2011).

3.2 Model Simulations

Three model scenarios were chosen that represent significant time slices in the life of the RCCP project. The scenarios can be explained as follows:

- **Simulation 1 –** represents a hypothesised set of conditions under pre mining under (steady state) conditions;
- **Simulation 2 –** proposed future mining operations schedule, up to October 2016 (end of existing consent), showing groundwater related impacts as a result of active mining in Pit 1 and Pit 3 and the progressive infilling of Pit 1 and the tailings emplacement area (Pit 2).
- **Simulation 3 –** 100 year recovery period, incorporating post-mining conditions.

3.3 Groundwater Model Predictions

3.3.1 Drawdown and Recovery Predictions

The main predictions for the main time slices have been summarised in Table 3.1. The projected mine foot print has been projected on to Figure 7 for reference purposes against the groundwater level predictions. Model outputs for each simulation are shown on Figures 8, 9 and 10.

Table 3.1: Model Simulation Summary

Simulation	Time Slice	Figure Ref	Maximum Drawdown Predicted (m)			Rate of Recovery Predicted (m)		
			Pit 1	Pit 3	Camberwell	Pit 1	Pit 3	Camberwell
1	Pre-mining Steady State Conditions	**8**	0	0	0	-	-	-
2	Expiry of existing consent at 2016	**9**	60	110	80	-	-	-
3	100 yrs following ceasation of mining at 2016	**10**	-	-	-	-40	-80	-80
						20*	30*	0

*value indicates difference between pseudo steady state (pre-mining)groundwater prediction and those predicted following 100 years of post mining recovery

Predicted drawdowns at the end of mining in 2016 are shown on Figure 9 and are summarised in Table 3.1. As expected, maximum predicted drawdowns are consistent with depth of mining and cumulative drawdown impacts are predicted within the active mining area between Pits 1 and 2 and the Camberwell Mine to the north. Drawdown propagation is limited by the low formation permeabilities and the maximum extent of drawdown is limited to approximately 1.5km north and south of active mining areas. Drawdown is constrained to the east and west by the outcrop of the Barrett seam and all impacts are confined to within the syncline structure.

The post-mining recovery prediction run was conducted as a 100 year transient model run. The site configuration for the recovery prediction reflects the conditions at 2016 and assumes that all mining activity associated with the RCCP ceased on that date. The recovery simulation also assumes that the main Camberwell Pits have been partially backfilled above groundwater level. Aquifer parameters representing backfill were applied to Pits 1 and 2 and Pit 3 was simulated as an open void and can be regarded as the only significant groundwater sink remaining. In addition, due to the 100 year recovery duration all other mining activity in the area was assumed to have ceased. The rates of recovery after 100 years (year 2116) of recovery are summarised in Table 3.1 and are illustrated in Figure 10.

The key components of the predictive simulations at 2016 are as follows:

- infilled Pits 1 and 2 act as flow through cells in continuity with groundwater flow outside their footprint;
- Camberwell mine and Pit 3 remain as groundwater sinks at 2016; and
- the recovery simulation assumes cessation of mining within the RCCP are with the Camberwell pits assumed as being backfilled.

3.4 Flux Predictions

Changes in groundwater flow to significant areas within the model domain at particular time slices have been assessed and are summarised in Table 3.2.

Flux values have been expressed in m^3/per day and represent predicted groundwater flow contributions to the specified receptor.

Table 3.2: Predicted Groundwater Fluxes

Time Slice	Rix's Creek	Pit 1	Pit 3	Camberwell Open Cut Mine Operations	Camberwell Underground Mine Operations (Glennies Creek)
Pre-mining	88	N/A	N/A	N/A	N/A
2011	52	1036	336	1273	647
2012	73	1474	811	1147	629
2013	96	1296	539	1034	500
2014	119	N/A	433	970	511
2015	78	N/A	581	1229	552
2016	64	N/A	520	1203	527
2116	62	N/A	N/A	N/A	N/A

The flux values represent volumes of water that transfer through the model to a particular feature within the model domain.

The predicted groundwater flux to Rix's Creek ranges from 52 – 119m^3/per day (0.6 – 1.4L/sec). Pit 1 flux's (inflow and seepage) range from 1036 – 1474m^3/per day (12 – 17L/sec) and Pit 3 ranges from 336 – 811m^3/per day (4 – 9L/sec). This supports seepage estimates (observed inh the field) that were given at around 4L/sec, therefore these modelled fluxes can be regarded as representative.

The Camberwell open cut operation is predicted to attract flux's comparable to those at Pit 1 between 970 – 1273m^3/per day (11 – 15L/sec). The predicted underground operation flux's are approximately half this volume ranging from 511 – 647m^3/per day (5.9 – 7.5L/sec).

3.4.1 Predicted Interaction with Rix's Creek

The predictive modelling has also allowed for a quantative assessment of the degree of interaction and influence the proposed 2016 landform will have long term on Rix's Creek. Figure 11 illustrates that fluxes in to Rix's Creek are limited only to the area close to the confluence with the Hunter River some distance from the mining area;

The most significant proportion of the contribution (more than 50%) is shown to be sourced from the gaining section in close proximity to the Hunter River. The cells that represent Rix's Creek in the model remain unchanged for the life of the project (pre-mining, predictive and recovery stages) with only the fluxes between the cells changing.

The quantification of impacts to Rix's Creek can best be shown by comparing the actual observations with those predicted. Of particular relevance in this case are ground water elevations observed at BH4 (RPS Aquaterra 2011) located close to the existing creek line. Groundwater monitoring has been taking place at this location since 2010. Groundwater levels data obtained has indicted that groundwater levels do not respond directly to rainfall, nor do they rise to a level that provides baseflow to the creek system, indicating that the creek remains ephemeral throughout.

The observed groundwater elevations recorded in September 2010 were recorded at 59.1mAHD. The modelled elevation (following calibration) was given as 55.1mAHD. The predicted elevation (at this location) in 2016 is 55.0mAHD, indicating little change from 2010 running up to 2016. The elevation predicted at 2116 (100 year recovery) is 50.04mAHD. The predicted hydrograph for BH4 (during mining activity) is shown in Figure 12.

The predictive modelling has indicated that there will be no baseflow contribution to the creek following 100 years of recovery and therefore water quality impacts (based on the current simulations) are considered negligible. It is recommended that the predictive capacity of the model be re-evaluated as additional data is captured from the ongoing groundwater monitoring program and other pertinent observations.

3.5 Water Quality Impacts

A major issue for closure planning of mining operations below the water table is evaporation from final void pit lakes and concentrations of salts, which can impact on downstream groundwater (and surface water) flows and quality. As summarised in Section 2.6 the projected landform as at 2016 (Figure 6) indicates that the long term management of both Pit 1 (North Pit) and Pit 2 (tailings emplacements area) will involve re-instatement or infilling of the pit voids above the groundwater level. The progressive infilling of voids (in preference to open voids) is often regarded as the most effective and (where possible) the preferred means of minimising the long term effects of mining activity post closure.

3.5.1 Salinity Predictions

An analytical model was developed to evaluate post closure salinity changes, in preference to invoking the numerical solute transport capabilities of Modflow. The use of Modflow in this situation would have been very problematic in terms of simulation times and input/calibration data requirements, due primarily to the regional scale of the groundwater flow model.

The analytical model was developed to evaluate post closure salinity changes and in particular the potential effects of increasing salinity to Rix's Creek. Primarily the analytical model has been used to assess salinity based on the proposed infilling of Pit 1. At this stage of assessment Pit 3 has been regarded as active (at 2016) therefore any accumulation of groundwater within the residual void is regarded as temporary and therefore not contributing to the overall salt balance.

The analytical model was constructed as a chain of linked mixing cells that represent water and salt mixing balances. The components of the mixing cells (inflows, outflows, leakage, evaporation, rainfall and recharge) were extracted from the completed numerical model. The groundwater quality of the water was taken from groundwater monitoring data that has been collected from the groundwater monitoring program (Aquaterra 2011).

As Pit 1 is projected to be back filled by 2016, evaporation from the backfilled area is assumed to be close to zero, however a conservative value of 2mm/d has been applied. Likewise, once the landform is revegetated, it is assumed that rainfall recharge will also be very low, and hence the leaching of any salts from within the spoil to the water table is considered to be negligible.

The analytical model uses two equations to derive salinity developing in, and flowing out of a pit lake to the downstream environment.

3.5.2 Equation 1

Development of groundwater salinity in a pit lake:

$$Ps(n+1) = (Vp \times Ps(n) + (Qtp + Ev) \times Sip - Qtp \times Ps(n)) / Vp$$

3.5.3 Equation 2

Salinity of groundwater flow to the aquifer downstream of the pit lake:

$$Stan(n) = Qtp \times Ps(n) + (Qta - Qtp) \times Stas / Qta$$

Table 3.4: Pit 1 Analytical Model Input Parameter Summary

Ps(n) = Water Salinity at Time Period 1	**6000µS/cm**
Vp = Volume of Pit (L)	**395,003,150L**
Qtp = Average outflow from Pit	**301814L**
Ev = Evaporative loss from Pit (L / time period) = Surface Area of Pit Water when full (A) x Av Pan Evaporation (Ep) x Pan Factor (PF)	**2mm**
Sip = Salinity of Inflow to Pit (mg/L)	**6000µS/cm**
Stas = Salinity of Flow in Aquifer Past the Pit	**6000µS/cm**
Qta = Total Flow in Aquifer	**301814L**

3.5.4 Analytical Model Results Assumptions and Conclusions

As evaporation losses from Pit 1 will be very low, there will be negligible concentration of salts within the back filled Pit. Due to the flow through nature of the in filled pit configuration the groundwater salinity is predicted to flat line at 6065uS/cm over the next 100 years (Figure 13). As a result there will be no net increase in groundwater salinity down gradient and no reduction in downstream water quality as a result of Pit 1 under the proposed closure plan.

As outlined above the analytical model assumes that Pit 3 is to remain active with groundwater level artificially suppressed around the residual void (creating a localised sink) at 2016. Hypothetically, if mining was to cease in Pit 3 at 2016 and remain open the increases in salinity as a result of progressive evaporation are predicted to rise to approximately 53,000uS/cm. As such Pit 3 will act as a sink and any accumulations of groundwater will be confined to that area. If mining were to cease at 2016, a long term closure option for Pit 3 would need to be considered.

4. IMPACT MITIGATION AND MANAGEMENT

4.1 Impact Mitigation Measures

The results of the predictive and analytical modelling suggest that impacts from the mine have been mitigated to a large extent by the landform configuration proposed at 2016. Broad scale backfilling (to above aquifer levels) has been considered throughout this assessment and this has directly affected the model predictions in terms of preventing potential impacts during, and at the end of mining and also during the equilibration stage. As outlined in Section 2.7 the progressive infilling of voids (in preference to leaving voids open) is often regarded as the most effective and (where possible) the preferred means of minimising the long term effects of mining activity post closure.

Groundwater levels are predicted to recover, however, due to ongoing mining in the area, groundwater levels in Pit 1 will remain artificially suppressed. No significant salinity impacts are predicted based on the final 2016 pit configuration and therefore no impact on downstream groundwater (and surface water) flows and quality are predicted at this stage.

The predictions in this assessment have also (in part) assumed that activity in Pit 3 will be ongoing. This premise has influenced potential impacts, particularly with regards to long term salinity trends. These predictions may have to be revised if the mining schedule changes running up to 2016 and thereafter.

4.2 Recommended Management

The recommended management options that should be considered are as follow:

- the continuation of ongoing routine monitoring to further understand and quantify the impacts from mining running up to 2016; and
- the predictive model should be revalidated using data captured from the ongoing monitoring to evaluate its predictive capacity.

5. REFERENCES

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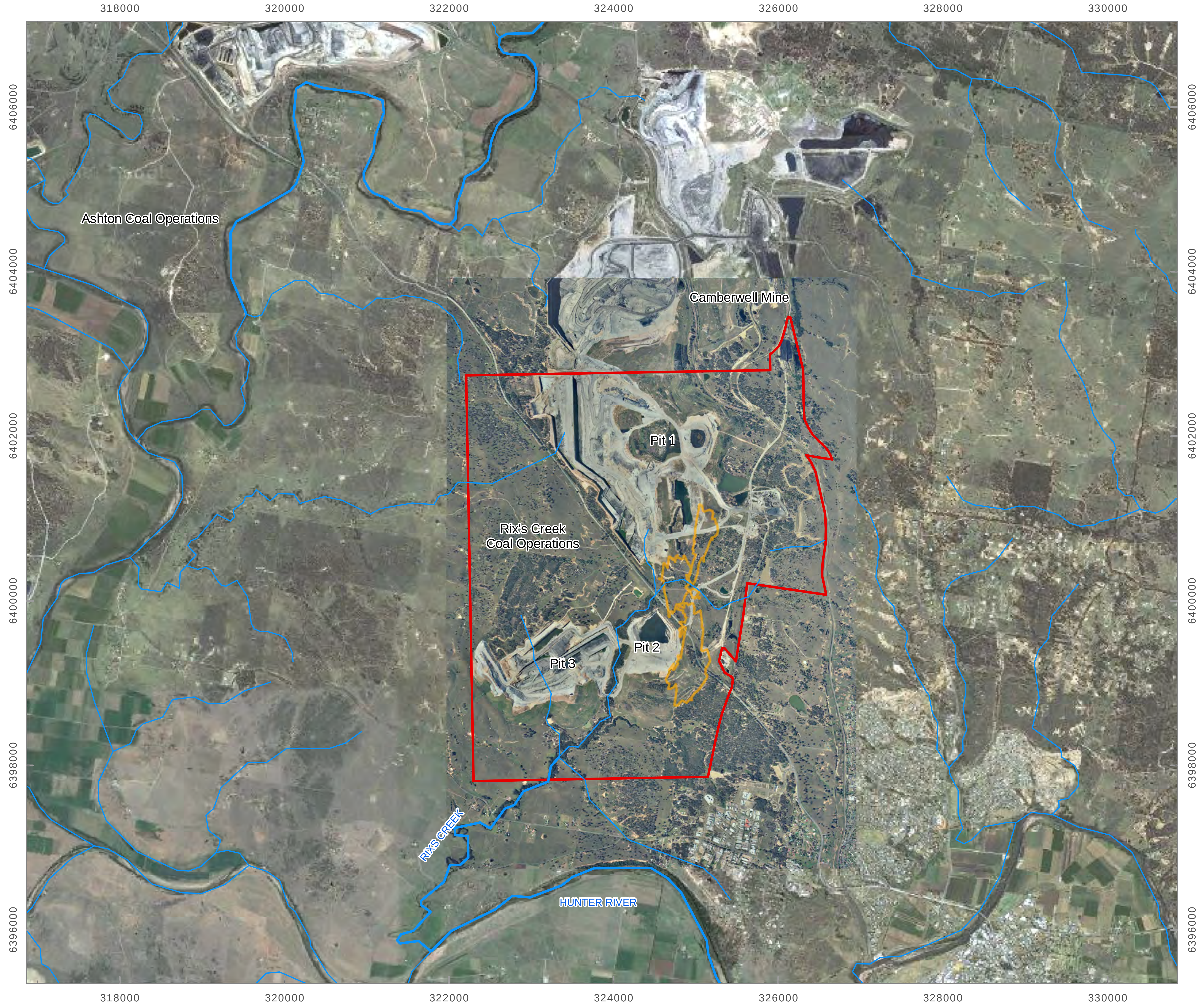
FIGURES



LEGEND

- Water Course
- Mine lease
- Underground Workings

0 625 1,250 2,500 Meters

N

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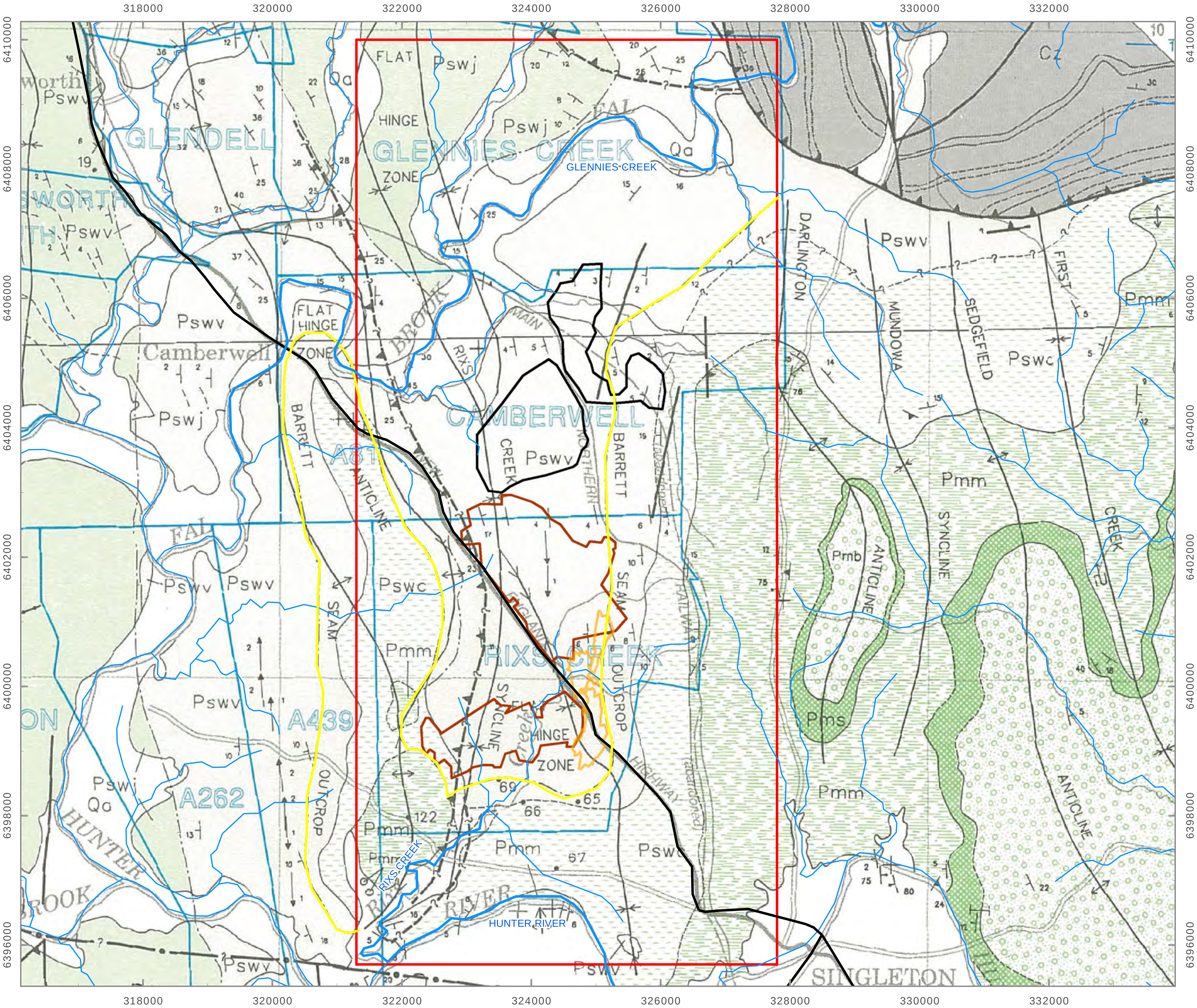
FIGURE 1

Rixs Creek Mine Footfprint (2011)

AUTHOR	HZ	PROJECT NO	S66C
CHECKED BY	CG	REVISION	A
DATE	21/12/2011	DRAWING NO.	014a



LEGEND

- Barrett OutCrop
- Principal Road
- Water Course
- Model Area
- Historic - Underground Workings
- Current Mine foot print
- Camberwell Outline
- Qa - Quaternary Alluvium
- Pswj - Wittingham Coal Measures
- Pmm - Mulbring Siltstone
- Pswv - Wittingham Coal Measures

0 750 1,500 3,000 Meters

N

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FIGURE 2

Rix's Creek Model Domain over Geological Map 9033

AUTHOR	HZ	PROJECT NO	S66C
CHECKED BY	CG	REVISION	A
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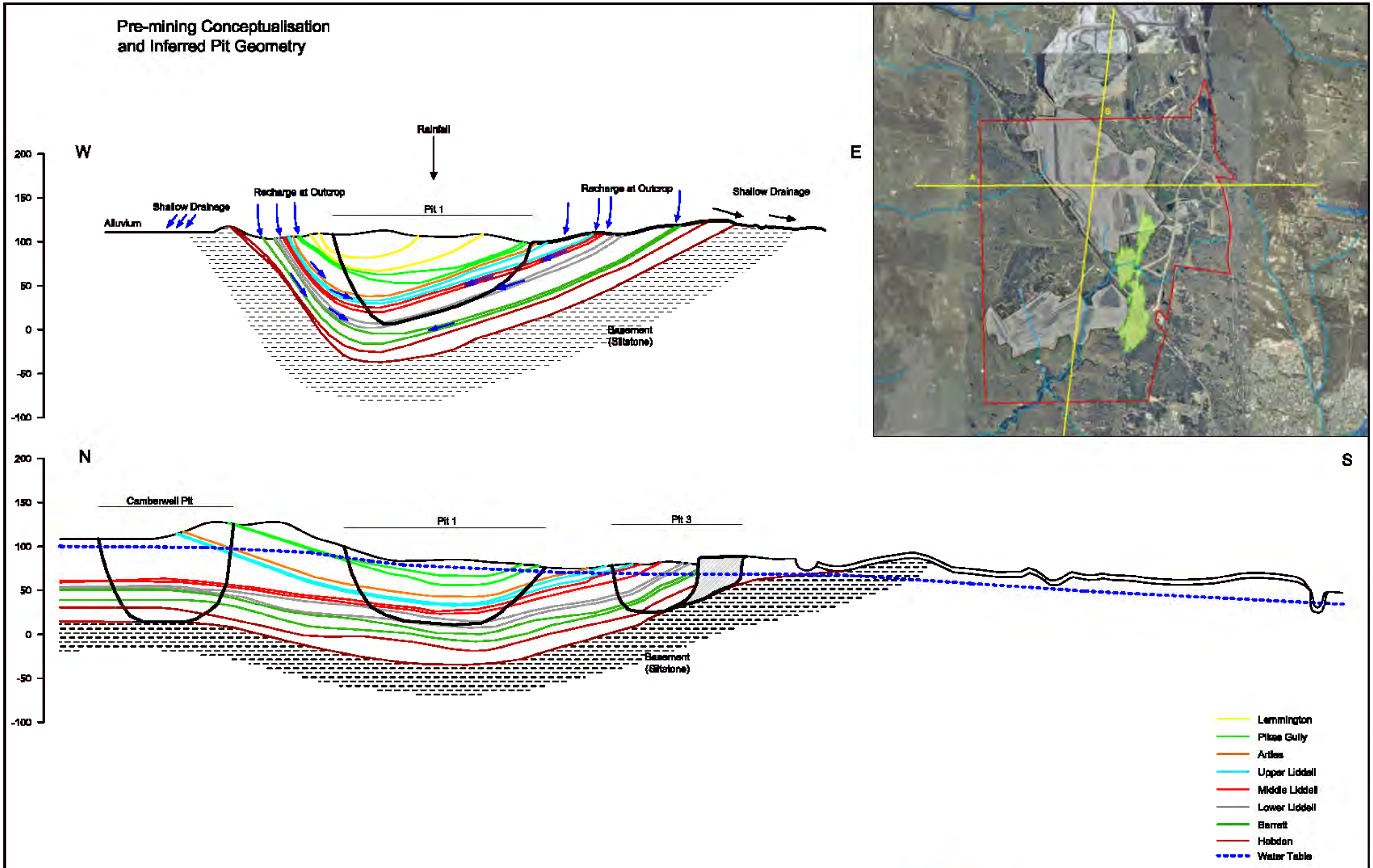

REV.	DESCRIPTION	DATE

GENERAL NOTES:

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DESIGN CHECK: D.MONAGHAN	CAD REFERENCE: S46-R0b
DRAWN: HZ	JOB No.: S46C
DRAWING CHECK: DS	SCALE: As Shown

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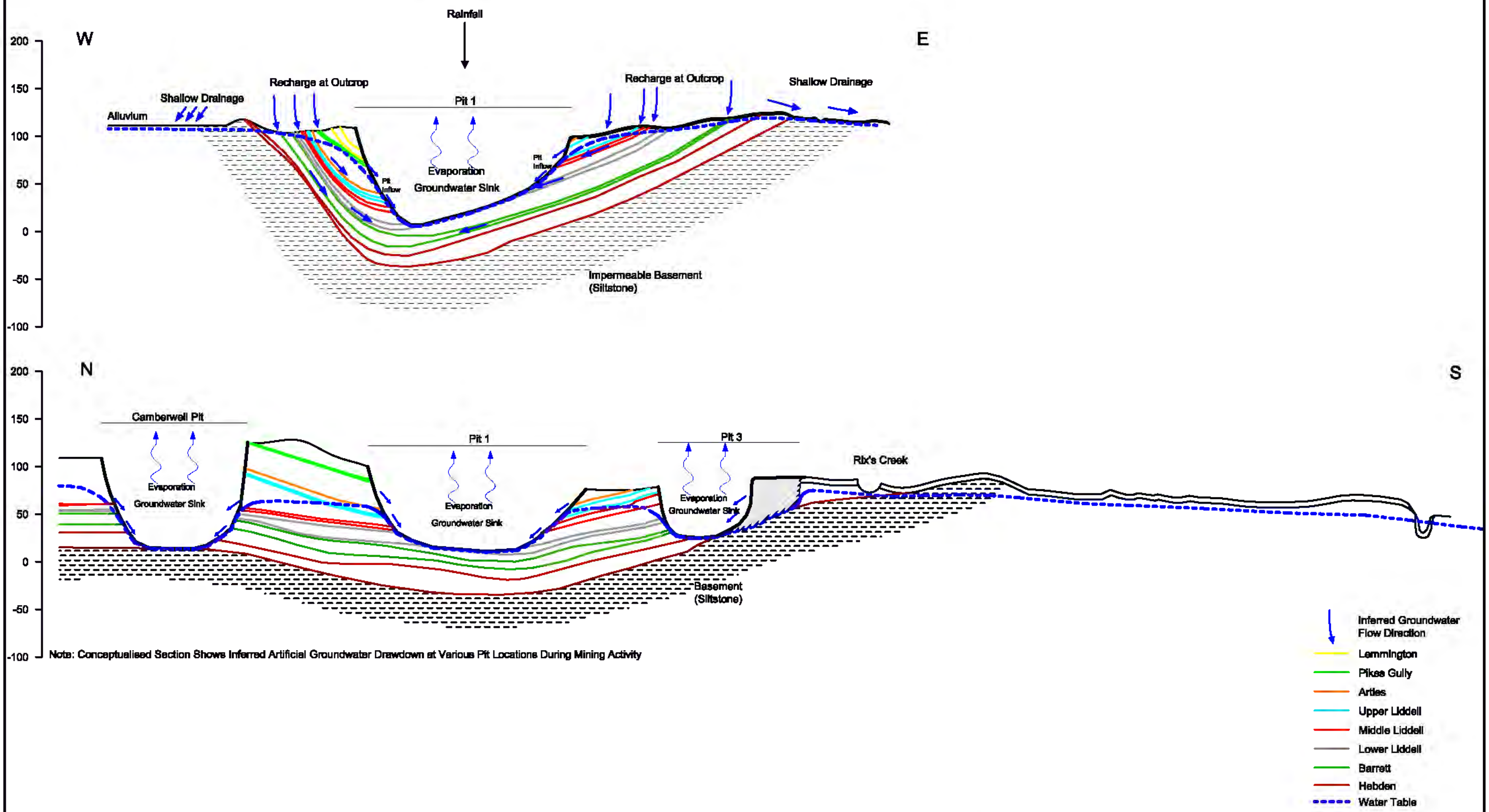
Conceptualised Sections Premining

SIZE:	SCALE:	JOB No.:	DRAWING No.:	REV.:
A3	As Shown	S66C	FIGURE 3	A

Conceptual Model - During Mining Activity



REV.	DESCRIPTION	DATE

GENERAL NOTES:

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DESIGN CHECK: D MONAGHAN	CAD REFERENCE: 566-001b
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DRAWING CHECK: CG	SCALE: As Shown

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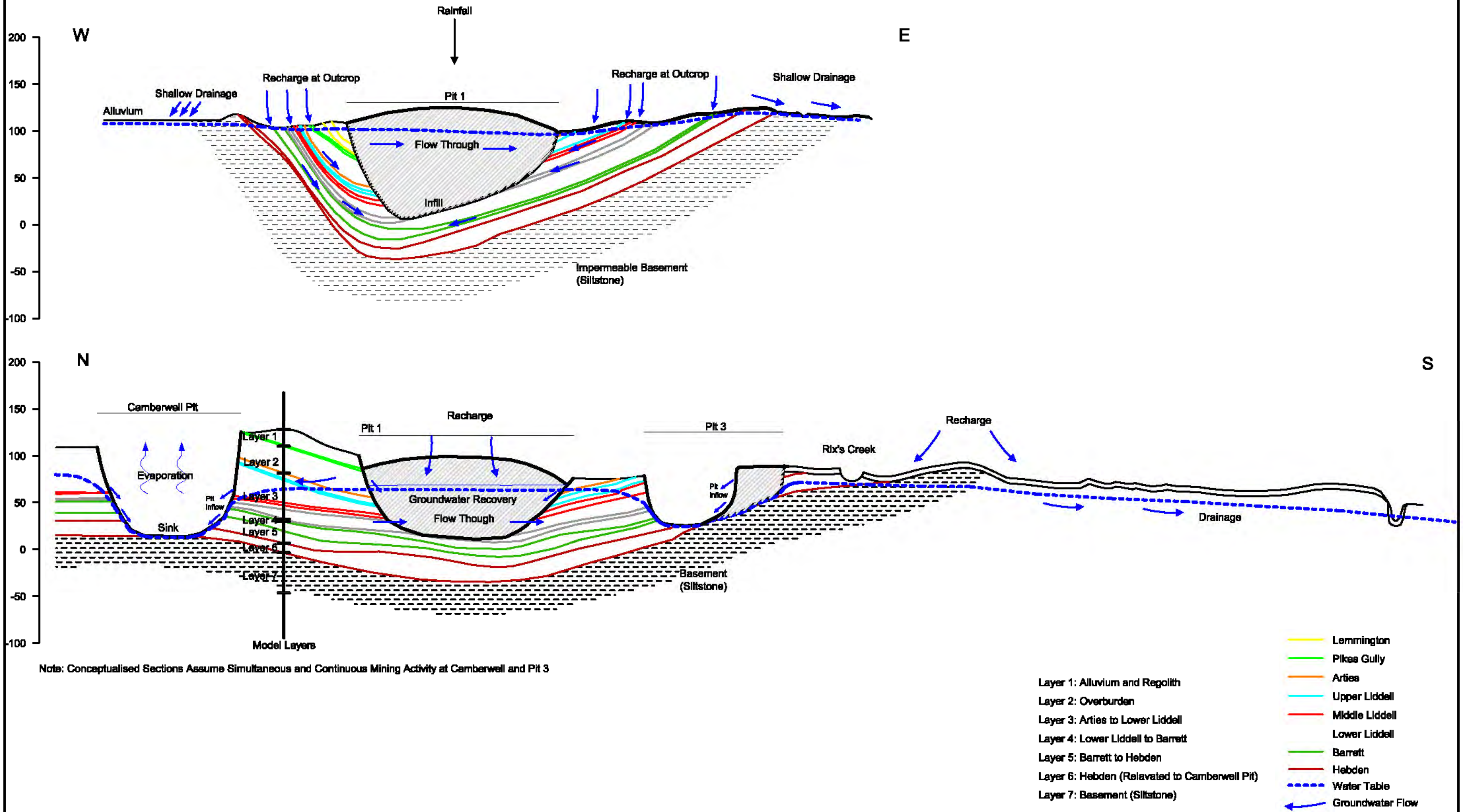
RIX'S CREEK PTY LTD

Conceptualised Sections During Mining Activity

SIZE:	SCALE:	JOB No.:	DRAWING No.:	REV.:
A3	As Shown	566C	FIGURE 4	A

Conceptual Model - Post Mining



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GENERAL NOTES:

DESIGNED: R.WRIGHT	PROJECT APPROVAL: R.WRIGHT
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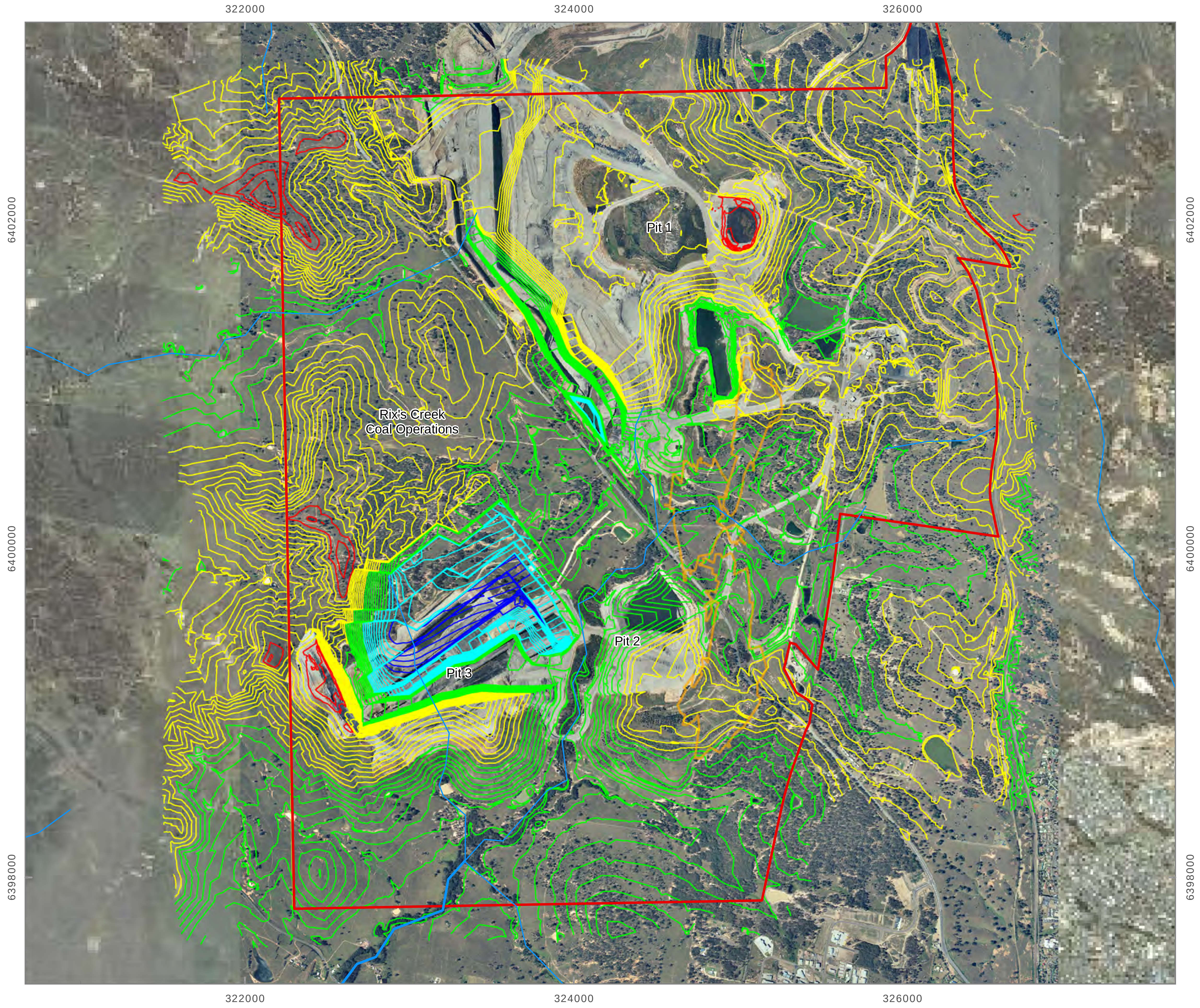
RIX'S CREEK PTY LTD

Conceptualised Sections Post Mining Activity (Projected 2016 Land Figuration)

SIZE:	SCALE:	JOB No.:	DRAWING No.:	REV.:
A3	As Shown	S66C	FIGURE 5	A

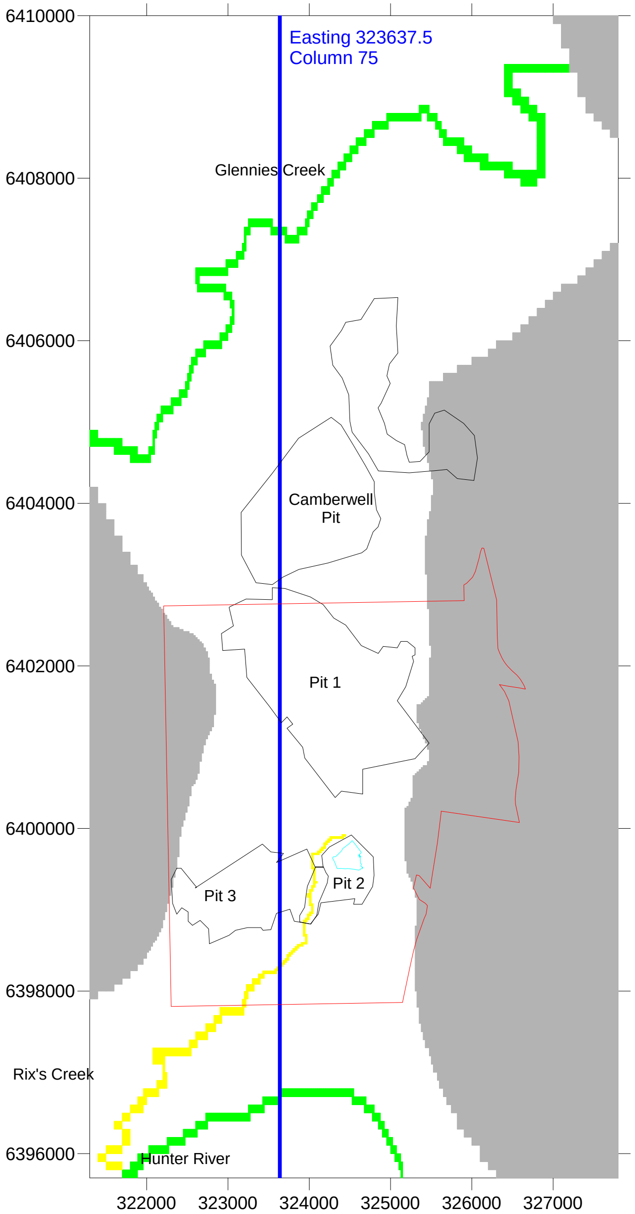


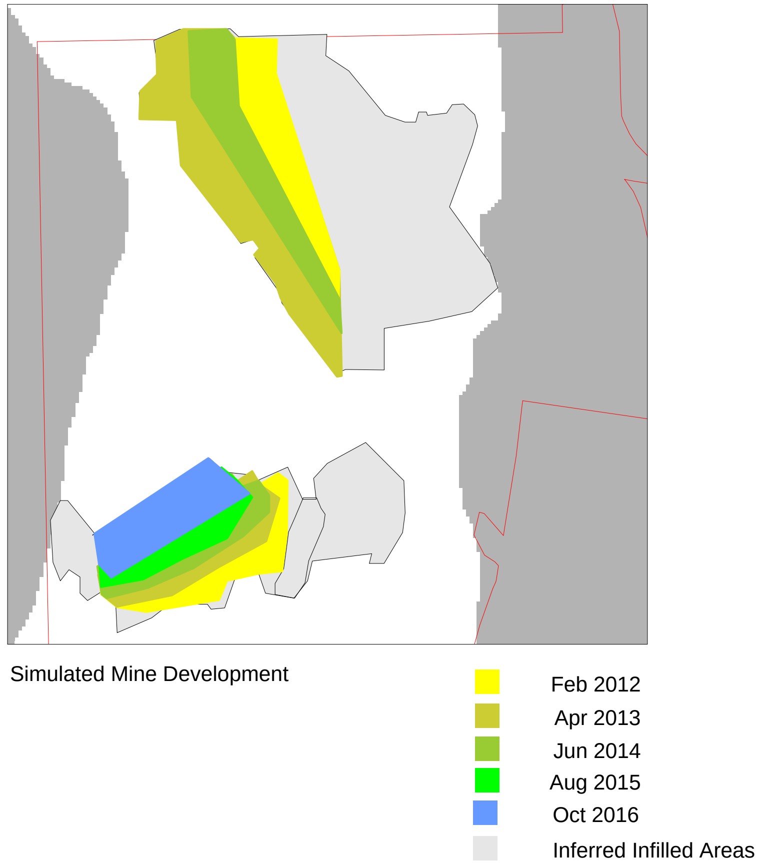
RPS Aquaterra

FIGURE 6

Projected Landform at 2016

AUTHOR	HZ	PROJECT NO	S66C
CHECKED BY	CG	REVISION	A
DATE	21/12/2011	DRAWING NO.	023

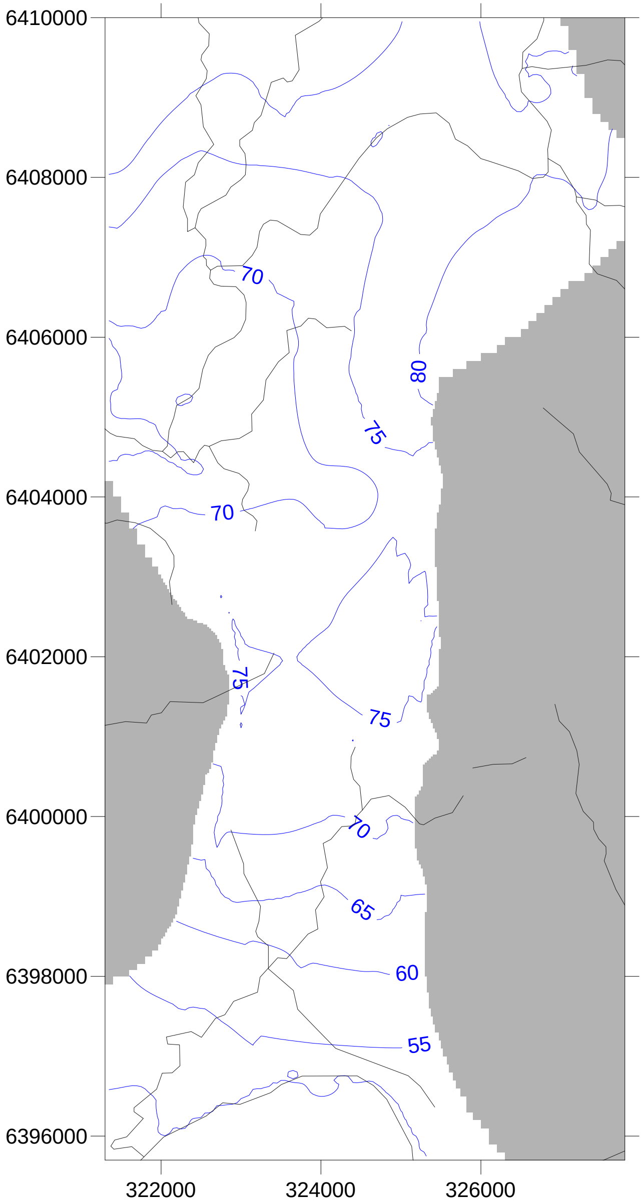


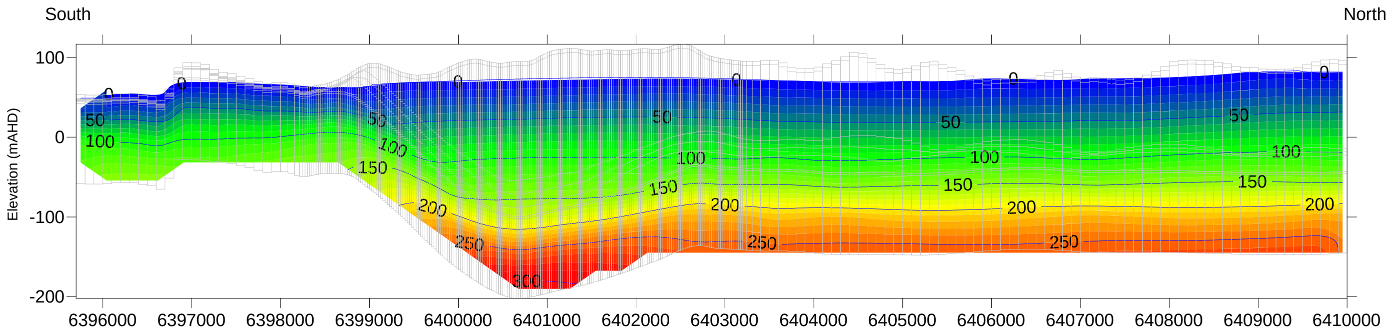


Simulated Mine Development

Dry Cells
Mine Lease
Mine Footprint

Date **21/12/2011**	Scale **As Shown**	**Rix's Creek Pty Ltd**
Initials **HZ**	Project **S66C**	**RCCP Mine Footprint and Simulated Mine Development**
Drawing Number **S66-201**	Revision **A**	
RPS Aquaterra		**Figure 7**





Section Illustrates Pressure Head Contouring for Simulation 1

Predicted Groundwater Level (mAHD)

Dry Cells

Mine Lease

Mine Footprint

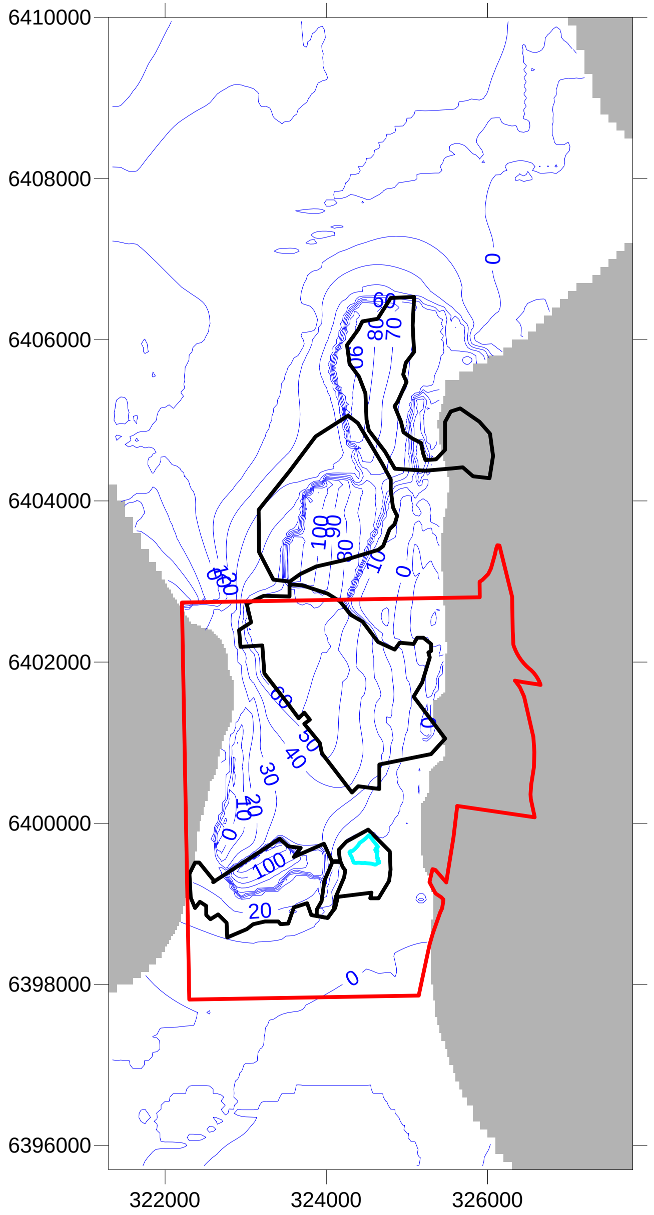
Date	21/12/2011	Scale	As Shown
Initials	HZ	Project	S66C
Drawing Number	S66-202	Revision	A

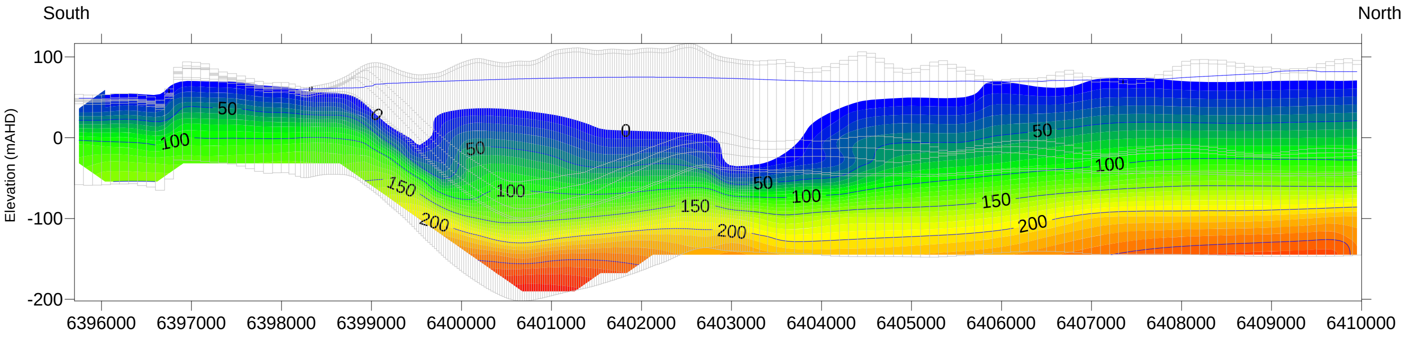
RPS Aquaterra

Rix's Creek Pty Ltd

Predicted Groundwater Levels
Pre - Mining

Figure 8

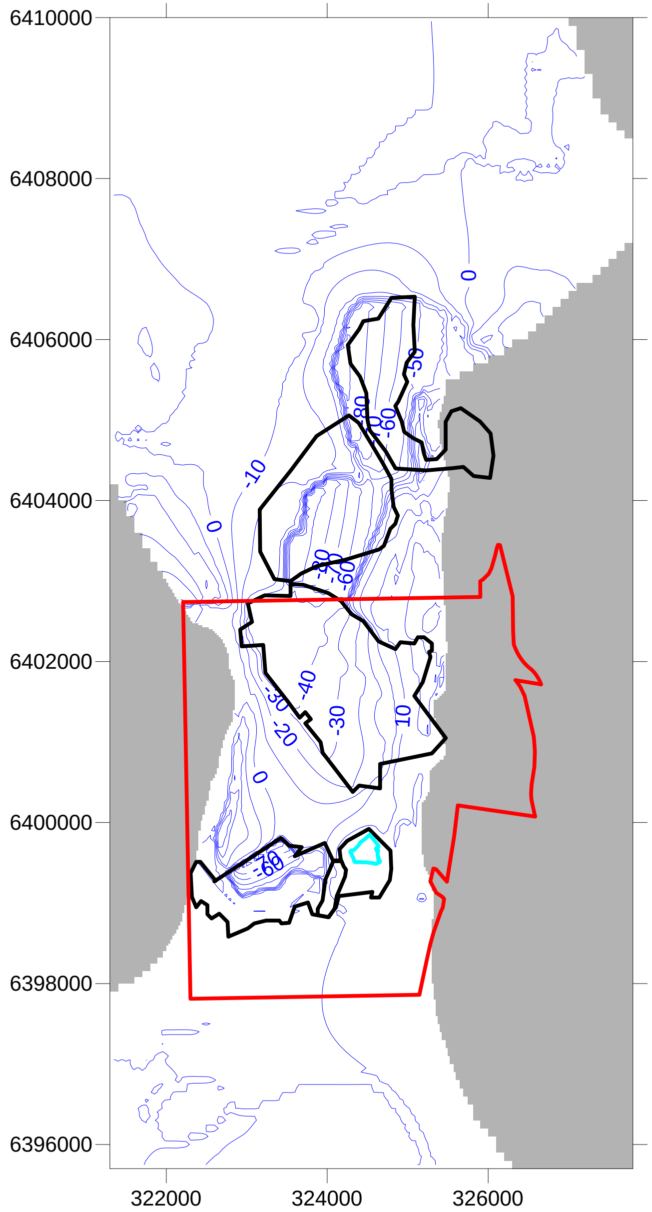


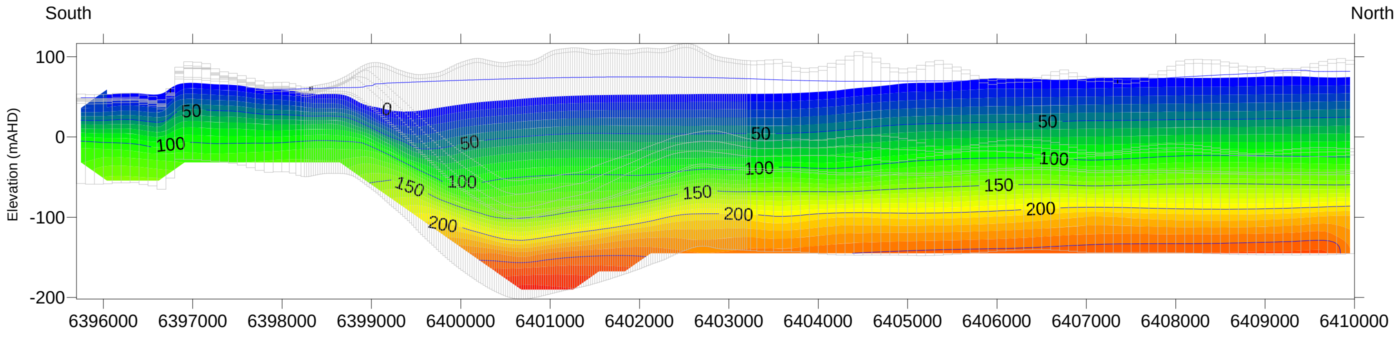


Section Illustrates Pressure Head Contouring for Simulation 2

Predicted Groundwater Drawdown (m)
Dry Cells
Mine Lease
Mine Footprint

Date **21/12/2011**	Scale **As Shown**	**Rix's Creek Pty Ltd**
Initials **HZ**	Project **S66C**	**Predicted Groundwater Drawdown at 2016**
Drawing Number **S66-203**	Revision **A**	
RPS Aquaterra		**Figure 9**

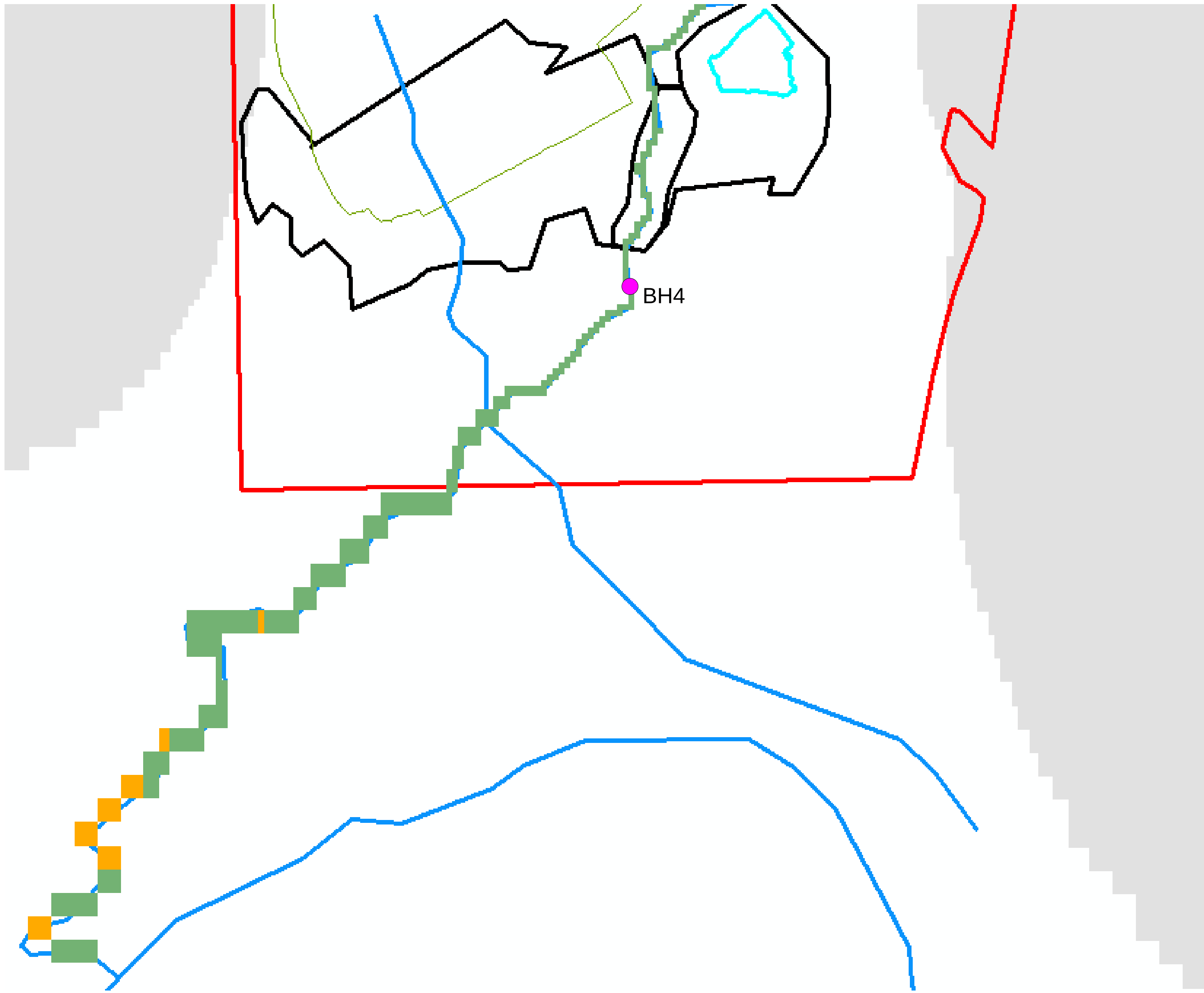




Section Illustrates Pressure Head Contouring for Simulation 3

Predicted Groundwater Drawdown (m)
Dry Cells
Mine Lease
Mine Footprint

Date	21/12/2011	Scale **As Shown**		**Rix's Creek Pty Ltd**
Initials	HZ	Project **S66C**		**Predicted Groundwater Drawdown at 2116 (100 Years Recovery)**
Drawing Number	**S66-204**	Revision **A**		
RPS Aquaterra				**Figure 10**



Dry Cells	
Mine Lease	
Mine Footprint	
Gaining	
Losing	

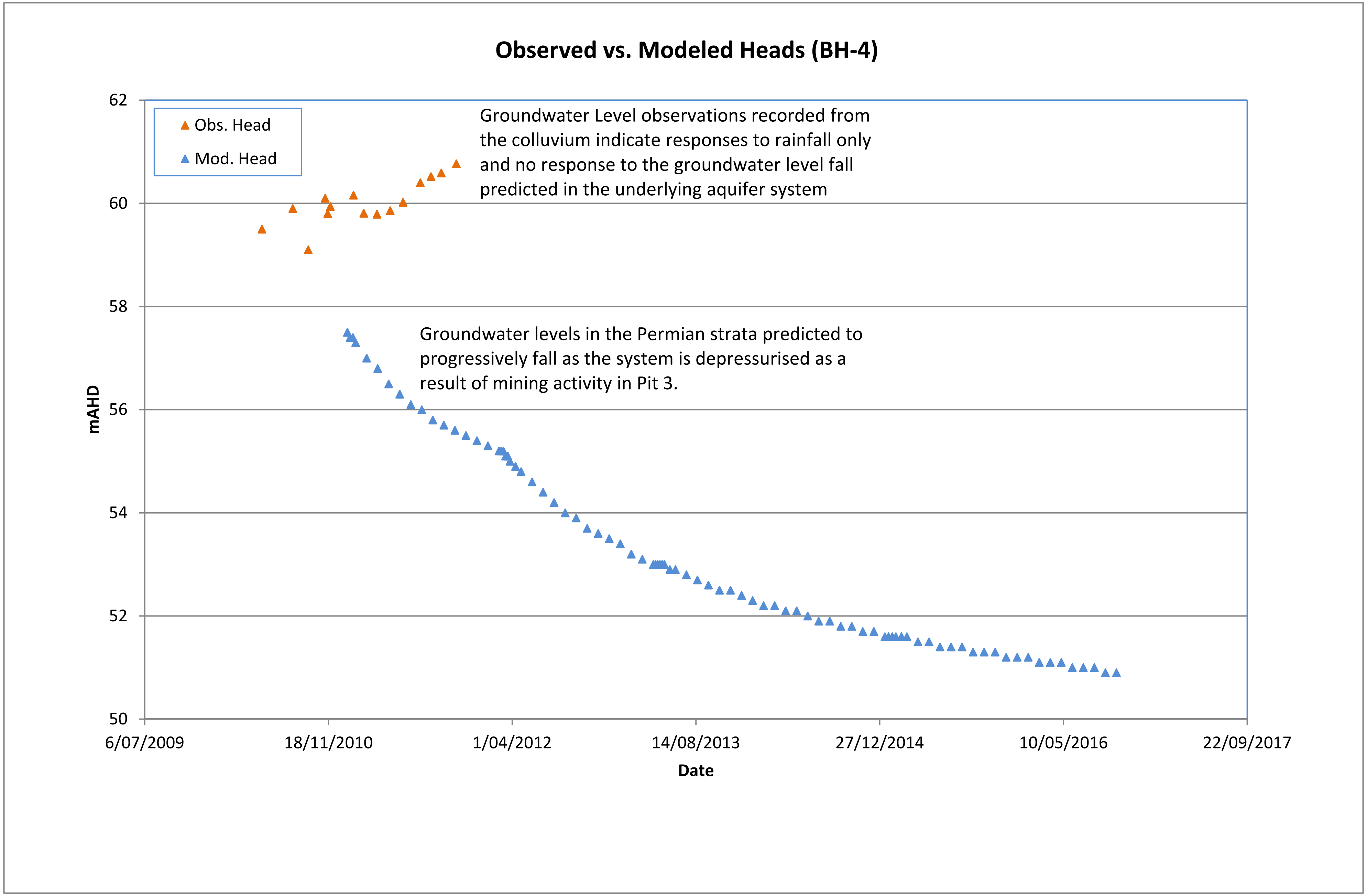
Date	21/12/2011	Scale	As Shown
Initials	HZ	Project	S66C
Drawing Number	S66-205	Revision	A

RPS Aquaterra

Rix's Creek Pty Ltd

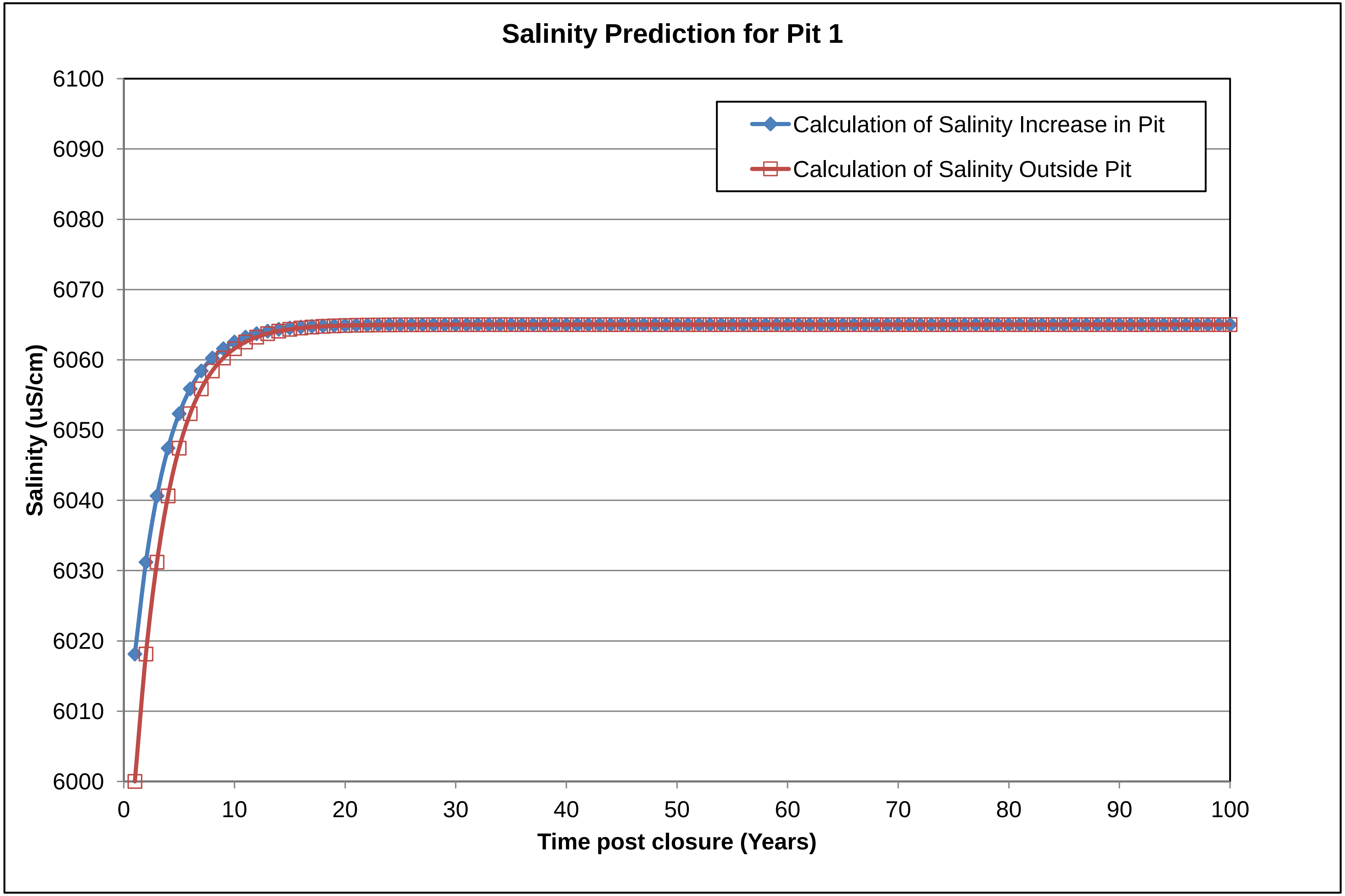
Rix's Creek Flux's

Figure 11



RPS Aquaterra

OBSERVED V MODEL HEADS FIGURE 12



Salinity Prediction FIGURE 13

APPENDIX A:
MODEL DEVELOPMENT AND CALIBRATION REPORT

RPS Aquaterra

RIX'S CREEK MINE
FINAL VOID MANAGEMENT PLAN
MODEL DEVELOPMENT AND CALIBRATION SUMMARY

RIX'S CREEK MINE
FINAL VOID MANAGEMENT PLAN
MODEL DEVELOPMENT AND CALIBRATION SUMMARY

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Our ref: S66C/600/031
Date: 20 January 2012

Document Status

	Issue Date	Purpose of Document
Revision A	19/12/2011	Model Development and Calibration Summary

	Name	Position	Signature	Date
Authors	Katharine Bond	Environmental Scientist		20/12/2011
Modeller	David Garces	Project Hydrogeologist		20/12/2011
Reviewer	Greg Sheppard	Principal Hydrogeologist		22/12/2011

TABLE OF CONTENTS

TABLES

FIGURES (compiled at end of report)

APPENDICES

1. GROUNDWATER MODEL DEVELOPMENT AND CALIBRATION REPORT

1.1 Overview

In order to develop the FVMP, a numerical model was constructed and calibrated to provide a predictive tool for measuring groundwater flow during and following mining operations. The model was constructed using the industry standard ModFlow Surfact code and developed over multiple stages;

Stage 1 - model conceptualisation and construction.

Stage 2 - steady state model calibration (pre-mining conditions, incorporating Rix's Creek underground works as they have been in operation for over 100 years).

Stage 3 - pseudo-steady state model calibration (mining operations over the last 10 years).

Stage 4 - transient model calibration (current mining operations).

Stage 5 - predictive model runs (five in total) up to October 2016 (proposed future mining operations schedule).

Stage 6 - recovery model run for 100 years (post-mining conditions).

Data acquired from the established groundwater monitoring program, as well as any regional groundwater data that was made available, was used as baseline data to enable model calibration.

A simplified modelling approach was enacted. The justification for which is as follows:

- the RCCP sites sit inside a relatively simple basin-like structure that effectively confines, and hence limits, the extent of any impacts from RCCP's operation.
- the potential for continued operations in Pit 3 and other mining activities in the area will control groundwater levels and keep them artificially low post 2016.

One predictive model scenario was run up to October 2016 which replicates the pit schedule information provided (refer to Section 2 of the Final Void Management Plan (FVMP) report). A subsequent recovery model was also run for 100 years in order to predict the conditions post-mining.

1.1.1 Modeling Software

A 3-Dimensional finite difference model was constructed using the MODFLOW SURFACT (Version 3) code to allow for both saturated and unsaturated flow conditions. The modelling was undertaken using the Groundwater Vistas (Version 5.16) software package (ESI, 2007).

The model structure, modelling approach, model calibration, the results of simulations and the assessment of potential impacts to the groundwater environment are discussed in detail in the following sections.

1.2 Model Design

1.2.1 Hydrogeological Conceptualisation

The conceptual model is a simplified representation of the real system, identifying the most important geological units and hydrogeological processes, while acknowledging that the real system is hydrologically and geologically more complex. The conceptual model forms the basis for the computational groundwater flow model.

Section 2 of the FVMP report outlines the hydrogeological conceptualisation for the Rix's Creek model area.

1.2.2 Model Extent and Boundary Conditions

The geometry of the model was delineated to the east and west by the Barrett seam outcrops. The southern boundary was represented by Rix's Creek and its confluence with the Hunter River. The northern boundary was set (conservatively) slightly north of Glennies Creek in order to consider the location of the inferred Hebden Thrust and further outcropping throughout this area. The model domain is shown in Figure 1.

The model boundary conditions have been assigned to represent the regional groundwater flow system in a realistic manner, taking into account stratigraphic and topographic controls. The transient calibration model boundary condition maps for each layer are illustrated in Appendix A.

The model was constructed with seven layers. The majority of the cells within each layer are active, with the exception of sections of inactive (no flow) cells to the west, east and north-east – representing the Barrett seam outcrop which acts to constrain the Basin (see figures of transient calibration model boundary conditions in Appendix A).

1.2.3 Model Layers and Grid

The model domain covers an area of 65km x 143km (9,295km^2). In order to optimise the accuracy of the model a refining grid pattern has been utilised. The grid pattern ranges from 100m on the periphery of the domain down to a constant 25m by 25m across the area of interest at the mine site. This gives a grid mesh of 294 rows and 177 columns, a total of 52,038 cells per layer, or 364,266 cells for the full seven-layer model. Due to the presence of the aforementioned no-flow areas, only 267,435 cells within the model are active.

The non-uniform grid size across the model domain was also selected to optimise the model run time and improve model efficiency, whilst still maintaining the 25 x 25m grid accuracy within the vicinity of the main RCCP operation. This approach was adopted to provide the capability for accurate modelling of potential design criteria and specifications for final landform configuration and to enable the assessment of the post-mining groundwater equilibration to meet consent condition 16C.

A seven layer modelling approach was considered to most appropriately represent the basin system (see Table 1.1). This approach provides the capability to represent surface and groundwater interactions and allow for activities relating directly to RCCP to be quantified, as well as take in to account other mining activity in the area and the proposed activities post 2016.

Table 1.1: Rix's Creek model layer set up

Layer Number	Lithology
1	Quaternary alluvium
	Weathered bedrock / Regolith
2	Overburden
3	Arties to Lower Liddell seam
4	Lower Liddell to Barrett
5	Barrett seam and interburden
6	Hebden seam
7	Basement (Siltstone)

Layers 1 to 7 were designated as MODFLOW SURFACT 'Type 3' layers, which allow each to behave as unconfined or confined depending on water levels relative to layer elevations.

1.2.4 Model Features for Recharge and Discharge

Surface Water Features

The numerical model uses MODFLOW River (RIV) cells to represent the Glennies Creek and the Hunter River (variable streams), located in the north and south of the model respectively (see Figure 2). Across all models (steady state and all transient), the river stage levels are set as a constant of one metre below surface elevation (top of layer 1), and the river base is set to one metre below the river stage height. River conductance (river skin hydraulic conductivity divided by skin thickness) is set to 100m/day.

The numerical model uses MODFLOW Drain (DRN) cells to represent Rix's Creek (groundwater discharge to gaining streams), located in the south of the model (see Figure 2). Across all models (steady state and all transient), the drain stage levels are set as a constant of one metre below surface elevation (top of layer 1). Drain conductance is set to 100m/day.

A tailings dam for Pit 2 is present within the transient calibration model, as well as the first three predictive models (backfilled post-2014). The numerical model uses a general head boundary (GHB) condition to simulate this feature. A stage of 56.0m AHD is set (John Hindmarsh, pers. comms).

Recharge

Recharge is applied using the MODFLOW Recharge (RCH) Package.

The steady state, pseudo-steady state and recovery models use the historical average rainfall value (698 mm/yr) from BOM station 061397 to calculate recharge zonations as follows:

- Alluvium – 10% of rainfall (70mm/yr).
- Backfill – 3.5% of rainfall (25mm/yr).
- Dams – 100% of rainfall (698mm/yr).
- All other areas - 2mm/yr.

The transient calibration model use actual recorded monthly data from the Rix's Creek weather station; while the transient prediction runs uses monthly averages. Recharge zonations are determined using the same method as above i.e. alluvium zone recharge is 10% of recorded rainfall. The average monthly rainfall rates are provided in Table 1.2 below.

Table 1.2: Average monthly rainfall rates

Month	Rainfall (mm/year)
January	884
February	939
March	836
April	683
May	541
June	694
July	603
August	493
September	548
October	603
November	705
December	873

Evapotranspiration

Evapotranspiration (ET) is applied using the MODFLOW Evapotranspiration Package.

For all models (steady state and transient) evapotranspiration is constant across the model domain, except where dams are present. In the transient models a slightly elevated ET is observed.

The steady state and recovery models uses a constant evapotranspiration rate of 650mm/yr, calculated as 50% of the average annual potential ET in the region as provided in the *Climate Atlas of Australia – Evaporation* (BOM 2001).

The pseudo-steady state and transient models (calibration and prediction runs) use constant monthly averages, calculated as 50% of the average monthly potential ET in the region as provided in the Climate Atlas of Australia – Evaporation (BOM 2001). These evapotranspiration rates are provided in Table 1.3 below.

Table 1.3: Average monthly evapotranspiration rates

Month	ET on model area (mm/years)	ET on dams (mm/year)
January	1,059	1,165
February	880	968
March	796	877
April	548	603
May	354	387
June	304	335
July	294	324
August	402	442
September	548	603
October	796	877
November	913	1,004
December	1,059	1,165

Across all groundwater models, the ET rate diminishes to zero at an extinction depth of 1.5m (which effectively limits its operation to areas with a very shallow water table).

Mine Operations

From the pseudo-steady state model and onwards, active mine pits are represented using MODFLOW Drain (DRN) cells. The drain cells are located across a number of layers (down to layer 6), with variable stage levels. Drain conductance is set to 1,000m/day.

1.2.5 Aquifer Hydraulic Parameters

A set of spatially uniform aquifer parameters were initially applied to each aquifer/aquitard unit, as well as the mine operation areas within the calibration models. During calibration, these parameters were altered (invoking a degree of spatial variation) within the expected parameter range to provide a good match to recorded water levels and patterns.

The final calibrated parameters are summarised in Table 1.4 and spatial variation of hydraulic conductivity within the transient calibration model is illustrated in Figures B1 to B7, Appendix B. The spatial variation has been based on the geological units found within the project area, as well as the proposed mine schedule, described further in Section 2 of the FVMP report and outlined in Table 1.5 as it relates to the predictive models.

Table 1.4: Summary of calibrated hydraulic parameters for Rix's Creek

Zone no.	Description	K_h (m/day)	K_v (m/day)	S_y (1/m)	S	Porosity
1	Regolith	1	0.1	5.0×10^{-4}	1.0×10^{-3}	1.0×10^{-3}
2	Glennies Alluvium	30	15	1.0×10^{-3}	2.5×10^{-1}	2.5×10^{-1}
3	Hunter Alluvium	30	15	5.0×10^{-4}	5.0×10^{-2}	5.0×10^{-2}
4	Rix's Creek Alluvium	10	5	5.0×10^{-4}	5.0×10^{-2}	5.0×10^{-2}
5	Basement	5.00×10^{-3}	5×10^{-5}	5.0×10^{-4}	1.0×10^{-3}	1.0×10^{-3}

Zone no.	Description	K_h (m/day)	K_v (m/day)	S_y (1/m)	S	Porosity
6	Overburden (layer 2)	1.08×10^{-2}	1.08×10^{-3}	1.0×10^{-5}	1.0×10^{-2}	1.0×10^{-2}
7	Leddell Seam (layer 3)	2.00×10^{-2}	8×10^{-4}	5.0×10^{-5}	5.0×10^{-2}	5.0×10^{-2}
8	Interburden (layer 4)	1.85×10^{-3}	1.85×10^{-5}	1.0×10^{-5}	1.0×10^{-2}	1.0×10^{-2}
9	Berrett Seam (layer 5)	2.00×10^{-2}	2×10^{-4}	5.0×10^{-5}	5.0×10^{-2}	5.0×10^{-2}
10	Hebden Seam (layer 6)	2.00×10^{-2}	8×10^{-4}	5.0×10^{-5}	5.0×10^{-2}	5.0×10^{-2}
11	Rix's UGW	100	100	4×10^{-2}	4.0×10^{-1}	8.0×10^{-1}
12	Backfill	1	0.1	5.0×10^{-5}	1.0×10^{-1}	0
13	Dam	1000	1000	5.0×10^{-5}	9.9×10^{-1}	0
14	--	--	--	--	--	--
15	Impact of Glennies UGW (Layer 2)	2.16×10^{-2}	1.08×10^{-1}	--	--	--
16	Impact of Glennies UGW (Layer 1)	2	1	--	--	--
17	Impact of Glennies UGW (Layer 4)	3.69×10^{3}	5.54×10^{-5}	--	--	--

Note: UGW stands for underground works

Table 1.5: Set up for predictive models

Model ID	From	To	Pit 1	Pit 2	Pit 3	Camberwell
1	1/1/11	29/2/12	No change	No change	No change	No change
2	1/3/12	30/4/13	Pit1_Pred1	No change	Pit2_Pred1	No change
3	1/5/13	30/6/14	Pit1_Pred2	No change	Pit2_Pred2	No change
4	1/7/14	31/8/15	Back Fill	Back Fill	Pit2_Pred3	No change
5	1/9/15	31/10/16	Back Fill	Back Fill	Pit2_Pred4	No change

The parameters provided in Table 1.4 are consistent with those applied in the numerical groundwater model for *Glennies Creek Open Cut Coal Mine Report No. 642/04* (AGE 2007). In addition, the vertical and horizontal hydraulic conductivity ratios are based on previous modelling studies and published literature.

The hydraulic parameters from the AGE (2007) are provided in Table 1.6 for comparison.

Table 1.6: Summary of hydraulic parameters applied in the Glennies Creek Open Cut Coal Mine numerical groundwater model (from AGE 2007)

Layer	K_h (m/day)	K_v (m/day)	S_y (1/m)	S_s (1/m)
Layer 1 (alluvium aquifers)	1 to 10	0.5 to 2.5	2.5×10^{-1}	1.0×10^{-3}
Layer 2 (overburden)	5.0×10^{-4} to 5	5.0×10^{-5} to 5	1.0×10^{-2}	1.0×10^{-5}
Layer 3 (Middle and Lower Liddel Seams)	1.8×10^{-3} to 5	1.8×10^{-4} to 5	5.0×10^{-2}	5.0×10^{-5}
Layer 4 (interburden)	5.0×10^{-4} to 5	5.0×10^{-5} to 5	1.0×10^{-2}	1.0×10^{-5}
Layer 5 (Barrett and Hebden Seams)	1.8×10^{-3} to 5	1.8×10^{-4} to 5	5.0×10^{-2}	5.0×10^{-5}
Layer 6 (Saltwater Creek Formation)	1.0×10^{-3}	5.0×10^{-6}	1.0×10^{-2}	1.0×10^{-5}

1.2.6 Time Discretisation

The pseudo-steady state and transient models were constructed with differing time discretisation; to enable appropriate model stress period timeframes for hydrological stresses encountered (e.g. recharge and changes in aquifer parameter values due to underground works). The time discretisation set up for each model is outlined in Table 1.7.

Table 1.7: Time discretisation set up in Rix's Creek models

Model	No. Stress Periods	Stress Period Length (days)	No. Time Steps	Time Step Multiplier
Steady state	n/a	n/a	n/a	n/a
Pseudo-steady state	1	1825	20	1.5
Transient	24	30	2	1
Predictive (1 – 5)	14	30	1	1
Recovery	1	36,500	25	1.1

The transient model was used to calibrate against observations made during the current mining operations. While the model was run for 24 stress periods (two years), only the latter 12 stress periods (one year – from May 2010 to April 2011) was used to calibrate against. The initial 12 stress periods were used to take into account storage effects.

1.3 Model Calibration

1.3.1 Calibration Approach

Calibration is the process by which the independent variables (parameters and boundary conditions) of a model are adjusted, within realistic limits, to produce the best match between simulated and measured data. The realistic limits on parameter values are constrained by the range of measured values from pumping tests and other hydrogeological investigations.

An iterative process was undertaken to calibrate the Rix's Creek model:

- A steady state model was built and run, based on pre-mining conditions (including Rix's Creek underground works).
- A pseudo-steady state model was run using a five year transient calibration, with initial heads provided by the water levels generated in the steady state model. This model accounted for the mining operations over the last ten years.
- A transient model was run over two years, with initial heads provided by the water levels produced in the pseudo-steady state model. Following a 12 month storage effects period, the latter 12 months of the model run period was used to calibrate against observed data during current mining operations (from May 2010 to April 2011).

Limited groundwater level data was available from the Rix's Creek Mine area with transient records only available from 2010 from a small number of groundwater monitoring bores initially. Hence, the steady state and pseudo-steady state calibration are of limited value, other than to determine a set of starting groundwater heads for a transient calibration.

At each step of the modelling process, model calibration performance was checked against a range of calibration targets, discussed in the following section.

1.3.2 Calibration Targets

At each step of the modelling process, model calibration performance was checked in quantitative (head value matches) and qualitative (pattern-matching) terms against a range of monitoring targets, in accordance with the model guidelines (Middlemis, 2001), including:

- Groundwater level based targets:
  - modelled versus measured head at key times (including calibration statistics); and
  - time-series hydrographs of modeled / measured heads at selected bores.
- Other water balance components over time.

The location of the calibration targets across the model domain are provided in Figure 3.

1.3.3 Steady State and Pseudo-Steady State Calibration

The Rix's Creek model was run in steady state mode to simulate the regional groundwater levels prior to mining activity conditions. The only mining operations incorporated in the calibration model were the Rix's Creek underground works (represented as zones of higher hydraulic conductivity and storativity), as they have been in operation for over 100 years. A subsequent pseudo-steady model was run to account for mining operations over the last ten years.

Due to the lack of observation bores within the study area prior to 2010, quantitative measures such as calibration statistics could not be determined. Hence, assessment of the accuracy of the steady state and pseudo-steady state water levels was determined semi-quantitatively by considering whether the modelled regional flow patterns are consistent with expected water levels.

The overall groundwater balance for the pseudo-steady state model is summarised in Table 1.8.

The total inflow is around 16.3ML/d, comprising leakage into the aquifer from the rivers (74.2%), rainfall recharge (18.4%) and storage (7.4%).

The total outflow of the aquifer system (16.5ML/d) comprises discharge from the groundwater into the river (baseflow of 64.8%), evapotranspiration (19.4%) as well as discharge to Rix's Creek and mine pits (represented by drain cells) (15.8%). The water balance discrepancy between the total inflow and outflow for the five year pseudo-steady state simulation period was 1.3%.

Table 1.8: Groundwater Budget for Rix's Creek Pseudo-Steady State Calibration

Component	Groundwater Inflow (ML/d)	Groundwater Outflow (ML/d)
Rainfall Recharge	3.0	0.0
Evapotranspiration (EVT)	0.0	3.2
River	12.1	10.7
Drains	0.0	2.6
Storage	1.2	0.0
TOTAL	16.3	16.5

1.3.4 Transient Model Calibration

The aim of the transient calibration was to achieve a history match to the observed groundwater level impacts during the period May 2010 to April 2011, which included the effects of Pit 1, Pit 2 (backfilled and tailing dam present), the Camberwell pit and the Glennies Underground Works, as well as varying recharge conditions in response to actual rainfall.

The transient model implements two time varying features, namely:

- Recharge (both rate and area); and
- Evapotranspiration.

The initial conditions in the transient model calibration were based on the heads generated by the pseudo-steady state model. The calibration process involved changing aquifer parameter values (horizontal and vertical hydraulic conductivity) within reasonable limits (constrained by available data and hydrogeological knowledge of the area) using parameter estimation software PEST (Doherty 2005), until reasonable matches were obtained between the observed and simulated hydrographs, and reasonable calibration statistics were obtained.

Despite this process, aquifer parameters are consistent between the steady state, pseudo-steady state and transient models. Aquifer parameters that were changed during the course of the transient calibration process were recycled into the pseudo-steady state models, with the latter models being re-run to generate new sets of initial water levels.

1.3.5 Transient Water Balance

The overall groundwater balance at the end of the transient calibration period (30 April 2011) is summarised in Table 1.9.

The total inflow is around 17.5ML/d, comprising leakage into the aquifer from the rivers (66.8%), rainfall recharge (24.0%), storage (8.6%) and leakage into the aquifer from Pit 2 tailings dam (represented by GHB cells) (0.6%).

The total outflow of the aquifer system (16.8ML/d) comprises discharge from the groundwater into the river (baseflow of 68.4%), evapotranspiration (11.3%), discharge to Rix's Creek and mine pits (represented by drain cells) (19.0%) and storage (1.8%). The water balance discrepancy between the total inflow and outflow at the end of the transient simulation period (30 April 2011) was 4.0%.

Table 1.9: Groundwater Budget for Rix's Creek Model Transient Calibration (April 2011)

Component	Groundwater Inflow (ML/d)	Groundwater Outflow (ML/d)
Rainfall Recharge	4.2	0.0
Evapotranspiration (EVT)	0.0	1.9
River	11.7	11.5
General Head Boundary	0.1	0.0
Drains	0.0	3.2
Storage	1.5	0.3
TOTAL	17.5	16.8

Comparison to pseudo-steady state model water balance

A comparison of the transient model water balance (Table 1.9) against the pseudo-steady state water balance (Table 1.8) indicates that, when based on current mine operations and measured data, the total groundwater inflow increases by approximately one megalitre per day (ML/d), while there is little change in the total groundwater outflow.

In terms of groundwater inflows, leakage to the aquifer from the rivers is still the dominant mechanism. This leakage has also increased both in terms of total volume and proportion of total inflow. Recharge also exhibits these increases in total volume and proportion of total inflow, when compared against the pseudo-state model. There is minimal leakage from the Pit 2 tailings dam to the aquifer.

In terms of groundwater outflows, discharge from the aquifer to the rivers is still the dominant mechanism. This discharge has also increased both in terms of total volume and proportion of total inflow. However evapotranspiration exhibits decreases in total volume and proportion of total inflow, when compared against the pseudo-steady state model. Aquifer storage is now also creating groundwater outflows, however the volumes are minimal.

1.3.6 Calibration to groundwater levels and trends

Hydrographs for calibration were available from the monitoring program undertaken by RPS Aquaterra for Bloomsfield Colliery between the period May 2010 and November 2011. Calibration bores were placed into an appropriate layer within the model, based on the screened interval depth, and hence targeted aquifer unit.

A number of monitoring bores were excluded from the transient calibration process. These are provided in Table 1.10, along with the justification for their exclusion.

Table 1.10: Justification for exclusion of specific monitoring bores

Monitoring bore	Justification
GC02	Inside/too close to the pit
GC05	Inside/too close to the pit
GC06	Inside/too close to the pit
GC08	Observed water levels are too low to enable match
BH-3	Immediately adjacent to No Flow cells

Calibration Statistics

Figure 4 shows a scatter plot of modelled versus measured groundwater levels (heads) for May 2010 to April 2011. These plots demonstrate that there is no systematic error present in the modelled results at any of the presented times.

The scaled RMS value is the major quantitative performance indicator, calculated as the RMS value divided by the range of measured heads across the model. The adopted calibration has an SRMS value of 9.3%.

Given uncertainties in the overall water balance volumes (e.g. it is difficult to directly measure evaporation, or baseflow to the rivers), it was considered that a scaled RMS value of between 5% and 10% for ground water levels would be an appropriate target for this project, consistent with the Australian best practice modelling guideline (MDBC, 2001).

Transient Calibration Groundwater Hydrographs

Detailed hydrographs comparing observed and predicted groundwater levels for the transient calibration can be seen in Appendix C. They show reasonable agreement between predicted and observed levels, taking into consideration the acknowledged lack of data for some aspects of the model, such as mine plan extent, evapotranspiration and boundary conditions.

Some general observations from the transient calibration hydrographs provided in Appendix C are as follows:

- Monitoring bores BH5 (layer 4) and GC01 (layer 6) provide excellent calibration matches, both in terms of groundwater levels (less than two metres) and trend;
- The majority of the hydrographs indicate differences between the measured and modeled groundwater levels of between five and ten metres. These occur across all layers, and in both Rix's Creek and the Camberwell mining operations area.
- Monitoring bore GC13 provides the poorest calibration match, with groundwater level differences greater than ten metres. It is located within layer 6, and is the closest to the eastern no-flow boundary near Camberwell.
- The majority of the hydrographs indicate flat or declining water level trends, both in terms of observed and modeled values (the latter occasionally more downwardly exaggerated than the former, but in general a reasonable match is produced).
- Monitoring bores BH4, BH5 and 20BL170864 are all located in layers 4 and 5 within the south-east section of the Rix's Creek mine area. Observed data from these three bores all indicate a rise in groundwater levels after mid-2011. However, this occurs following the model transient calibration period and hence a match was not attempted.
- A number of bores are located in proximity to pits, where high groundwater level gradients and uncertainty relating to mine plan extents may result in the poor modeled to observed matches observed.

Modelled Groundwater Level Contours

The modelled water level contours for May 2010 and April 2011 are shown in Figures D1 to D6 (Appendix D).

The groundwater level contours indicate that the general direction of the groundwater flow is towards the centre of the model, with higher water levels produced around the model boundary edges. This is in agreement with the initial hydrogeological conceptualisation that the RCCP is confined within a geological basin structure.

A comparison of the water level contours for May 2010 and April 2011 indicate that there is little difference in flow patterns at these two times. This is observed in all the model layers (water levels contours for layers 2, 4 and 6 are provided in Appendix D).

1.4 Modelling Assumptions

The following assumptions and limitations, relating predominantly to the development and calibration of the Rix's Creek model, should be taken into consideration when assessing the results from the prediction and recovery analysis:

- There are inherent unknowns in terms of pre-mine conditions (including land use and climatic data).
- River and creek stages were taken as 1.0m below the terrain elevation as shown in the 2.0 m contour maps (SRTM Elevations). Detailed contour mapping was provided for the area within the lease boundary, the SRTM data was regarded as the most accurate topographical data to cover the extent of model domain outside the lease.
- The coal seam thickness outside the area of interest (lease 1432) was inferred. The aerial extent was based on seam outcrop and the thickness was assumed to be uniform across the model domain based on an average thickness observed within the lease area.
- The basement under the Hebden Seam was assumed to be completely impermeable, representing a seal underlying the basin structure.
- The mine plan extent (relates to drain cell and hydraulic conductivity zonation model setup) is based on the known extent at one period in time (early 2011).
- The criteria to select the transient calibration time span was determined by the availability of the (limited) monitoring bore data, as well as actual rainfall data.
- The mining schedule was hypothesised and was based on the 2011 mining footprint and the projected 2016 land form configuration. Stages of mining were represented in annual increments across approximately 5 years (2011-16). The overall change in the mining footprint from 2011 – 16 was then divided in to 5 portions to represent an approximate schedule for each year.

2. REFERENCES

AGE (2007) *Glennies Creek Open Cut Coal Mine – Groundwater Assessment*. Prepared for Integra Coal Operations Pty Ltd by Australasian Groundwater and Environmental Consultants Pty Ltd.

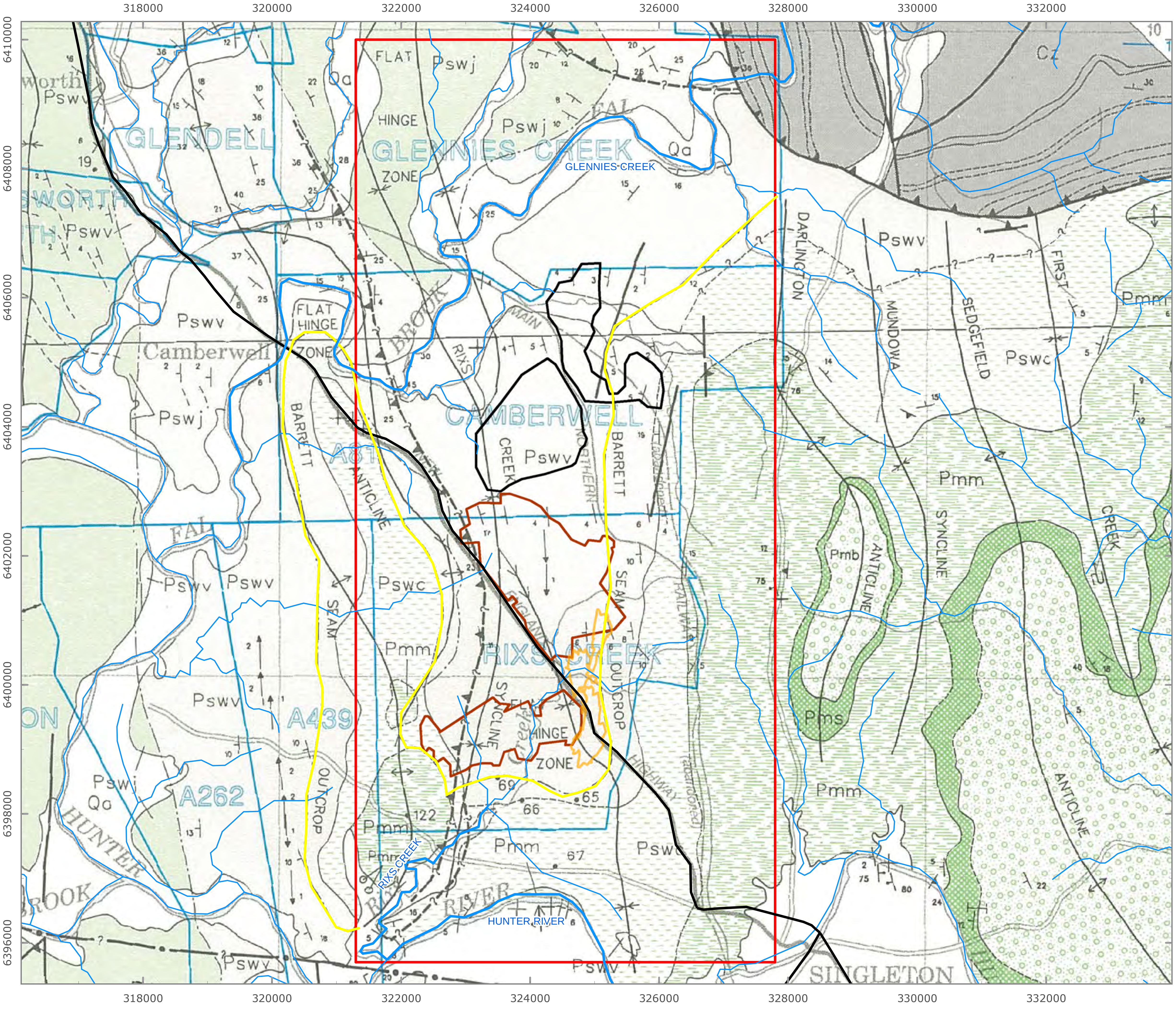
BOM (2001) *Climatic Atlas of Australia – Evaporation*. Australian Bureau of Meteorology.

Doherty (2005) *PEST Model-Independent Parameter estimation User Manual*. 5th Edition. Watermark Numerical Computing.

ESI (2006) *Guide to using Groundwater Vistas – Version 5.* Environmental Simulations, Inc.

Middlemis, H., Merrick, N. and J. Ross (2001) *Groundwater Flow Modelling Guide*. Prepared for Murray-Darling Basin Commission by Aquaterra Consulting Pty Ltd.

FIGURES



LEGEND

- Barrett OutCrop
- Principal Road
- Water Course
- Model Area
- Historic - Underground Workings
- Current Mine foot print
- Camberwell Outline

Qa - Quaternary Alluvium
Pswj - Wittingham Coal Measures
Pmm - Mulbring Siltstone
Pswv - Wittingham Coal Measures

0 750 1,500 3,000 Meters

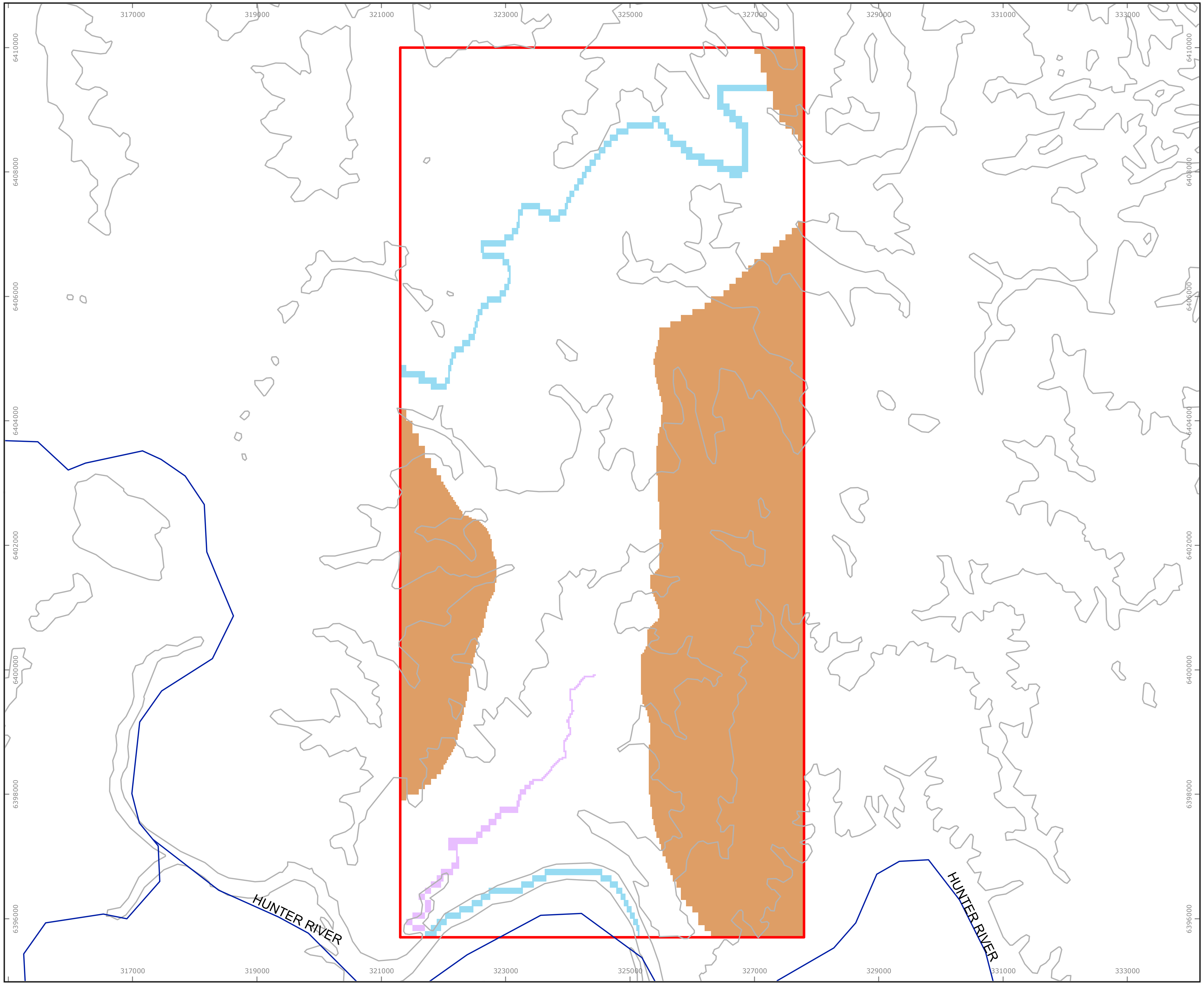
N

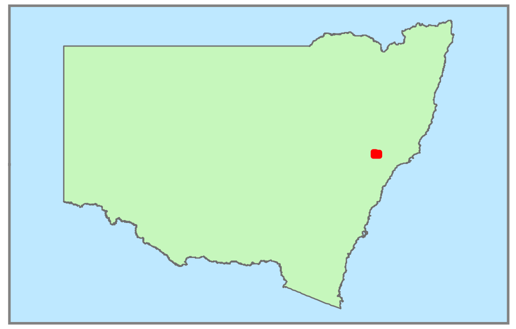
RPS Aquaterra

FIGURE 1

Rix's Creek Model Domain over Geological Map 9033

AUTHOR	HZ	PROJECT NO	S66C
CHECKED BY	CG	REVISION	A
DATE	21/12/2011	DRAWING NO.	021





LEGEND

- Rivers
- Elevation contours
- Model area
- Drain cells
- River cells
- No flow area

N

0 500 1,000 2,000

Metres

SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

DATA SOURCES

Input data sources here

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FIGURE 2

Modelled surface water features.

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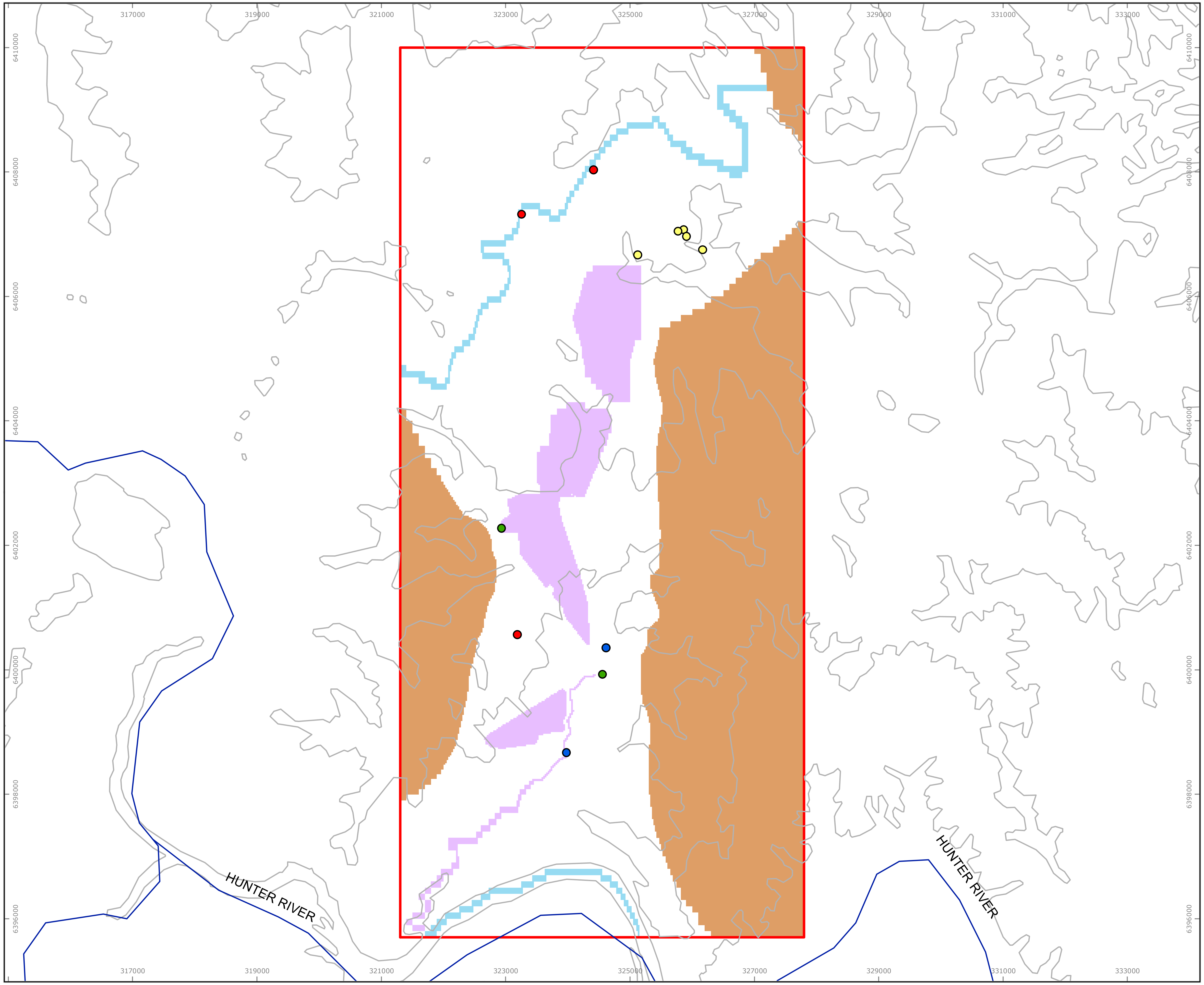

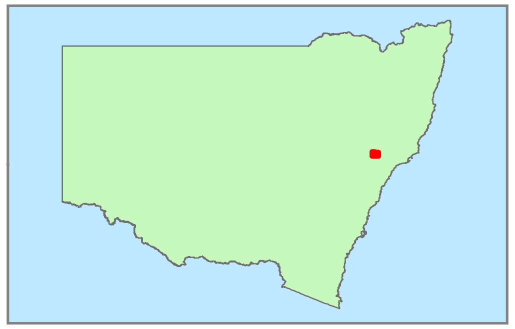

LEGEND

Calibration targets

- Layer 2
- Layer 4
- Layer 5
- Layer 6
- Rivers
- Elevation contours
- Model area
- River cells
- Inactive model areas
- Drain cells

N

0 500 1,000 2,000

Metres

SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

DATA SOURCES

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FIGURE 3

Rix's Creek transient calibration targets

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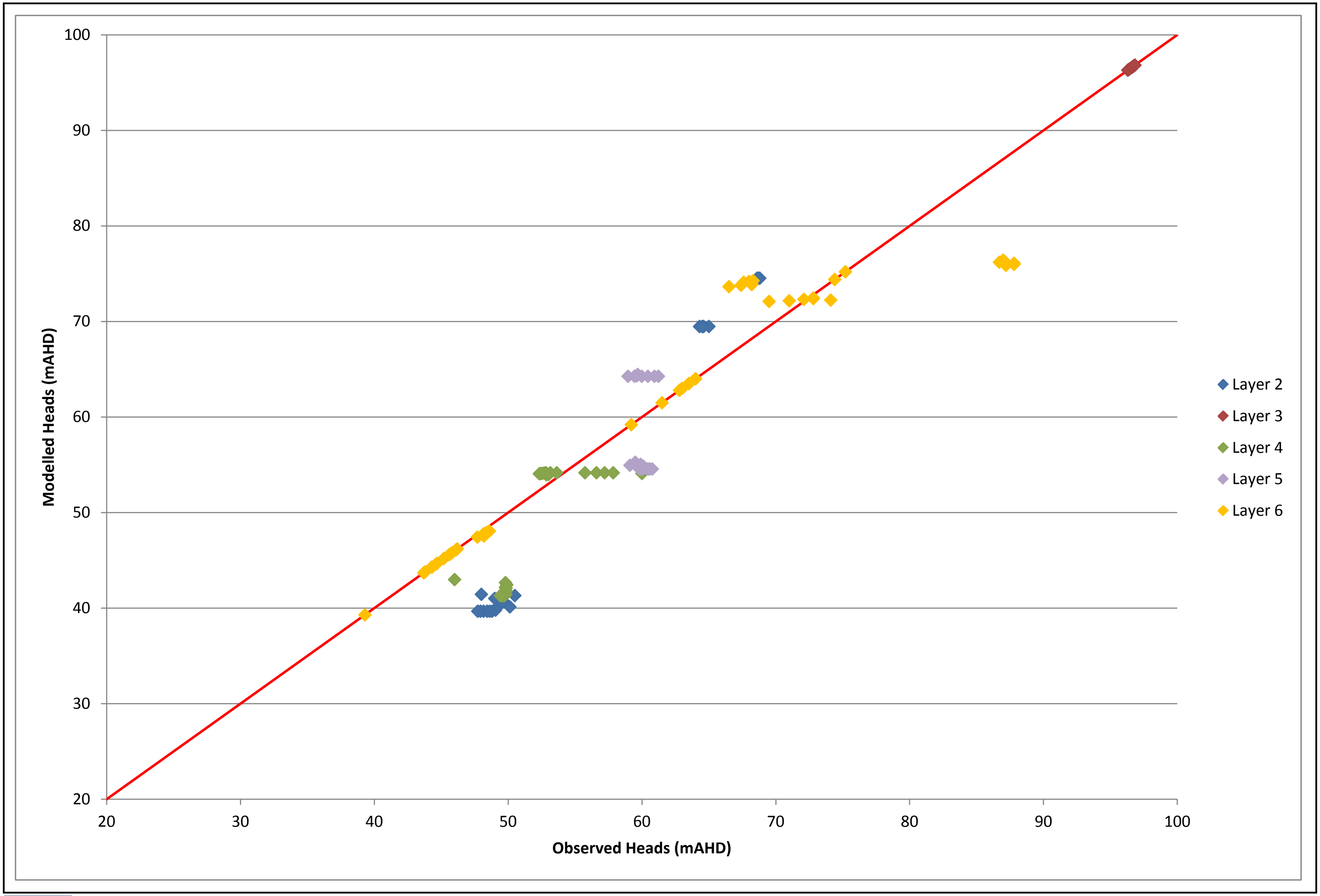

RPS Aquaterra

RIX'S CREEK TRANSIENT CALIBRATION SCATTERPLOT FIGURE 4

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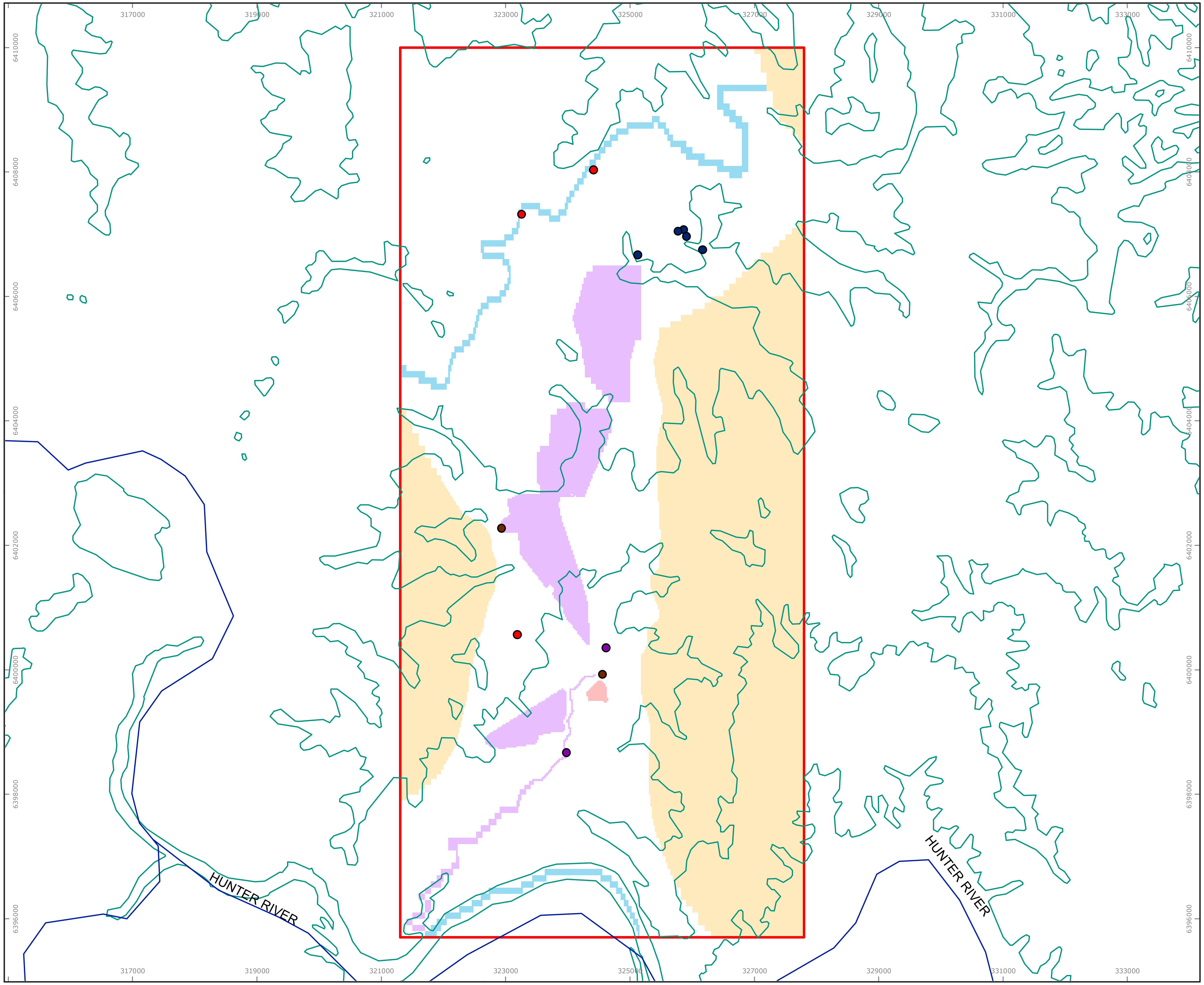
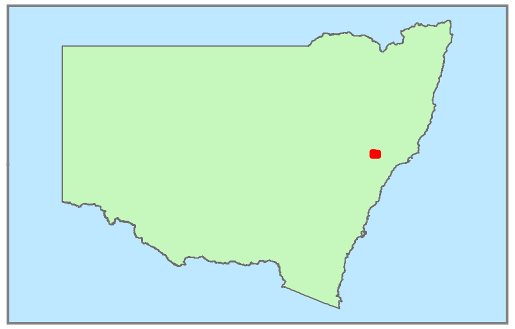
APPENDIX A: TRANSIENT CALIBRATION MODEL BOUNDARY CONDITIONS





LEGEND

Calibration targets

- Layer 2
- Layer 4
- Layer 5
- Layer 6
- Rivers
- Elevation contours
- Model area
- Drain cells
- GHB cells
- Inactive model area
- River cells

N

0 500 1,000 2,000
Metres

SCALE 1:59,583 @ A3

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DATA SOURCES

Input data sources here

APPENDIX A

Boundary conditions: Layer 1

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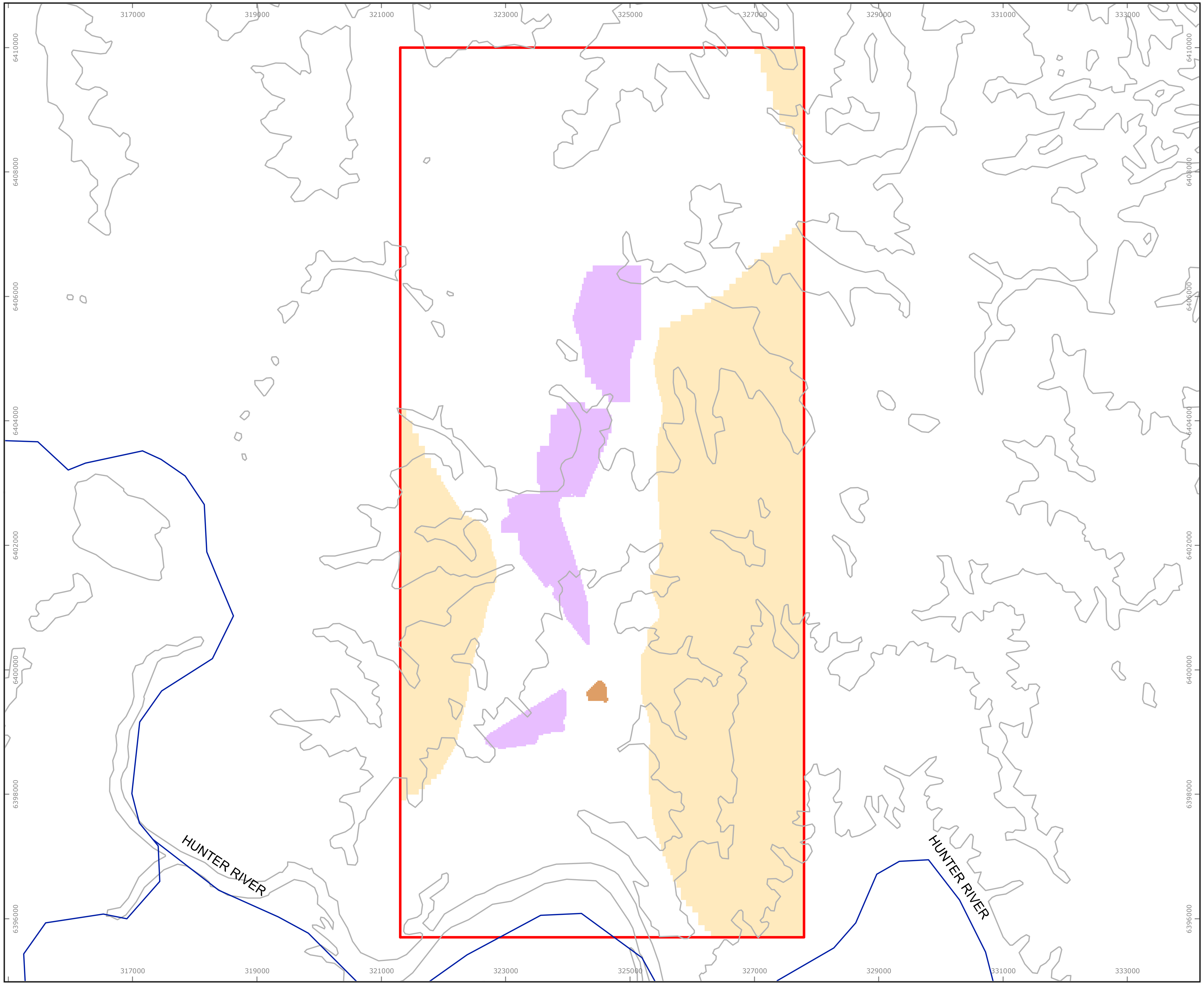
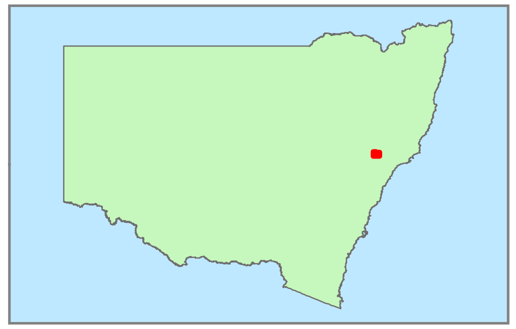
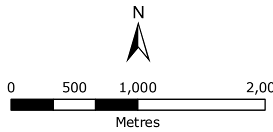




LEGEND

- Rivers
- Elevation contours
- Model area
- GHB cells
- Drain cells
- No flow cells



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DATA SOURCES

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APPENDIX A

Boundary Conditions: Layer 2

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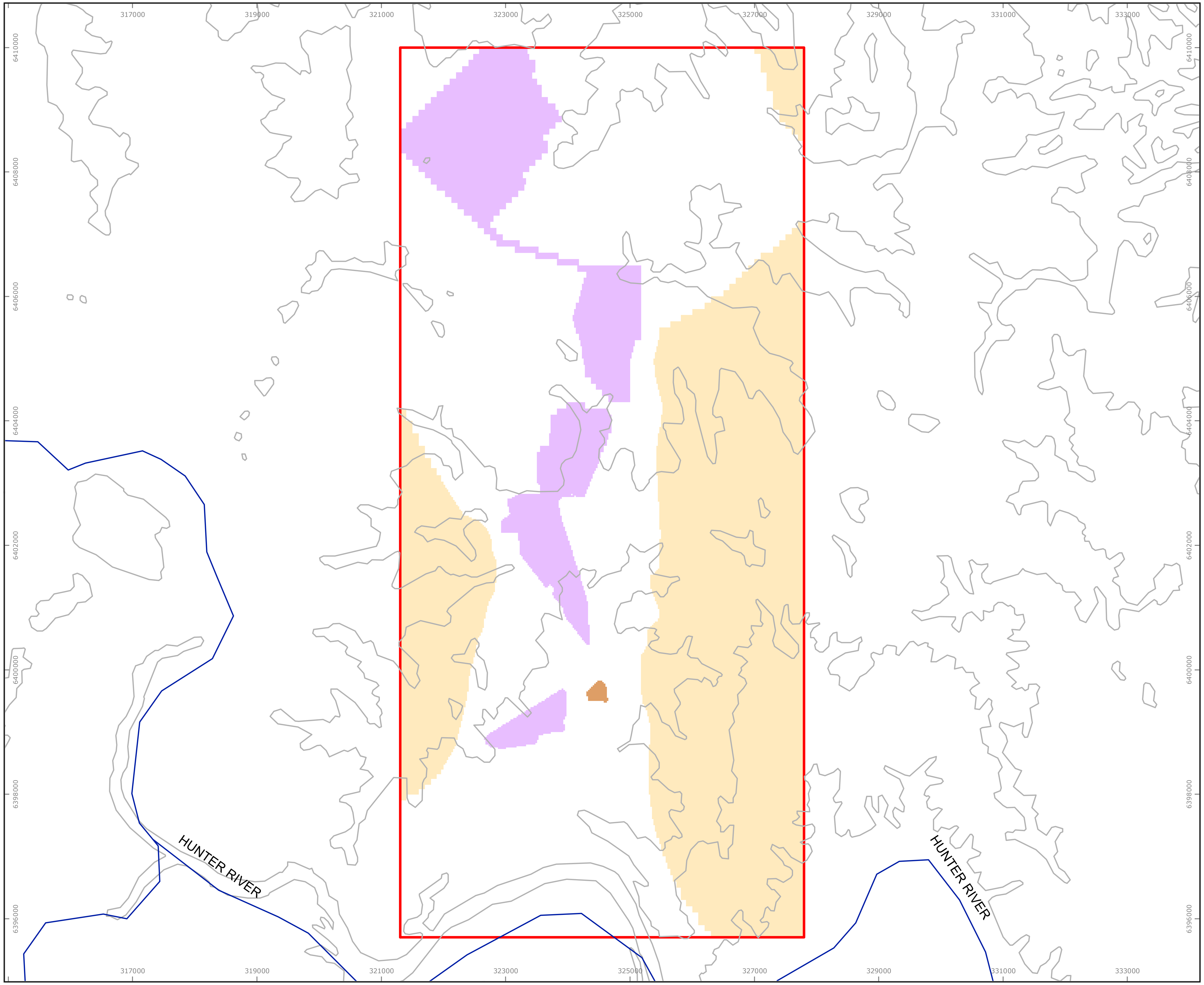

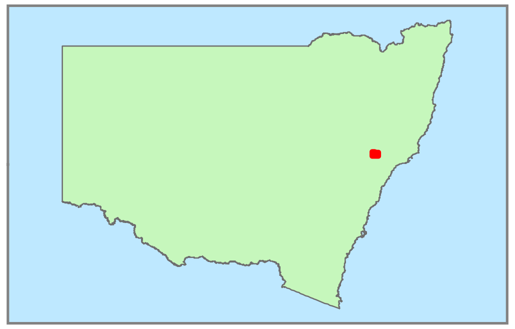

LEGEND

- Rivers
- Elevation contours
- Model area
- Drain cells
- GHB cells
- Inactive model area

N

0 500 1,000 2,000
Metres

SCALE 1:59,583 @ A3

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APPENDIX A

Boundary conditions: Layer 3

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DATE	18/1/2012	JOB NO.	S66C

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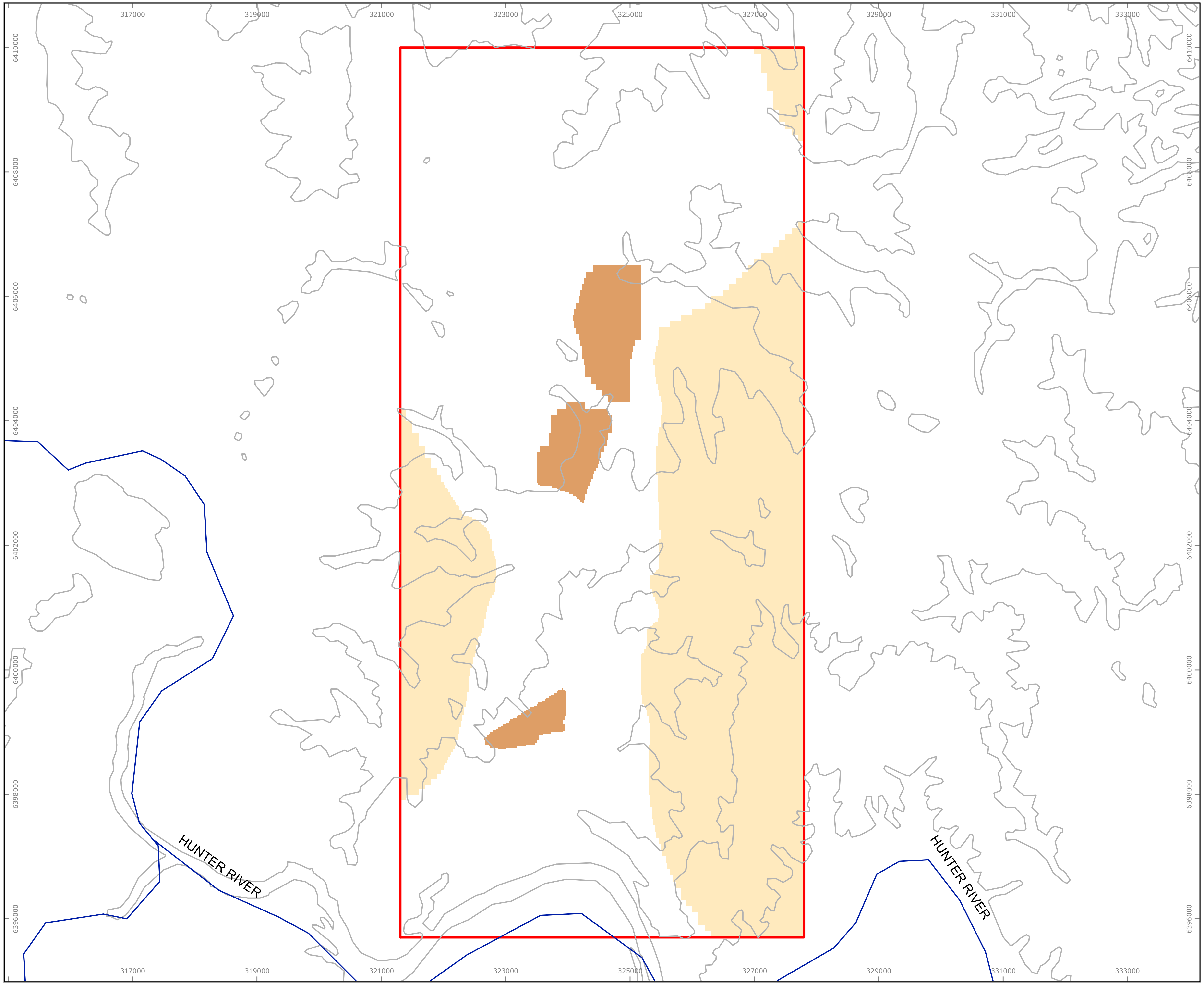

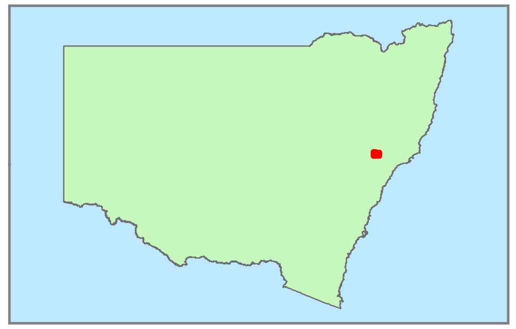

LEGEND

- Rivers
- Elevation contours
- Model area
- Drain cells
- Inactive model area

N

0 500 1,000 2,000

Metres

SCALE 1:59,583 @ A3

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APPENDIX A

Boundary conditions: Layer 4

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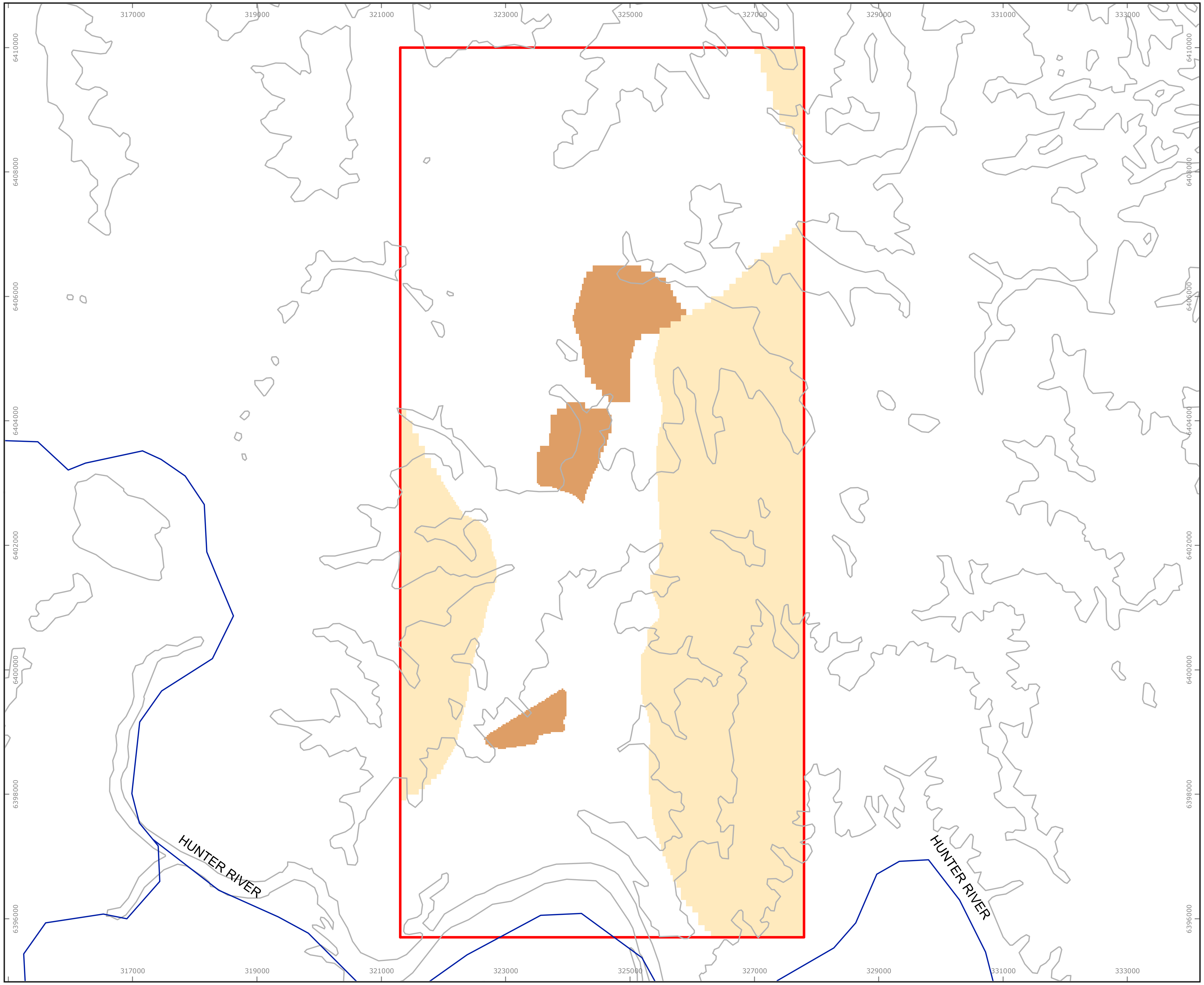
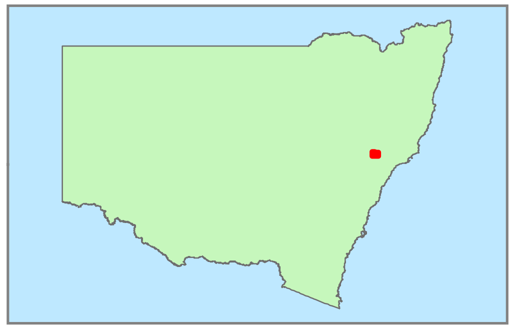
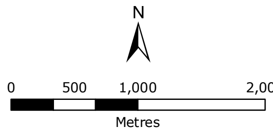
DATE	18/1/2012	JOB NO.	S66C





LEGEND

- Rivers
- Elevation contours
- Model area
- Drain_cells_L5
- Inactive model area



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APPENDIX A

Boundary conditions: Layer 5

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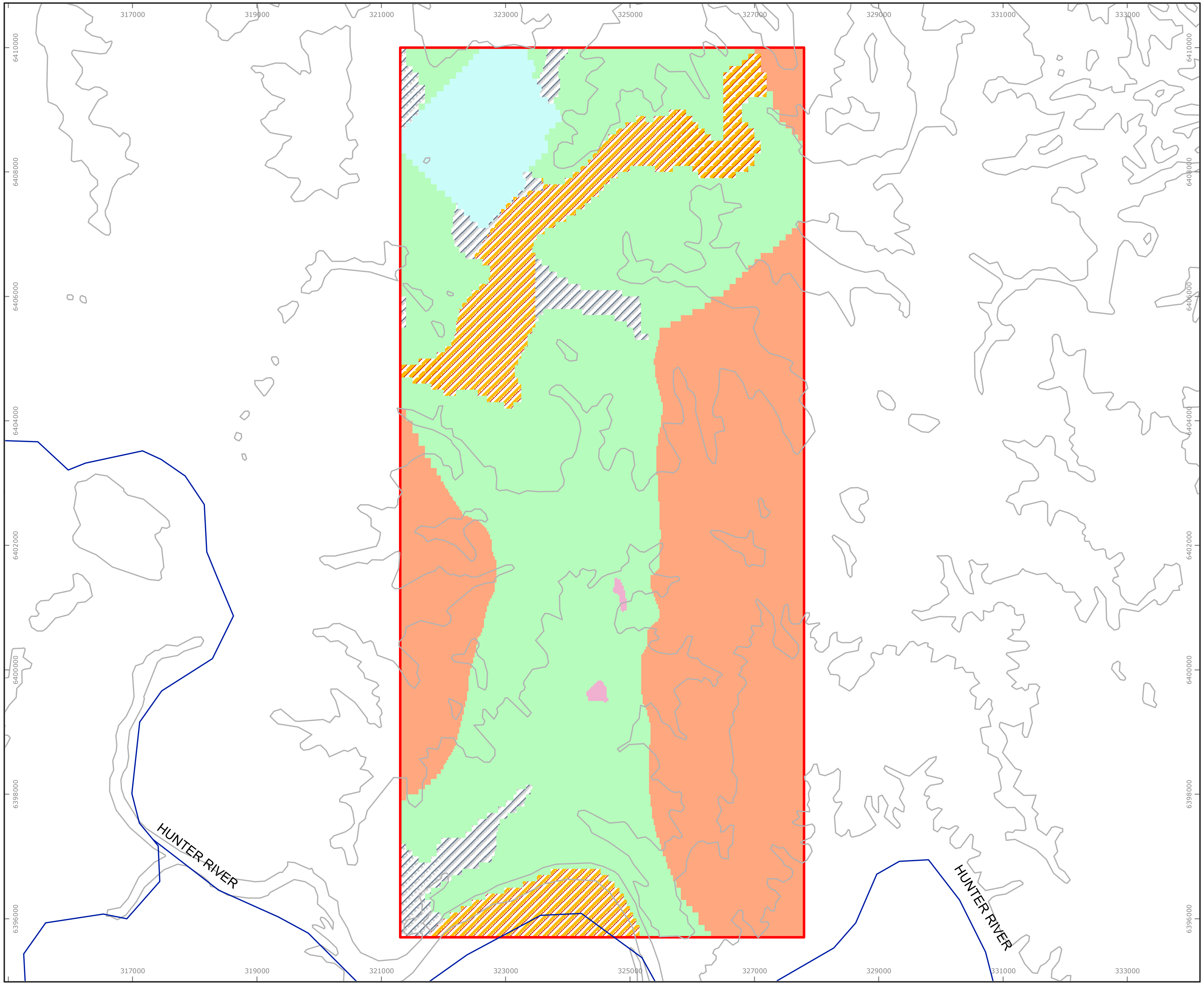
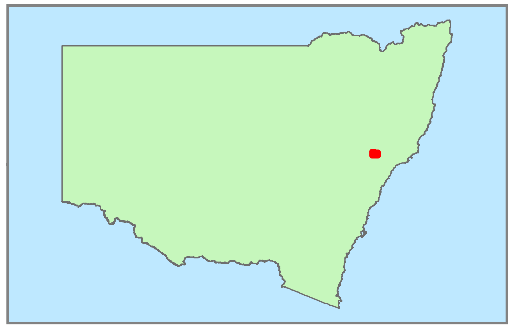
DATE	18/1/2012	JOB NO.	S66C

APPENDIX B: MODELLED TRANSIENT CALIBRATION HYDRAULIC CONDUCTIVITY





LEGEND

Rivers

Elevation contours

Model area

K_h zones (m/day)

1

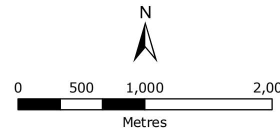
2

10

30

1000

Inactive model area



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DATA SOURCES

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APPENDIX B

Modelled transient calibration hydraulic conductivity: Layer 1

AUTHOR	KB	REPORT NO	031a
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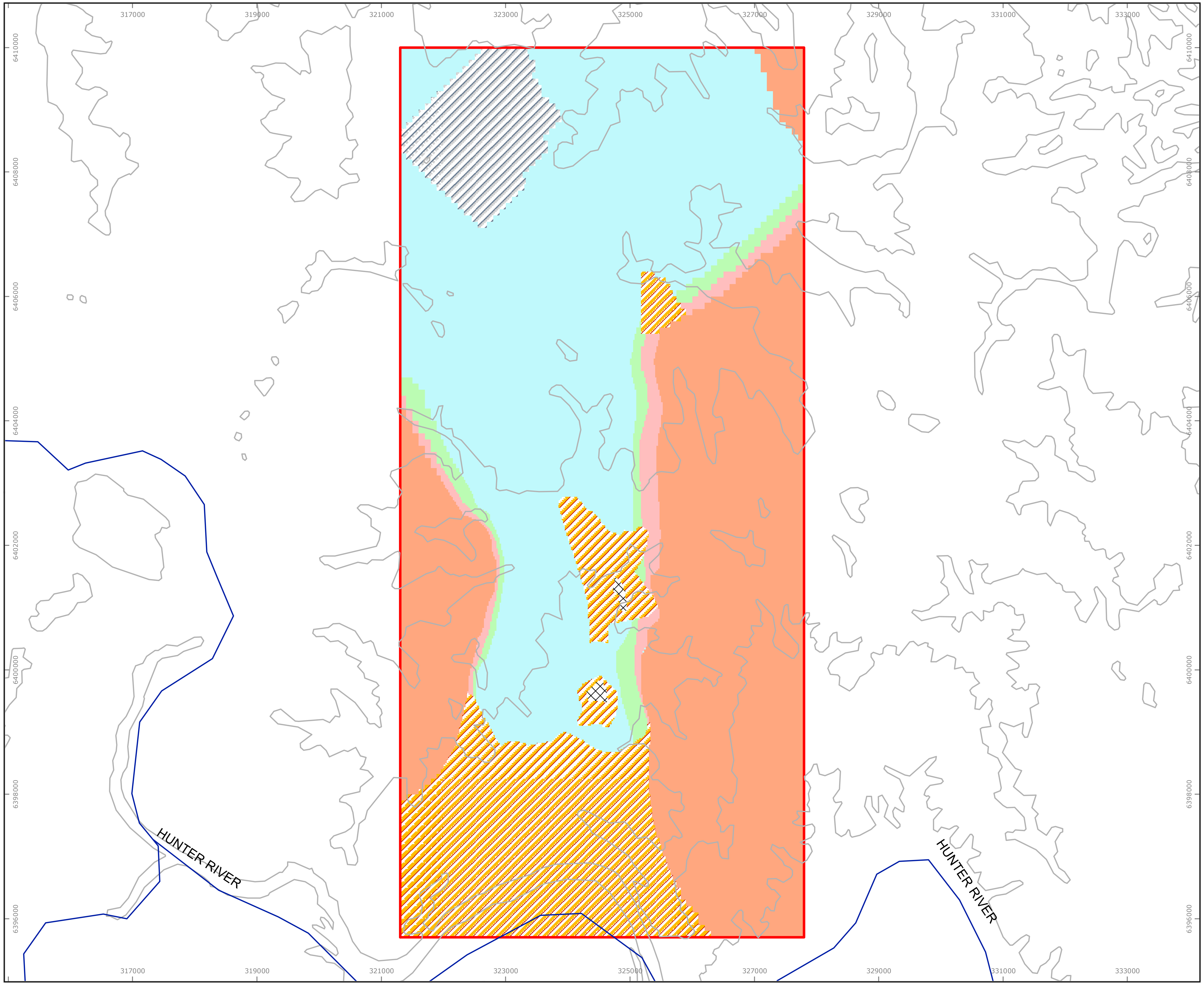

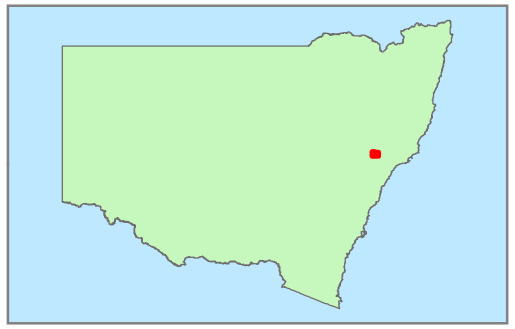

LEGEND

Rivers

Elevation contours

Model area

K_h zones (m/day)

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0.010779

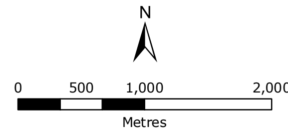
0.02

0.021559

1

1000

Inactive model areas



SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

DATA SOURCES

Input data sources here

APPENDIX B

Modelled transient calibration hydraulic conductivity: Layer 2

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DRAWN	AB	REVISION	a
DATE	18/1/2012	JOB NO.	S66C

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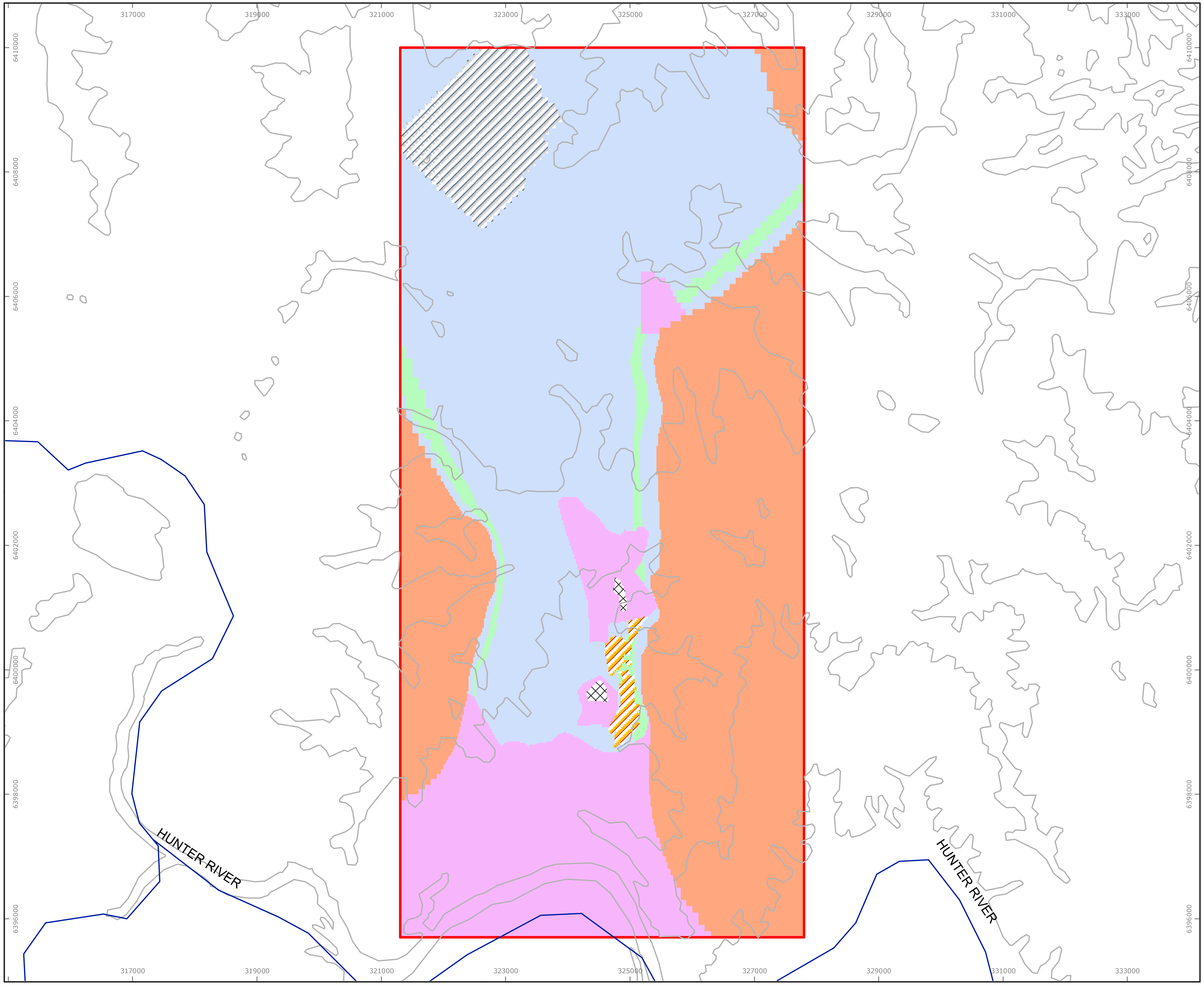
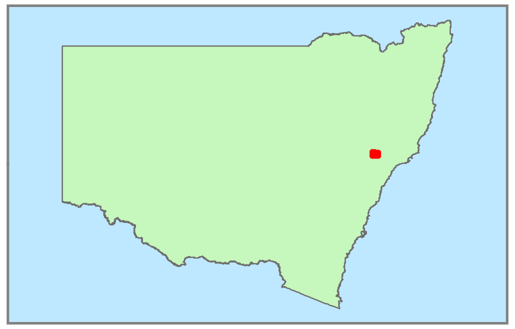


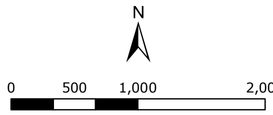


LEGEND

- Rivers
- Elevation contours
- Model area

K_h zones (m/day)

- 0.001846
- 0.02
- 1
- 10
- 100
- 1000
- Inactive model areas



SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

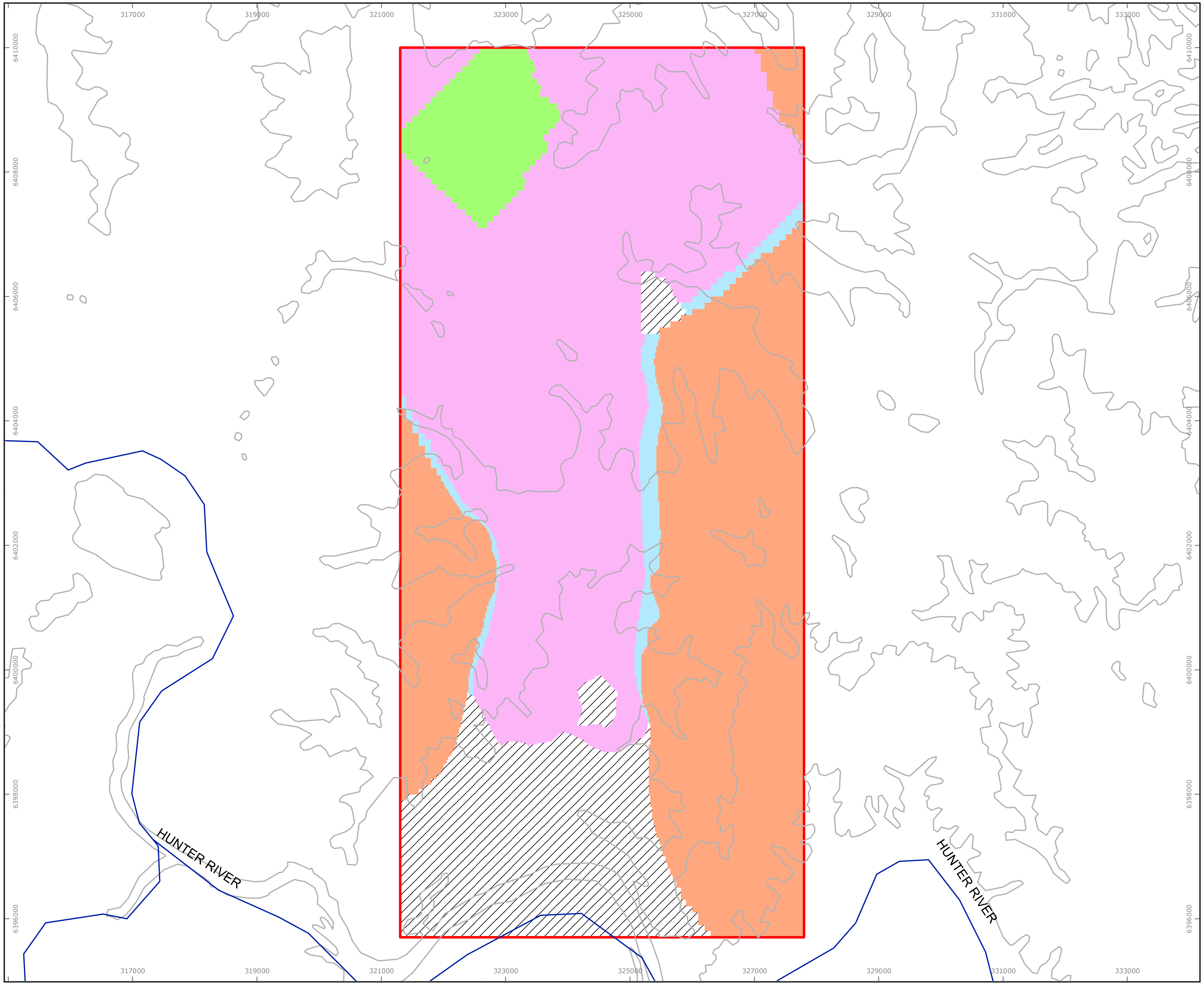
DATA SOURCES

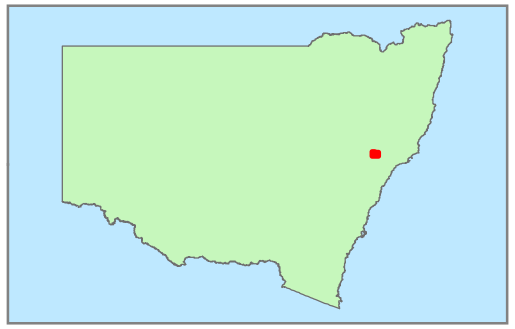
Input data sources here

APPENDIX B

Modelled transient calibration hydraulic conductivity: Layer 3

AUTHOR	KB	REPORT NO	031a
DRAWN	AB	REVISION	a
DATE	18/1/2012	JOB NO.	S66C





LEGEND

- Rivers
- Elevation contours
- Model area

K_h zones (m/day)

- 0.001846
- 0.003691
- 0.02
- 1
- Inactive model areas

N

0 500 1,000 2,000

Metres

SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

DATA SOURCES

Input data sources here

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APPENDIX B

Modelled transient calibration hydraulic conductivity: Layer 4

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DRAWN	AB	REVISION	a
DATE	18/1/2012	JOB NO.	S66C

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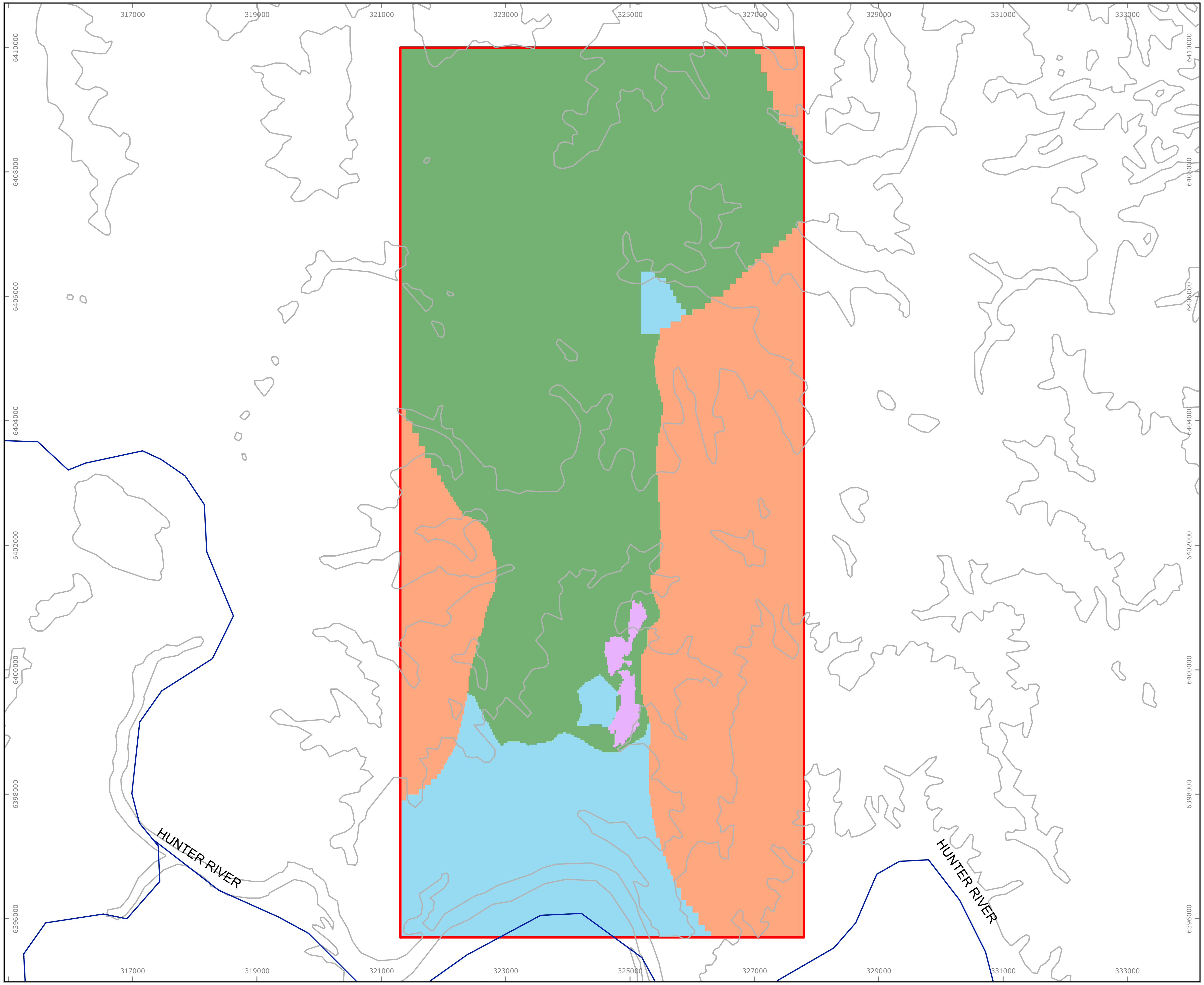
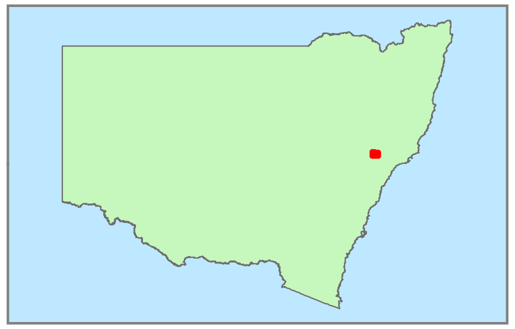




LEGEND

- Rivers
- Elevation contours
- Model area

K_h zones (m/day)

- 0.02
- 1
- 100
- Inactive model areas

N

0 500 1,000 2,000
Metres

SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

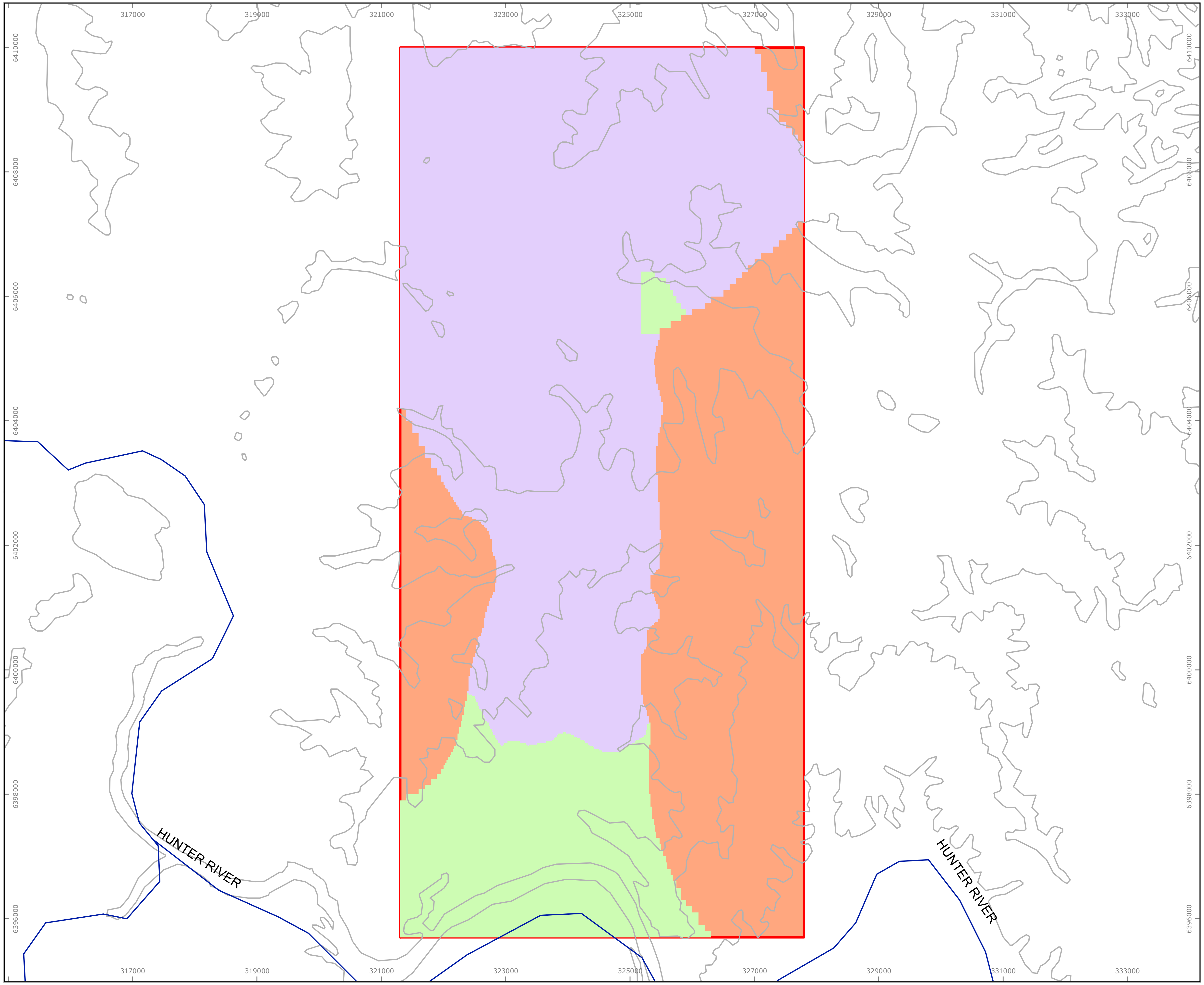
DATA SOURCES

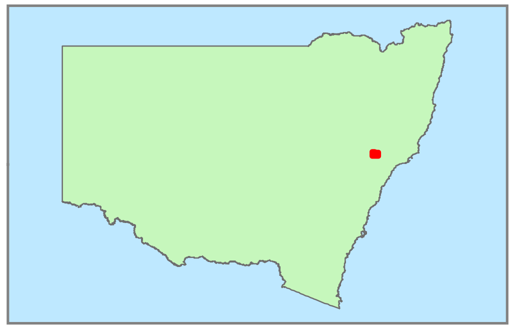
Input data sources here

APPENDIX B

Modelled transient calibration hydraulic conductivity: Layer 5

AUTHOR	KB	REPORT NO	031a
DRAWN	AB	REVISION	a
DATE	18/1/2012	JOB NO.	S66C





LEGEND

- Rivers
- Elevation contours

K_h zones (m/day)

- 0.02
- 1
- Model area
- Inactive model areas

N

0 500 1,000 2,000

Metres

SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

DATA SOURCES

Input data sources here

APPENDIX B

Modelled transient calibration hydraulic conductivity: Layer 6

AUTHOR	KB	REPORT NO	031a
DRAWN	AB	REVISION	a
DATE	18/1/2012	JOB NO.	S66C

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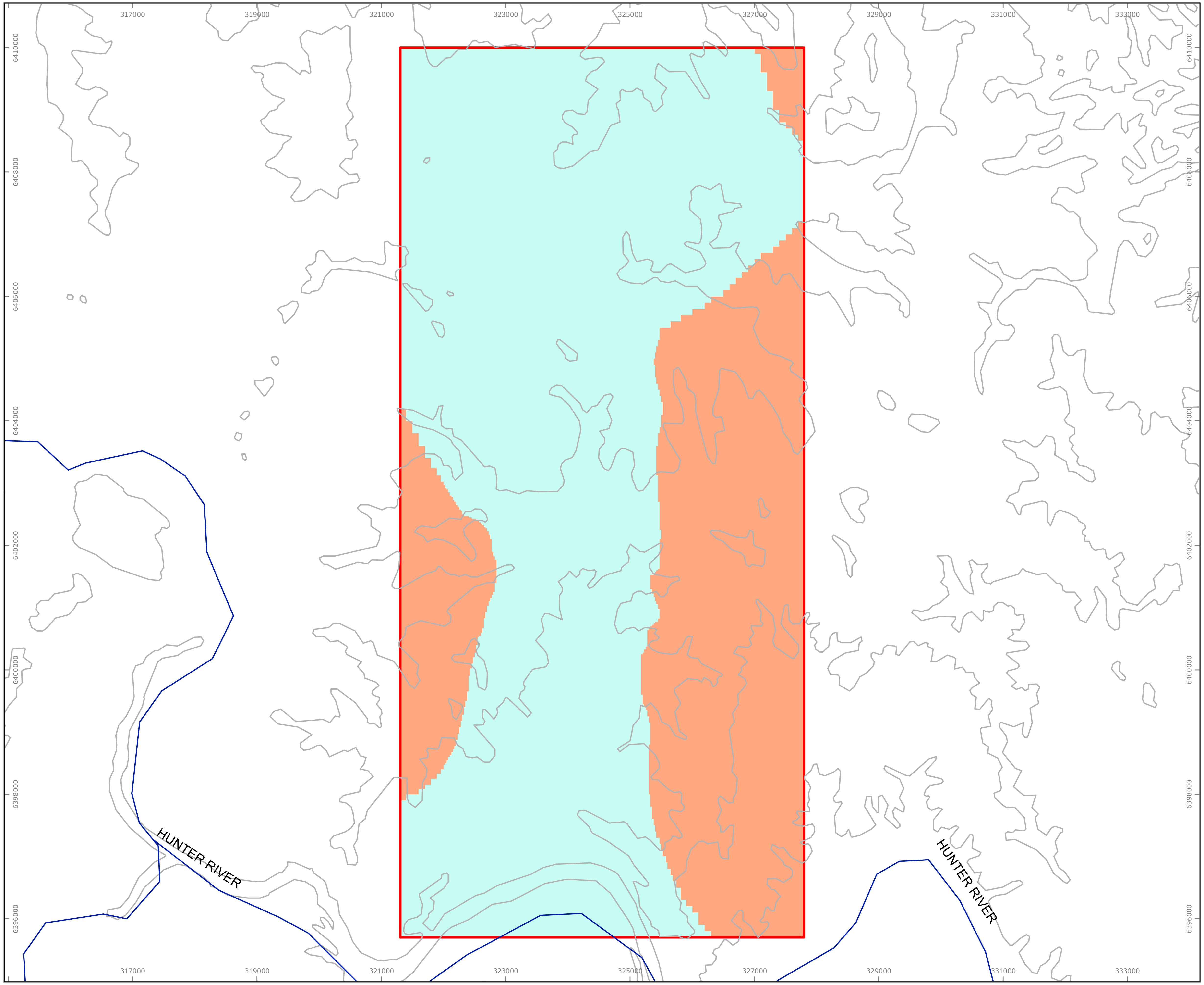
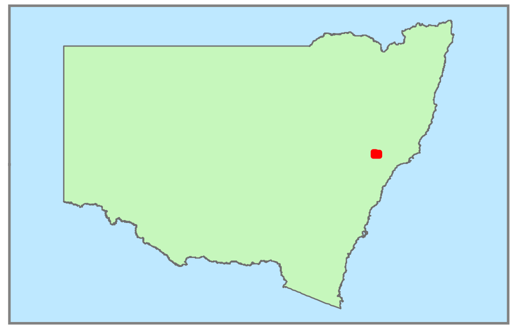


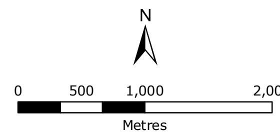


LEGEND

- Rivers
- Elevation contours
- Model area

K_h zones (m/day)

- 0.005
- Inactive model areas



SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

DATA SOURCES

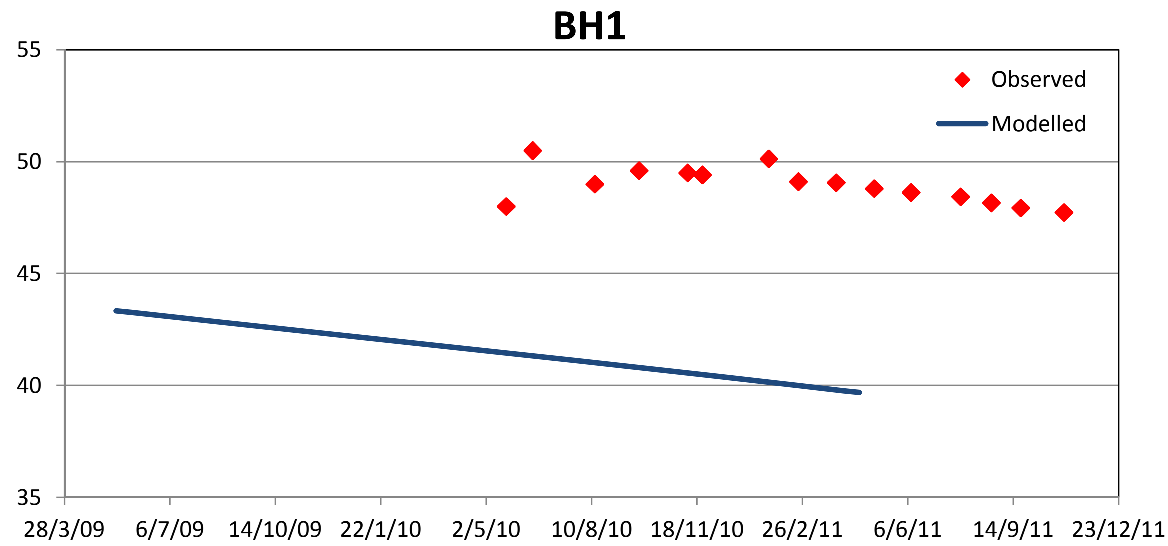
Input data sources here

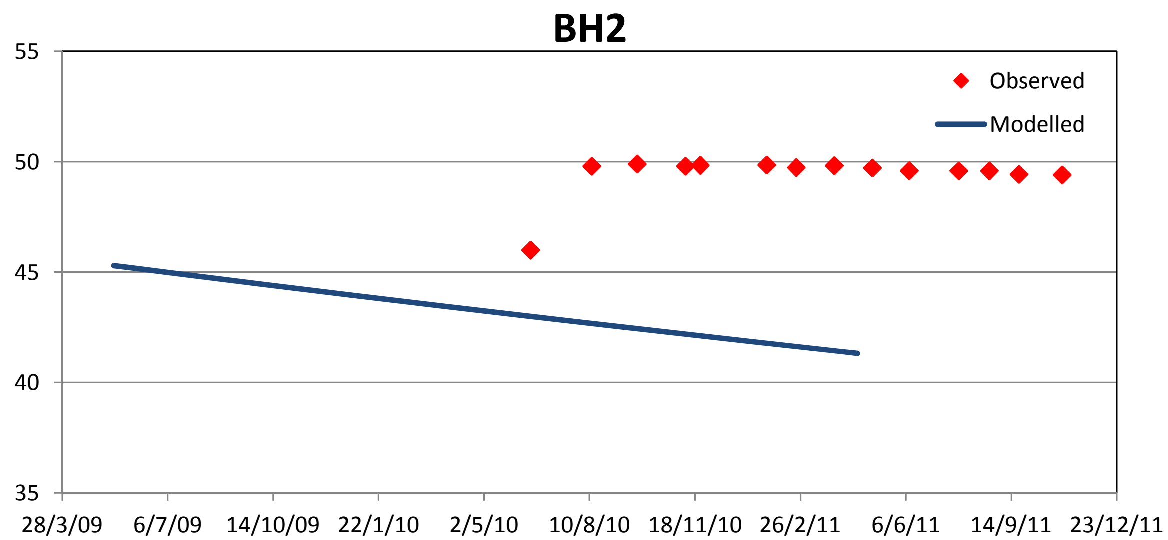
APPENDIX B

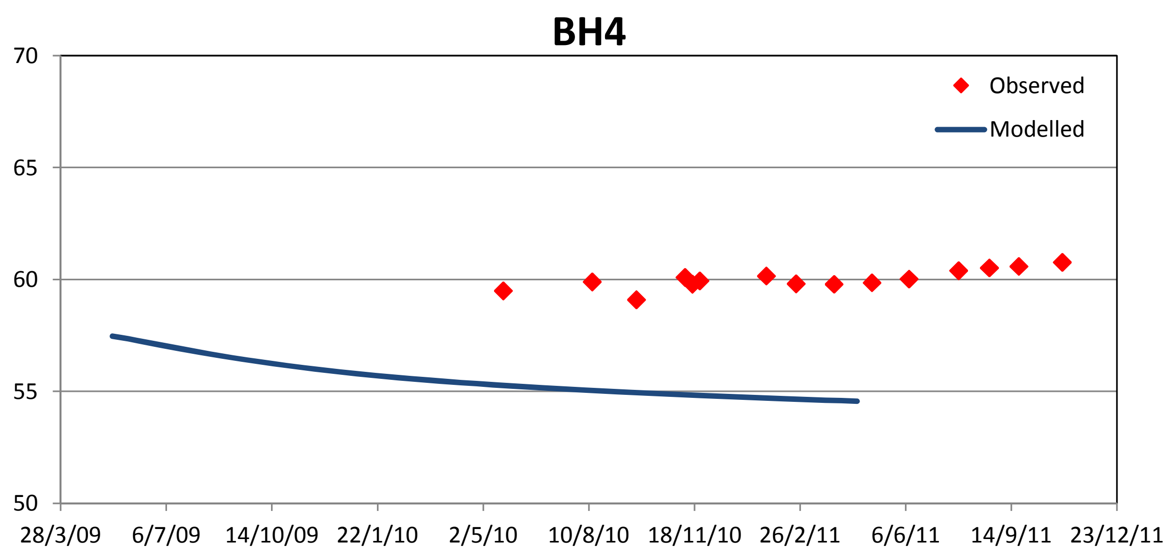
Modelled transient calibration hydraulic conductivity: Layer 7

AUTHOR	KB	REPORT NO	031a
DRAWN	AB	REVISION	a
DATE	18/1/2012	JOB NO.	S66C

APPENDIX C: TRANSIENT CALIBRATION WATER LEVEL HYDROGRAPHS



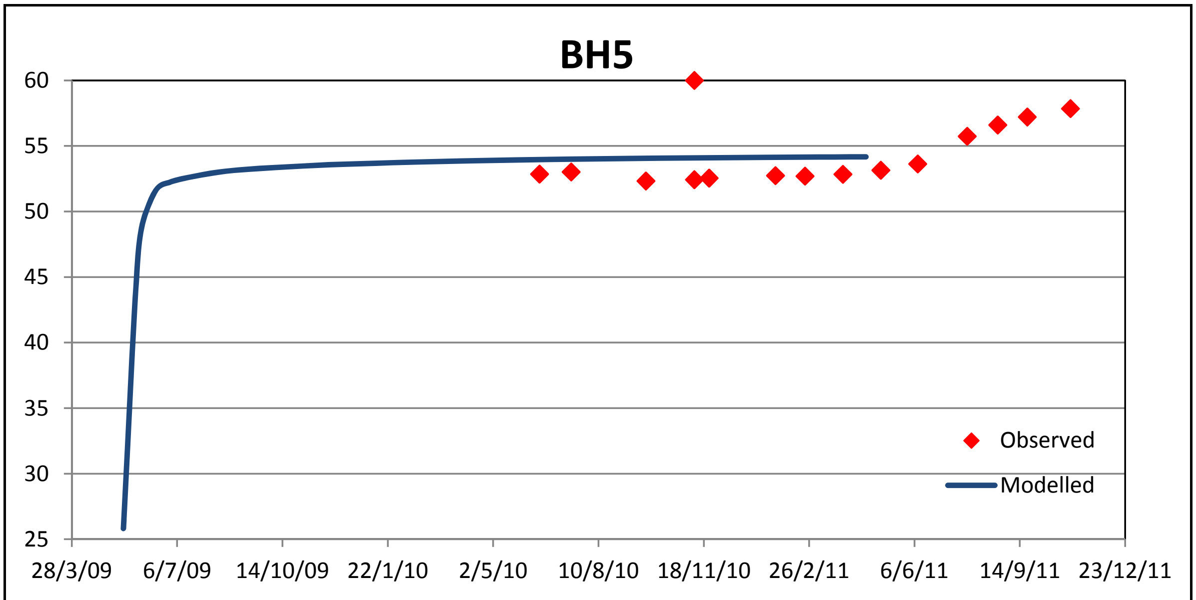


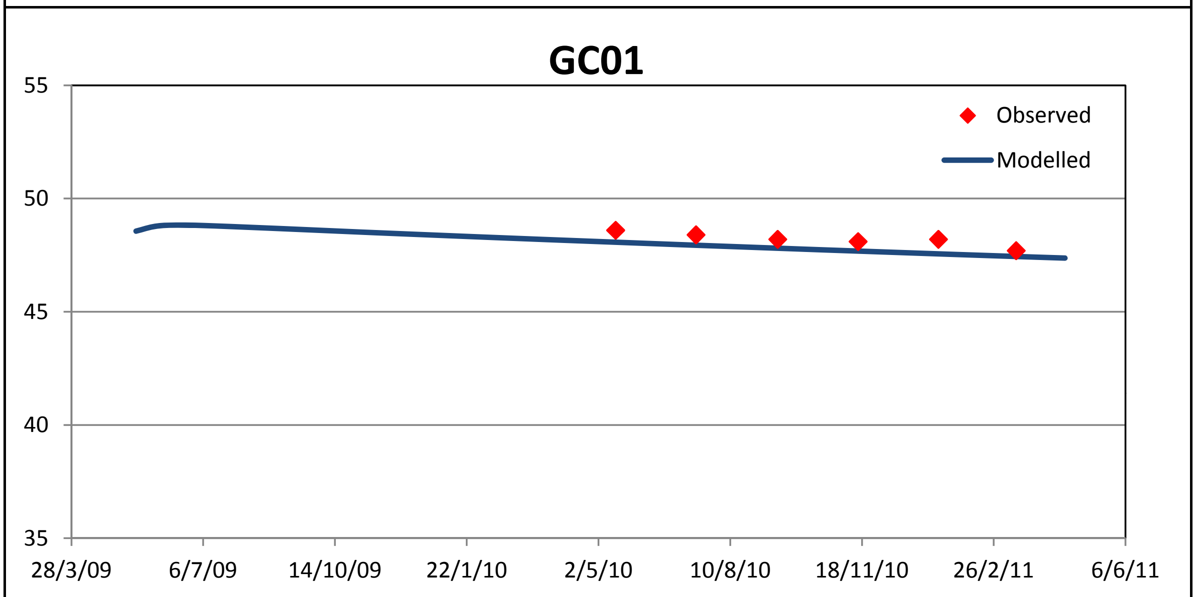


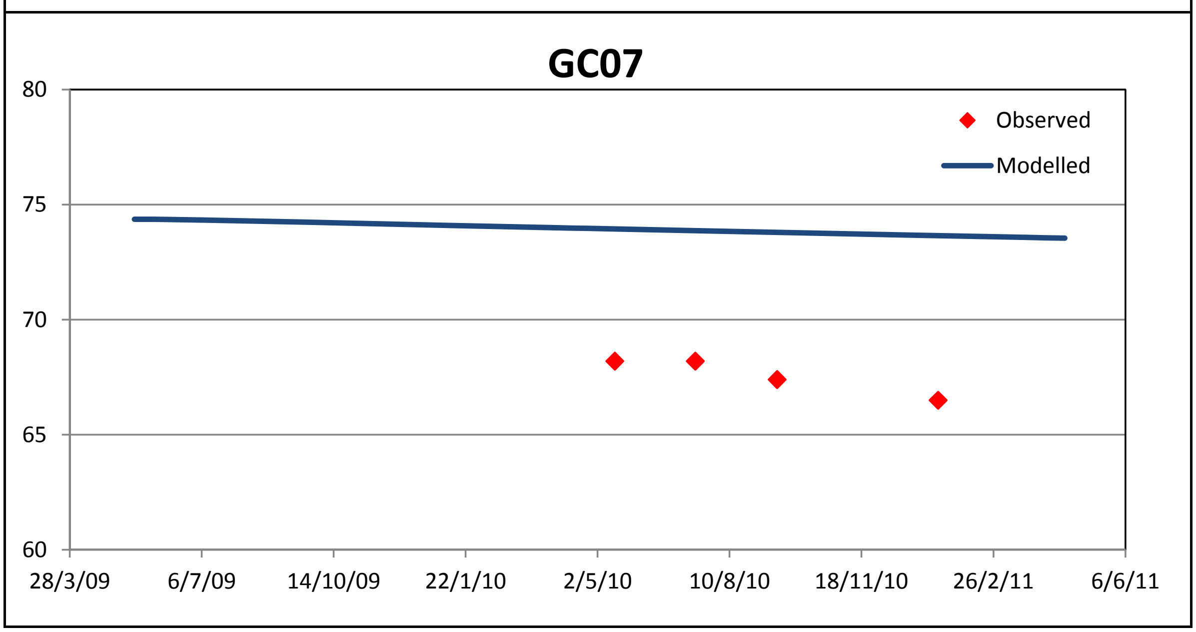
RPS Aquaterra

TRANSIENT CALIBRATION WATER LEVEL HYDROGRAPHS FIGURE C1

F:\Jobs\S66C\600\Modelling_report\Appendices\[Appendix_C.xlsx]FigC1







RPS Aquaterra

TRANSIENT CALIBRATION WATER LEVEL HYDROGRAPHS FIGURE C2

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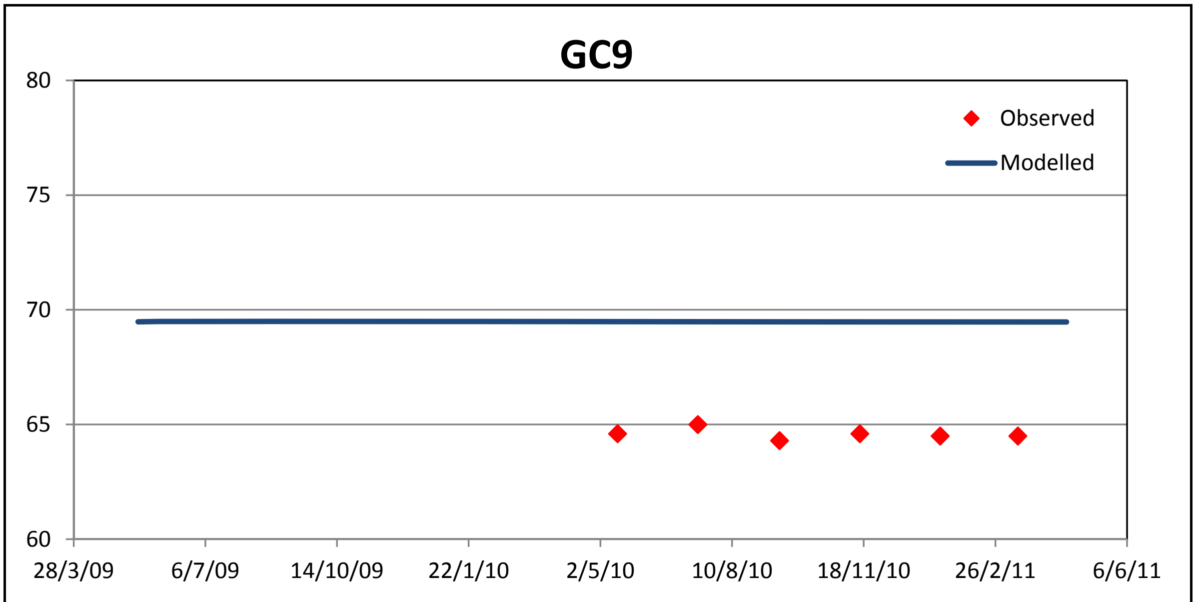

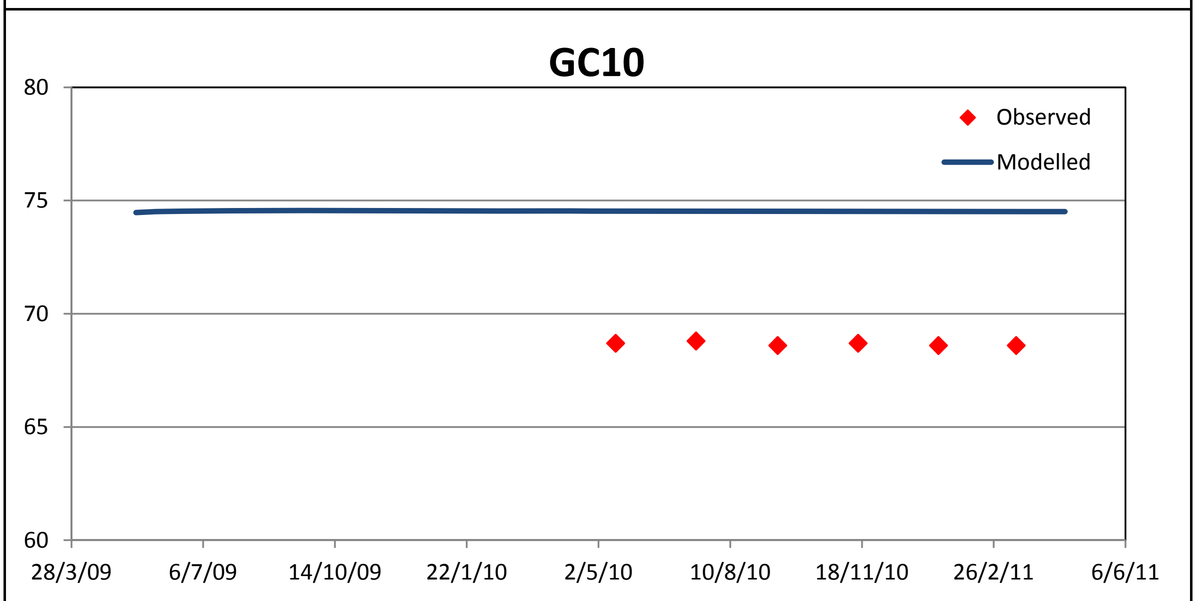

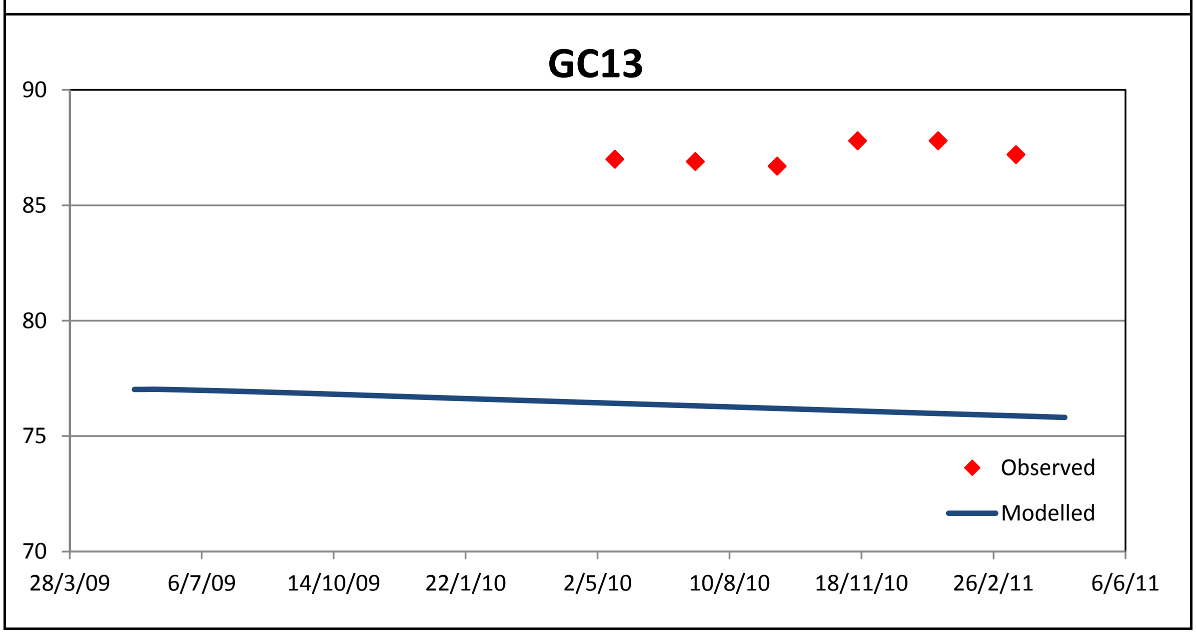

RPS Aquaterra

TRANSIENT CALIBRATION WATER LEVEL HYDROGRAPHS FIGURE C3

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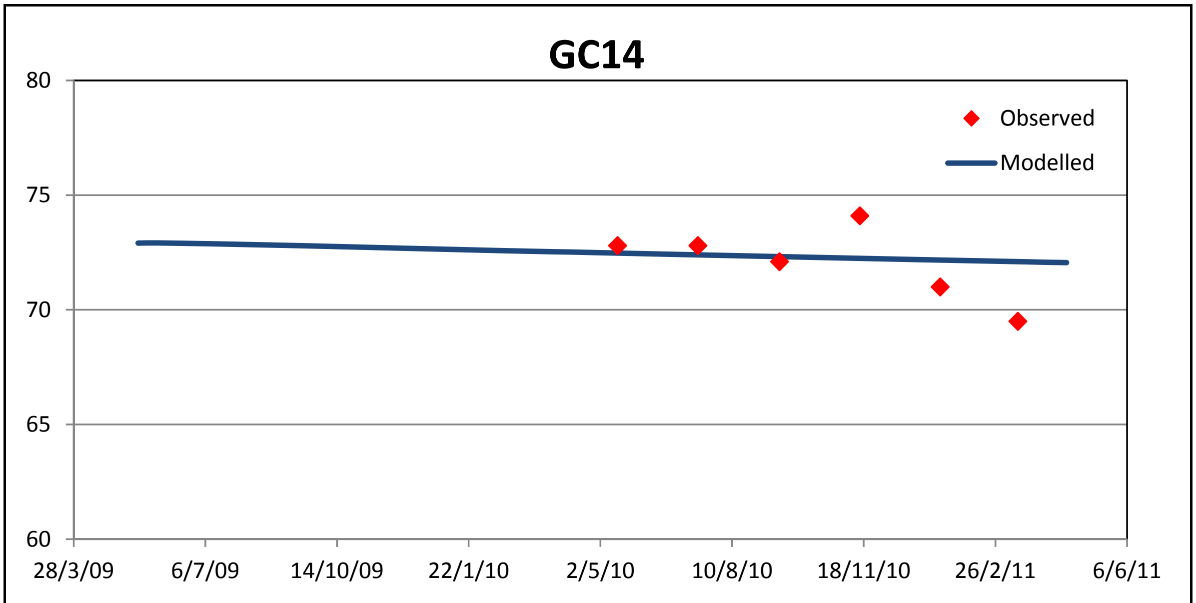

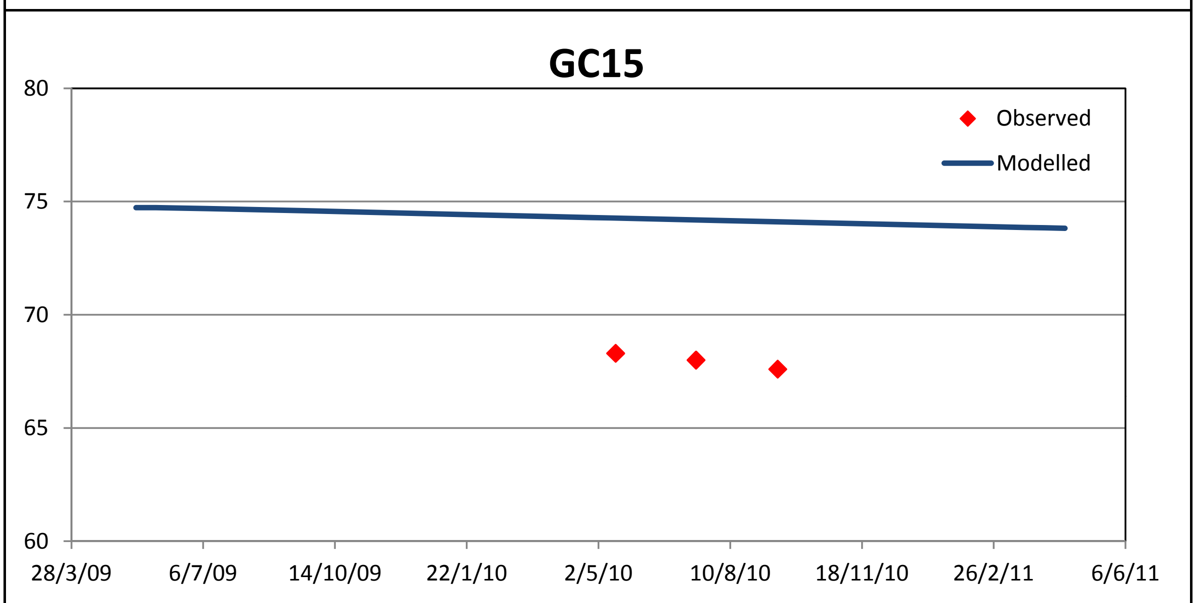

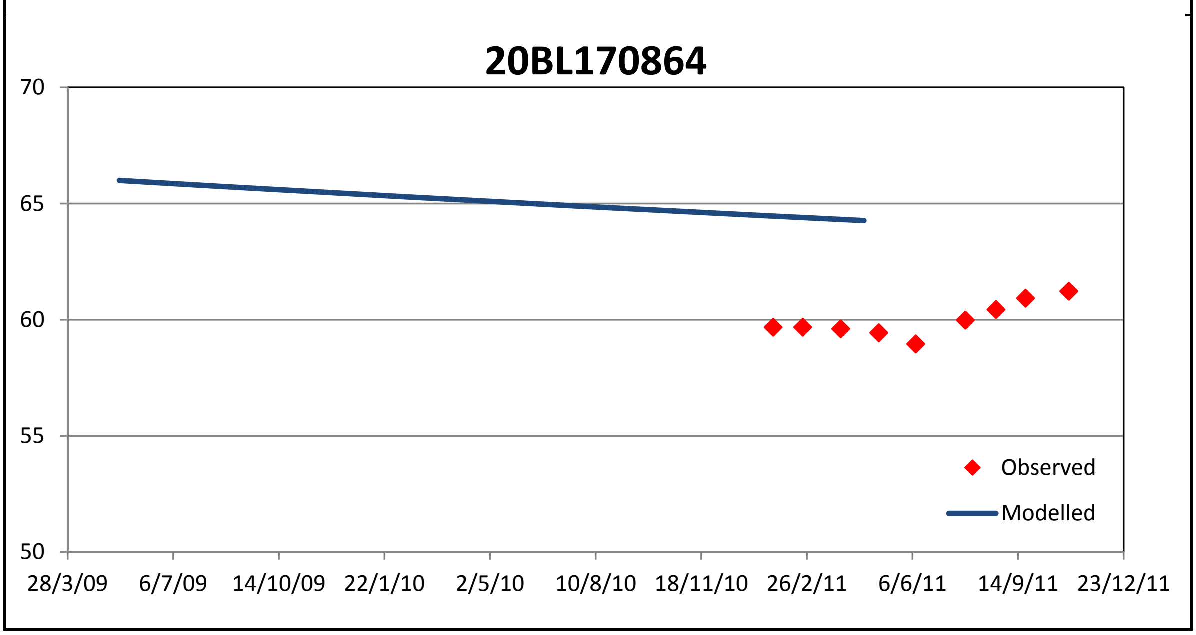

RPS Aquaterra

TRANSIENT CALIBRATION WATER LEVEL HYDROGRAPHS FIGURE C4

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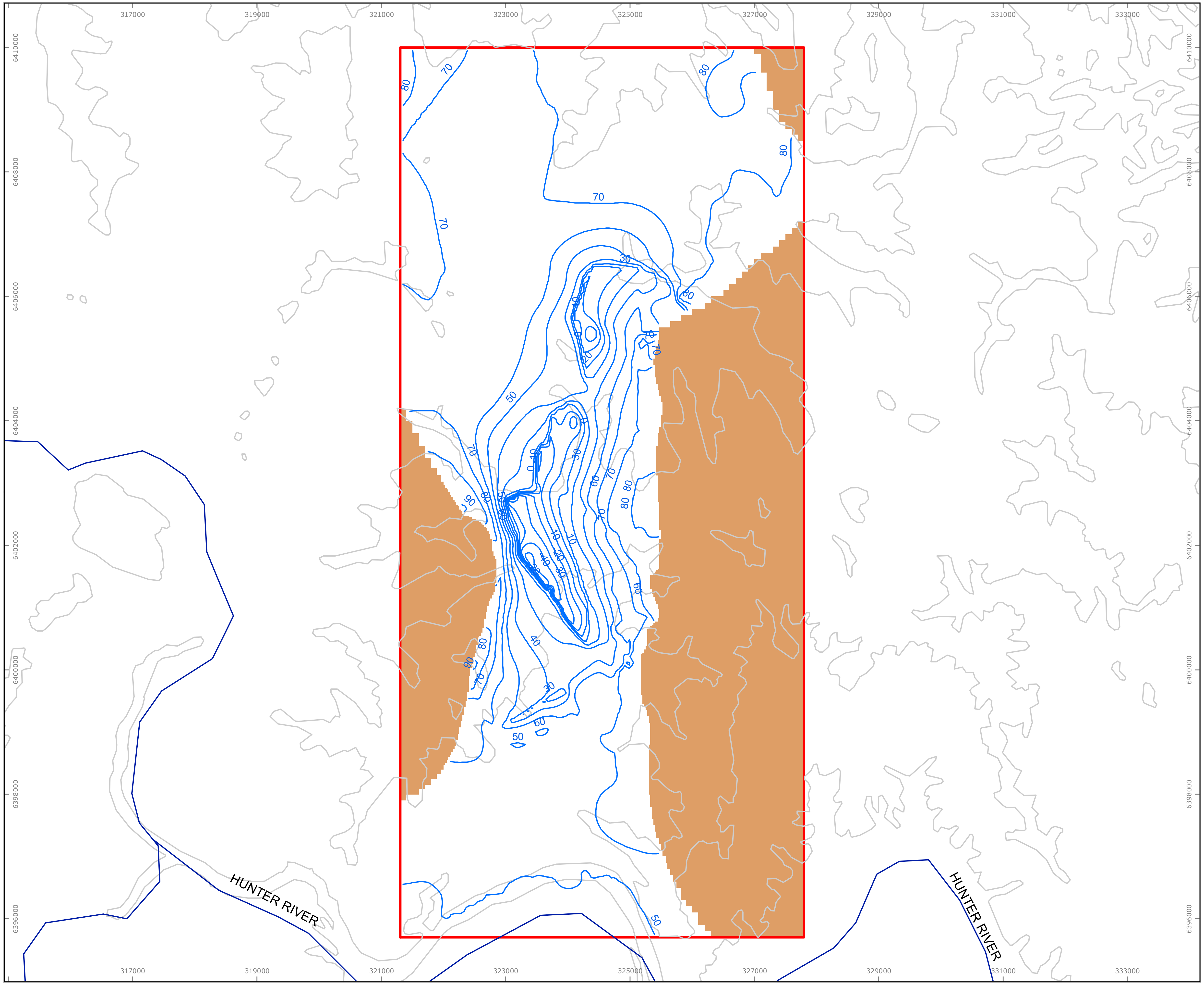
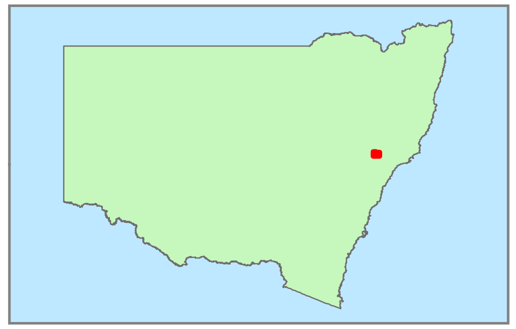
APPENDIX D: TRANSIENT CALIBRATION WATER LEVEL CONTOURS – MAY 2010 AND APRIL 2011





LEGEND

- Modelled groundwater levels (mAHD)
- Rivers
- Elevation contours
- Model area
- Inactive model area

N

0 500 1,000 2,000

Metres

SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

DATA SOURCES

Input data sources here

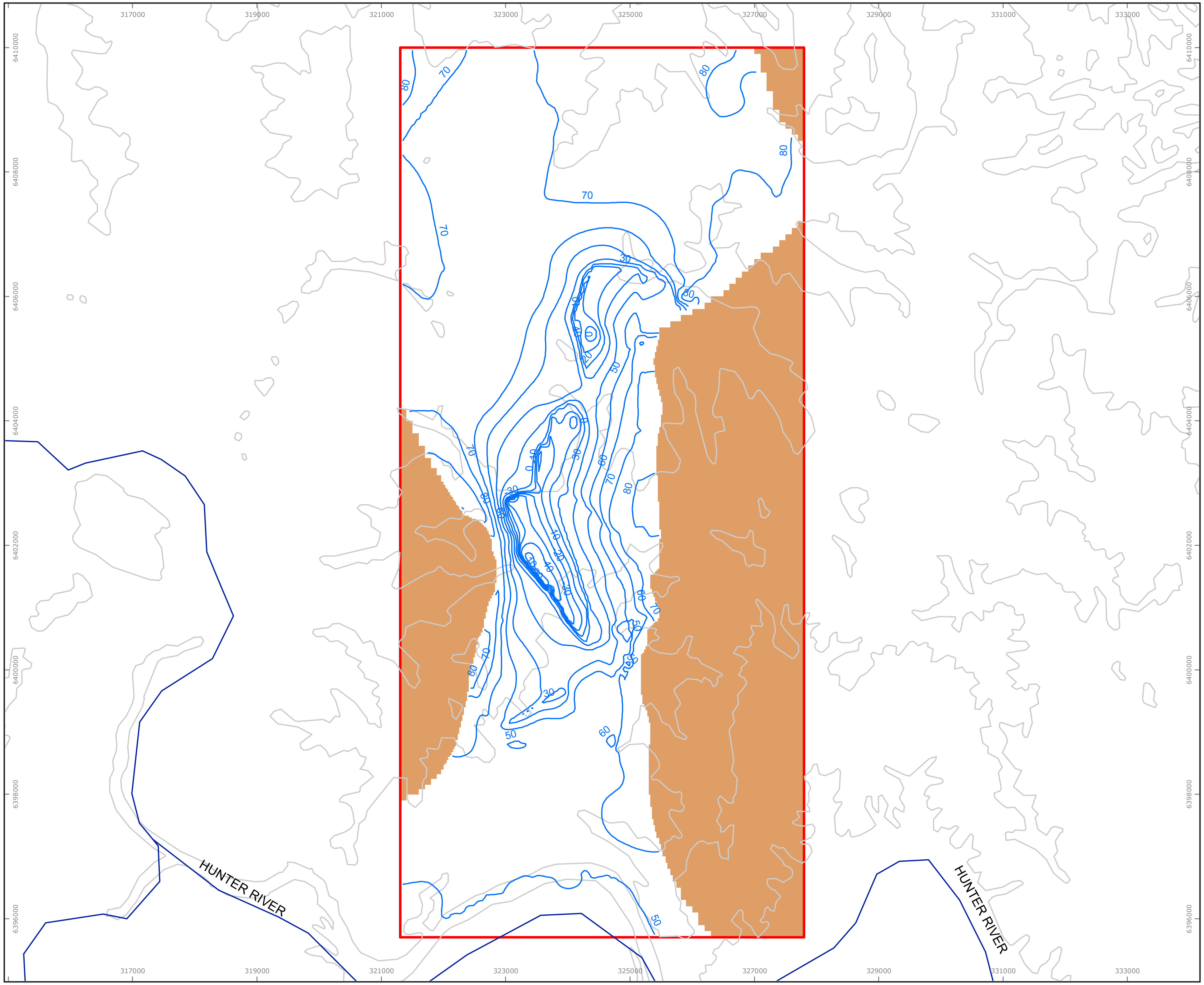
Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Please verify the accuracy of all information prior to use.

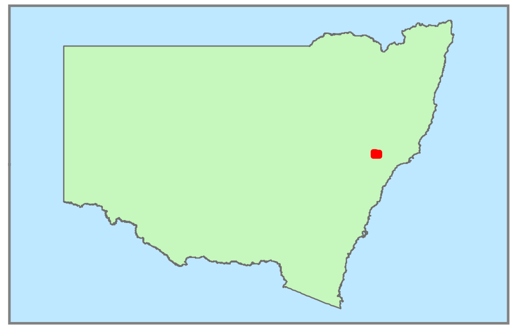
APPENDIX D

Transient calibration modelled water level contours: Layer 2 May 2010

AUTHOR	KB	REPORT NO	031a
DRAWN	AB	REVISION	a
DATE	18/1/2012	JOB NO.	S66C

D:\Work Information\Aquaterra\Template\A4_Landscape.mxt





LEGEND

- Modelled groundwater levels (mAHD)
- Rivers
- Elevation contours
- Model area
- Inactive model area

N

0 500 1,000 2,000

Metres

SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

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APPENDIX D

Transient calibration modelled water level contours: Layer 2 April 2011

AUTHOR	KB	REPORT NO	031a
DRAWN	AB	REVISION	a
DATE	18/1/2012	JOB NO.	S66C

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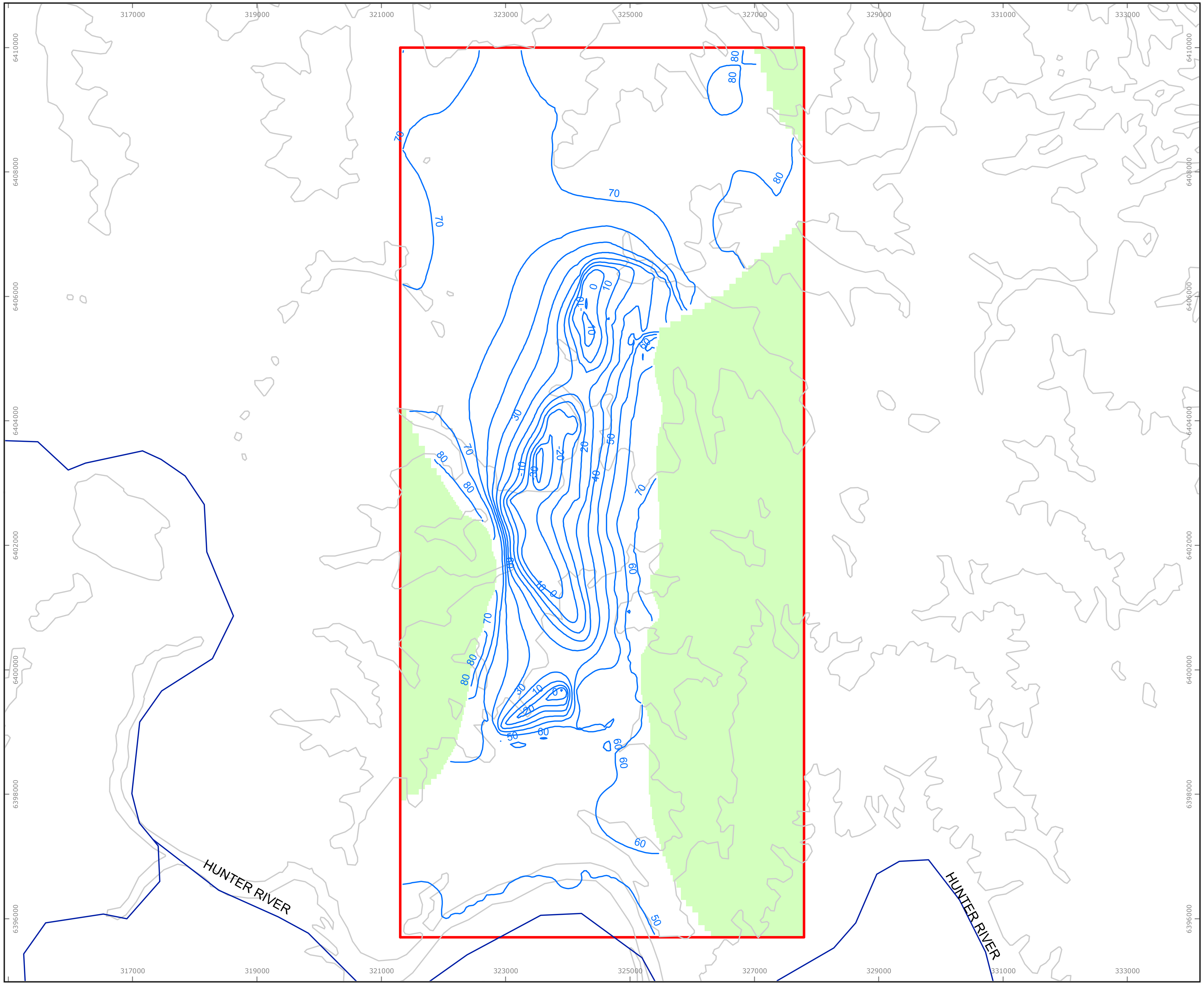

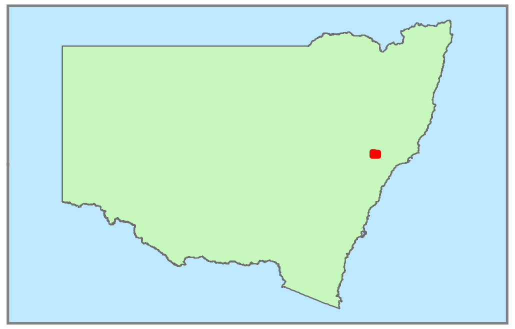

LEGEND

- Modelled groundwater levels (mAHD)
- Rivers
- Elevation contours
- Model area
- Inactive model area

N

0 500 1,000 2,000

Metres

SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

DATA SOURCES

Input data sources here

APPENDIX D

Transient calibration modelled water level contours: Layer 4 May 2010

AUTHOR	KB	REPORT NO	031a
DRAWN	AB	REVISION	a
DATE	18/1/2012	JOB NO.	S66C

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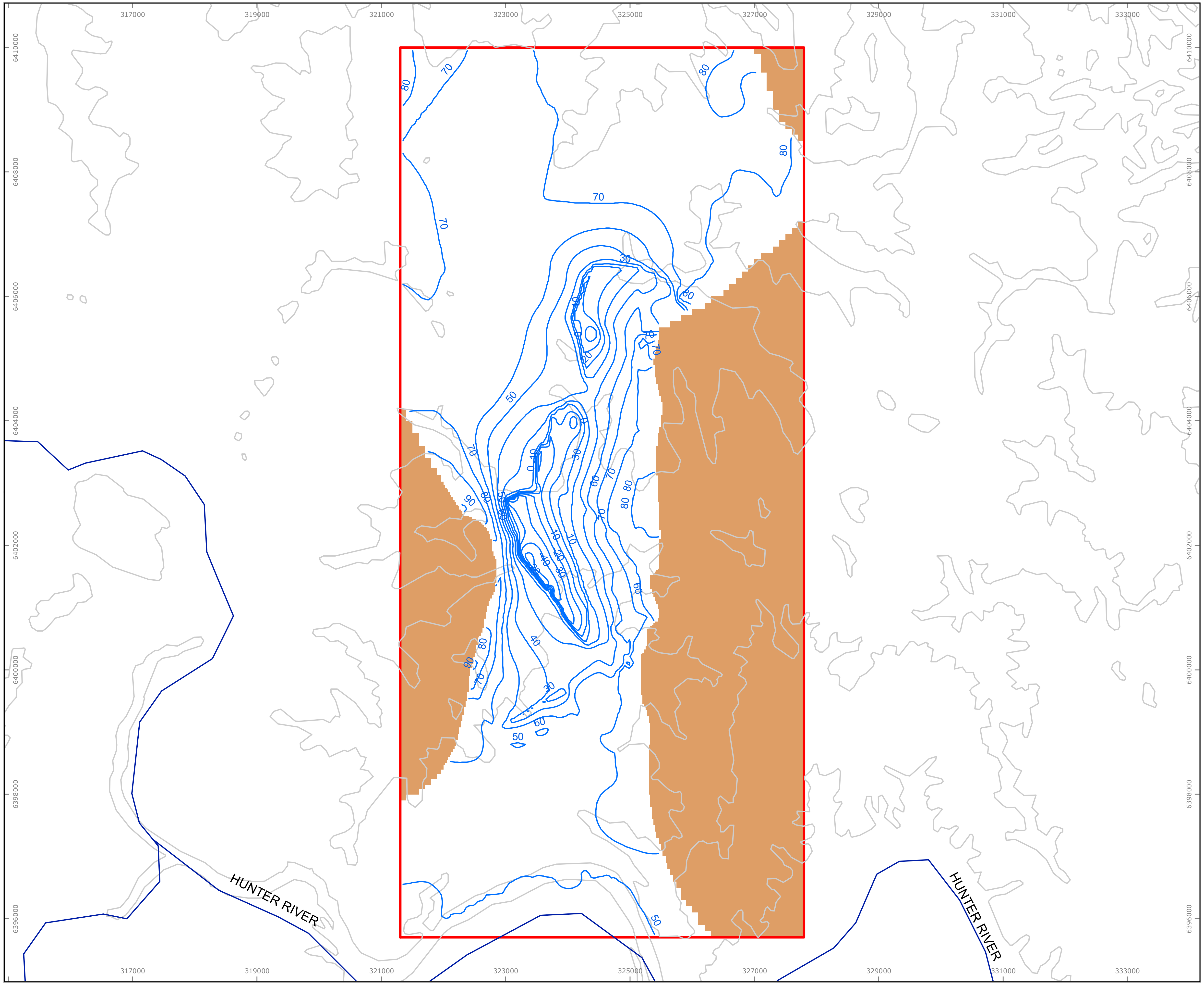
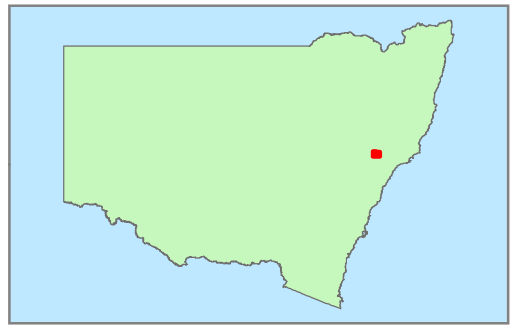
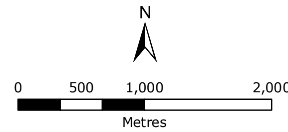




LEGEND

- Modelled groundwater levels (mAHD)
- Rivers
- Elevation contours
- Model area
- Inactive model area



SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

DATA SOURCES

Input data sources here

APPENDIX D

Transient calibration modelled water level contours: Layer 4 April 2011

AUTHOR	KB	REPORT NO	031a
DRAWN	AB	REVISION	a
DATE	18/1/2012	JOB NO.	S66C

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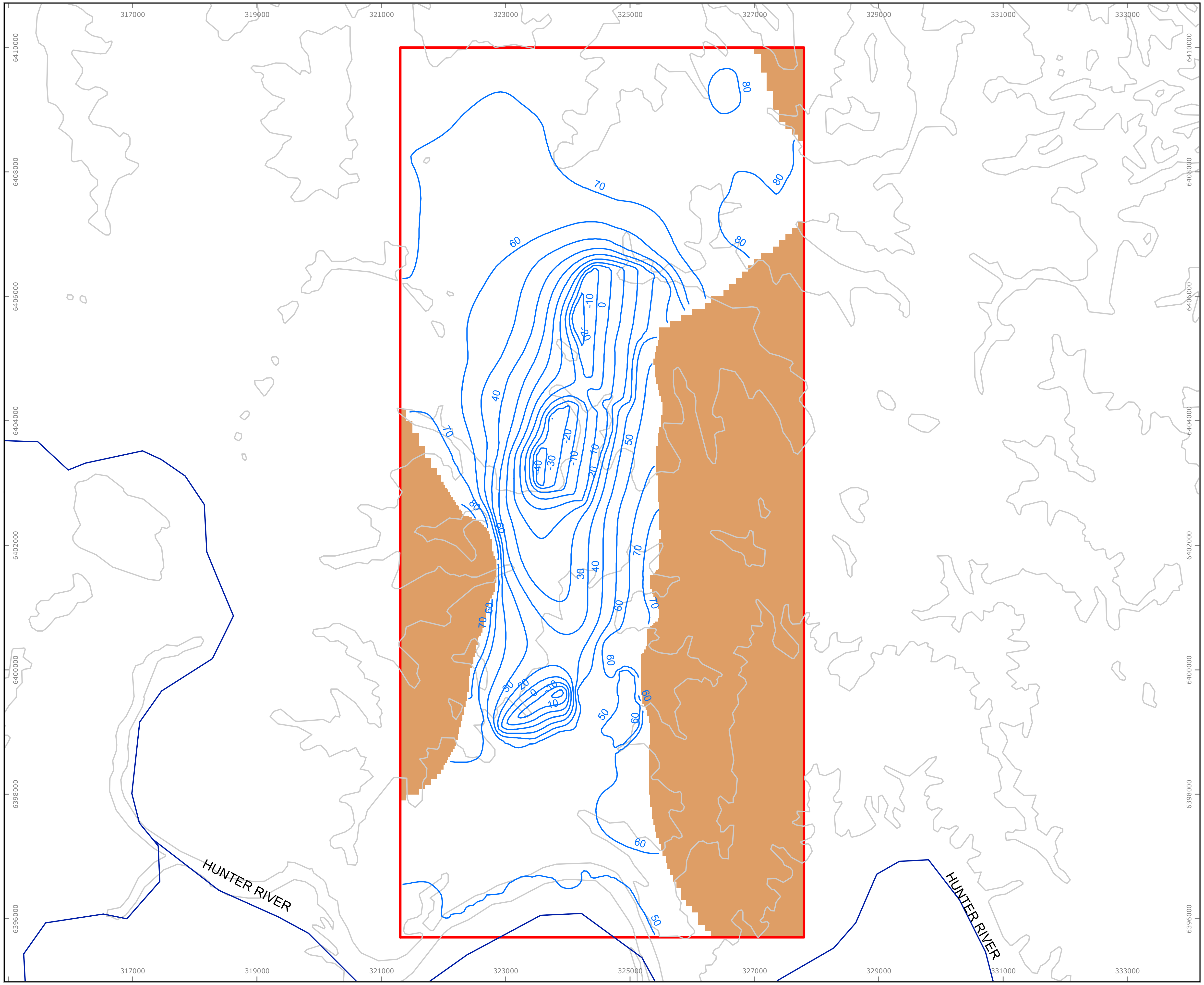

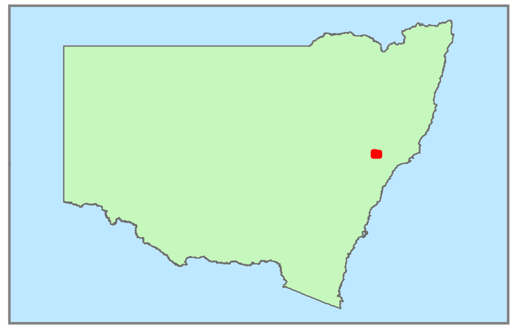

LEGEND

- Modelled groundwater levels (mAHD)
- Rivers
- Elevation contours
- Model area
- Inactive model area

N

0 500 1,000 2,000

Metres

SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

DATA SOURCES

Input data sources here

APPENDIX D

Transient calibration modelled water level contours: Layer 6 May 2010

AUTHOR	KB	REPORT NO	031a
DRAWN	AB	REVISION	a
DATE	18/1/2012	JOB NO.	S66C

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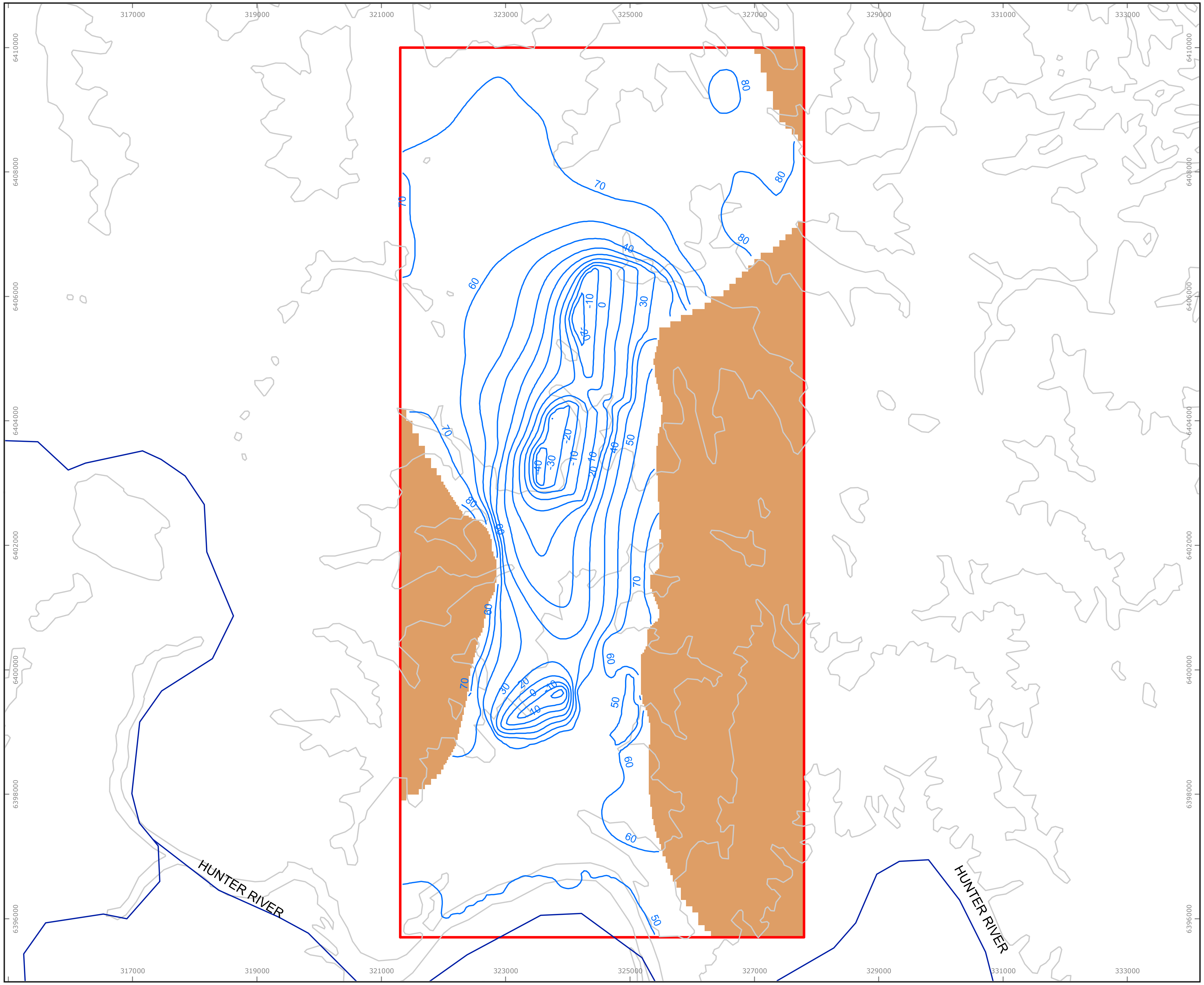
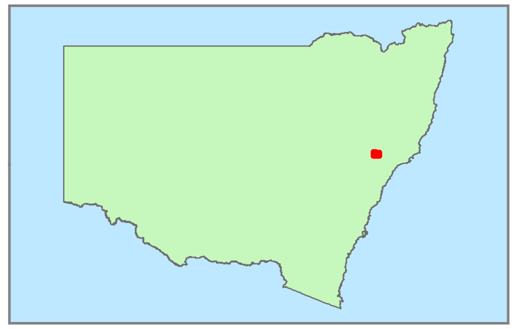
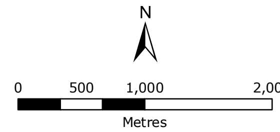




LEGEND

- Modelled groundwater levels (mAHD)
- Rivers
- Elevation contours
- Model area
- Inactive model area



SCALE 1:59,583 @ A3

GDA 1994 MGA Zone 54

DATA SOURCES

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APPENDIX D

Transient calibration modelled water level contours: Layer 6 April 2011

AUTHOR	KB	REPORT NO	031a
DRAWN	AB	REVISION	a
DATE	18/1/2012	JOB NO.	S66C

D:\Work Information\Aquaterra\Template\A4_Landscape.mxt

APPENDIX E:
MANAGEMENT PLAN APPROVAL- DPE

NSW GOVERNMENT | Planning & Infrastructure

Contact: Scott Brooks
Phone: 6575 3402
Fax: 6575 3415
Email: scott.brooks@planning.nsw.gov.au
Our ref: DA 49/94

Mr John Hindmarsh
Environmental Officer
Rix's Creek Pty Limited
PO Box 4
EAST MAITLAND NSW 2323

Dear John

Rix's Ck – Approval of Management Plans

Thank you for forwarding a number of management plans for review as required by your mine Approval DA 49/94. We have reviewed the following management plans.

Traffic Management Plan (Condition 9, Schedule 2);
Water Management Plan (Condition 15, Schedule 2);
Erosion and Sediment Control Plan (Condition 15a, Schedule 2);
Landscape Management Plan (Condition 16, Schedule 2), this includes;
  Rehabilitation Management Plan (Condition 16b, Schedule 2);
  Final Void Management Plan (Condition 16c, Schedule 2);
  Mine Closure Plan (Condition 16d, Schedule 2).

The Department has reviewed the management plans identified above and can advise they have been approved by the Director General.

Accordingly, the Department requests that a copy of the management plans marked "final" are forwarded to the Singleton office, by the end of January 2014, as a soft copy for our records.

If you require further information please contact Ann Hagerthy on 6575 3403 or by email to ann.hagerthy@planning.nsw.gov.au.

Yours sincerely

Scott Brooks
Team Leader Compliance
2-1-2014
As nominee for the Director-General

APPENDIX F:
EVIDENCE OF CONSULTATION

Mr Fergus Hancock
Major Projects, Mine Assessments & Planning Unit
NSW Office of Water
Dept Environment Climate Change & Water
PO Box 2213
DNAGAR NSW 2309

Wednesday, February 10, 2010

Dear Fergus,

DA49/94 – Bloomfield Collieries Pty Ltd, Rix's Creek Mine.
Landscape Management Plan – DECCW Consultation.

The modified conditions of consent issued in September 2009 relating top the Rix's Creek Mine, require consultation with Office of Water for the preparation of a Landscape Management Plan.

> ***Landscape Management***
> *16A. The Applicant shall prepare and implement a detailed Landscape Management Plan for the development to the satisfaction of the DII and the Director-General. This plan must:*
> *(i) be prepared in consultation with DECCW, the Office of Water and Singleton Shire Council by suitably qualified expert/s whose appointment/s have been approved by the Director-General;*
> *(ii) include a:*
> - *Rehabilitation Management Plan to be submitted for approval by the Director- General by 31 March 2010;*
> - *Final Void Management Plan to be submitted for approval by the Director- General by 31 December 2011; and*
> - *Mine Closure Plan to be submitted for approval by the Director-General by 31 December 2011.*

Please notify the Company of any recommendations you wish you make on matters to be included in the preparation of the Landscape Management Plan.

If you would you like to receive a draft of the Plan for comment prior to submission to the Dept of Planning also let us know.

If you require any further information please do not hesitate to contact me.

Yours faithfully

John Hindmarsh
Environmental Officer
Telephone:- 02 65788806
Mobile:- 0427 436285
E-mail:- jhindmarsh@rixs.com.au

General Manager
Singleton Council
PO Box 314
SINGLETON NSW 2330

Wednesday, February 10, 2010

Dear Sir,

DA49/94 – Bloomfield Collieries Pty Ltd, Rix's Creek Mine.
Landscape Management Plan – Singleton Shire Council Consultation.

The modified conditions of consent issued in September 2009 relating top the Rix's Creek Mine, require consultation with Singleton Shire Council for the preparation of a Landscape Management Plan.

> ***Landscape Management***
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If you would you like to receive a draft of the Plan for comment prior to submission to the Dept of Planning also let us know.

If you require any further information please do not hesitate to contact me.

Yours faithfully

John Hindmarsh
Environmental Officer
Telephone:- 02 65788806
Mobile:- 0427 436285
E-mail:- jhindmarsh@rixs.com.au

Mr Mitchell Bennett
Head Regional Operations Unit – Hunter Region
Dept Environment Climate Change & Water
PO Box 488G
NEWCASTLE NSW 2300

Wednesday, February 10, 2010

Dear Mitchell,

DA49/94 – Bloomfield Collieries Pty Ltd, Rix's Creek Mine.
Landscape Management Plan – DECCW Consultation.

The modified conditions of consent issued in September 2009 relating top the Rix's Creek Mine, require consultation with DECCE for the preparation of a Landscape Management Plan.

Landscape Management

16A. The Applicant shall prepare and implement a detailed Landscape Management Plan for the development to the satisfaction of the DII and the Director-General. This plan must:

(i) be prepared in consultation with DECCW, the Office of Water and Singleton Shire Council by suitably qualified expert/s whose appointment/s have been approved by the Director-General;

(ii) include a:

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Please notify the Company of any recommendations you wish you make on matters to be included in the preparation of the Landscape Management Plan.

If you would you like to receive a draft of the Plan for comment prior to submission to the Dept of Planning also let us know.

If you require any further information please do not hesitate to contact me.

Yours faithfully

John Hindmarsh
Environmental Officer
Telephone:- 02 65788806
Mobile:- 0427 436285
E-mail:- jhindmarsh@rixs.com.au

NSW GOVERNMENT | Office of Water

John Hindmarsh
Rixs Creek Coal Mine
PO Box 4
East Maitland NSW 2323

Contact: Fergus Hancock
Phone: 02 4904 2532
Fax: 02 4904 2503
Email: Fergus.Hancock@dnr.nsw.gov.au

Our ref: NEW0003707-2
Your ref:

February 18 2010

Dear John

Subject: Rixs Creek Coal Mine Landscape Management Plan

I refer to your letter dated 10 February 2010, requesting input from the Department of Environment, Climate Change and Water (NSW Office of Water) (NOW) on the Landscape Management Plan (LMP) for Rixs Creek coal mine.

NOW is the State water management regulator, including statutory regulation regarding riverine corridor management, water access and aquifer interference, and management and protection of groundwater dependent ecosystems. Therefore, those elements of the LMP which involve reconstruction or remediation of riverine corridors, management or recovery programmes to groundwater dependent ecosystems or final void configuration and management require consideration of relevant State policies and the principles of the *Water Management Act 2000* (WMA).

Specific issues for inclusion in the LMP include:

- Identification of any groundwater dependent ecosystems which exist on the site or may be included in rehabilitation of the post-mining landscape, and;
- Justification for final void(s) in terms of groundwater salinity, displacement of groundwaters from account water(s) managed under Water Sharing Plans, and final landscape design, including minimising risk of dryland salinity
- Objectives for mine closure related to landscape design to manage saline/hypersaline groundwater, riparian land management to maximise ecosystem and post-mine life land use options

If you require any further information or clarification of information provided in this submission, please contact Fergus Hancock on (02) 4904 2532.

Yours sincerely

Per Mark Mignanelli
Manager, Major Projects Assessments
NSW Office of Water

Department of
Environment, Climate Change and Water NSW