Appendix B

Flow Regime

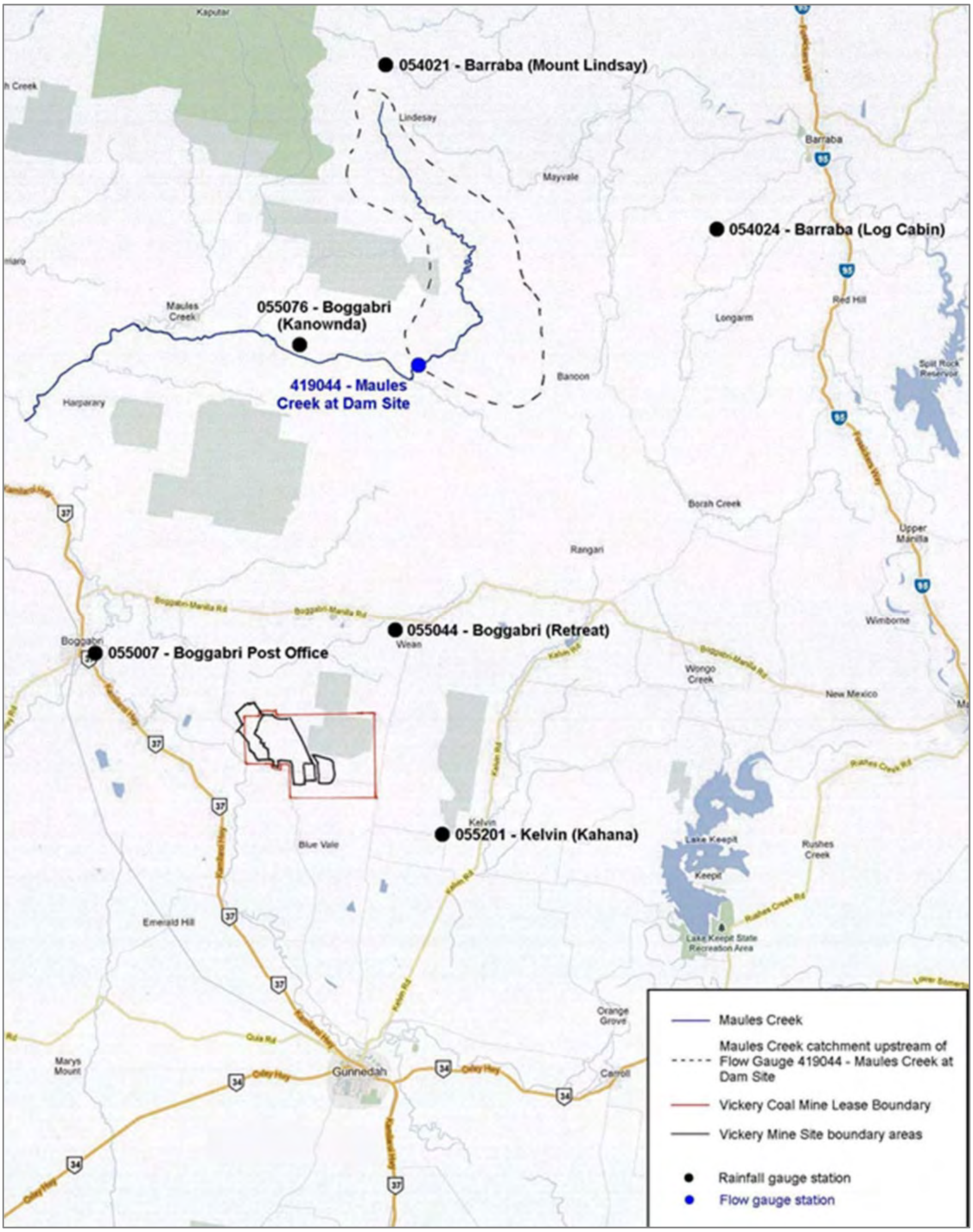

Figure 1: Location of rainfall and flow gauges used for calibration, validation & Project Area modelling

Appendix C

Water Quality Data

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1.1 Introduction

This report provides an assessment of surface water quality information for drainage lines in the vicinity of the Vickery Coal Project (the Project). Since there is only a limited amount of water quality data available for creeks and drainage lines within the Project area, data for various creeks and other water bodies in the region has been drawn from the following three sources:

1) surface water quality monitoring conducted by Whitehaven in the immediate area of the proposed mine (2011 and 2012);
2) the 1986 Namoi Valley Coal Project Environmental Impact Statement (EIS) for the original Vickery Coal Mine; and
3) publically available documentation containing details of water quality monitoring conducted at nearby mine sites. Only mine sites with negligible upstream mine activity were included.

1.2 Monitoring Site Locations

The locations of monitoring sites from which data has been collated are shown on **Figure 1** and are coloured accordingly:

1) **Red monitoring sites** – Data sourced from the existing Project surface water quality monitoring program.
2) **Black monitoring sites** – Data sourced from the 1986 Namoi Valley Coal Project EIS.
3) **Blue monitoring sites** – Data sourced from publically available documentation on nearby mine sites.

Table 1 provides an indication of the relative positioning of the monitoring sites with respect to the local drainage lines. **Table 2** provides details of the upstream catchment characteristics for monitoring sites with data sourced from publically available documentation on nearby mine sites.

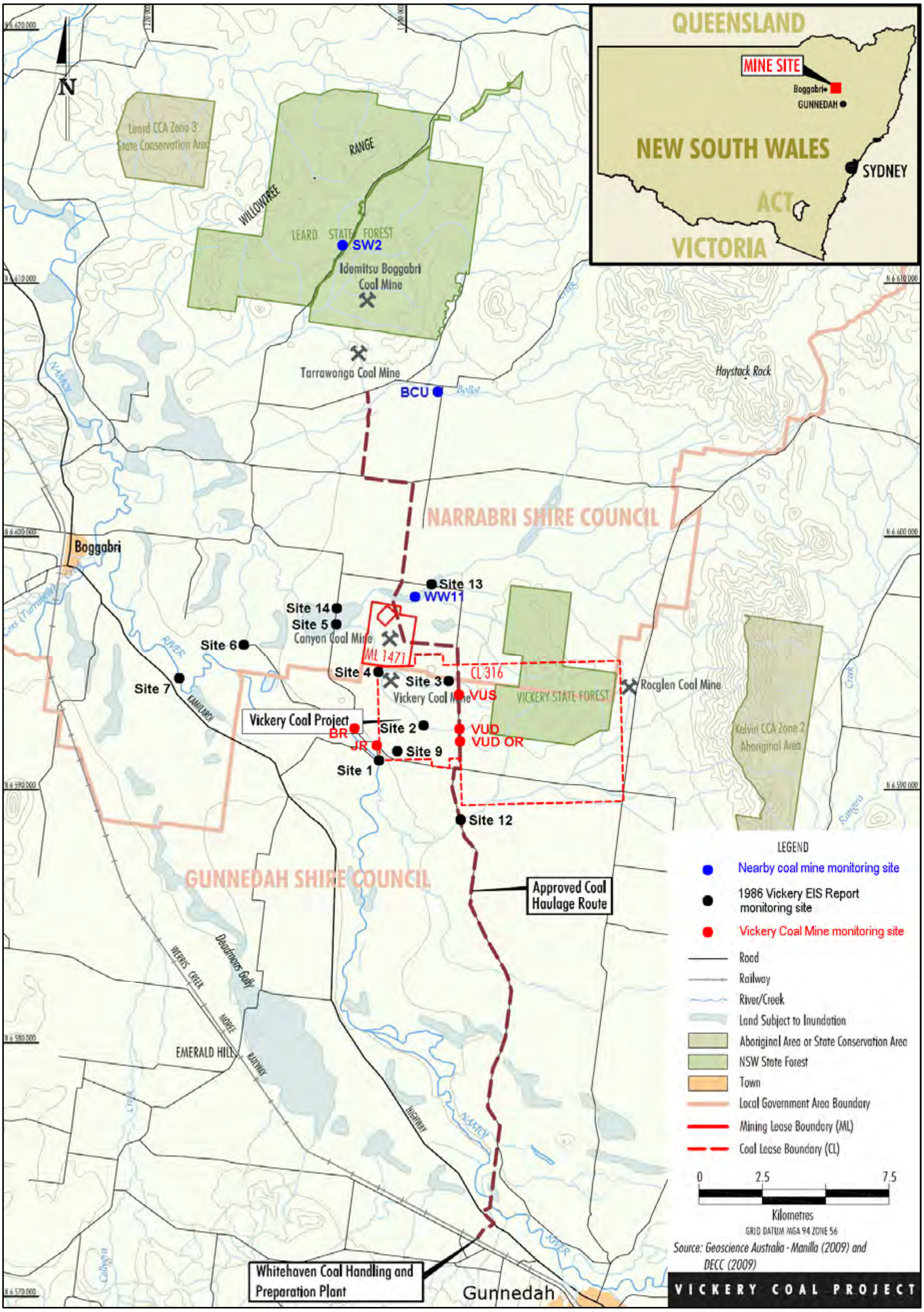

Figure 1: Locations of Surface Water Quality Monitoring Sites

Table 1: Water Quality Monitoring Sites

Respective Location	Water Body	Monitoring Site
-	Nagero Creek	SW2
-	Bollol Creek	BCU
Upstream ↓ Downstream	Driggle Draggle Creek	Site 13 WW11 Site 14 Site 5 Site 6 (Barbers Lagoon)
Upstream ↓ Downstream	North-West Drainage Line	VUS Site 3 Site 4 (intersection of North-west Drainage Line and Western Drainage Line)
Upstream ↓ Downstream	West Drainage Line	VUD and VUD OR Site 2 Site 4 (intersection of North-west Drainage Line and Western Drainage Line)
-	South Creek	Site 12
Upstream ↓ Downstream	Just off Namoi River	Site 9 Site 1 JR BR Site 7

Table 2: Characteristics of Surface Water Quality Monitoring Sites Representative of Catchments Unaffected by Mining

Site Name	Relevant Mine Site	Creek Name	Location	Upstream Catchment Characteristics	Distance from Project	Number of Samples
WW11	Canyon Coal Mine	Driggle Draggle Creek	Approximately at the midpoint of the 'Gundawarra', 'Merton' and 'Whitehaven' properties, downstream of the unnamed track running east-west. Downstream on flat terrain.	Predominately rural farms collecting upstream waters from Wean Creek, Barneys Spring Creek, Glenrock Creek and Bayley Park Creek (including Bayley Park Dam). Headwaters mostly generated from Vickery State Forest, Kelvin State Forest and Haystack Rock.	5 km North of Project	17
BCU	Tarrawonga Coal Mine	Bollol Creek	Just west of the 'Matong' property, downstream of the unnamed track running north-south. Slightly downstream of foot-slopes.	Some rural farms but mostly forested areas collecting upstream waters from Dripping Rock Creek, Nihi Creek, The Well Gully and Mihi Creek. Headwaters mostly generated from Goonbri Mountain, Dripping Rock and Haystack Rock.	13 km North of Project	8
SW2	Boggabri Coal Mine	Nagero Creek	Just upstream of approximately the midpoint of the main unnamed track running southwest to northeast within Leard State Forest boundary (amongst forested mid-slopes).	Predominately collecting only from the southern headwaters of Nagero Creek within Leard State Forest.	19 km North of Project	4

1.3 Monitoring Site Data

1.3.1 Project Data

As of the date of this report, five rounds of surface water quality monitoring have been conducted by Whitehaven as part of the Project surface water monitoring program. The locations of the monitoring sites are shown in red on **Figure 1**. The results of the monitoring to date are provided in **Table 3**, together with the default Australian and New Zealand Environment Conservation Council (ANZECC) 'trigger values' for upland rivers in south-eastern Australia.

Table 3: Project Surface Water Quality Monitoring Results

Sample Location	Date	Time	EC (lab) (µS/cm)	pH (lab)	TSS (mg/L)	TOC (mg/L)	Grease & Oil (mg/L)
BR	13-Sep-11	9:55	136	3.9	200	12	<5
BR	29-Sep-11	10:05	27	6.6	318	5	<5
BR	24-Nov-11	12:00	78	6.7	158	16	<5
BR	06-Feb-12	10:40	216	7.0	27	41	<5
JR	13-Sep-11	9:40	113	7.5	134	8	<5
JR	29-Sep-11	9:05	44	6.9	21	9	<5
JR	24-Nov-11	12:15	94	6.8	15	31	<5
JR	06-Feb-12	10:20	218	7.2	13	23	<5
VUD	06-Feb-12	9:40	111	7.3	10	19	<5
VUD	13-Sep-11	8:15	37	6.8	34	12	<5
VUD	29-Sep-11	9:35	38	7.2	28	8	<5
VUD	24-Nov-11	12:35	72	6.5	10	21	<5
VUDOR	13-Sep-11	8:00	36	7.1	42	9	<5
VUDOR	29-Sep-11	9:30	34	7.1	20	9	<5
VUDOR	24-Nov-11	12:30	92	7.1	24	20	<5
VUDOR	06-Feb-12	9:20	214	7.2	8	28	<5
VUDOR	04-Jun-12	12:45	56	7.2	48	19	<5
VUDOR	04-Jun-12	12:55	47	7.1	45	14	<5
VUS	13-Sep-11	8:35	35	6.8	25	13	<5
VUS	29-Sep-11	9:40	32	6.9	24	9	<5
VUS	24-Nov-11	12:45	90	7.1	35	18	<5
VUS	06-Feb-12	9:59	224	7.2	8	32	<5
VUS	04-Jun-12	1:10	39	7.1	57	19	<5
ANZECC *default* 'trigger values' (range)			**30 – 350**	**6.5 – 8.0**	**-**	**-**	**-**

1.3.2 1986 Environmental Impact Statement Data

The 1986 Namoi Valley Coal Project EIS provided surface water quality monitoring data at eleven sites. The locations of these monitoring sites are shown in black on **Figure 1.** Results from these sites have been reproduced in **Table 4** together with the default ANZECC 'trigger values'. The report did not identify the number of samples collected or the duration of the sampling program.

Table 4: Namoi Valley Coal EIS Water Quality Monitoring Results

Sample Location	EC (µS/cm)	pH	TSS (mg/L)
Site 1	511	8.0	43
Site 2	151	8.8	50
Site 3	165	8.4	32
Site 4	185	9.1	18
Site 5	154	8.4	221
Site 6	273	8.5	74
Site 7	517	7.7	39
Site 9	2,489	7.4	39
Site 12	373	7.8	179
Site 13	96	6.8	-
Site 14	98	7.8	-
ANZECC default 'trigger values' (range)	**30 – 350**	**6.5 – 8.0**	**-**

The 1986 Namoi Valley Coal Project EIS identified that the surface water flowing within the Project area is suitable for common uses, including livestock watering, crop irrigation, industry, domestic and agricultural uses (except for watering the most salt sensitive crops).

Two main surface water types in and around the Project area were recognised:

1) Namoi River water - which has a TDS level of 300-400 mg/L, principally calcium, sodium, bicarbonate, sulphate and 1-2 mg/L of iron.
2) Site runoff – which has a TDS level of 150-180 mg/L (TDS above 200 mg/L are usually attributable to dissolved inorganic matter), principally calcium, sodium, potassium, bicarbonate, sulphate and 1-30 mg/L iron.

1.3.3 Surrounding Mine Site Data

The following three water quality monitoring sites were identified from publically available documentation as having negligible upstream catchment area affected by mine sites (also shown in blue on **Figure 1**):

1) WW11 (monitored as part of Canyon Coal Mine);
2) BCU (monitored as part of Tarrawonga Coal Mine); and
3) SW2 (monitored as part of Boggabri Coal Mine).

With the exception of Site WW11 (which has a very small area of the Rocglen Mine Site within its catchment), these sites have zero mining activity in their associated upstream catchments. **Table 5** provides a statistical summary of the key parameters measured for these sites, together with the default ANZECC 'trigger values'.

Table 5: Surface Water Quality Data for Sites in the Vicinity of the Project

Water Quality Parameter	WW11 Driggle Draggle Creek	BCU Bollol Creek	SW2 Nagero Creek	ANZECC *Default* 'trigger values' (range)
Number of samples	**17**	**8**	**4**	
EC (µS/cm)				
Mean	97	139	62	**30 – 350**
Std deviation	*35*	*66*	*20*	
Minimum	55	63	33	
10th %ile	58	64	40	
20th %ile	62	77	47	
50th %ile	98	135	64	
80th %ile	127	174	78	
90th %ile	145	209	82	
Maximum	170	275	86	
pH (field)				
Mean	7.0	6.9	7.0	**6.5 – 8.0**
Std deviation	*0.5*	*0.2*	*0.7*	
Minimum	6.4	6.7	5.9	
10th %ile	6.5	6.8	6.2	
20th %ile	6.6	6.8	6.6	
50th %ile	6.9	6.8	7.1	
80th %ile	7.4	7.2	7.4	
90th %ile	7.8	7.3	7.6	
Maximum	8.1	7.3	7.8	
TSS (mg/L)				
Mean	80	165	77	**N/A**
Std deviation	*67*	*184*	*30*	
Minimum	12	20	32	
10th %ile	19	31	42	
20th %ile	24	39	52	
50th %ile	58	93	83	
80th %ile	115	209	103	
90th %ile	155	339	107	
Maximum	280	616	110	

1.4 Data Assessment

Whilst the data in **Table 3**, **Table 4** and **Table 5**: indicate some variation between the monitoring sites, common features include:

1) Generally low EC indicating negligible sources of salt in the catchments. The recorded EC for Site 9 reported in the 1986 EIS appears anomalous and is possibly due to salt concentration in a pool as a result of evaporation during an extended period of no rainfall or flow;
2) pH is generally consistent with the ANZECC default trigger ranges (with some exceptions in each of the differently sourced sets of data);
3) Generally low TSS but with occasional significantly higher values reflecting the episodic nature of sediment transport.

A review of the Annual Environmental Management Reports for the Rocglen, Tarrawonga and Canyon Coal Mines indicates the following trends and issues relating to surface water discharge and water quality from the existing mines in the Boggabri area:

1) Compared to earlier drought years, wet weather discharge was a relatively common occurrence in 2009/10 with high levels of TSS in mine sediment dams and discharges.
2) The wet conditions in 2009/10 together with the priority given to mine pit water for dust suppression purposes appear to have led to situations in which sediment basins could not be drawn down sufficiently following rainfall. This led to subsequent discharge of high turbidity water. The occurrence of such discharge suggests that the assumed overburden runoff characteristics may have been underestimated or the main water storage dams may be undersized.
3) In response to high turbidity in sediment dams, flocculants are being assessed in order to reduce the turbidity levels. The need for such treatment suggests that the soils in the area are more dispersive than anticipated at the time of the design of the water management systems.
4) EC levels in the mine water dam at Rocglen are in the range 1,400 – 4,200 µS/cm, which is within the acceptable range of water quality that could be used for irrigation of salt tolerant plant species. Subject to advice from the groundwater hydrologist, we assume that water within the Project open cut is likely to be comparable.
5) The Water Management Plan for the Canyon Coal Mine (undated) notes that a program of data collection was to be commenced to “more accurately assess annual production and/or use from various sources, e.g. groundwater bores, the open cut, sediment dams, ‘clean’ water storages...” and indicates that records were to be collated monthly.
6) The surface water and groundwater tri-annual review for the Tarrawonga Coal Mine (from the 2009/2010 Annual Environmental Management Reports) noted that, on occasions, the water quality in Nagero Creek had higher TSS and lower pH downstream compared to upstream.

1.5 Discharge License Conditions

Operations of the three existing mines in the vicinity of the Project area are covered by the following Environment Protection Licenses (EPLs):

1) Canyon Coal Mine EPL 10094
2) Rocglen Coal Mine EPL 12870
3) Tarrawonga Coal Mine EPL 12365

Table summarises the surface discharge water quality monitoring conditions associated with the EPLs for the Canyon, Rocglen and Tarrawonga Coal Mines while

Table summarises the relevant surface water quality monitoring requirements.

Table 6: Summary of Surface Water Discharge Licence Conditions

Monitoring Site / Purpose	Monitoring Frequency	Sampling Method	Parameter	Units	Discharge Concentration Limits		
					50%	90%	100%
Canyon							
Wet weather discharge from storage dams	Each overflow event	Grab	Oil & grease	mg/L	-	-	10
			pH		-	-	6.5 – 9.0
			TSS	mg/L	20	35	50
Tarrawonga							
Wet weather discharge from sediment basin or storage dam	As soon as practical after discharge commences	Grab	Conductivity	µS/cm	-	-	-
			Oil & grease	mg/L	-	-	10
			pH		-	-	6.5 – 8.5
			TSS	mg/L	20	35	50
			TSS	mg/L	-	-	-
Rocglen							
Wet weather discharge from sediment basin or storage dam	As soon as practical after discharge commences	In situ	Conductivity	µS/cm	-	-	-
		In situ	pH		-	-	6.5 – 8.5
		Grab	TOC	mg/L			
		Grab	Oil & grease	mg/L	-	-	10
		Grab	TSS	mg/L			50
Mine void	Annual	Grab	Aluminium, Arsenic, Bicarbonate, Chloride, Iron, Manganese, sodium	mg/L	-	-	-

Table 7: Summary of Routine Surface Water Quality Monitoring Conditions

Monitoring Site / Purpose	Monitoring Frequency	Sampling Method	Parameter	Units
Tarrawonga				
Ambient water quality upstream of discharge	As soon as practical after discharge commences	Grab	Conductivity	µS/cm
			Oil & grease	mg/L
			pH	
			TSS	mg/L
Mine void	Quarterly	Grab	Conductivity	µS/cm
			Oil & grease	mg/L
			pH	
			TSS	mg/L
Rocglen				
Ambient water quality upstream of discharge	As soon as practical after discharge commences	In situ	Conductivity	µS/cm
		In situ	pH	
		Grab	TOC	mg/L
		Grab	Oil & grease	mg/L
		Grab	TSS	mg/L
Mine void	Quarterly	In situ	Conductivity	µS/cm
		In situ	pH	
		Grab	TOC	mg/L
		Grab	Oil & grease	mg/L
		Grab	TSS	mg/L
Mine void	Annual	Grab	Aluminium, Arsenic, Bicarbonate, Chloride, Iron, Manganese, sodium	mg/L

Table and

Table indicate some significant differences in the licence conditions for the three mines, probably reflecting the priority water quality issues at the time when the original EPL was issued. Any EPL conditions for the Project can be expected to be similar to, or more stringent than, the EPL conditions for Rocglen.

Annexure C-1:

Surface Water Quality Monitoring Data

Mine Site	**Sample Location**	**Date** *(italics indicative only)*	**Time**	**EC** (µS/cm) (Red indicates 'lab' result)	**pH** (Red indicates 'lab')	**TSS** (mg/L)	**TOC** (mg/L)	**Grease & Oil** (mg/L)
Tarrawonga	BCU	01-Mar-07	1600	165	6.8	193	-	<2
Tarrawonga	BCU	23-Aug-07	1100	180	6.8	46	-	2
Tarrawonga	BCU	06-Feb-08	1505	120	7.1	20	-	<2
Tarrawonga	BCU	23-Sep-08	1400	95	6.8	92	-	<2
Tarrawonga	BCU	17-Feb-09	1418	275	6.8	35	-	<2
Tarrawonga	BCU	22-Dec-09	1100	150	7.3	220	25	-
Tarrawonga	BCU	15-Feb-10	1445	63	7.2	94	13	<5
Tarrawonga	BCU	10-Aug-10	1250	65	6.7	616	8	<5
Boggabri	SW2	23-Sep-08	-	56	5.9	99	-	-
Boggabri	SW2	06-Oct-08	-	72	7.0	32	-	-
Boggabri	SW2	13-Dec-08	-	86	7.8	66	-	-
Boggabri	SW2	17-Feb-09	-	33	7.1	110	-	<5
Canyon	WW11	11-Jul-07	1125	170	6.7	48	-	<2
Canyon	WW11	20-Aug-07	1410	55	7.6	280	-	<2
Canyon	WW11	06-Feb-08	1400	55	6.4	81	-	<2
Canyon	WW11	03-Sep-08	1655	100	8.1	166	-	<2
Canyon	WW11	07-Oct-08	1050	165	7.2	22	-	<2
Canyon	WW11	15-Dec-08	1250	130	6.8	12	-	<2
Canyon	WW11	17-Feb-09	1320	60	6.6	72	-	<2
Canyon	WW11	29-Dec-09	1425	61	7.0	114	8	-
Canyon	WW11	04-Jan-10	1405	98	7.4	14	15	<5
Canyon	WW11	15-Jan-10	1320	76	6.8	69	5	<5
Canyon	WW11	15-Feb-10	1130	71	6.4	33	21	<5
Canyon	WW11	10-Aug-10	1430	66	7.3	54	14	<5
Canyon	WW11	20-Aug-10	1410	106	8.1	22	19	18
Canyon	WW11	02-Sep-10	-	-	-	-	-	<5
Canyon	WW11	10-Sep-10	1330	81	6.9	115	18	<5
Canyon	WW11	12-Nov-10	1015	114	6.6	58	25	<5
Canyon	WW11	06-Dec-10	1500	112	6.7	45	16	<5
Canyon	WW11	09-Sep-11	900	131	7.0	147	15	<5
Vickery	Site 1	*01-Jan-86*	-	511	8.0	43	-	-
Vickery	Site 2	*01-Jan-86*	-	151	8.8	50	-	-
Vickery	Site 3	*01-Jan-86*	-	165	8.4	32	-	-
Vickery	Site 4	*01-Jan-86*	-	185	9.1	18	-	-
Vickery	Site 5	*01-Jan-86*	-	154	8.4	221	-	-

Mine Site	**Sample Location**	**Date** *(italics indicative only)*	**Time**	**EC** (µS/cm) (Red indicates 'lab' result)	**pH** (Red indicates 'lab')	**TSS** (mg/L)	**TOC** (mg/L)	**Grease & Oil** (mg/L)
Vickery	Site 6	*01-Jan-86*	-	273	8.5	74	-	-
Vickery	Site 7	*01-Jan-86*	-	517	7.7	39	-	-
Vickery	Site 9	*01-Jan-86*	-	2,489	7.4	39	-	-
Vickery	Site 12	*01-Jan-86*	-	373	7.8	179	-	-
Vickery	Site 13	*01-Jan-86*	-	96	6.8	-	-	-
Vickery	Site 14	*01-Jan-86*	-	98	7.8	-	-	-
Vickery	BR	13-Sep-11	9:55	136	3.9	200	12	<5
Vickery	BR	29-Sep-11	10:05	27	6.6	318	5	<5
Vickery	BR	24-Nov-11	12:00	78	6.7	158	16	<5
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Vickery	VUD	29-Sep-11	9:35	38	7.2	28	8	<5
Vickery	VUD	24-Nov-11	12:35	72	6.5	10	21	<5
Vickery	VUDOR	13-Sep-11	8:00	36	7.1	42	9	<5
Vickery	VUDOR	29-Sep-11	9:30	34	7.1	20	9	<5
Vickery	VUDOR	24-Nov-11	12:30	92	7.1	24	20	<5
Vickery	VUDOR	06-Feb-12	9:20	214	7.2	8	28	<5
Vickery	VUDOR	04-Jun-12	12:45	56	7.2	48	19	<5
Vickery	VUDOR	04-Jun-12	12:55	47	7.1	45	14	<5
Vickery	VUS	13-Sep-11	8:35	35	6.8	25	13	<5
Vickery	VUS	29-Sep-11	9:40	32	6.9	24	9	<5
Vickery	VUS	24-Nov-11	12:45	90	7.1	35	18	<5
Vickery	VUS	06-Feb-12	9:59	224	7.2	8	32	<5
Vickery	VUS	04-Jun-12	1:10	39	7.1	57	19	<5

Appendix D

Preliminary Flood Assessment

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WHITEHAVEN COAL

VICKERY MINE PROJECT

Flood Assessment

Issue 2

29th January 2012

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WHITEHAVEN COAL

VICKERY MINE PROJECT
Flood Assessment

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Project: 301015-03001 – VICKERY MINE PROJECT – FLOOD ASSESSMENT

REV	DESCRIPTION	AUTHOR	REVIEWER	WORLEY-PARSONS APPROVAL	DATE
A	Issued for Review	NM N MARTIN	WJH W HONOUR		29/06/12
0	Draft	NM N MARTIN	WJH W HONOUR		2/07/12
1	Final Report	NM N MARTIN	WJH W HONOUR	C THOMAS	1/11/12
2	Incorp. Adequacy Review Comments	NM N MARTIN	WJH W HONOUR	C THOMAS	29/01/13

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LIST OF FIGURES

1. INTRODUCTION

This report provides results of an assessment of the potential impacts of the proposed Vickery Mine Project on flood conditions in the Namoi River and its immediate floodplain. The report focuses on two specific areas where facilities associated with the mine project might affect, or might be affected by, flood conditions in the Namoi River between Gunnedah and Boggabri. The two areas are:

- The proposed extent of the mine pit and mine infrastructure area (*MIA*) located to the south of Shannon Harbour Road
- A proposed haul road overpass over the Kamilaroi Highway near the Whitehaven Coal Handling and Preparation Plant (*CHPP*) which is located approximately 6 kilometres west of Gunnedah.

Because flooding in these areas is predominantly due to mainstream flooding, the existing hydraulic model for the Namoi Valley between Carroll and Boggabri (*SMEC, 2004*) has been adopted to represent 'base case' conditions. The relevant data files representing the channels, floodways, floodplain and inflow hydrographs for various historic floods have been provided by the Inland Flood Unit of the NSW Office of Environment and Heritage (*OEH*).

In addition, OEH provided copies of a LiDAR survey undertaken for purposes of defining the floodplain topography for incorporation in the hydraulic model. The OEH noted that, at the time the data was originally obtained, discrepancies of up to 0.5 metres had been identified in some locations where data for adjacent 'tiles' overlapped. These concerns were taken into account in reconciling the additional topographic data derived for this project with the LiDAR data provided by OEH.

Flood records in the Namoi Valley extend back to 1864 when a flood level equivalent to 9.85 metres on the Gunnedah gauge was recorded. Other significant floods occurred in 1908 and 1955 (*9.65 and 9.60 metres, respectively, on the Gunnedah gauge*). On the basis of this historic record, the 'Carroll – Boggabri Flood Study' identified the flood of February 1955 as having an Annual Exceedance Probability (*AEP*) of 1% at Gunnedah.

Following the preparation of the Flood Study a draft Carroll-Boggabri Floodplain Management Study was prepared (*Webb McKeown & Associates, 2005*) under the direction of the Carroll-Boggabri Floodplain Management Committee which included representatives of state agencies, local government, rural industry groups and landholders. For purposes of managing potential impacts of floodplain development in a manner that adequately represented flood conditions in different parts of the valley, a 'Reference Flood' was adopted which combined elements of the observed floods of 1955 and 1984.

Following consultation with the Inland Flood Unit of OEH, the 1955 flood was adopted as the 'design' flood for assessment of the potential impacts of the mine related proposals in the reach of the Namoi River between Gunnedah and Boggabri.

Section 8 of the Flood Study provides an assessment of the impacts that various constructed levees have had on flood levels and flows along different reaches of the river system. Unfortunately, the model data files representing the 'with levees' condition could not be located in the OEH archives or those of the original consultants. Accordingly, it was agreed with OEH that the 'pre levees' data files be used as the basis for assessing any significant changes in flood levels or flow distribution associated with the proposed mine project.

It should be noted that the flood modelling results outlined in the following report are provided in the context of informing the environmental assessment for the works. Limited analysis of the implications of the predicted flood impacts has been undertaken as part of this report.

2. FLOODING TO THE SOUTH OF VICKERY MINE PIT AND INFRASTRUCTURE AREA

Figure 1 shows the proposed layout of the Vickery Mine at the completion of mining and its location relative to the Namoi River and an unnamed creek that drains to the river from the east. Following the terminology adopted for this catchment by Lyall & Macoun (*1990*), this drainage line is referred to as 'Stratford Creek'.

Unfortunately, Stratford Creek is not separately identified in the existing Namoi Valley flood model. Accordingly, the flooding conditions associated within this creek system in the vicinity of the mine were modelled in the following manner:

- The 1% AEP flood hydrograph for the creek was estimated using the XP-RAFTS hydrologic modelling software.
- Additional cross-sections were added to the Namoi River MIKE-11 flood model to represent the topography of the floodplain and the channel of Stratford Creek on the east bank of the Namoi River, including a smaller tributary of the creek that flows through the mine site from the north.
- Flood levels along Stratford Creek were assessed for conditions in which the peak of the flood from Stratford Creek was coincident with the peak of the 1955 flood in this reach of the Namoi River.

2.1 HYDROLOGIC MODELLING

Stratford Creek has a total catchment area upstream of the mine site of approximately 65 km^2. A tributary known as "South Creek" flows into Stratford Creek from the north in the vicinity of the site (*refer* **Figure 2**). The estimated flood hydrograph for a 1% AEP flood was derived using the XP-RAFTS hydrologic modelling software package. The model that was developed includes nine sub-catchments of Stratford Creek upstream of the site and a single sub-catchment for South Creek. **Figure 2** shows the structure of the XP-RAFTS model. **Table 1** summarises the input parameters for each sub-catchment within the model.

Testing of the XP-RAFTS model indicates that the critical duration for the catchment upstream of the site is 3 hours. The peak discharge in Stratford Creek during the critical 1% AEP flood event was calculated to be 255 m^3/s. The peak discharge in South Creek during the critical 1% AEP flood event was calculated to be 16.1 m^3/s.

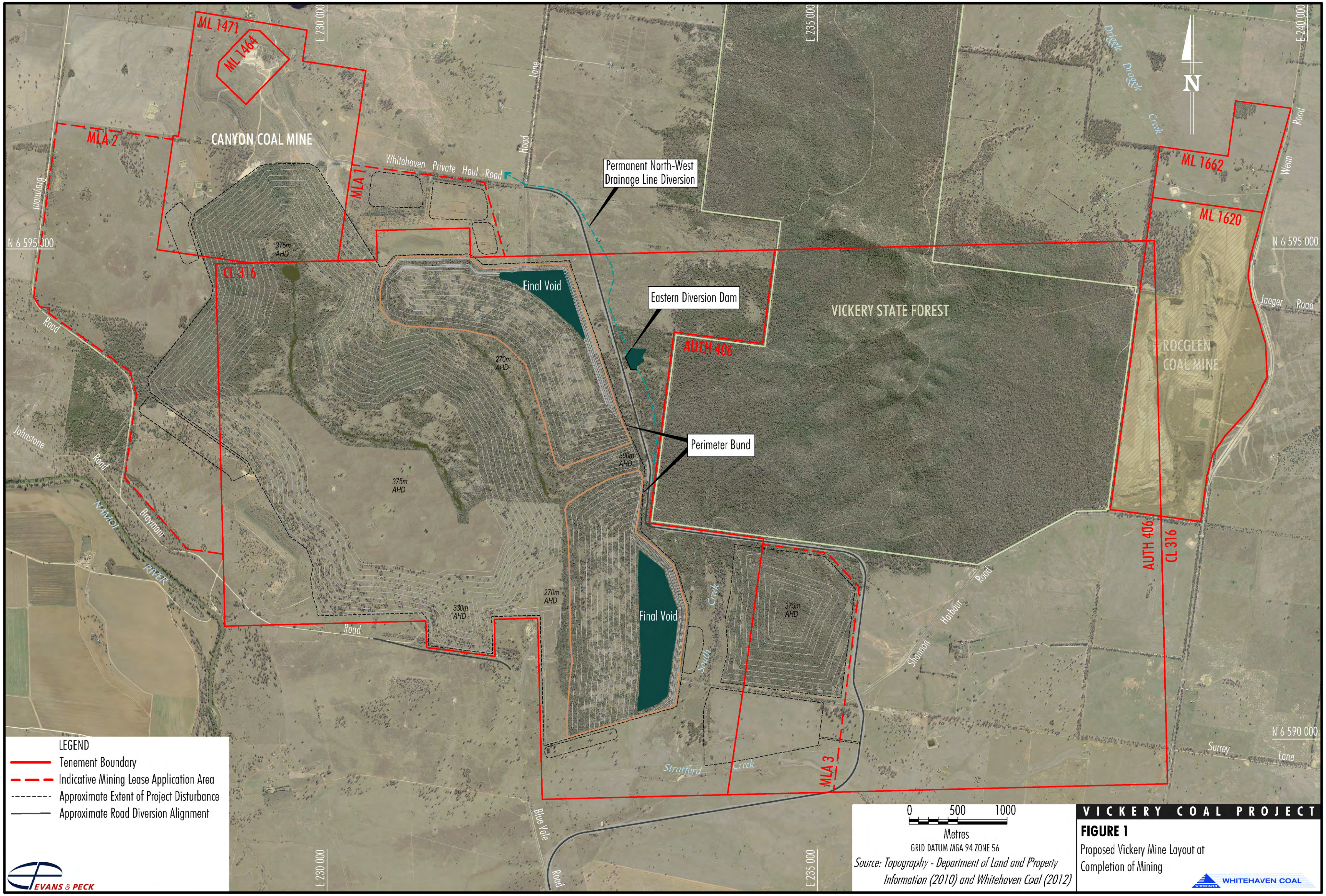

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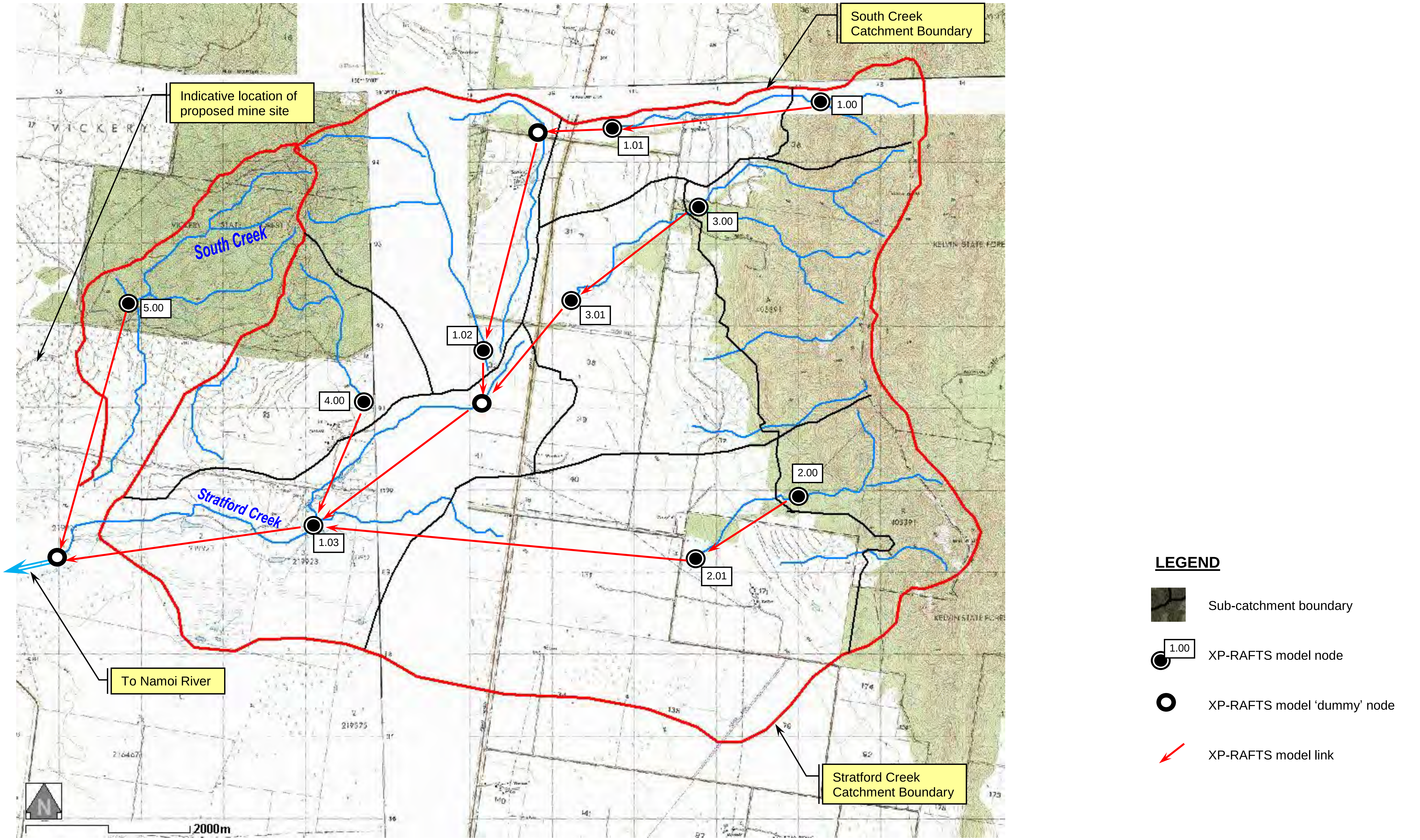
FIGURE 2



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301015-03001 – Vickery Mina Project
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NODE AND LINK ARRANGEMENT FOR XP-RAFTS HYDROLOGIC MODEL

Table 1 SUMMARY OF SUB-CATCHMENTS WITHIN XP-RAFTS MODEL

	XP-RAFTS SUB-CATCHMENT									
	1.00	1.01	1.02	1.03	2.00	2.01	3.00	3.01	4.00	5.00*
Catchment Area [km^2]	1.79	2.56	7.79	7.55	4.04	15.4	6.56	8.13	4.50	6.96
Vectored Slope [%]	21	2.1	2.7	0.2	19	1.3	24	1.5	5.2	3.2
Pervious 'n' Value	0.15	0.04	0.15	0.04	0.15	0.04	0.15	0.04	0.15	0.15

* *Sub-catchment of South Creek*

2.2 MODIFICATION OF EXISTING HYDRAULIC MODEL

Additional cross-sections were added to the Namoi River MIKE-11 flood model in order to represent the topography of the floodplain and channel of Stratford Creek on the east bank of the Namoi River. To ensure consistency with the topography used to develop the Namoi River MIKE-11 flood model, topographic data for the cross-sections was extracted from the same LiDAR dataset.

A total of 32 additional cross-sections were added to the model, as follows:

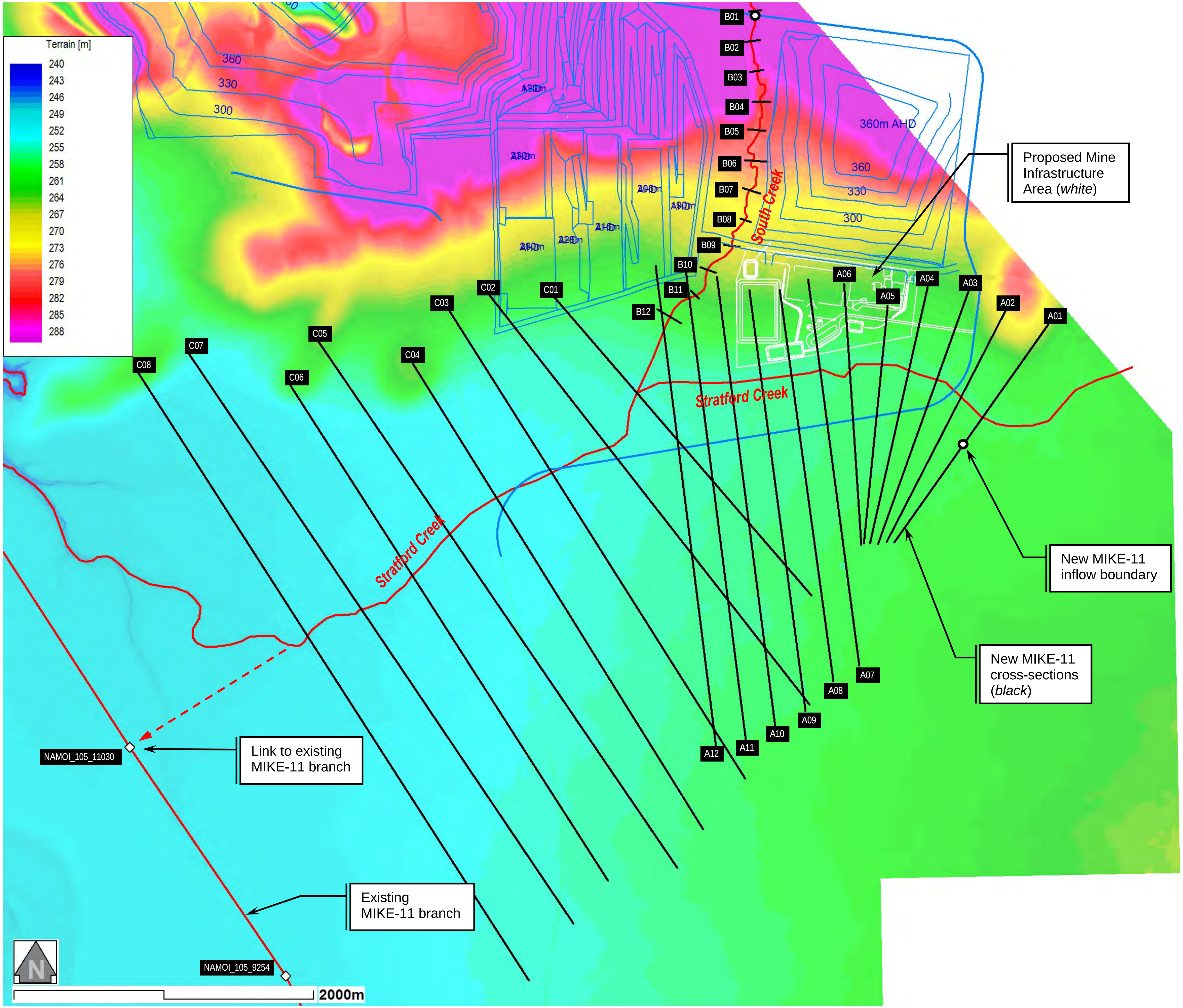
- 12 cross-sections (*spaced approximately 20 metres apart*) representing the Stratford Creek channel upstream of its confluence with South Creek;
- 12 cross-sections (*spaced approximately 20 metres apart*) representing South Creek; and,
- 8 cross-sections (*spaced approximately 40 metres apart*) representing the Stratford Creek channel downstream of its confluence with South Creek and upstream of its confluence with the Namoi River.

Two additional inflow boundary locations were also incorporated into the model at the upstream cross-sections of the Stratford Creek and South Creek. The hydrographs derived from the XP-RAFTS hydrologic model for the two streams were entered into the model at these locations.

A schematic representation of the additional branch of the flood model is shown in **Figure 3**.

Note that, since additional flows were to be directed into the newly added branch of the model, the corresponding inflow hydrograph along the Namoi River (*'Gunnedah to Boggabri'*) needed to be

FIGURE 3



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LAYOUT OF ADDITIONAL MIKE-11 MODEL CROSS-SECTIONS IN VICINITY OF PROPOSED VICKERY MINE SITE

adjusted accordingly. That is, flow values were subtracted from the inflows entering the Namoi River (*at branch NAMOI_102, chainage 2270*) at the corresponding times.

2.3 FLOOD MODELLING RESULTS

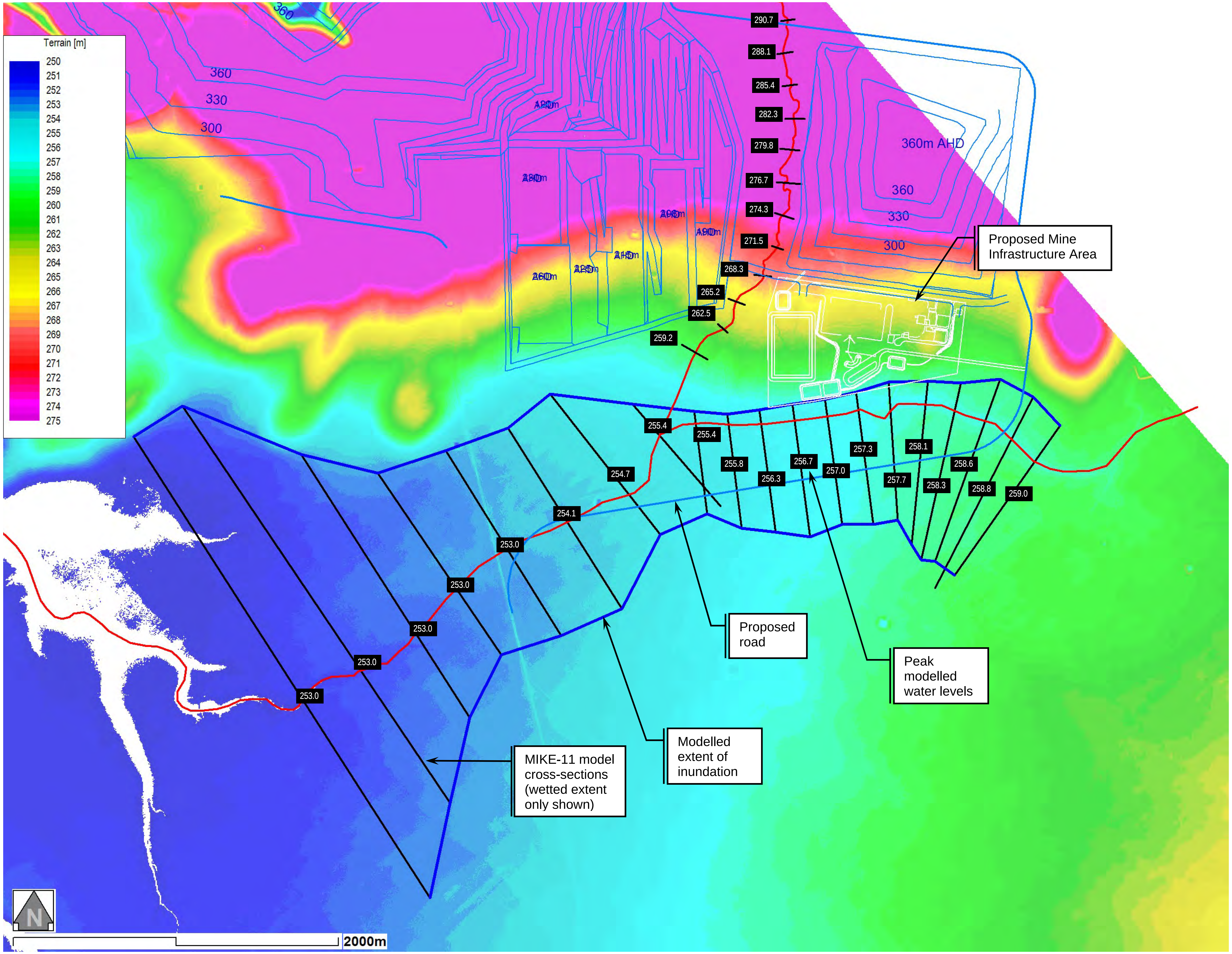
Figure 4 shows the extent of flooding and peak flood levels along Stratford Creek for a local 1% AEP event (*3 hour storm*) in conjunction with the peak of the 1955 flood simulation in the Namoi River. The dark blue line-work in the figure represents the flood extent, as manually drawn over the digital terrain model that was developed from the LiDAR data.

The proposed Mine Infrastructure Area (MIA) layout has been developed recognising the design flood extent and is identifiable as the white line-work shown in **Figure 4**. The MIA will be located outside of the 1955 (*1% AEP*) flood extent and is therefore, not expected to have any impact on flood characteristics along Stratford Creek. Accordingly, detailed modelling of the post-works scenario is not required and has not been undertaken.

As shown in blue line-work in **Figure 4**, a proposed haul road will pass across the creek alignment. At this stage it has been assumed that the road would be constructed on-grade; i.e., the post-development scenario does not incorporate any associated filling or earthworks for the road. Local catchment flows would be expected to discharge across the road unimpeded and therefore, the road is not expected to have any impact on flood characteristics.

Note that the flood levels along South Creek are not expected to extend beyond the cross-section extents shown in **Figure 3**. As such, no flood extent mapping has been provided for this small tributary. It is understood that provision will be made for this flowpath in the configuration of the proposed works and therefore, no impact on flow conveyance is expected.

FIGURE 4



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fg301015-03001nm130214-fig04_Existing 1955 Flood Extent.doc

MODELLED EXTENT OF 1955 FLOOD EVENT (1% AEP LOCAL FLOW) FOR EXISTING (UNDEVELOPED) SITE CONDITIONS

3. FLOODING IN THE VICINITY OF THE PROPOSED KAMILAROI HIGHWAY OVERPASS

A concept design has been developed for a proposed private haul road and overpass to allow coal trucks from the Vickery Mine to deliver coal to the Whitehaven Coal Handling and Preparation Plant (*CHPP*) without travelling along the Kamilaroi Highway. The proposed overpass starts just north of the CHPP and passes over the highway from south-west to north-east just east of the existing intersection of the highway and the access road to the CHPP. Once clear of the highway, the overpass follows in a north-westerly alignment, approximately parallel with the highway. The overpass then connects with Bluevale Road approximately 100 metres north-east of its intersection with the highway.

3.1 MODIFICATION OF EXISTING HYDRAULIC MODEL

Additional cross-sections were added to the Namoi River MIKE-11 flood model in order to represent the topography of the streams and floodplain areas in the vicinity of the proposed overpass. To ensure consistency with the topography that was used to develop the Namoi River MIKE-11 flood model, topographic data for the cross-sections was extracted from the same LiDAR dataset. Details of the alignment and levels of the proposed overpass were then superimposed onto the existing LiDAR data in order to simulate the post-development scenario.

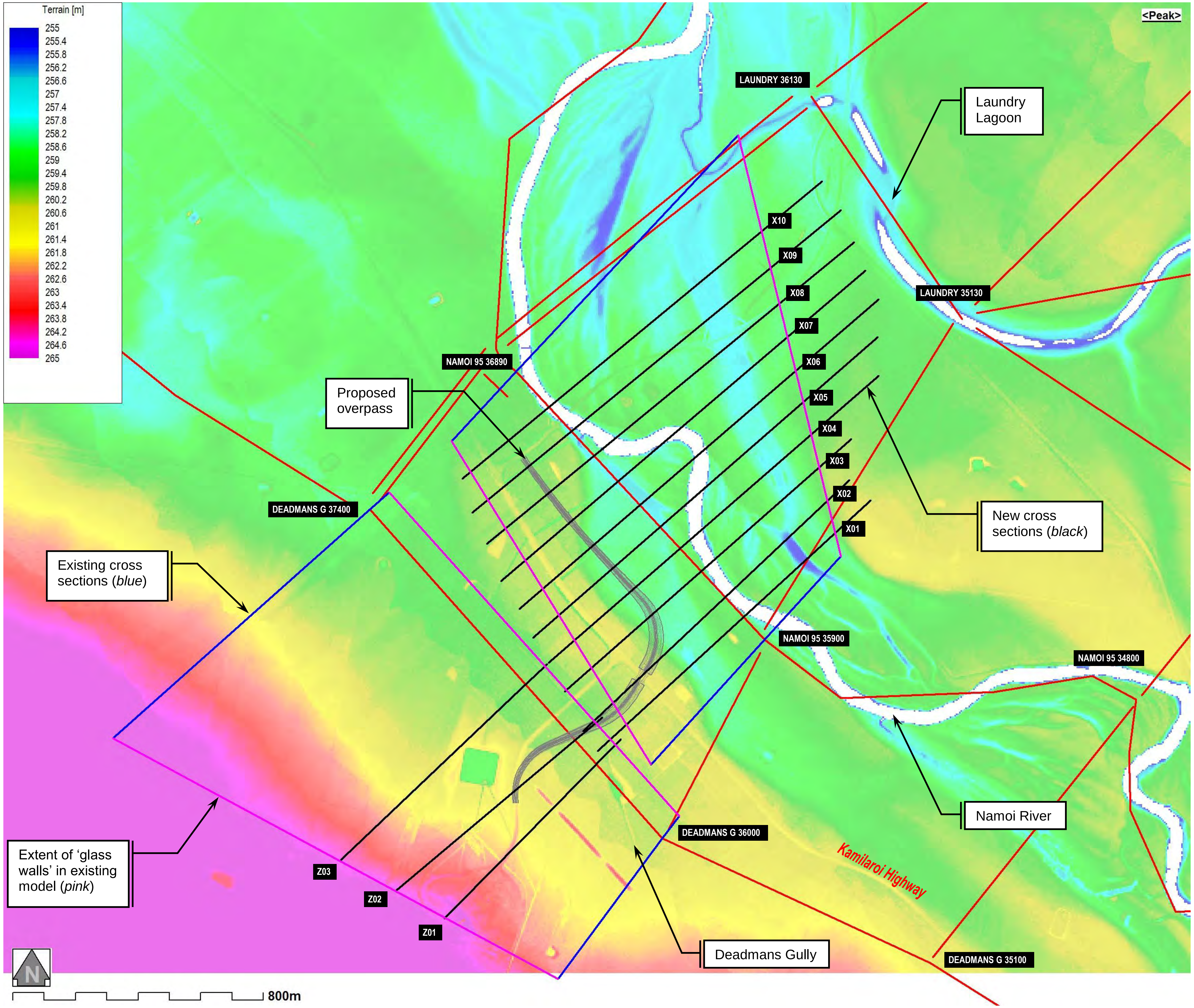
A total of 13 additional cross-sections were added to the model in the vicinity of the proposed overpass, as follows:

- 10 cross-sections along the Namoi River between the existing cross-sections at chainages 35,900 and 36,890; and,
- 3 cross-sections along Deadmans Gully between the existing cross-sections at chainages 36,000 and 37,400.

A schematic representation of the additional cross-sections in the model is shown in **Figure 5**.

It should be noted that the wider floodplain of the Namoi River as it passes by the site of the proposed overpass is represented by several parallel branches within the original Namoi River MIKE-11 model (*as supplied*). These parallel branches include Deadmans Gully, Namoi River and Laundry Lagoon. As such, the extents of the cross-sections of the individual branches were limited and a substantial amount of 'glass-walling' occurs at the intersections of the extents of the adjacent branches. It is recognised that this practice is a likely to have been a deliberate choice by the developers of the original model to enable a more complex representation of the individual branches across the width of the floodplain. Accordingly, the newly formulated cross-sections in the vicinity of the proposed overpass were limited at the extents defined by the cross-sections upstream and downstream of the overpass location (*refer* **Figure 5**).

FIGURE 5



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LAYOUT OF ADDITIONAL MIKE-11 MODEL CROSS-SECTIONS IN VICINITY OF PROPOSED OVERPASS OF KAMILAROI HIGHWAY

It was also assumed that the proposed overpass will be constructed with limited permeability to floodwaters. According to the peak flood levels obtained from the Namoi River Flood Study the majority of the overpass structure will be constructed above the modelled 1955 peak flood levels. As such, it was conservatively assumed that the passage of water through the proposed structure will be limited to the bridge opening for the Kamilaroi Highway (*at cross section X02*) and an assumed culvert structure constructed to convey Deadmans Gully flows through the structure (*at cross section Z02*). Accordingly, the bridge opening was modelled as a 40 metre wide opening in the overpass. A rectangular 5 metre wide culvert structure was assumed at the location where Deadmans Gully passes beneath the overpass.

The updated model configuration was then simulated for the 1955 flood event using an existing topography scenario and an assumed post-development scenario. That is, the post-development scenario assumed the existing topography with the overpass structure, bridge and culvert incorporated within appropriate cross-sections.

3.2 FLOOD MODELLING RESULTS

3.2.1 Impact on Flood Levels

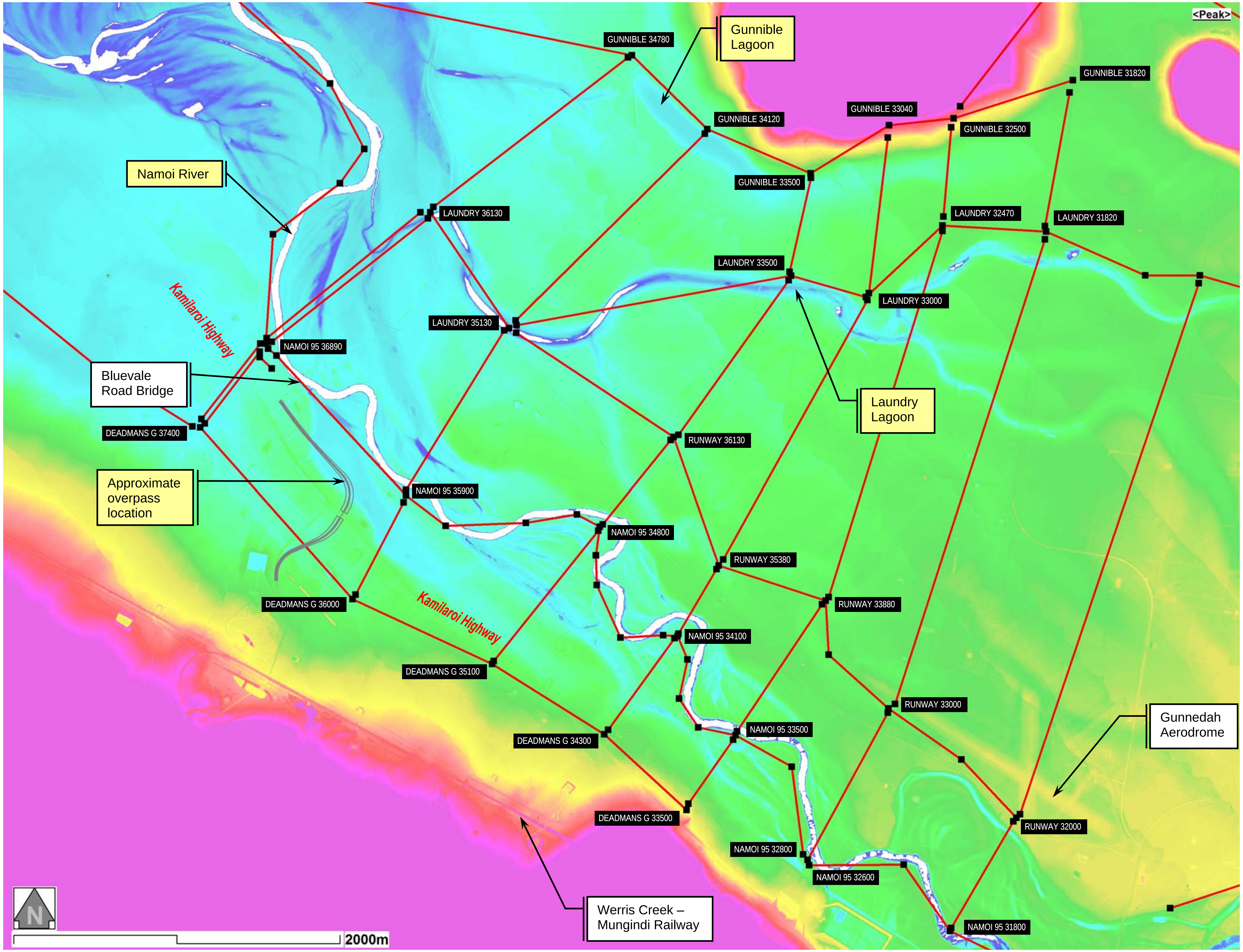
Table 2 provides a summary of the peak 1955 flood levels at each of the model cross-sections in the vicinity of the overpass, including along Deadmans Gully and the Namoi River channel, as well as along arms of the floodplain further to the north-east including Laundry Lagoon and Runway Creek. The locations of the model cross-sections in the vicinity of the proposed overpass and further upstream are shown in **Figure 6**.

Table 2 also shows the predicted impact (*change in peak flood level*) at each cross-section. Cross-sections where the increase in flood level was more than 30 mm are highlighted in pink.

As the overpass structure is to be constructed to above the existing peak 1955 flood level in Deadmans Gully, flows in the gully were restricted in the model aside from those that passed through a proposed 5 metre wide rectangular culvert. As a result, the impact on peak levels within Deadmans Gully at the overpass (*section Z02*) was found to be significant. Increases of 0.47 metres are predicted at the overpass itself and 0.39 metres at a point about 90 metres upstream.

It should be noted that Whitehaven Coal owns the properties in this vicinity up to the Werris Creek – Mungindi Railway, including up to a point 600 metres upstream from the overpass, where the flood level impact is reduced to about 0.07 metres. The impact at the nearest private dwelling upstream from the overpass is about 0.05 metres.

FIGURE 6



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LAYOUT OF CROSS-SECTIONS IN MIKE-11 MODEL UPSTREAM OF PROPOSED OVERPASS OF KAMILAROI HIGHWAY

Table 2 SUMMARY OF PEAK FLOOD LEVELS (EXISTING & POST-DEVELOPMENT)

WORLEY-PARSONS' XS	MIKE-11 MODEL BRANCH	CHAINAGE *[metres]*	Peak Flood Level Existing *[mAHD]*	Peak Flood Level Proposed *[mAHD]*	IMPACT *[metres]*
	NAMOI 95	32600	263.38	263.38	0.00
	NAMOI 95	32800	263.22	263.22	0.01
	NAMOI 95	33500	262.76	262.77	0.01
	NAMOI 95	34100	262.52	262.54	0.02
	NAMOI 95	34800	262.24	262.27	0.03
	NAMOI 95	35900	261.66	261.74	0.08
X01	NAMOI 95	35983	261.61	261.68	0.08
X02	NAMOI 95	36047	261.55	261.64	0.09
X03	NAMOI 95	36152	261.48	261.55	0.07
X04	NAMOI 95	36236	261.41	261.49	0.08
X05	NAMOI 95	36316	261.38	261.45	0.07
X06	NAMOI 95	36397	261.35	261.40	0.06
X07	NAMOI 95	36484	261.32	261.37	0.05
X08	NAMOI 95	36580	261.27	261.30	0.03
X09	NAMOI 95	36669	261.23	261.24	0.01
X10	NAMOI 95	36759	261.19	261.19	0.00
	NAMOI 95	36890	261.11	261.11	0.00
	DEADMANS	33500	262.70	262.72	0.01
	DEADMANS	34300	262.52	262.54	0.02
	DEADMANS	35100	262.25	262.28	0.03
	DEADMANS	36000	261.66	261.76	0.09
Z01	DEADMANS	36317	261.37	261.75	0.39
Z02	DEADMANS	36407	261.28	261.75	0.47
Z03	DEADMANS	36654	261.11	260.77	-0.34
	DEADMANS	37400	260.80	260.76	-0.04
	RUNWAY	33000	263.27	263.27	0.00
	RUNWAY	33880	262.79	262.80	0.01
	RUNWAY	35380	262.53	262.55	0.02
	RUNWAY	36130	262.25	262.28	0.03
	LAUNDRY	31820	263.15	263.15	0.00
	LAUNDRY	32470	262.84	262.85	0.01
	LAUNDRY	33000	262.57	262.59	0.02
	LAUNDRY	33500	262.26	262.28	0.02
	LAUNDRY	35130	261.66	261.74	0.08
	LAUNDRY	36130	260.97	261.00	0.03

The eastern extent of the proposed overpass (*as it runs parallel to the Kamilaroi Highway*) is located within a designated "floodway" area adjacent to the Namoi River (*refer Figure 9 of the Carroll-Boggabri Floodplain Management Study, 2005*). Blockages or constrictions in such areas would typically be expected to have an impact on upstream flood levels.

Flood level impacts along the Namoi River were calculated to be up to 0.09 metres (*at the most constricted section as the Kamilaroi Highway passes beneath the structure – section X02*). However, these impacts are predicted to dissipate with distance toward the north-western extent of the overpass (*section X10*).

The impacts of the works are expected to extend across the floodplain, with 20 to 30 mm increases occurring 1 to 2 kilometres upstream of the overpass in all four "streams" across the floodplain, including the Laundry Lagoon and Gunnible Lagoon arms of the model (*refer* **Figure 6**). As the various streams that constitute the floodplain are inter-linked in the model, it is difficult to determine the specific impacts on the individual streams or the aspects of the proposed overpass that cause the greatest impact.

Regardless of the limitations in the configuration and data analysis capabilities of the current model, unless the proposed overpass is constructed to be highly permeable, it is likely to block a significant proportion of the flood flow carried along Deadmans Gully and will restrict flows within the designated floodway area of the Namoi River. A number of alternative approaches for modelling flow through the overpass were trialled. However, similar impacts were determined for the range of the simulations that were tested.

3.2.2 Impact on Flood Extent

Detailed flood extent mapping has not been produced as part of this investigation, which is primarily due to the limitations in outputs from the 1-Dimensional MIKE-11 model. However, the available LiDAR data has been interrogated to determine the approximate increase in flood extent at the areas of predicted flood level increases.

The increases in levels across the wider floodplain are expected to dissipate to a maximum of 0.04 metres at the northern limit of the floodplain (*Gunnible Lagoon arm*). Given the slope of the land at the edge of the floodplain, this is not expected to manifest as any notable increase in lateral flood extent (*i.e., less than 2 metres, compared to a total floodplain width of ~ 4,000 metres*).

To the south-west of the proposed overpass, the maximum flood level increase of 0.47 metres along Deadmans Gully at the upstream side of the overpass is expected to translate to an increase in flood extent of between 50 and 60 metres. It is understood that Whitehaven Coal owns the land where such increases will occur, including up to the higher ground at the Werris Creek – Mungindi Railway (*refer* **Figure 6**).

3.2.3 Impact on Flow Velocities

Flow velocities have also been extracted from the MIKE-11 model results. Comparison between existing conditions and post-development conditions shows that the overpass will lead to minimal increases in flow velocities (*if any*) in the vicinity of the works or across the wider floodplain. Typical changes in velocity are less than 0.01 m/s.

Velocity increases along the Laundry Lagoon arm of the flood model (*refer* **Figure 6**) are predicted up to 0.06 m/s, but this reflects an increase of only about 5% above the existing velocity of 1.2 m/s and so this would not manifest as any notable change in flood hazard.

There is expected to be a significant reduction in flow velocities along Deadmans Gully, immediately upstream from the overpass and also at downstream locations.

3.2.4 Impact on Flow Distribution

As to be expected, the model results show that there will be a significant reduction in peak flow along the Deadmans Gully arm of the flood model (*refer* **Figure 6**). A reduction of about 260 m^3/s is expected to occur due to the impediment caused by the ramp and overpass. There will also be a reduction in peak flow of about 60 m^3/s along the Namoi River channel; however, this represents a reduction of less than 3% relative to the existing peak flow.

The model results show that a portion of this flow will be effectively “pushed” across the floodplain towards the Laundry Lagoon and Gunnible Lagoon arms of the model (*refer* **Figure 6**). The increase in peak flow along Laundry Lagoon is predicted to be approximately 200 m^3/s, which represents an increase of less than 10% above the existing flow. The increase in peak flow along the Gunnible Lagoon arm is expected to be approximately 110 m^3/s, which is an increase of about 5%.

In reference to the discussion above and **Table 2**, these increases in peak flow are expected to manifest as relatively localised increases in flood levels, minimal increase in flood extents, and only minor increases in flow velocities, which are not expected to impact on the existing flood hazard classification.

The measure of stream power is directly related to discharge and therefore, similar increases in stream power (*i.e., 5 to 10%*) are expected to occur in the Gunnible Lagoon and Laundry Lagoon arms. As a further measure of the potential for bank and channel erosion, the impact on flow velocities was considered with respect to the Hjulstrom diagram, which relates flow velocity and grain size to sediment transport and erosion. At the peak velocity of 1.2 m/s the potential for erosion and transport would be high under existing conditions. This would apply to a wide range of grain sizes from clay to cobbles and therefore, would cover the grain size distribution for the Namoi River floodplain. An increase in velocity of up to 0.06 m/s is not expected to manifest as a significant impact on the already high erosion and transport potential at the peak of the flood.

3.2.5 Impact on Critical Infrastructure

The impact on flood levels at critical infrastructure is documented in **Table 3**.

As shown, the increase in flood depth across the Kamilaroi Highway is expected to be up to 0.09 metres. This results in an increase in depth across the highway from 0.85 to 0.94 metres, which is equivalent to an increase of about 10%. Under existing conditions the highway at this location will be exposed to High Hazard floodwaters, as defined according the flood depth and velocity (*NSW Floodplain Development Manual 2005)*. The predicted increase in flood levels will not manifest as any change to this hazard classification.

Table 3 MAXIMUM FLOOD LEVEL IMPACTS AT CRITICAL INFRASTRUCTURE

CRITICAL INFRASTRUCTURE	MODEL CROSS-SECTION *(refer Figures 5 and 6)*	SURFACE LEVEL *[mAHD]*	POST-WORKS FLOOD LEVEL *[mAHD]*	IMPACT ON FLOOD LEVEL *[metres]*	INCREASE IN FLOOD DEPTH
Kamilaroi Highway	X02	~ 260.7	261.64	0.09	10.6%
Bluevale Road Bridge	X09	~ 258	261.23	0.01	< 0.5%
Werris Creek –Mungindi Railway	Z02	~ 266	261.75	Outside flood extent	Outside flood extent
Gunnedah Aerodrome	RUNWAY 33000	~ 261.6	263.15	0	0

The impact on flood levels at Bluevale Road Bridge is expected to be minimal and will not manifest as a notable impact on flood characteristics. The modelling results also show that Gunnedah Aerodrome, located about 3 km upstream from the proposed overpass, will not be impacted.

As indicated in **Table 3**, the Werris Creek – Mungindi Railway line is located on higher ground to the south-west of the Kamilaroi Highway. It is elevated at least 4 metres above the 1955 design flood level and will not be affected by flooding in either the existing case or the proposed case.

4. CONCLUSIONS

Whitehaven Coal is planning the following works as part its proposed Vickery Mine Project:

- Extension of the mine pit and Mine Infrastructure Area (*MIA*) to the south of Shannon Harbour Road; and,
- A haul road overpass over the Kamilaroi Highway near the Whitehaven Coal Handling and Preparation Plant (*CHPP*), located approximately 6 kilometres west of Gunnedah.

One-dimensional flood modelling was undertaken using the existing MIKE-11 hydraulic model for the Namoi River between Carroll and Boggabri (*SMEC, 2003*). The model was modified in the vicinity the proposed works in order to quantify the potential impacts on flood characteristics during a flood event similar to that experienced in the area in 1955. The 1955 flood is considered to be equivalent to a 1% AEP flood.

The modelling identified the extent of flooding likely to occur in the vicinity of the proposed mine site during the 1955 flood event (*refer* **Figure 4**), and also allowing for local catchment flows from Stratford Creek. The boundary for the proposed Mine Infrastructure Area, shown as white line-work in **Figure 4**, has been adopted to ensure that mine activities are located outside this flood extent and therefore, the proposed works are not expected to have any impact on flooding.

The flood modelling results also show that the currently proposed alignment of the overpass over the Kamilaroi Highway will result in increases in peak flood levels along the Namoi River in the vicinity of the site of up to 0.09 metres (*9 centimetres*). As a result, the works are likely to increase peak 1% AEP flood levels across an area extending 1 to 2 kilometres upstream of the overpass location; a maximum of about 0.08 metres and typically 0.03 metres or less.

Flood level impacts are likely to be more significant at Deadmans Gully due to the effective blockage of flow into and along the gully caused by the proposed overpass. Flood level increases would be up to 0.47 metres at the overpass and 0.39 metres about 90 metres upstream. It is noted that Whitehaven Coal owns the land along Deadmans Gully across which these increases are expected to occur. The flood level impacts at upstream private properties are significantly less, with increases of about 0.05 metres at the nearest private dwelling.

5. REFERENCES

- Lyall & Macoun (1990), '*Vickery Coal Project Haul Road – Review of Flood Effects*'.
- New South Wales Government (*2005*), '*Floodplain Development Manual; the Management of Flood Liable Land*'.
- SMEC Australia Pty Ltd (*2003*), '*Carroll-Boggabri Flood Study*'.
- Webb, McKeown & Associates (*2005*), '*Carroll-Boggabri Floodplain Management Study (Draft)*'.
- Webb, McKeown & Associates (*2006*), '*Carroll-Boggabri Floodplain Management Plan*'.

Appendix E

Water Balance Analysis

Whitehaven Coal Limited

Vickery Coal Project – Surface Water Assessment

Appendix E: Water Balance Analysis

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1 Background

The Vickery Coal Project will involve open-cut mining over a total footprint of approximately 21 square kilometres (km^2) comprising:

- an active open cut of up to about 300 hectares (ha);
- overburden emplacements of about 1,750 ha, which will be progressively rehabilitated;
- approximately 28 kilometres (km) of haul roads, not all of which will be active at any one time; and
- a mine infrastructure area (MIA) of about 40 ha.

While the climate of the project site is relatively dry (average annual rainfall of about 580 millimetres [mm]), the large footprint of the mine will require a range of water storage dams and sediment basins to provide water for the mine operations and to control the quality of water discharged. A fundamental premise of proposed the water management system is that it would provide clear separation of water of different quality:

- runoff draining into the site from undisturbed land would, where possible, be diverted away from the operational area;
- runoff draining from overburden dumps would be captured in sediment control basins that would be sized and operated in accordance with the requirements *of Managing Urban Stormwater: Soils & Construction – Volume 1* (Landcom, 2004) and *Managing Urban Stormwater: Soils & Construction– Volume 2E: Mines and Quarries* (DECC, 2008). Water from these basins would either be transferred to the mine water management system or discharged off site once the suspended solids concentration had reduced to a level suitable for off-site discharge;
- water collected in the open cut (runoff from the open cut itself and surrounding overburden) as well as groundwater inflow would be directed into the mine water management system. This water will be retained on site at all times and used for operational needs, primarily dust suppression on haul roads and at a crushing plant; and
- runoff from the mine infrastructure area, which will contain a coal stockpile, will be directed into the same mine water management system as the water collected within the open cut.

This appendix documents the water balance analysis undertaken to assess the performance of the water management systems over the life of the mine in terms of:

- security of water supply for operational purposes; and
- frequency and volume of discharge from the sediment basins.

In addition to surface runoff from the land area directly impacted by the mine, Whitehaven Coal Limited (Whitehaven) has a range of water access licences (both surface and groundwater) which are capable of providing in excess of 1,000 megalitres (ML) per year of water to supplement runoff derived from the active mine area. The mine water management systems have been designed to utilise the on-site sources whenever possible, and to draw on licensed external water only when necessary to maintain operations.

2 Methodology

The water balance model of the Vickery Coal Project has been set up to represent the daily inflows and outflows from each of the separate elements of the mine water management system as set out in **Table 1**.

Table 1: Components of the Vickery Coal Project Water Balance Model

Inflows	Outflows and Losses
Catchment runoff reporting to each sediment control dam.	Water required for dust suppression
Catchment runoff reporting to the open cut and mine infrastructure area.	Water required for operation in the mine infrastructure area including coal crushing and vehicle wash-down
Groundwater inflow to the open cut.	Controlled discharge from sediment dams in accordance with the guidelines
Direct rainfall onto the surface of the mine water storage dams	Evaporation and seepage losses from the mine water storages
Raw water supply (when required) from licensed water sources.	Off-site spills from sediment control dams.
Transfers between water storage structures	

The model has been set up in a manner that permits an assessment of the risk of shortfall or discharge at any stage of the mine life. This is achieved by modelling the progressive development of the mine over 30 years combined with 110 climate scenarios representing all the different sequences of 30 years of rainfall represented in the historic climate record.

The model utilises 112 years of daily the rainfall record from Boggabri (Retreat) which commenced recording in 1899. For the purposes of providing as many rainfall sequences as possible, the rainfall record after 2011 was simulated by repeating the rainfall sequence starting in 1899. Further details of the climate data are provided in **Section 2.1**.

The model was configured to represent the progressive development of the mine over 30 years, based on mine plans prepared for Mine Years (MY) 2, 7, 17 and 26. Each of the years represented by the mine plans was analysed to determine the catchment areas reporting to various sediment control dams or the open cut, and the area within each represented by different land surface characteristic (bare spoil, active rehabilitation, etc.). This data was subsequently analysed in further detail to account for the progressive expansion of the overburden emplacements and the progressive rehabilitation. Data relating to the progressive development of the open cut itself was derived from annual mine plans showing area of active mining. Further details of are provide in **Section 2.2**.

2.1 Climate Data

For purposes of water balance modelling, the following climate datasets were used:

- daily rainfall from Boggabri (Retreat): July 1899 – June 2011;
- daily pan evaporation data from Gunnedah Research Station: July 1967 – July 2011; and
- monthly potential evapotranspiration for the site from the digital version of the *Climatic Atlas of Australia: Maps of Evapotranspiration* (Version 1.0, Bureau of Meteorology, 2002).

As recommended by Boughton (2010), the monthly potential evapotranspiration data was used to account for evaporation and evapotranspiration losses from the contributing catchments in the rainfall:runoff component of the water balance model (see **Section 2.4**).

Because the requirement for water for dust suppression is variable on a day to day basis depending on the temperature and wind, the daily pan evaporation data from Gunnedah was used as the ‘driver’ for assessment of dust suppression water demand (see **Section 2.5.1**). In order to create a synthetic dataset corresponding to all years where there is no historic pan evaporation record, the following procedure was adopted:

- the years for which there are both rainfall and pan evaporation data available, the years were ranked in order of total annual rainfall; and
- for years which did not have corresponding pan evaporation data, the pan evaporation data set was inserted corresponding to the year with closest matching rainfall for which data was available.

2.2 Catchment Areas

For modelling purposes, catchment areas and the state of the surface (active emplacement, progressive rehabilitation, fully rehabilitated, etc.) were determined from mine layout plans for MY 2, 7, 17, 26 and the final landform. In general it has been assumed that changes in the mine layout between these years would occur in a linear manner. Exceptions to this were situations when it was known that a step change could occur, such as completion of rehabilitation of an area reporting to a particular sediment basin, which could then be allowed to drain off-site without the need for management in order to achieve sediment control.

In addition, Whitehaven provided annual ‘snapshots’ of the location and area of the active open cut. These areas were used to define the area of the active open cut for modelling purposes (as opposed to mine areas below natural ground level that are being progressively backfilled).

The results of the analysis of contributing catchment areas are shown in **Figure 1** and **Figure 2**.

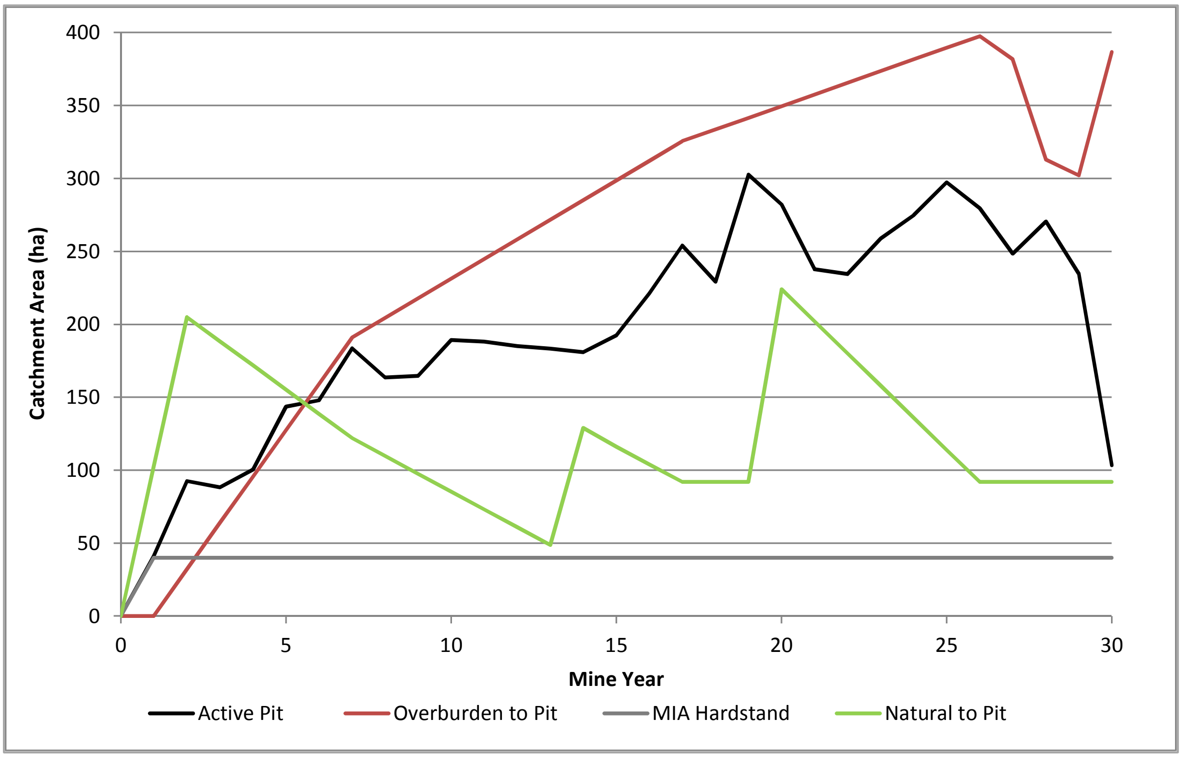

Figure 1: Progressive Development of Catchment Areas

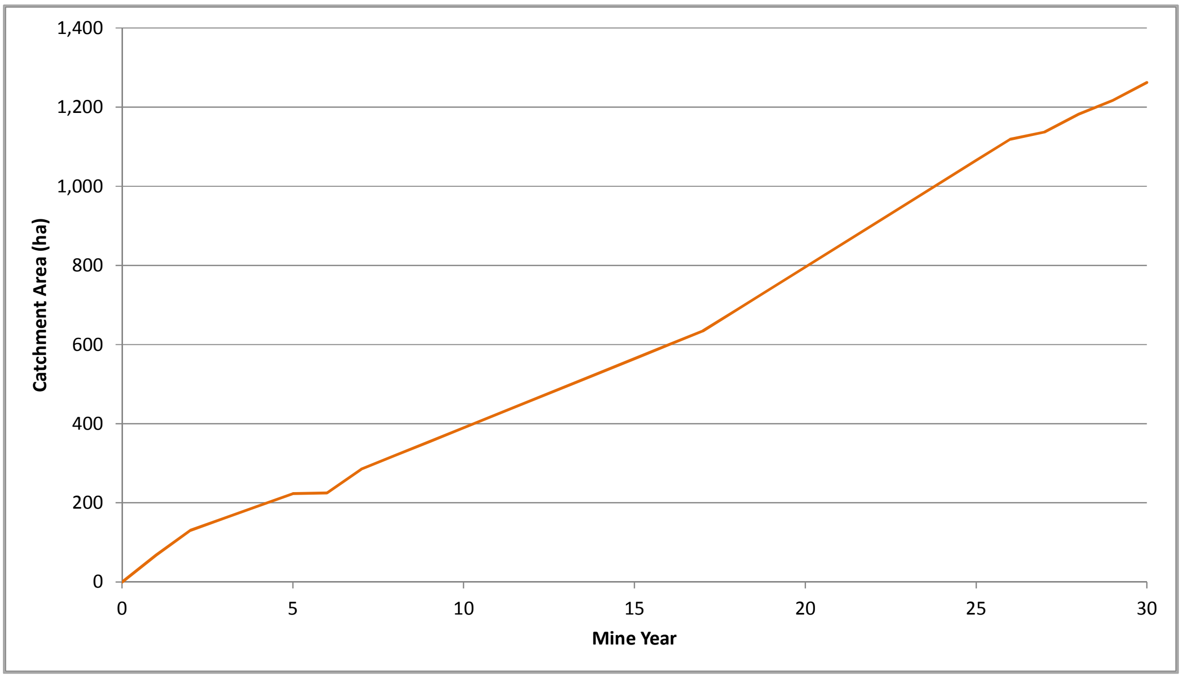

Figure 2: Progressive Development of Western Emplacement Catchment

2.3 Storages

The mine plan involves a number of water storage structures for different purposes which are detailed in **Table 2**:

- diversion dams that are only intended to provide a structure from which water can be diverted away from the active mining area and the flow rate controlled by means of a restricted spillway. It is not intended that water would be drawn from these dams for operational purposes;
- sediment control dams from which water can either be transferred to the mine water management system or discharged off site once the suspended solids concentration has reduced to a level suitable for off-site discharge;
- a pollution control dam located within the MIA. Any water collected in this dam will be transferred to the mine water management system and will not be discharged off-site, except in the rare event of an overflow; and
- a number of storages within the mine water management system including a surge storage dam located in the remnant Blue Vale void.

Table 2: Vickery Coal Project Water Storage Structures

Area	Water Storage	Permanency	Approximate Lifetime[1]	Approximate Catchment (ha)	Indicative Maximum Volume (ML)[1]
Diversion Dams					
North-East Drainage Line	DD-1[3]	Permanent	Years 1 - 30	169	80
	DD-2[3]	Temporary	Years 7 – 17+	205	20
Storage Dam					
West Drainage Line	SD-1	Temporary	Years 2+ only	205	59
Sediment Basins					
Western Emplacement	SB-1	Permanent	Years 1 - 30	103	30
	SB-2	Permanent	Years 1 - 30	45	13
	SB-3	Temporary	Years 1-3y	32	9
	SB-7	Temporary	Years 7 – 17+	264	76
	SB-8	Permanent	Years 2 – 30	252	73
	SB-9	Permanent	Years 17 - 30	325	95
	SB-10	Permanent	Years 17 - 30	85	24
Eastern Emplacement	SB-4	Permanent	Years 4 - 30	257	74
Mine Infrastructure	SB-5/6	Permanent	Years 1 - 30	40	20
Mine Water Dams					
Adjacent to MIA	MWD-1	Permanent	Years 1 - 30	n/a	400
North of Pit	MWD-2	Temporary	Years 7 – 17+	n/a	400
	MWD-3	Temporary	Years 17 – 30	n/a	400
Mine Water Surge Storage					
Blue Vale Void	MWSS-1	Permanent	Years 1 – 30	n/a	1,000
North of Pit	MWSS-2	Temporary	Years 24 - 30	n/a	1,000

Note [1]: Sediment basin capacity will vary in stages over the life of the mine depending on the contributing catchment area.

The proposed sequence for construction and commissioning of the various mine water storage dams is as follows:

At mine start-up:	MWD-1 (400 ML) located at the MIA
	MWSS-1 (1,000 ML) – Blue Vale void
Approximately Year 7:	MWD-2 (400 ML) located to the north of the open cut
Approximately Year 17:	MWD-3 (400 ML) located to the north of the open cut – as substitute for MWD-2 which will be subsumed by the open cut.
Approximately Year 20	MWSS-2 (1000 ML) located to the north of the open cut

Apart from the MWSS which will be created by placing an embankment across the south-eastern end of the Blue Vale void, the other significant water storages will be constructed as 'turkeys nest' dams.

In the water balance model direct rainfall onto the water surface and evaporation and seepage losses from the mine storage dams (MWD-1 to MWD-3) and the mine water surge storage (MWSS) are accounted for as depth of gain or loss depending of the climate on a particular day; and are converted to a volume by multiplying by the surface area of the storage that is a function of the volume of water held in the storage. The relationship between surface area and storage volume has been established from the geometry of each storage.

2.4 Runoff Modelling

Justification of the approach to modelling runoff and the selection of realistic model parameters are a key element of the assessment of site water balance. For this study the AWBM model (Boughton, 1984; Boughton & Chiew, 2003) has been used to estimate daily runoff volumes from the various catchments depicted in **Figure 1** and **Figure 2**. AWBM is a rainfall:runoff model which uses daily rainfall and evapotranspiration to estimate the runoff depth from land surfaces with different runoff generating characteristics. AWBM was developed for Australian catchments and has the advantage of maintaining a relatively simple structure (and relatively few parameters), whilst adequately representing the key runoff processes. Further details of the structure and operation of the AWBM model are provided in **Appendix 1** of the *Surface Water Assessment*. The runoff depth calculated by AWBM is converted to a volume of runoff by multiplying by the relevant catchment area.

AWBM utilises a total of 9 parameters to characterise the runoff characteristics of the land in terms of:

- the fraction of the catchment area represented by three soil stores;
- the soil moisture holding capacity (expressed in mm) of each of the stores;
- a baseflow index which sets the proportion of runoff directed to baseflow; and
- a baseflow recession constant which governs the rate at which water discharges from the baseflow store.

The model also provides for a recession in the rate of surface runoff to reflect the lag effect observed in large catchments. This feature is not relevant for the relatively small catchments of relevance to this report.

Experience of the use of AWBM over a number of years (Boughton, 2006, 2010,) has shown that the volume of runoff can be adequately characterised by a single parameter which represents the average soil moisture capacity of the land surface (AveCap) which is the sum of the product of the soil storage area fraction and the soil moisture holding capacity of each store.

For purposes of selecting appropriate parameters to represent the runoff characteristics of the various surfaces, parameters derived from various sources were tested to determine the volume and flow distribution that would occur using the entire 112 year daily climate dataset complied for this report (see **Section 2.1**). The main sources of data for this analysis were:

- parameters derived from rainfall and runoff data collected from open-cut mines in the Hunter Valley and Queensland (Australian Coal Association Research Program, 2001);
- published parameters adopted for other surface water assessments for mine projects including Tarrawonga, Maules Creek, Bickham and Mt Thorley; and
- calibrated parameters for AWBM for the Maules Creek catchment based on recorded rainfall and runoff (see **Appendix 1** of this *Surface Water Assessment*).
- published AWBM parameters for ungauged catchments (Boughton & Chiew, 2003)

The results of testing different parameters are summarised in **Table 3** in which the parameters adopted for this study are shaded.

Table 3: Percentage Runoff for AWBM Parameters Representing Different Land Surfaces

Land Surface	Data Source	Ave Cap	Runoff %
Open cut	Tarrawonga Mine	18	28.0%
	Tarrawonga variation	15	36.7%
	Tarrawonga variation	13	39.8%
	Maules Creek Mine	14	41.7%
	Mt Thorley Mine	5	54.2%
	Bickham Mine	9	58.8%
Bare Spoil	Tarrawonga Mine	74	11.6%
	ACARP (Maximum AveCap)	69	14.5%
	ACARP (Average AveCap)	49	17.9%
	ACARP (Minimum AveCap)	27	28.4%
	Mt Thorley Mine	10	42.6%
Hard Stand	Tarrawonga Mine	2	64.5%
	Maules Creek Mine	14	41.7%
	Mt Thorley Mine	5	54.2%
Partially Rehabilitated	Mt Thorley Mine	80	6.1%
	ACARP (Maximum AveCap)	94	6.2%
	ACARP (Average AveCap)	68	10.0%
	Tarrawonga Mine	57	12.3%
	ACARP (Minimum AveCap)	42	15.7%

Table 3: Percentage Runoff for AWBM Parameters Representing Different Land Surfaces

Land Surface	Data Source	Ave Cap	Runoff %
Rehabilitated	ACARP (Maximum AveCap)	117	5.3%
	ACARP (Median AveCap)	87	7.1%
	Tarrawonga Mine	76	8.7%
	Mt Thorley Mine	60	11.2%
	ACARP (Minimum AveCap)	38	20.4%
Natural	Maules Creek Gauge	269	5.3%
	Kingdon Ponds Gauge	160	6.0%
	Maules Creek Mine	120	7.8%

In assessing the applicability of various sets of model parameters, consideration was also given to the distribution of runoff over time as represented by the flow duration curve, taking account of the statistics of rainfall depth as summarised in **Table 4**. A typical runoff distribution graph is shown in **Figure 3**.

Table 4: Average Daily Rainfall Distribution for Boggabri (Retreat) (1899 – 2011)

Rainfall	Average Days per Year	Percentage of Time
Days with rainfall >0.1 mm	53.9	14.8%
Days will < 2mm	9.9	2.5%
Days with 2 – 5 mm	11.5	3.4%
Days with 5 – 10 mm	13.1	3.6%
Days with 10 – 20 mm	12.0	3.3%
Days with 20 – 50 mm	7.5	2.1%
Days with > 50 mm	0.8	0.2%

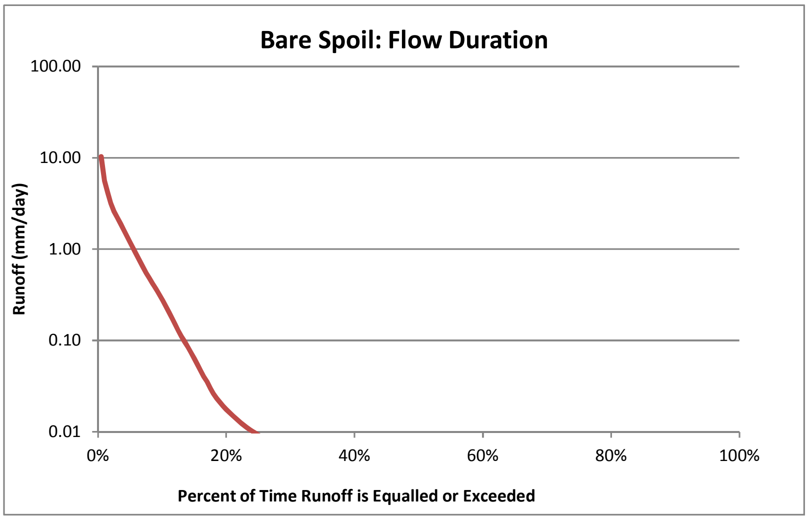

Figure 3: Flow Duration for Runoff from Bare Spoil

In addition, a comparison was undertaken against runoff characteristics derived for the Rocglen mine based on records of dam levels and overflow events between December 2009 and February 2010 (GSS Environmental, 2010). **Table 5** summarises the initial loss and runoff percentage values derived for the Rocglen Mine (provided by GSS Environmental) and the resulting average runoff as a percentage of rainfall. In general the runoff parameters derived for Rocglen indicate that total site runoff could be about 25% lower than the results derived from application of the AWBM model. These results have been taken into account is selecting appropriate parameters for assessment of the water balance for the Vickery Mine project.

Table 5: Estimated Runoff Characteristics for Different Land Surfaces at Rocglen Mine

Land Surface	Initial Loss (mm)	Runoff Percentage	Runoff (%)
Natural	20	20%	3.5%
Bare Spoil	30	15%	1.2%
Partial Rehabilitation	20	25%	4.4%
Rehabilitated	20	20%	3.5%
Disturbance Areas	15	35%	9.2%
Mine Pit	5	70%	43.8%

2.5 Water Demands

2.5.1 Dust Suppression

The water requirements for dust suppression on haul roads and hardstand areas are closely related to the daily weather (since hot windy days can be expected to generate dust). Thompson and Visser (2002) studied the water requirements for dust suppression on mine haul roads and demonstrated a robust relationship between water requirements for dust suppression and the potential evaporation on the day, while taking into account any incident rainfall. An algorithm based on the work of Thompson and Visser has been benchmarked against estimated mine water use at two mines in the Hunter Valley and has been adopted for the site water balance model. This element of the water balance model takes account of:

- the area of active haul road;
- daily rainfall;
- daily evaporation.

The modelling of water requirements for dust suppression also takes account of the water application requirements specified for “Level 2” control of dust, as adopted for the dust emissions analysis for this project. “Level 2” dust suppression assumes an application of 2 L/m^2/hour in order to maintain a surface moisture content of 3.5% on the working surface. For a notional 12 hour day when water loss could occur because of incident solar radiation and wind, this equates to 24 mm depth of water application. For modelling purposes, the depth of water application was taken as function of the difference between pan evaporation and incident rainfall with a maximum of 24 mm/day.

2.5.2 Coal Crusher and Vehicle Wash-down

Water requirements within the mine infrastructure area, including dust suppression on the coal crusher and vehicle wash-down has been estimated by Whitehaven at 0.16 ML/day. The water balance model includes provision for this daily use.

2.6 Groundwater

The *Groundwater Assessment* (Appendix A to the Vickery Coal Project EIS) assesses the groundwater inflow to the Vickery open cut and discharge to the groundwater from any water stored in the Blue Vale void, which will be used as a mine surge storage dam.

Figure 4 shows the estimated groundwater inflow to the open cut which has been taken into account in the water balance model. Because of the size of the open cut (up to 303 ha) and the length of its perimeter (up to 14.8 km) any groundwater inflow during dry weather will be lost as evaporation at the seepage face. Accordingly, the water balance model includes a facility that only includes groundwater as a component in the water balance when surface runoff is retained in the open cut.

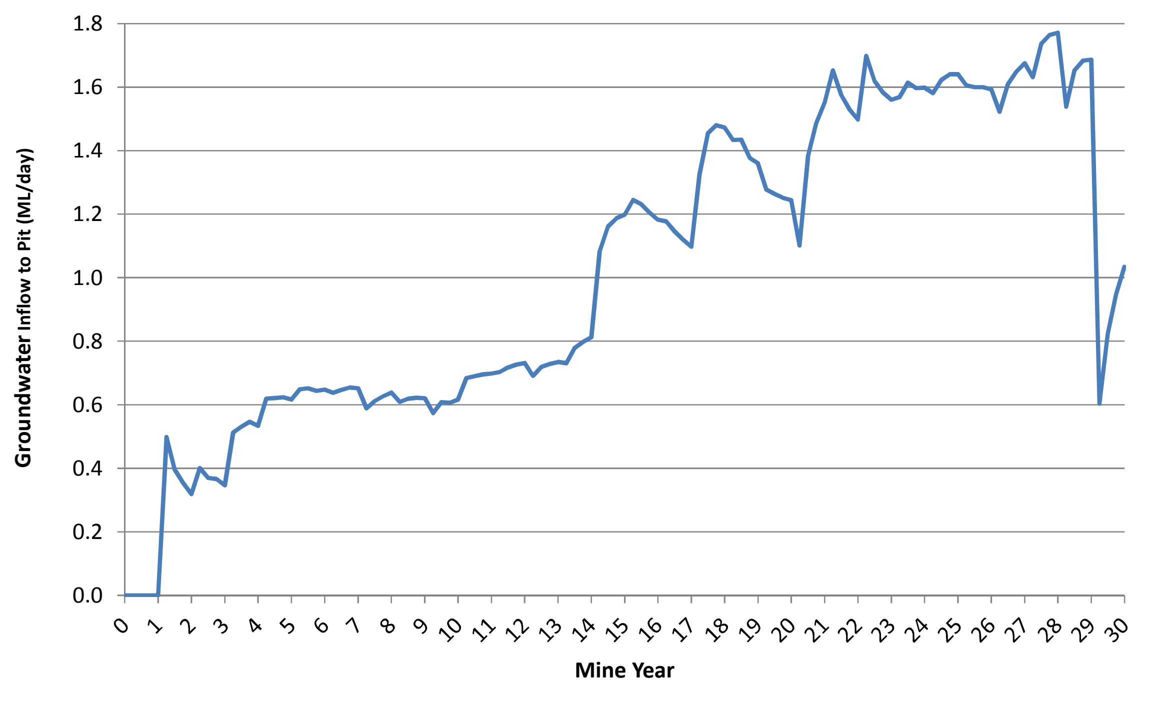

Figure 4: Estimated Daily Groundwater Inflow to the Open Cut

The Blue Vale void represents the final void which has been rehabilitated following completion of earlier mining. The coal seam that underlies the void dips to the west and is considered a potential pathway for water loss from the open cut. Groundwater modelling indicates that for a water level in the Blue Vale void of 265 m AHD, the flow out of the open cut would be 81 m^3/day, corresponding to a loss of 2.5 mm/day. This loss has been included in the water balance model for all days on which there is water stored in Blue Vale void.

2.7 External Water Sources

Whitehaven has a number of water access licences for water from the Namoi River and from groundwater. These access licences, which include water from sources with different reliability total over 3,000 ML/year.

For purposes of water balance modelling, it has been assumed that access to water from these sources would only be undertaken on a 'campaign' basis in which 25-100 ML would be transferred into the mine water management system when total water in the mine water system fell below a specified level (see **Section 2.8** for further details).

2.8 Water Transfers and Operating Rules

As described in Sections 2.2, 2.3 and 2.5, the Vickery Coal Project water management system comprises a number of water sources and storages which will be interlinked with pipes. For purposes of characterising the overall water balance of the mine water management system the following operating rules and assumptions have been adopted:

- all water required for dust suppression on haul roads and hardstand areas, and for operations within the mine infrastructure area, is assumed to be drawn from one of the mine water dams (MWD-1, MWD-2 or MWD-3). In practice, intermediate water cart fill points would be established adjacent to the larger sediment basins and water would be taken from these dams when it is available;
- up to Year 7 the model assumes that runoff captured in the sediment basins would be transferred to the water management system on the same basis as would be required if the retained water was held for 5 days following a runoff event in order to sediment to settle;
- the model assumes a limit of 20 ML/day for transfer of water from the open cut to one of the mine water storage dams;
- the model assumes a limit of 10 ML/day for:
  - transfer from the MIA sediment basins to MWD-1; and
  - transfer between any of the mine water dams and the MWSSs depending on the volume held in the mine water storage dams and the available 'air space' in the MWSSs;
- transfer of water into, or out of, the mine water dams is assumed to occur according to the following priorities and rules:
  - water from the MIA sediment basins is automatically transferred to MWD-1 at the nominated rate until the basins are empty;
  - if the combined contents of the MWDs is less than 90% of available capacity, water is transferred from the open cut at the nominated rate;
  - if the combined contents of the MWDs exceed 90% and the MWSSs are not full, water would be transferred to the MWSSs;
  - up to Year 7, if the contents of MWD-1 are less than 70% of capacity, and there is water held in the sediment basins, water would be transferred from the sediment basins at a rate equivalent to that required to empty the basin in five days;

  - if the combined contents in the MWDs is less than 50% of the capacity and there is water held in the MWSSs, water would be transferred back to the MWDs at the nominated rate; and
  - if the combined contents in the MWDs falls to less than 5% of the total capacity, water is imported from an external source. For simplicity of modelling the volume imported is assumed to be 5% of the capacity of the MWDs;
- water required for dust suppression is based on the evaporation excess for the day multiplied by the length of active haul road. Analysis of the mine plan indicates that the maximum length of haul roads amounts to 28 km. However, Whitehaven has advised that a maximum of 21 km would be active at any one time. To account for this, and the progressive growth in the length of haul road over the mine life, the water balance model accounts for the progressive growth in haul road length in the following manner:
  - for haul road lengths up to 5 km, all the haul road is assumed to require watering; and
  - for haul road lengths between 5 km and 28 km, 75% of the additional haul road length is assumed to require water.

3 Model Results

Because the water balance model keeps track of all runoff, water transfers and volumes in various storages on a day to day basis, a vast quantity of data is generated even for a single scenario which tracks all these flows and volumes over life of the mine for a 30 year climate sequence. For purposes of understanding the overall performance of the system and the probability of having an excess or shortfall of water, the model has been run for 110 separate climate sequences, which further compounds the quantity of data generated. For purposes of demonstrating the performance of the system, a selection of the consolidated model results is presented in the following sections:

- graphs illustrating the variation of water held in the various water storages over the life of the mine for representative climate sequences;
- a graph showing the probability of water being retained in the mine open cut at any stage in the mine life;
- a table summarising the statistics of runoff, transfers and water use over the life of the mine for all climate sequences; and
- a table summarising the performance of the sediment basins in terms of:
  - the volume of controlled transfer or discharge; and
  - the frequency and volume of overflow.

3.1 Representative Behaviour of Mine Water Storages

Figures 5 to **13** show the modelled results for the volume of water retained over the life of the mine in the MWDs (combined), the MWSS and the open cut for climate sequences in which the start of mining corresponds with 1 July in 1900 and then every decade up to 1980.

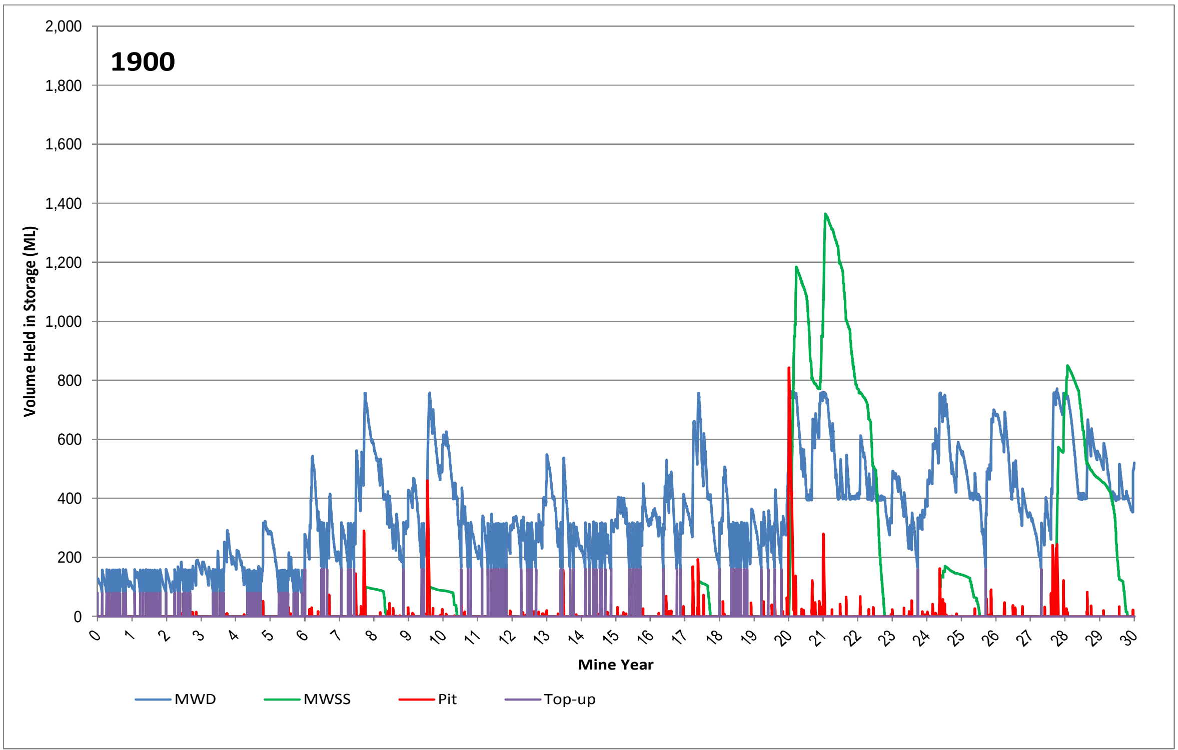

Figure 5: Volume of Water Held in Various Storages and Top-up Water over the Life of the Mine for a Climate Sequence Starting in July 1900

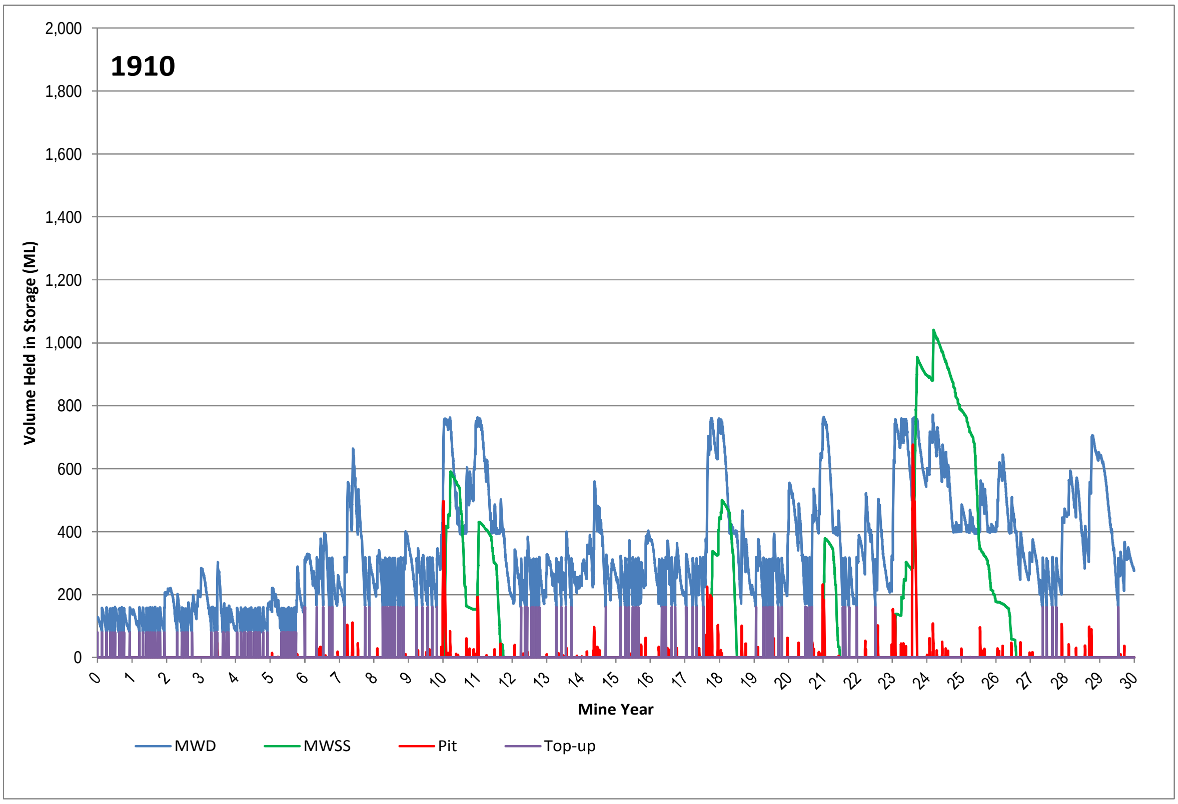

Figure 6: Volume of Water Held in Various Storages and Top-up Water over the Life of the Mine for a Climate Sequence Starting in July 1910

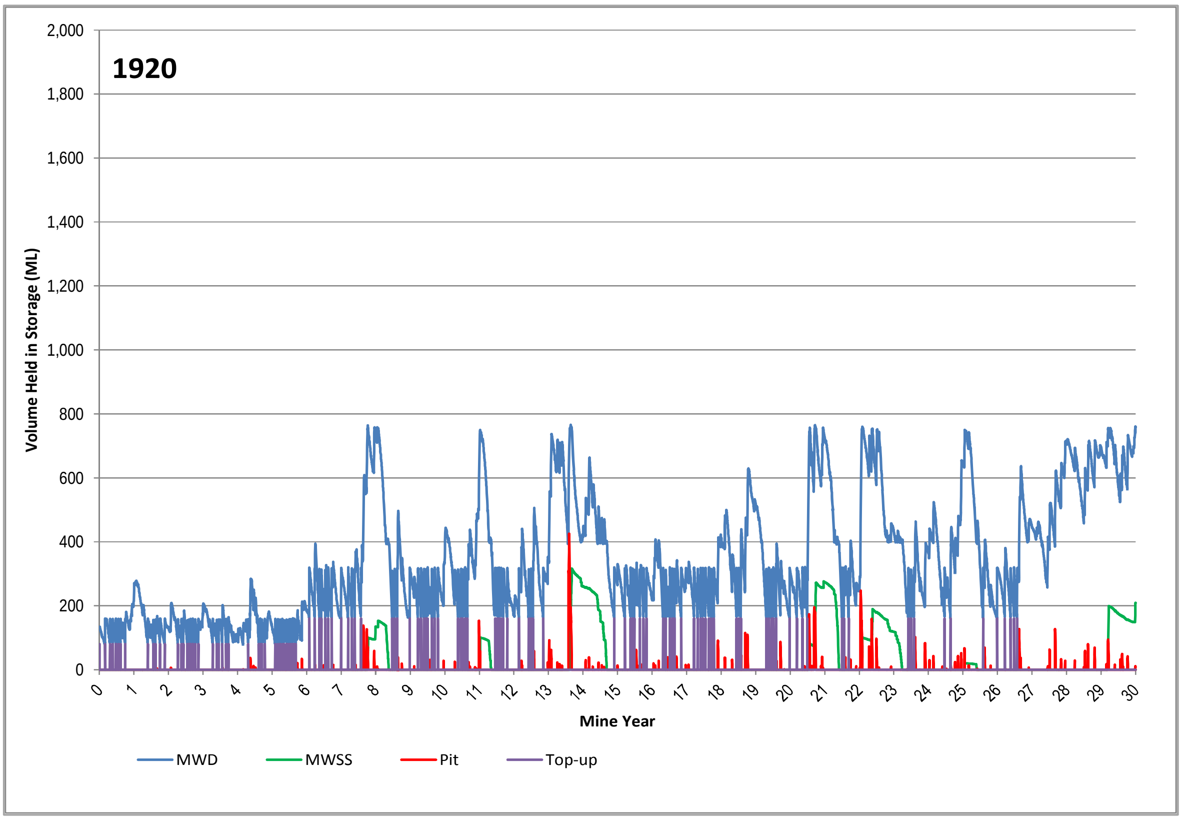

Figure 7: Volume of Water Held in Various Storages and Top-up Water over the Life of the Mine for a Climate Sequence Starting in July 1920

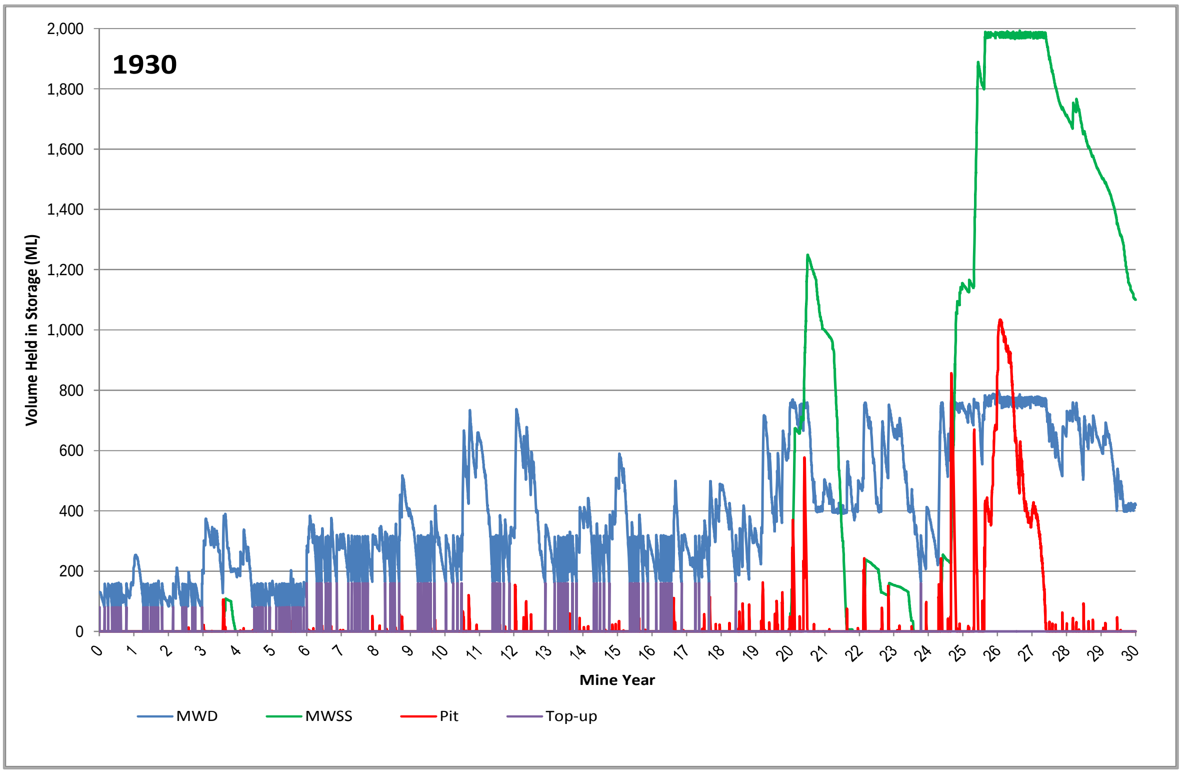

Figure 8: Volume of Water Held in Various Storages and Top-up Water over the Life of the Mine for a Climate Sequence Starting in July 1930

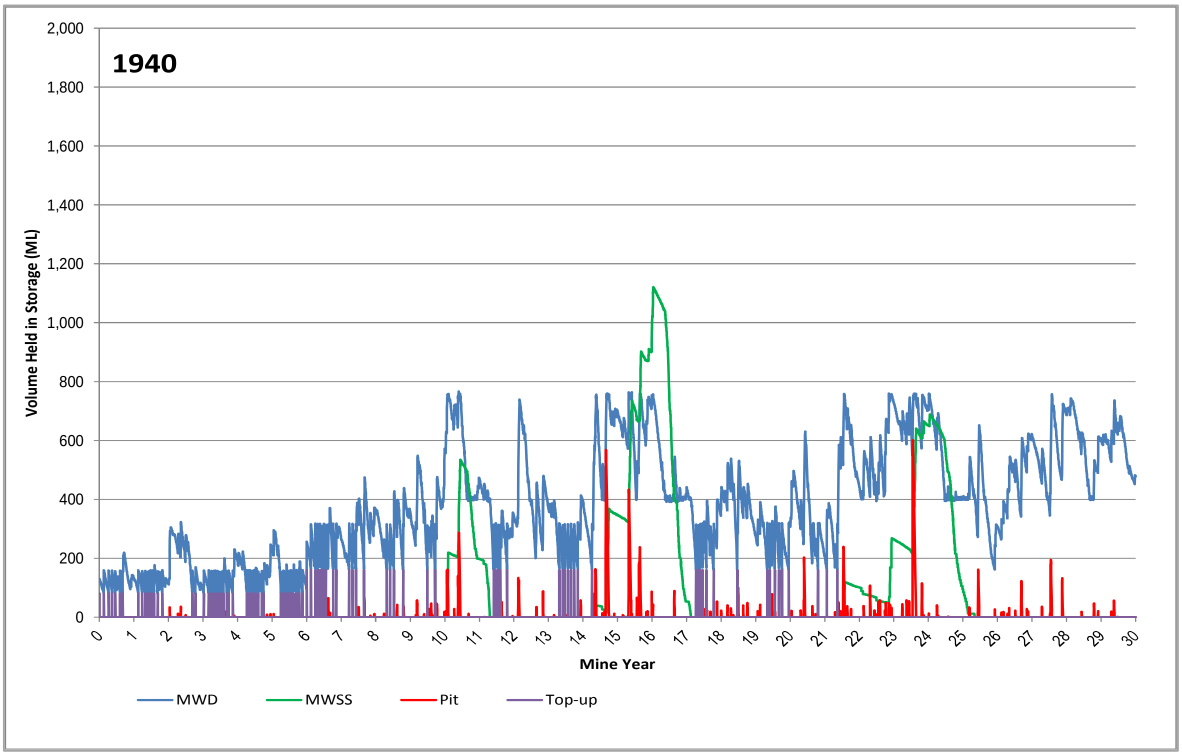

Figure 9: Volume of Water Held in Various Storages and Top-up Water over the Life of the Mine for a Climate Sequence Starting in July 1940

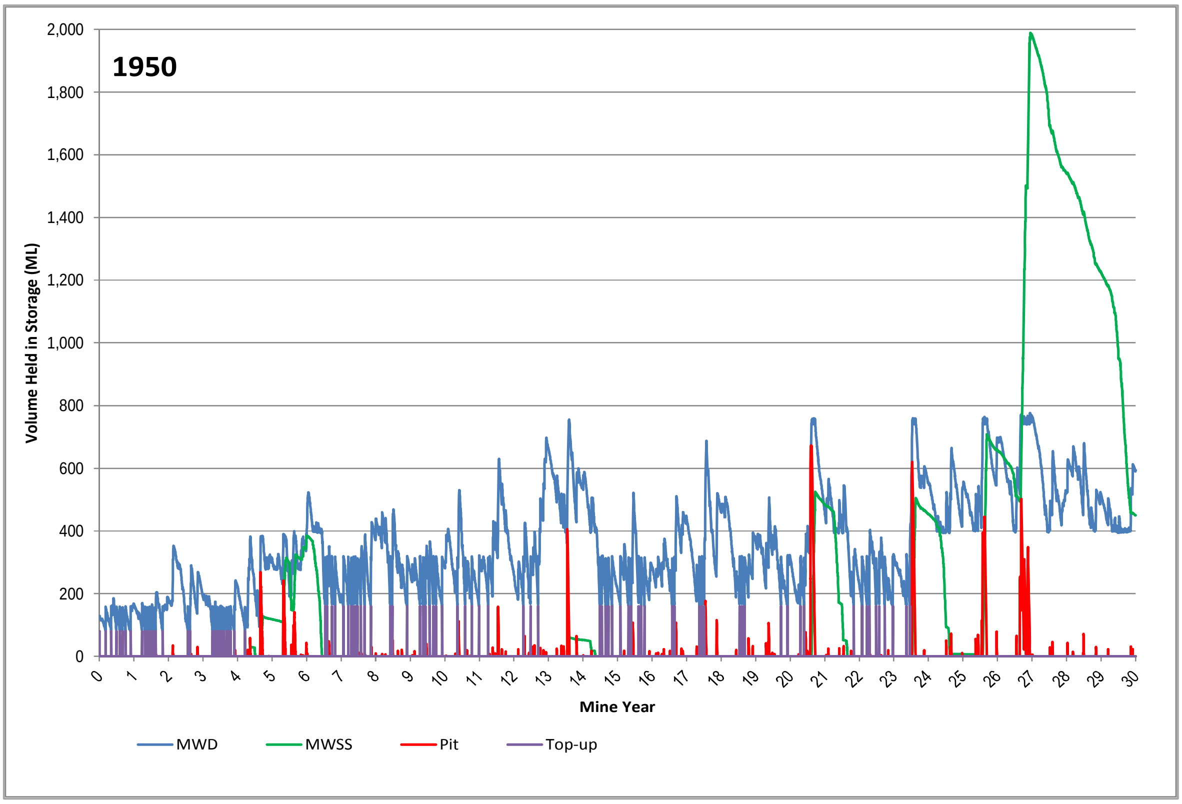

Figure 10: Volume of Water Held in Various Storages and Top-up Water over the Life of the Mine for a Climate Sequence Starting in July 1950

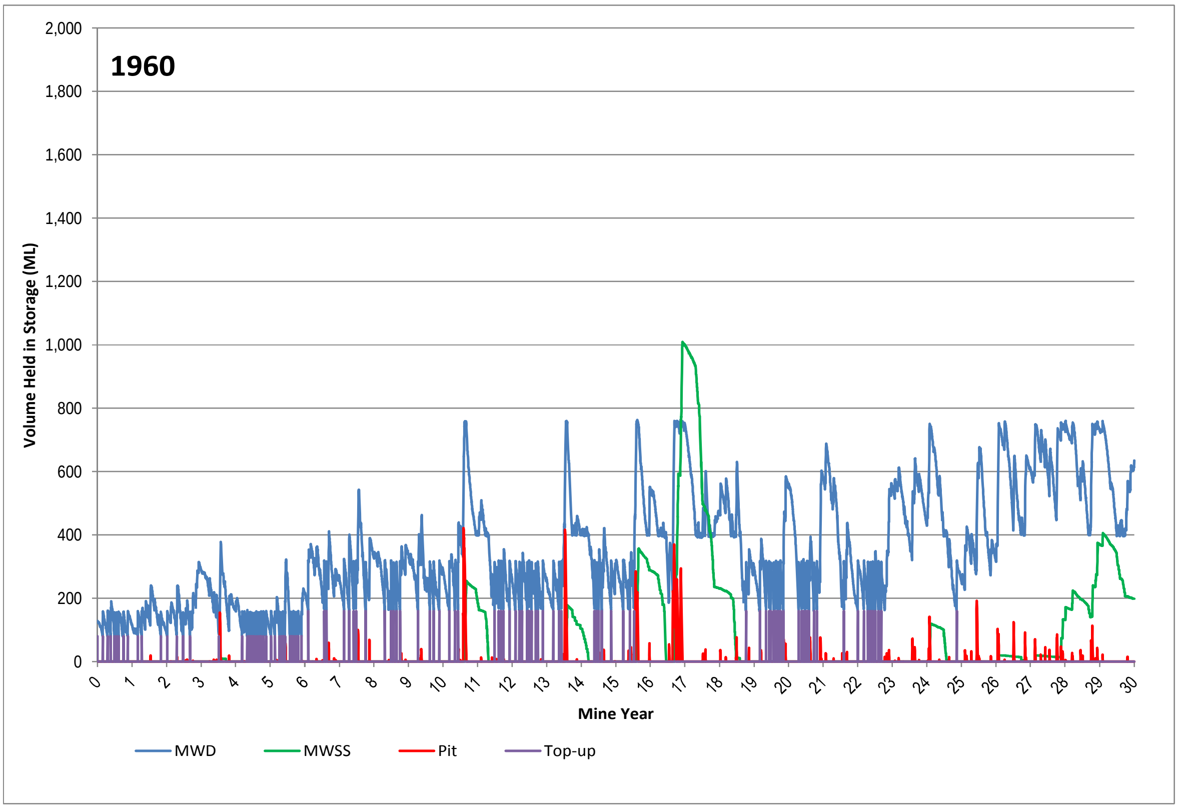

Figure 11: Volume of Water Held in Various Storages and Top-up Water over the Life of the Mine for a Climate Sequence Starting in July 1960

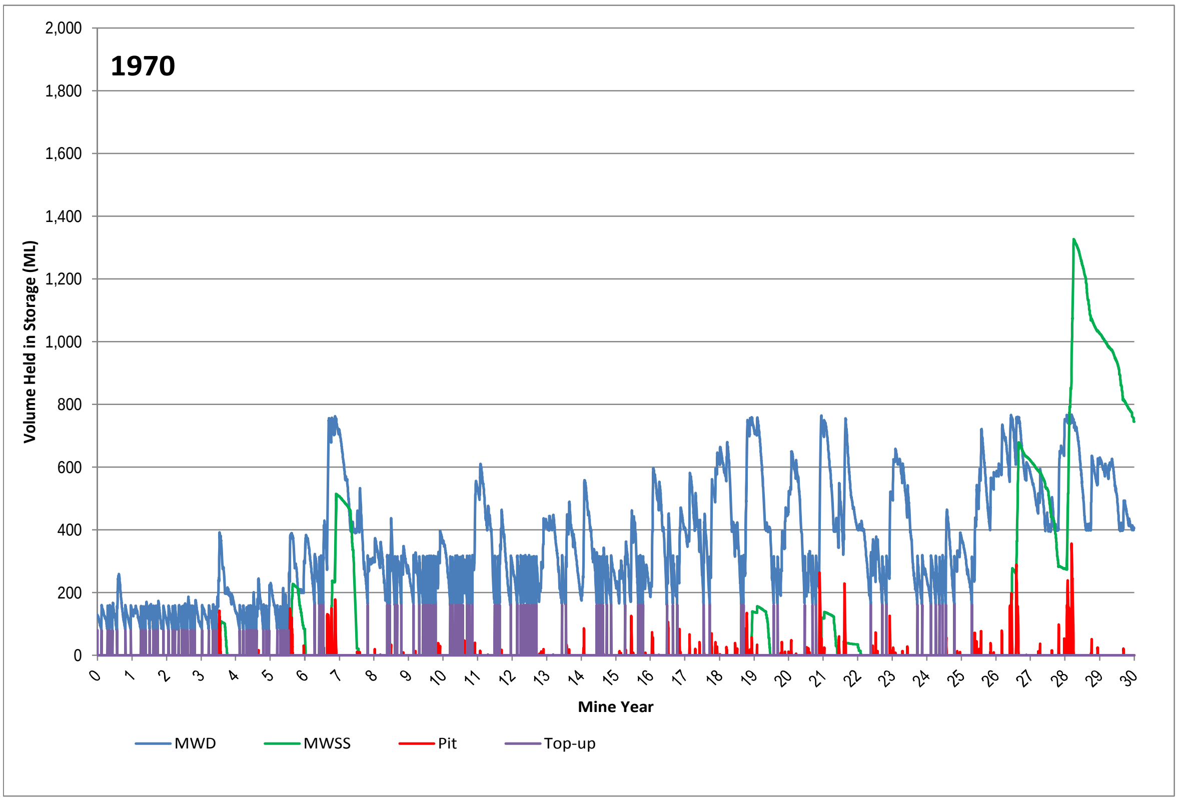

Figure 12: Volume of Water Held in Various Storages and Top-up Water over the Life of the Mine for a Climate Sequence Starting in July 1970

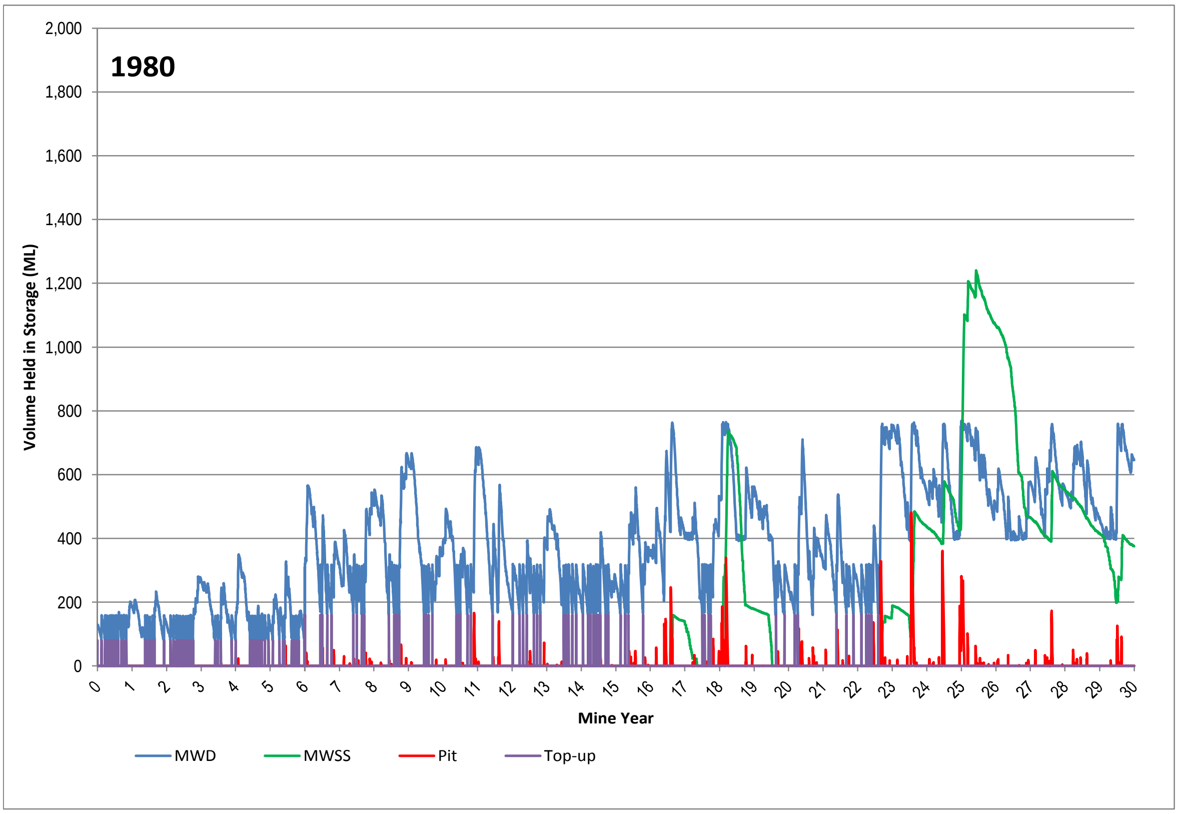

Figure 13: Volume of Water Held in Various Storages and Top-up Water over the Life of the Mine for a Climate Sequence Starting in July 1980

These sequences, starting a decade apart, have been selected to illustrate a number of key features of the behaviour of the mine water management system. Two particular figures illustrate the two extremes that could be expected:

- The climate sequence starting in 1920 (**Figure 7**) represents conditions in which the water management system could be expected to perform as well as possible, but with frequent short periods when water would be retained in the open cut (red line) prior to transfer to the MWD and subsequently on the MWSSs. In this scenario, the MWDs have sufficient capacity to retain mine runoff for the majority of the time and relatively little use would be made of the MWSSs (green line). Supplementary supply (purple line) would be required for a large proportion of the early years of the mine life. Notwithstanding the adequacy of available storage, water would be retained within the open cut (red line) for short periods because of the limitation placed on pumping from the open cut (20 ML/day).
- The climate sequence starting in 1930 (**Figure 8**) represents conditions in which the water management system could be expected to perform adequately up to Year 20. After Year 20 the combination of the larger catchment area draining to the open cut and the very wet conditions in 1949 and 1950 (821 mm and 882 mm respectively) lead to the MWSSs filling up and excess water being retained in the open cut for up to two years. The conditions illustrated in **Figure 8** represent the worst possible historic climate sequence which would lead to filling of the MWDs (800 ML), the MWSSs (2,000 ML) and retention of a maximum of up to about 1,000 ML within the open cut. Although extremely unlikely to occur, such conditions could be managed without the need for discharge of mine water by transferring excess water to a separate area of the open cut while operations occurred in other active areas.

The climate sequences starting in 1900 (**Figure 5**) and 1910 (**Figure 6**) represent intermediate conditions to those illustrated in **Figure 7** and **Figure 8**, in which periods of heavy rainfall towards the end of the mine life would require MWSS capacity of 1,000 to 1,400 ML to be available.

The climate sequences starting in 1940 (**Figure 9**) and 1950 (**Figure 10**) represent intermediate conditions in which the very heavy rainfall in 1949, 1950 and 1955 occur earlier in the mine life and do not lead to as much water in the open cut as shown in **Figure 8**, but do, however, lead to water being retained in the open cut for a number of short periods during the life of the mine. In the case shown in **Figure 10**, the mine would require about 2,000 ML of MWSS capacity for a short period but could avoid holding water in the mine pit for extended periods.

The climate sequences starting in 1960 (**Figure 11**), 1970 (**Figure 12**) and 1980 (**Figure 13**) illustrate moderate climate conditions in which the MWDs would provide adequate storage for most of the time with the occasional requirement, particularly towards the end of the mine life, for us of MWSS capacity of the order of 1,000 ML to 1,200 ML.

3.2 Probability of Water Being Held in the Open cut

As noted previously, the water balance model assumes that any water from the open cut or the MIA would be retained within the water management system and would not be discharged off-site. The model includes transfer rules that ensure that any water in excess of the capacity of the mine water dams and the mine water surge storages is retained within the open cut.

As illustrated in **Figure 5** to **Figure 13**, different climate sequences give rise to a requirement to retain water in the open cut at different stages in the mine life**. Figure 14** is a graph that has been prepared from the statistics of all 110 climate sequences. For each year of the mine life it shows the maximum volume of water that would need to be held in all the mine water storages and the open cut associated with different risks of occurrence in each year. For reference the graph also shows the proposed combined storage capacity of the MWDs and the MWSSs over the life of the mine (dashed black line).

The overall conclusion to be drawn from **Figure 14** is that the proposed sequence of construction of MWDs and MWSSs would allow the mine to keep operating in the worst historic climate conditions up to Year 15 (total storage - dashed black line - is above the orange line which represents that maximum storage required in any of the historic climate sequences). Following Year 15 there would be a slightly increased risk (generally less than 5%) of needing to store excess water in the open cut for a period in order to avoid the need to discharge mine water.

It should be noted, however, that the proposed sequence for the commissioning of water storage capacity in the MWDs and MWSSs would provide for more than double the required storage capacity for 50% of the time (dashed black line compared to green line). It should also be noted that, for all climate sequences there would be short periods when there would be water held in the open cut (red lines). In most situations illustrated in **Figure 5** to **Figure 13,** the duration of water being held is governed by the assumed rate of pumping out of the open cut rather than the availability of storage in the MWDs or the MWSSs. The exception to this is shown in **Figure 8** which shows a combination of mine year and rainfall that would lead to all storages being full for a period of about two years coinciding with Year 27 and 28. However, as shown in **Figure 14**, the risk of such conditions is very low.

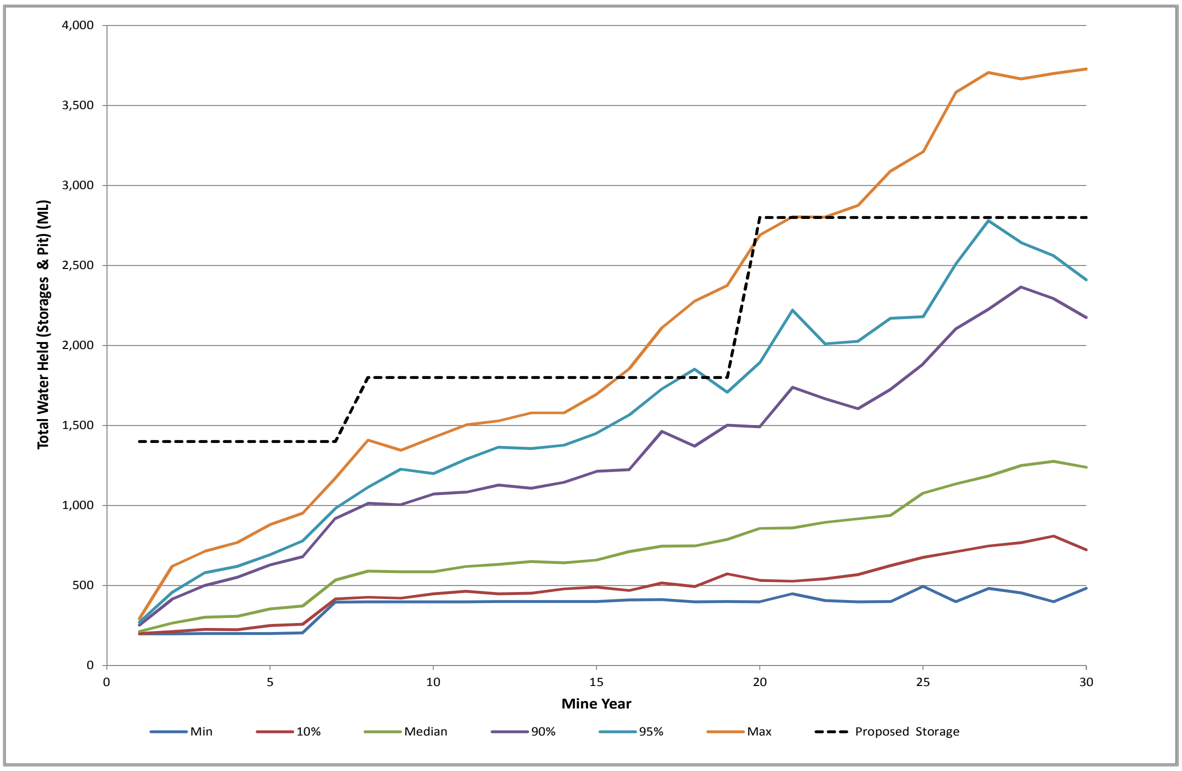

Figure 14: Probability of Total Volume of Water Held in the Mine Water Storages exceeding the Combined Volume of the MWDs and MWSS over the Life of the Mine

3.3 Runoff, Transfers and Water Use

Table 6 summarises the statistics for runoff, transfers and water use from the 110 different climate sequences. Note that, apart from the last column, all values represent the total volume collected, transferred or used over the life of the mine.

Table 6: Summary Water Balance Statistics Over 30 Year Mine Life

	Total Volume (ML) over 30 Year Mine Life						Annual Ave
	Ave	Min	10%	50%	90%	Max	
Runoff reporting to:							
Open Cut	16,834	15,033	15,629	16,597	18,635	19,241	561
MIA	3,973	3,718	3,806	3,961	4,164	4,417	132
Western Emplacement	7,008	5,742	6,183	6,834	8,035	9,047	234
Eastern Emplacement	615	344	415	602	819	1,228	21
Rehabilitated Catchments	3,485	2,118	2,779	3,434	4,264	5,293	116
Transferred to Mine Water Dam from:							
Open Cut	17,104	15,184	15,827	16,821	19,105	19,611	570
MIA	3,971	3,718	3,804	3,961	4,160	4,417	132
Western Emplacement	2,904	2,492	2,654	2,895	3,166	3,373	97
Eastern Emplacement	110	56	81	106	146	176	4
Rehabilitated Catchments	1,522	1,168	1,353	1,543	1,673	1,787	51
Water Use:							
Total Water use	35,367	34,186	34,557	35,394	36,214	36,488	1,179
External Top-up	14,793	11,500	12,910	14,750	16,400	17,900	493
Years when Top-up Required	21	17	18	22	24	26	21

Key aspects of note relating to the water balance results in **Table 6** are:

- runoff reporting to the open cut (53%) and MIA (12%) account for the majority of the total runoff from the Project area. This occurs because of the higher runoff potential of the open cut itself and MIA, but is also affected by the relatively large active waste emplacement area that reports to the open cut from Year 17 onwards;
- over the life of the mine, the average water use for dust suppression, crushing and other operational purposes amounts to 1,179 ML/year;
- over the life of the mine, the average water transferred to the MWDs from all mine sources amounts to 854 ML/year (excluding external top-up in times of shortage); and
- an average top-up volume of 493 ML/year would be needed in those years in which top-up water is required because of a short term shortfall of water for mine operations.

3.4 Sediment Basin Performance

Table 6 lists the total volumes of runoff and water transferred to the mine water dams from the three classes of sediment dams considered in the water balance model:

- sediment basins that collect runoff from the Western Emplacement;
- sediment basins that collect runoff from the Eastern Emplacement; and
- sediment basins on both emplacements which have fully rehabilitated catchments. Runoff from these catchments is free to drain off-site without the need for treatment.

Table 7 summarises the average annual performance of the sediment basins over the life of the project and shows that overall:

- about 40% of the runoff from the waste emplacements would be transferred to the MWDs (predominantly in the early years of the Project);
- 45% of the runoff would be discharged from the sediment basins in accordance with the requirements to allow for settlement of suspended sediment prior to discharge;
- 15% of runoff would overflow in storms that exceed the capacity of the sediment basins; and
- overflow would occur on 6 days per year on average.

Table 7: Average Performance of Sediment Basins

	Average
Runoff (ML/Year)	371
Transferred to MWDs (ML/Year)	152
Controlled discharge (ML/Year)	167
Overflow (ML/Year)	51
Overflow days	6

4 Mine Closure

Following completion of mining the open cut area would be rehabilitated to produce:

- a Northern Void with a total contributing catchment area of about 244 ha; and
- a Southern Void with a total contributing catchment area of about 247 ha.

The 'recovery' run of the groundwater model indicates that both voids would remain 'sinks' and that, depending on the water level established within the void, the inflow would progressively decline from about 1.1 to 0.8 ML/day in the northern void and from about 1.7 to 0.6 ML/day in the southern void.

4.1 Water Balance in Mine Voids

A water balance analysis has been undertaken to establish the water surface areas that would achieve a balance between inputs (runoff, groundwater inflow and direct rainfall) and losses (evaporation) using the following assumptions:

- for existing climate conditions, average rainfall (583 mm/year) and open water evaporation (1,489 mm/year) remain constant but the rainfall varies from year to year;
- future climate change effects would lead to:
  - 10% reduction in rainfall;
  - 30% reduction in runoff (to account for the rainfall elasticity of streamflow (Chiew, 2006); and
  - 12% increase in evaporation;
- the contributing catchment above the pit lake water level would be rehabilitated to woodland vegetation;
- based on the monitoring reported in ACARP (2001), an 'pan factor' of 0.7 has been adopted to account for the fact that the lake within each void would be partially shaded and sheltered, leading to lower evaporation loss than if the water was fully exposed at the land surface; and
- the permeable overburden backfill between the final voids would allow water to flow from the void with the higher water level to the other. For purposes of this analysis a permeability of 1 m/day has been assumed.

The modelling accounts for the geometry of each void (depth, area, volume) as determined from the mine plans. For purposes of this analysis a synthetic 1,000 year climate sequence was generated by random selection of years taken from the historic record. **Figure 15** and **Figure 16** show the modelled variation of water level in each void for the existing climate. For the climate change scenario, the water levels show similar fluctuation, but of the order of 4 – 5 m lower level as a result of the reduction in rainfall and runoff and the increase in evaporation.

Table 8 summarises the average and maximum water levels and depths for each void for the two climate scenarios while **Table 9** provides the corresponding water surface areas. The model results show that, because of the flow of water from the Northern Void to the Southern Void, the Southern Void can be expected to stabilise at about 10 m deeper, but maintain a difference between the water levels of about 20 m.

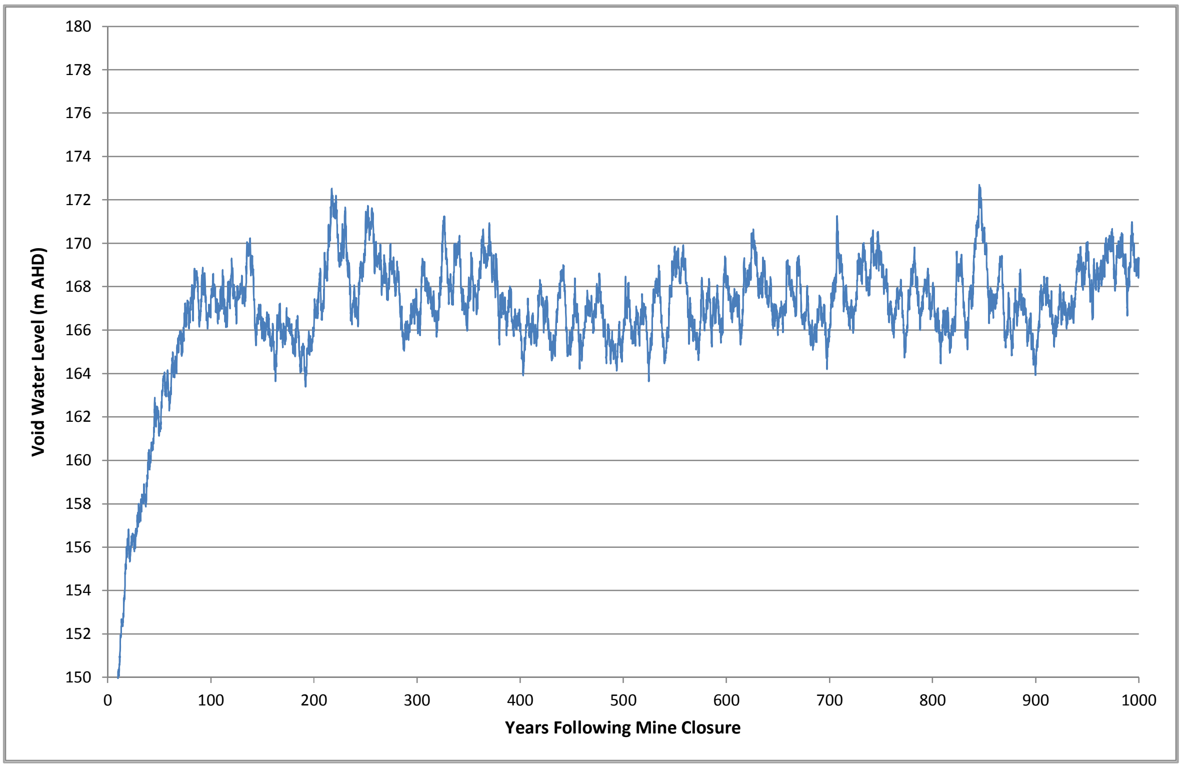

Figure 15: Modelled Water Level Variation in the Northern Void Following Mine Closure

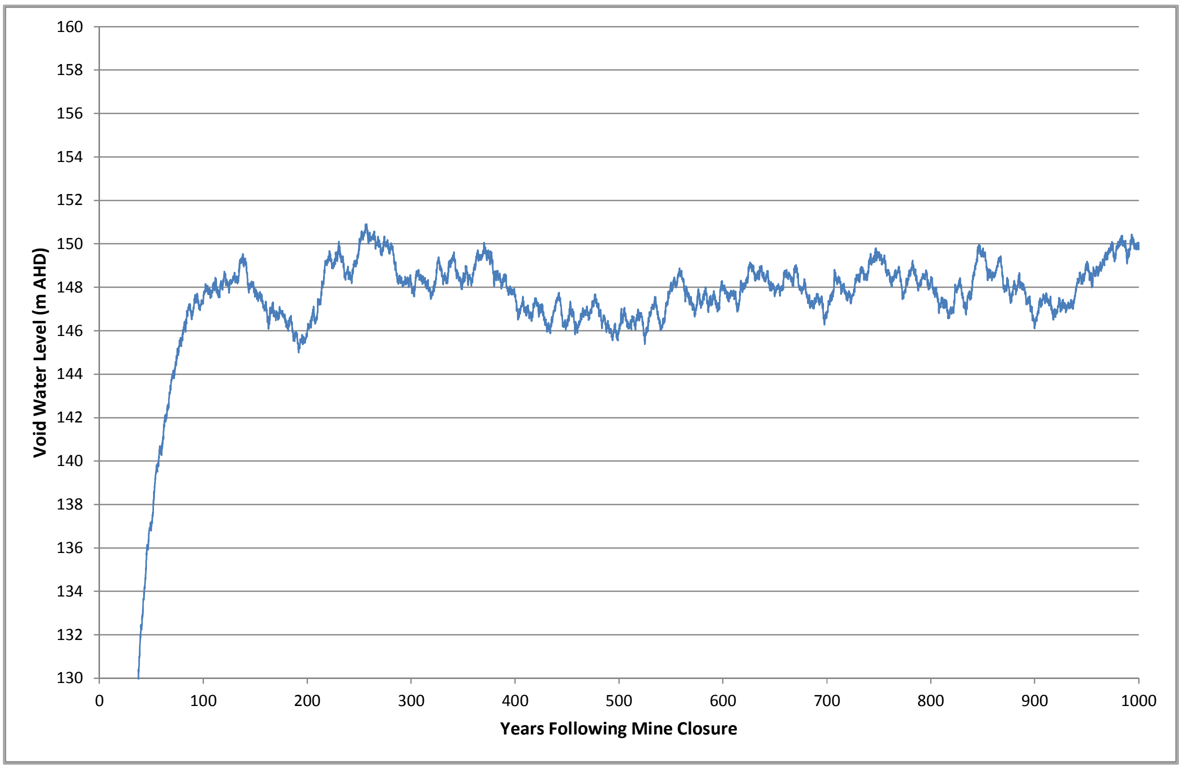

Figure 16: Modelled Water Level Variation in the Southern Void Following Mine Closure

Table 8: Water Level Variation in Voids for Current Climate and Climate Change Scenarios

Void	Climate	Level (m AHD)		Depth (m)	
		Average	Maximum	Average	Maximum
Northern	Current Climate	166.8	172.7	46.8	52.7
	Climate Change	161.7	166.8	41.7	46.8
Southern	Current Climate	146.7	150.9	56.7	60.9
	Climate Change	142.6	146.4	52.6	56.4

Table 9: Water Surface Area Variation in Voids for Current Climate and Climate Change Scenarios

Void	Climate	Average Area (ha)	Maximum Area (ha)
Northern	Current Climate	27.3	35.6
	Climate Change	21.1	27.1
Southern	Current Climate	49.0	54.3
	Climate Change	44.5	48.5

4.2 Salinity in Mine Voids

The long term water balance model also keeps track of the progressive accumulation of salt associated with the groundwater inflows and surface runoff loads into each void which will remain a ‘sink’ for groundwater, leading to a progressive accumulation of salt. The salinity predictions are based on the following salt loads:

- median groundwater salinity in the area is 2,400 mg/L (pers. com. Merrick, 2012);
- average salinity of surface runoff is assumed to be 100 mg/L (160 µS/cm) based on typical water quality in the creek systems in the area; and
- the salt load associated with the flow of water through the overburden between the pits was accounted for, with a delay of 35 years based on an average flow velocity through the overburden and the width of the intervening barrier.

The results of the salinity analysis for the first 100 years are shown in **Figure 17** and **Figure 18**. As shown in **Figure 17**, under the either climate scenario the salinity in the Northern Void could be expected to increase in an almost linear manner to about 5,000 mg/L in 100 years. The longer term results show that the salinity in the Northern Void would stabilise in the range of in the rage of 5,500 – 6,000 mg/L for either climate scenario.

As a result of the drainage of water from the Northern Void towards the Southern Void, the salinity in the Southern Void can be expected to show a different trend to that in the Northern Void. As shown in **Figure 18**, under the current climate scenario, the salinity in the Southern Void would increase to about 6,000 mg/L after 35 years followed by a decrease over the next 10 years as relatively fresh water (that left the Northern Void 35 years earlier) contributes to the Southern Void. Thereafter, the salinity could be expected to increase to about 7,000 mg/L after 100 years. For the climate change scenario, the salinity could be expected to be of the order of 10,000 mg/L after 100 years. In the longer term, because it represents the final 'sink' for water in the landscape, the salinity in the Southern Void can be expected to continue to progressively increase over time and reach concentrations of the order of 85,000 mg/L under the existing climate scenario or 100,000 mg/L under climate change conditions after 1,000 years.

Figure 17: Progressive Increase in Salinity in the Northern Void under Different Climate Scenarios

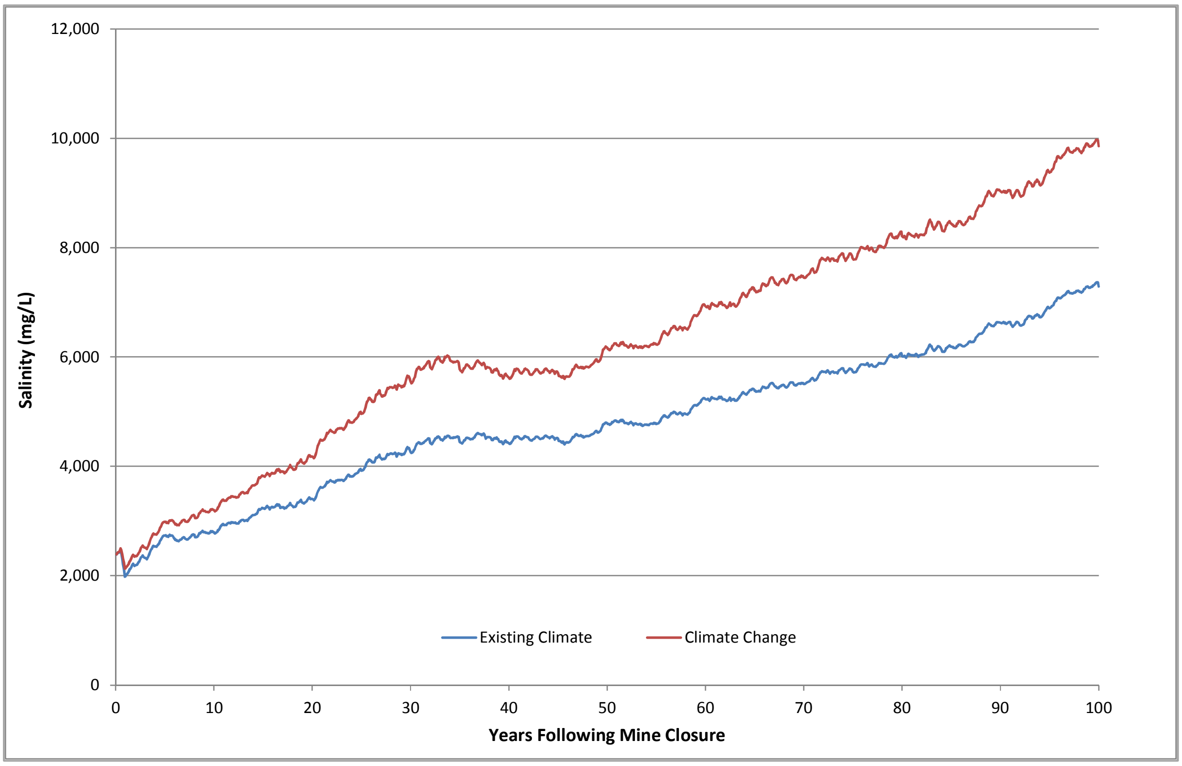

Figure 18: Progressive Increase in Salinity in the Southern Void under Different Climate Scenarios

An inspection of the details of the analysis that underpins the trends shown in **Figure 17** and **Figure 18** indicates that the primary source of salt is the estimated groundwater inflow which contributes about 85% of the water and over 99.5% of the salt load.

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