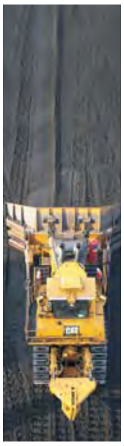
DURALIECOAL
Part of the Yancoal Australia Group

Duralie Open Pit Modification
Environmental Assessment



APPENDIX D

SURFACE WATER ASSESSMENT

YANCOAL
兖煤澳大利亚有限公司

Resource Strategies

HYDROLOGY AND WATER MANAGEMENT CONSULTANTS

Gilbert & Associates Pty Ltd

REPORT

DURALIE OPEN PIT MODIFICATION

Surface Water Assessment

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1.0 INTRODUCTION

This Surface Water Assessment has been prepared to support an application to modify Project Approval (08_0203) for the Duralie Coal Mine (DCM) under section 75W of the New South Wales (NSW) *Environmental Planning and Assessment Act 1979*. The proposed Duralie Open Pit Modification is referred to hereafter as 'the Modification'.

The DCM is located approximately 10 kilometres (km) north of the village of Stroud and approximately 20 km south of Stratford in the Gloucester Valley in NSW (Figure 1). Duralie Coal Pty Ltd (DCPL) is the owner and operator of the DCM. DCPL is a wholly owned subsidiary of Yancoal Australia.

To reflect the results of ongoing mine exploration and mine planning, the following changes to the currently approved DCM are proposed for the Modification:

- Increase in the maximum depth of the Clareval open pit.
- A minor increase in the extent of surface development of the DCM of approximately 2.5 hectares (ha) (Figure 2), resulting from:
  - a reduction in low wall angles of the Clareval open pit and the removal of a pillar between the Clareval and Weismantel open pits to improve geotechnical stability; and
  - associated relocation of the upstream diversion to the west of the Clareval open pit.
- Revised mining sequence (i.e. progression of mining in the Clareval and Weismantel open pits).
- Increased height of the central portion of the waste emplacement (i.e. the backfilled open pit) from the currently approved elevation of approximately 110 metres Australian Height Datum (m AHD) to approximately 135 m AHD.

The Modification would result in no change to the following key elements of the currently approved DCM:

- Maximum annual ROM coal production.
- Maximum annual waste rock extraction.
- Mine life.
- Mining tenements (i.e. Mining Leases (ML) 1467 and 1646).
- Mining method (i.e. conventional open pit mining methods and equipment).
- Coal seams mined (i.e. Clareval and Weismantel).
- Duralie shuttle train rail movements or hours.
- Waste rock geochemistry management measures.
- Extent and use of irrigation areas for the disposal of excess water.
- First flush protocol and controlled release of water in accordance with the concentration limits of Environment Protection Licence (EPL) 11701.
- Rehabilitation of surface disturbance areas.
- Operational workforce.
- Visitors and deliveries.
- Power supply.

DURALIE OPEN PIT MODIFICATION

FIGURE 1

Regional Location

GCL-14-23_Mod2_Flora_102B

DURALIE OPEN PIT MODIFICATION

FIGURE 2

Modification General Arrangement

DURALIECOAL

GCL-14-23_Mod2_SWA_111A

2.0 BASELINE HYDROLOGY

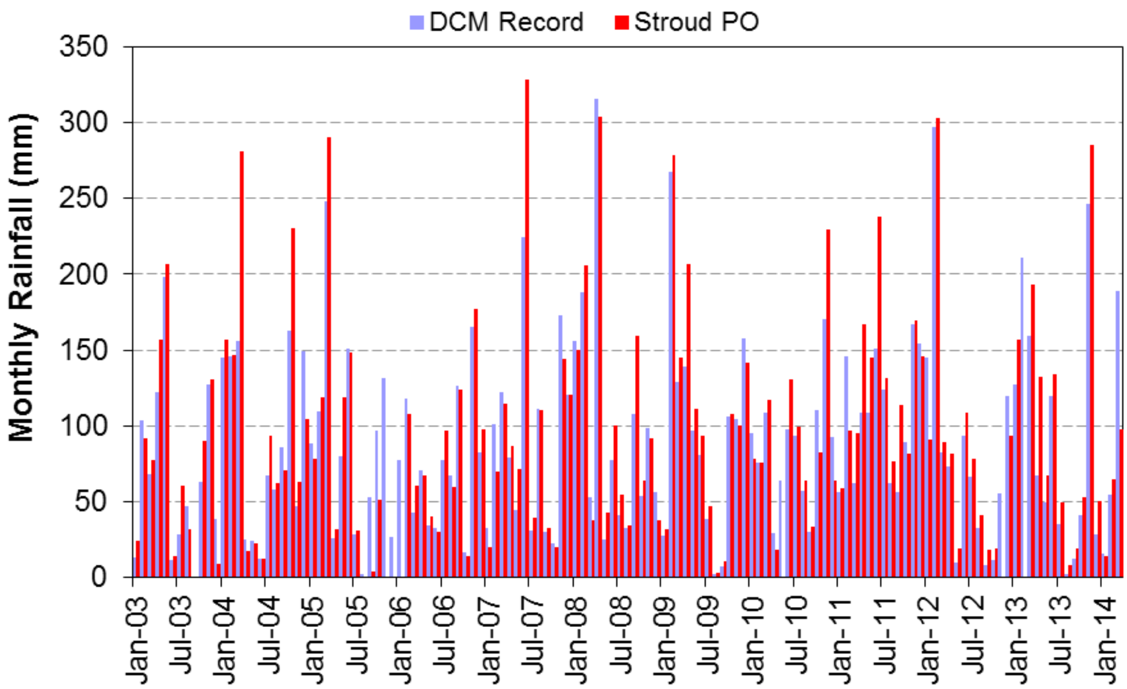
The DCM is situated in the Gloucester Valley which is bounded by Buckley's Range to the east and the Linger and Die Ridges to the west. Mammy Johnsons River flows past the eastern limit of the DCM area. The area surrounding the DCM has been extensively cleared for grazing on native and improved pastures, and is also used for intensive poultry farming.

There is significant topographic relief in the DCM area ranging from approximately 50 m AHD[1] along the river flats of the Mammy Johnsons River to 150 m AHD on the ridge tops to the west of the DCM. The top of Tombstone Hill, which lies between the Weismantel open pit and the Mammy Johnsons River, is approximately 130 m AHD.

2.1 Climate

The DCM area experiences a temperate climate which is influenced by local orographic effects and distance from the coast (Woodward-Clyde, 1996).

Meteorological conditions have been monitored at the DCM weather station since 1995. Complete annual records of daily rainfall are available from 2003. A plot of monthly rainfall totals from the DCM weather station and Bureau of Meteorology (BoM) rain gauge at the Stroud Post Office from 2003 are shown in Figure 3. Rainfall at Stroud Post Office averages 1,146 millimetres (mm) per year over the full period of available data (i.e. from 1889 to present). For the period of data in Figure 3, rainfall at Stroud Post Office averages 1,127 mm per year[2], while at DCM the average is 1,054 mm per year (BoM, 2014).



Source: BoM (2014)

Figure 3 Monthly Rainfall Totals

1 m AHD is approximately equivalent to mean sea level.
2 Averaged from June 1995 to March 14.

Table 1 presents mean monthly rainfall statistics for the following BoM stations: Stroud Post Office (BoM site 061071 – data available from 1889) located 10 km south-east of DCM; Monkerai Upper (Redleaf) (BoM site 061045 – data available between 1914 to 1970) located 8 km west of DCM; and Wards River (Moana) (BoM site 061045 – data available between 1968 to 1979) located 5 km north-east of DCM. Rainfall at DCM is typically lower during the winter months with maxima generally experienced during the summer months.

A summary of evaporation calculated[3] from the DCM weather station and Data Drill are presented in Table 2. Data Drill is a system which provides synthetic datasets for a specified point by interpolation between surrounding points records held by the BoM. The Data Drill record is similar but somewhat lower than the DCM site evaporation calculated using the Penman Equation. The Data Drill data has been used as a basis for simulating evaporation losses in the water balance modelling.

2.2 Catchments and Surface Water Resources

The DCM area is situated within the Mammy Johnsons River catchment, a tributary of the Karuah River. The Karuah River, which rises in the Chichester State Forest, drains to Port Stephens some 40 km south of the DCM. Mammy Johnsons River has a similar catchment area and length to the Karuah River above their confluence near the village of Stroud Road. The Mammy Johnsons River rises in the Myall State Forest east of the DCM area.

The DCM is predominantly situated in the catchment of Coal Shaft Creek, which flows into the lower reaches of Mammy Johnsons River. Coal Shaft Creek has been diverted around the current DCM workings. The northern parts of the mining operations extend beyond the Coal Shaft Creek catchment boundary and into the catchment of a small unnamed drainage which is referred to as the Unnamed Tributary. The Unnamed Tributary flows generally eastward into the Mammy Johnsons River.

The Modification would involve minor extensions of the DCM surface development area into the catchment of the Unnamed Tributary.

A summary of the catchments within the DCM area and surrounds is provided in Table 3.

2.3 Runoff and Streamflow

Streamflow in the Mammy Johnsons River is characterised by low flows for long periods, with periods of higher discharge confined to periods during and following heavy rains. Such rainfall response is typical of small and medium sized upland catchments. Averaged over the full period of available data, streamflow in Mammy Johnsons River is estimated to amount to some 28 percent (%) of rainfall (Gilbert & Associates, 2010).

The flow characteristics of Coal Shaft Creek are likely to be similar to Mammy Johnsons River due to the similar catchment conditions and climatic regime. Runoff rates are likely to be slightly higher (due to the greater proportion of cleared catchment compared with the forested cover of the upper Mammy Johnsons River) and is estimated to average about 30% of rainfall. Anecdotally (based on site observations of flow in the diverted Coal Shaft Creek), flow persistence in Coal Shaft Creek is less than Mammy Johnsons River, with greater periods of zero flow. The upper reaches of Coal Shaft Creek are ephemeral and baseflow contributions in these portions of the creek are likely to be small. The Unnamed Tributary flow characteristics are likely to be similar to those of Coal Shaft Creek.

3 Calculated using the Penman equation.

Table 1
Summary of Mean Rainfall Statistics from Regional Climate Monitoring Stations

Station Name	**DCM Weather Station**		**Stroud Post Office**		**Monkerai Upper (Redleaf)**		**Wards River (Moana)**	
No. Years of Data	7[1]		124		56		11	
BoM Station No:	N/A		061071		061045		060089	
	Rainfall (mm)[3]	No. of Rain Days	Rainfall (mm)[3]	No. of Rain Days[2]	Rainfall (mm)[3]	No. of Rain Days[2]	Rainfall (mm)[3]	No. of Rain Days[2]
January	77.4	11.9	113.3	9.0	156.0	13.8	191.0	8.2
February	147.6	12.3	127.0	9.4	150.4	13.3	133.5	0.7
March	117.2	11.9	146.4	10.1	146.2	13.8	196.8	7.7
April	111.1	15.9	101.5	8.8	118.1	12.6	66.0	4.9
May	71.9	14.4	91.5	9.1	79.2	11.3	75.6	5.8
June	84.3	15.4	102.2	8.8	99.6	10.4	137.8	5.8
July	44.8	12.7	75.2	8.3	71.6	10.1	31.8	3.5
August	53.1	8.8	64.5	7.8	70.7	10.4	53.7	3.6
September	80.7	11.0	62.5	7.3	75.3	10.0	52.1	6.5
October	60.5	9.0	77.4	8.1	90.2	11.8	85.0	7.5
November	112.8	10.9	84.0	8.4	92.4	11.3	113.2	9.5
December	92.7	12.4	101.0	8.5	137.0	13.3	108.2	7.0
Annual	1,054	147	1,147	104	1,287	142	1,245	71

Source: DCPL (2014); BoM (2014).
[1] Summary for data collected from January 2003 to March 2014 inclusive.
[2] Anomalous BOM Data was removed and not included in the data set.
[3] mm = millimetres.

Table 2
Summary of Average Evaporation Statistics (mm)

Month	DCM Weather Station[1]	Data Drill
January	179.7	173.6
February	146.4	136.7
March	123.6	122.2
April	89.9	93.3
May	73.4	67.2
June	59.7	57.6
July	73.6	66.1
August	102.9	89.1
September	142.1	112.4
October	159.5	142.7
November	163.4	155.6
December	192.5	176.7
Annual Average	1,507	1,393

[1] Calculated using the Penman Equation.

Table 3
Catchment Area Summary

Stream	Location	Catchment Area (km^2)
Coal Shaft Creek	With existing DCM disturbance area and additional Modification disturbance areas.	5.2
Unnamed Tributary to Mammy Johnsons River	With additional Modification disturbance areas.	2.1
Mammy Johnsons River at confluence with Karuah River	Flows east and south of the DCM area.	320
Karuah River downstream of confluence with Mammy Johnsons River	Flows west and south of the DCM area.	1,470

km^2 = square kilometres.

2.4 Local and Regional Surface Water Quality

In accordance with the Surface Water Management Plan, DCPL monitors surface water quality on and surrounding the DCM by manual and automated sampling from a series of locations, including water management storages on site. Surface water samples are tested for a range of parameters including pH, electrical conductivity (EC), turbidity, dissolved oxygen (DO), total suspended solids (TSS), total dissolved solids (TDS), acidity/alkalinity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), aluminium (Al), calcium (Ca), chloride (Cl), dissolved iron (Fe), magnesium (Mg), manganese (Mn), sulphate (SO_4), zinc (Zn), sodium (Na), bicarbonate (HCO_3), carbonate (CO_3), nitrogen (N), phosphorus (P), arsenic (As), boron (B), cadmium (Cd), copper (Cu), lead (Pb), chromium (Cr), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), barium (Ba), uranium (U), molybdenum (Mo), fluoride (F) and ammonia (NH_3). DCPL also maintains continuous EC sensors/loggers on Mammy Johnsons River upstream and downstream of the DCM – at MJR US EC and High Noon.

Table 4 summarises surface water monitoring conducted to date at the DCM. The locations of surface water monitoring sites are shown on Figures 4 and 5 below.

Table 4
Summary of Surface Water Quality Monitoring

Site Name	Site Description	Frequency	Current Suite of Parameters	Period of Record[2]
SW1	Karuah River (Mine Entrance)	Monthly and Event	pH, EC, turbidity, DO, TSS, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, Cu.	30/08/2002 – 30/09/2013
SW1A	Mine Entrance	Spot	TSS, turbidity.	26/05/2003 – 18/03/2005
SW2	Coal Shaft Creek (lower)	Monthly and Event	pH, EC, turbidity, DO, TSS, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, Cu, F, NH_3.	30/08/2002 – 21/03/2014
SW2 (RC)	Coal Shaft Creek (rail culvert)	Monthly and Event	pH, EC, turbidity, DO, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	22/03/2004 – 21/03/2014
SW2 (U/S)	Coal Shaft Creek (upstream)	Weekly and Event	pH, EC, turbidity, DO, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	26/05/2003 – 30/09/2013
SW3 (Major)	Main Water Dam	Weekly and Event	pH, EC, turbidity, TDS, TSS, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	30/04/2003 – 21/03/2014
SW3 (Minor)	Main Water Dam	Weekly and Event	pH, EC, turbidity.	4/04/2003 – 21/03/2014
SW4	Open Pit	Weekly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, Cu.	28/03/2003 – 21/03/2014
SW6	Culvert at Rail Siding	Monthly and Event	pH, EC, turbidity, DO, TSS, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, Cu.	21/11/2003 – 21/03/2014
SW7	Ex Holmes	Monthly and Event	pH, EC, turbidity, DO, TSS, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe.	24/02/2010 - 30/12/2010
SW8	Ex Zulumovski	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Na, Cl.	10/12/2007 – 11/02/2009
SW9	FisherWebster	Monthly and Event	pH, EC, turbidity, DO, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	20/04/2009 – 21/03/2014
SW10	Ex Holmes (upslope)	Monthly and Event	pH, EC, turbidity, DO, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, COD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	10/12/2007 – 21/03/2014
GB1	Mammy Johnsons River (upstream)	Weekly and Event	pH, EC, turbidity, DO, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	1/10/2008 – 21/03/2014
Site 9	Karuah River (Stroud Road)	Monthly and Event	pH, EC, turbidity, DO, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	30/08/2002 – 21/03/2014
Site 11	Mammy Johnsons River (downstream)	Weekly and Event	pH, EC, turbidity, DO, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	24/09/2002 – 21/03/2014

Table 4 (Continued)
Summary of Surface Water Quality Monitoring

Site Name	Site Description	Frequency	Current Suite of Parameters	Period of Record[2]
Site 12	Mammy Johnsons River (Relton)	Monthly and Event	pH, EC, turbidity, DO, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, COD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	30/08/2002 – 21/03/2014
Site 15	Mammy Johnsons River (Tereel)	Monthly and Event	pH, EC, turbidity, DO, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	30/08/2002 – 21/03/2014
Site 19	Karuah River (Washpool)	Weekly and Event	pH, EC, turbidity, DO, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	24/09/2002 – 21/03/2014
RS1	Rail Siding Sediment Dam	Spot	pH, EC, turbidity, TSS.	10/12/2002 - 1/4/2009
RS2	Rail Siding Sediment Dam	Spot	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Na, Cl.	28/07/2003 – 21/11/2003
RS6	Rail Siding Sediment Dam	Spot	pH, EC.	5/9/2003 - 28/9/2009
VC1	Out of Pit Waste Emplacement Dam	Spot	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl (one sample).	23/3/2004 - 28/9/2009
DDD1	MWD Diversion Drain	Spot	pH, EC, turbidity, TSS, SO_4 (one sample).	2/4/2004 - 2/10/2009
DDD2	MWD Diversion Drain	Spot	pH, EC, turbidity, TSS, SO_4 (one sample).	2/4/2004 - 1/10/2009
DDD3	MWD Diversion Drain	Spot	pH, EC, turbidity, TSS, SO_4 (one sample).	25/9/2003 - 31/3/2009
SD	MWD Diversion Southern Drain	Monthly and Event	pH, EC, turbidity, TSS.	21/10/2004 – 21/03/2014
ND	MWD Diversion Northern Drain	Monthly and Event	pH, EC, turbidity, TSS.	21/10/2004 – 21/03/2014
Dam 1	Coal Shaft Creek Diversion Dam	Spot	pH, EC, TSS, turbidity (one sample).	12/4/2005 – 1/10/2009
Dam 3	Coal Shaft Creek Diversion Dam	Spot	pH, EC.	9/8/2006 – 1/10/2009
Dam 4	Coal Shaft Creek Diversion Dam	Spot	pH, EC, SO_4.	31/10/2005 – 1/10/2009
Dam 5	Coal Shaft Creek Diversion Dam	Spot	pH, EC, SO_4.	25/10/2005 – 1/10/2009
HRC	Haul Road Culvert	Spot	pH, EC, turbidity, TSS.	30/10/2004 – 2/12/2005
TLT	Train Leachate Tray	Spot	pH, EC.	2/04/2003 – 26/10/2011
AD1	Auxiliary Dam 1	Spot	pH, EC (one sample).	1/10/2009
	Clareval Pit	Weekly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, Cu.	20/04/2011 – 21/03/2014
	Mammy Johnsons River (Highnoon)	Weekly and Event	pH, EC, turbidity, DO, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	14/11/2011 – 21/03/2014

Table 4 (Continued)
Summary of Surface Water Quality Monitoring

Site Name	Site Description	Frequency	Current Suite of Parameters	Period of Record[2]
	Mill Creek	Spot	pH, EC, turbidity, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	4/04/2011 – 16/05/2011
	Saggers Creek	Spot	pH, EC, turbidity, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P (one sample).	4/04/2011
	Blacksoil Creek	Spot	pH, EC.	14/09/11 – 21/02/2014
	Unnamed Tributary	Spot and Discharge	pH, EC, turbidity, DO, TDS, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, COD, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P.	1/02/2012 – 251/03/2014
	Ex Hattam	Spot	pH, EC, turbidity, TSS, hardness, acidity/alkalinity, SO_4, Cl, Ca, Mg, Al, Mn, Zn, Fe, carbonate, bicarbonate, COD, BOD, Na, As, Ba, Cd, Cr, Cu, Pb, Mo, Ni, Se, Ag, U, B, Hg, F, NH_3, NO_2, NO_3, N, P (one sample).	30/06/2013

1 An event is defined as a runoff-producing rainfall event (i.e. 20 mm or greater of rainfall in a 24-hour period).
2 Represents total period of record of monitoring at site. Not all parameters have been monitored for the complete period of record.

A summary of salinity (EC) monitoring results for Coal Shaft Creek, the Unnamed Tributary, Mammy Johnsons River and Karuah River are provided in Table 5. EC values have more regularly exceeded guideline values for slightly disturbed streams in Coal Shaft Creek than in the Mammy Johnsons River, the Unnamed Tributary or the Karuah River.

Table 5
Summary of Electrical Conductivity Monitoring Results

Watercourse	No. of Samples	Minimum[1]	Median[1]	Maximum[1]	Percentage Exceedance (%)[2]
Coal Shaft Creek (including diversion)[3]	487	40	**560**	**2,460**	74
Unnamed Tributary to Mammy Johnsons River[4]	34	70	193	**740**	26
Mammy Johnsons River[5]	1,013	61	280	**600**	40
Karuah River[6]	537	25	190	**790**	5

1 Bolded values are above the upper limit of the aquatic ecosystem guideline (300 microSiemens per centimetre [µS/cm]) for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).
2 Percentage of samples that are above the upper limit of the aquatic ecosystem guideline (300 µS/cm) for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).
3 Summary of data from SW2, SW2 (U/S), SW2 (RC), SW7, SW10 and HRC.
4 Summary of data from SW8, SW9 and UT.
5 Summary of data from GB1, Site 11, Site 12, Site 15 and High noon.
6 Summary of data from SW1, Site 9 and Site 19.

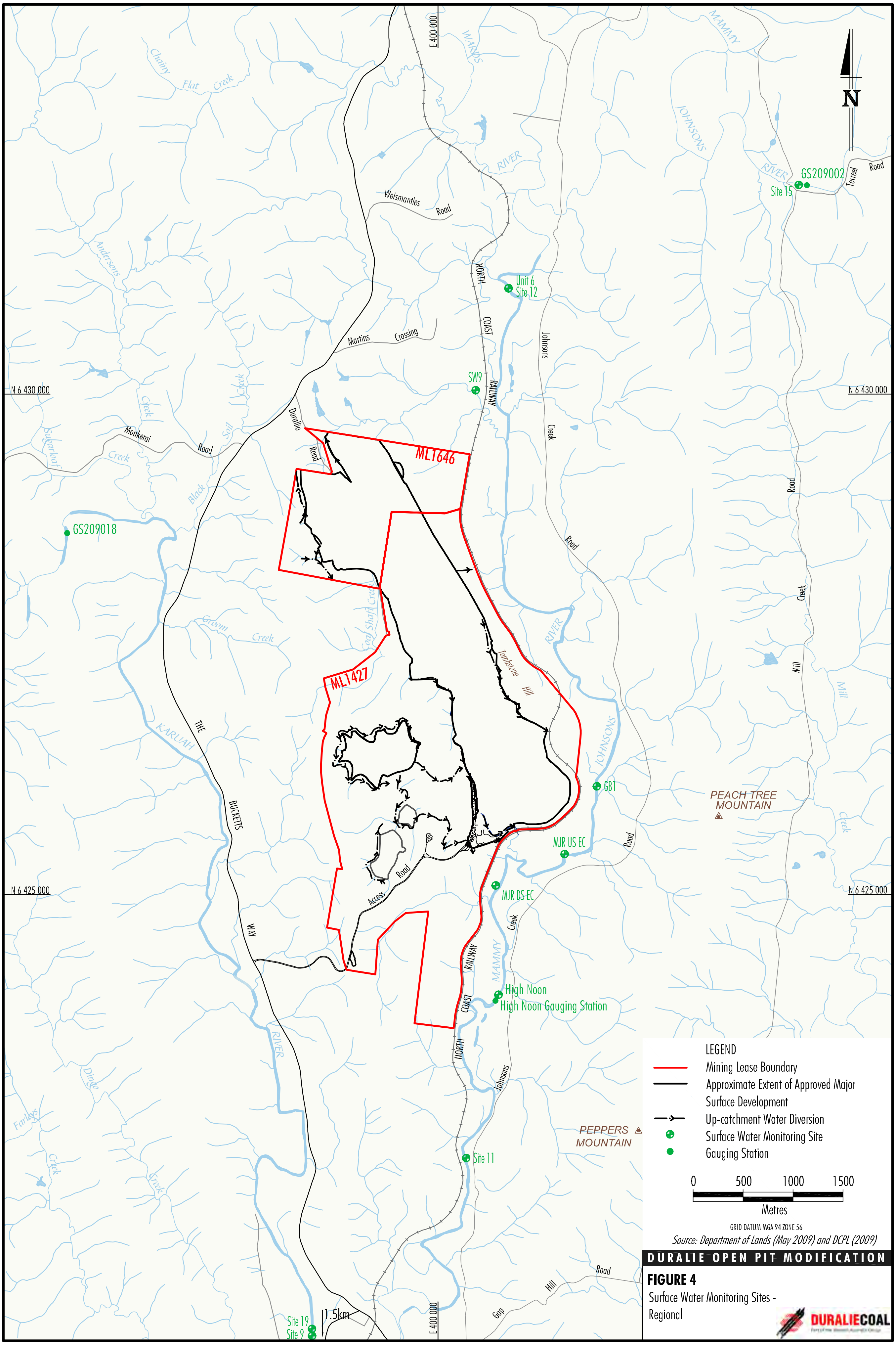


FIGURE 4
Surface Water Monitoring Sites - Regional

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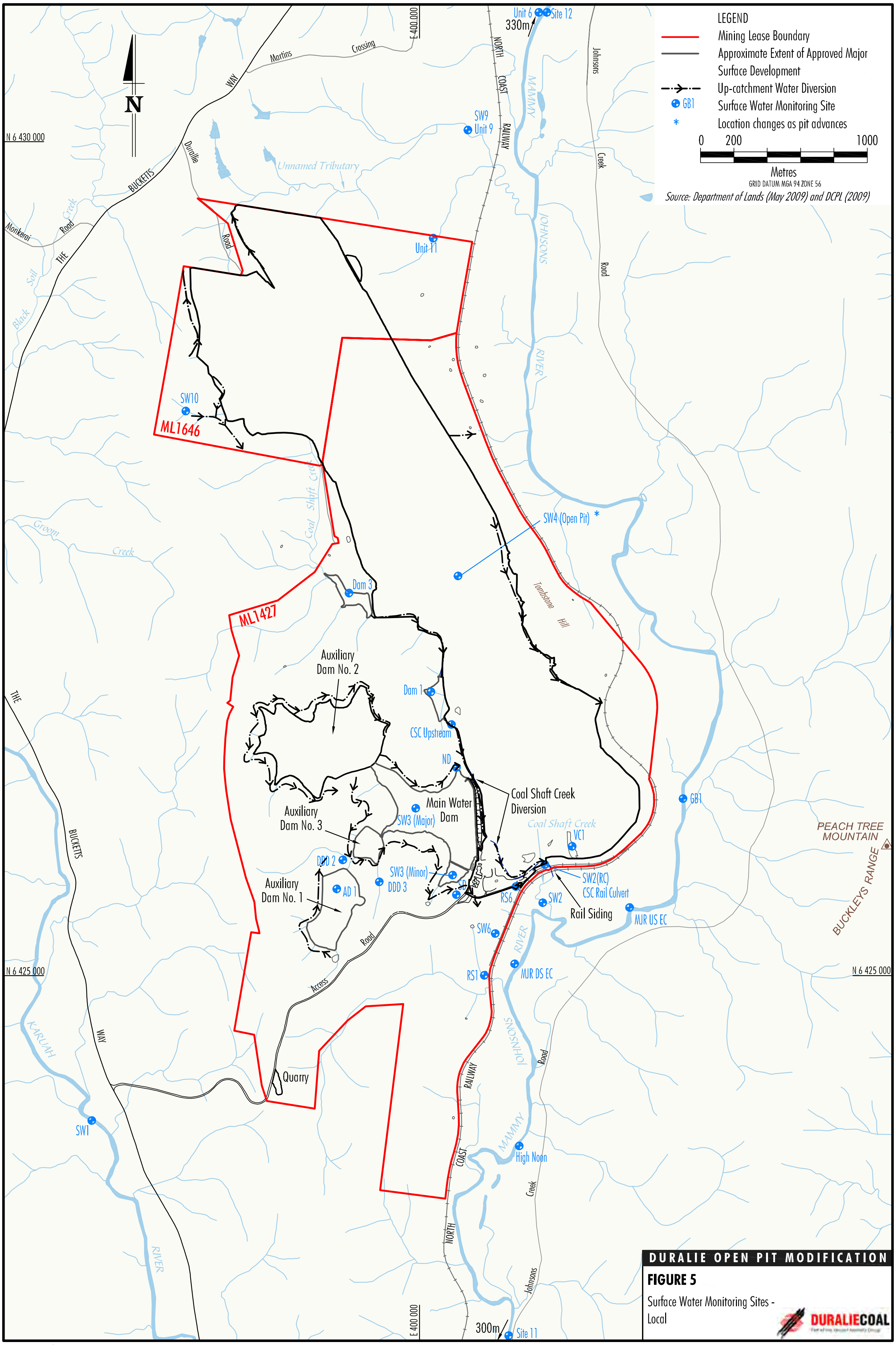


FIGURE 5

Surface Water Monitoring Sites - Local

GCL-14-23_Mod2_SWA_102C

The monitoring data show that Coal Shaft Creek is generally more saline than Mammy Johnsons River and the Karuah River (Table 5). It is considered that Coal Shaft Creek is generally more saline due to its ephemeral nature and the outcropping/sub-cropping of coal seams within the catchment.

Table 6 provides a summary of pH monitoring data in the watercourses surrounding the DCM area. Near neutral to slightly alkaline pH has been recorded at Coal Shaft Creek, the Unnamed Tributary, Mammy Johnsons River and Karuah River. pH values have exceeded guideline values for slightly disturbed streams more regularly in the Unnamed Tributary and to a lesser extent, Coal Shaft Creek than in Mammy Johnson River. This is also expected to be due to the ephemeral nature and the outcropping/sub-cropping of coal seams within these catchments.

Table 6
Summary of pH Monitoring Results

Watercourse	No. of Samples	Minimum[1]	Median[1]	Maximum[1]	Percentage Exceedance (%)[2]
Coal Shaft Creek (including diversion)[3]	512	**5.9**	7.4	**8.6**	7
Unnamed Tributary to Mammy Johnsons River[4]	39	**5.7**	7.1	**8.6**	21
Mammy Johnsons River[5]	1,013	6.3	7.3	**8.9**	4
Karuah River[6]	557	6.1	7.5	**8.9**	10

[1] Bolded values are outside the aquatic ecosystem guideline of pH 6.5-8.0 for slightly disturbed lowland rivers in south-east Australia (ANZECC/ARMCANZ, 2000a).
[2] Percentage of samples that are outside the aquatic ecosystem guideline of pH 6.5-8.0 for slightly disturbed lowland rivers in south-east Australia (ANZECC/ARMCANZ, 2000a).
[3] Summary of data from SW2, SW2 (U/S), SW2 (RC), SW7 and HRC.
[4] Summary of data from SW8 and SW9.
[5] Summary of data from GB1, Site 11, Site 12 and Site 15.
[6] Summary of data from SW1, Site 9 and Site 19.

Graphs showing the water quality results for a number of key parameters versus time are provided in Attachment A.

Elevated Al, Cu, Cr and Zn concentrations, relative to the ANZECC/ARMCANZ aquatic ecosystems guideline in these watercourses, have been regularly recorded in the Karuah River, Mammy Johnsons River, Coal Shaft Creek and the Unnamed Tributary including sites both upstream and downstream of DCM. There does not appear to be any trend evident for any of the parameters monitored in the period of available data at these sites.

There is an apparent trend of increasing sulphate in Coal Shaft Creek at monitoring site SW2(RC). This increase does not appear to be affecting water quality in the Mammy Johnsons River downstream where there is no trend apparent in water quality.

Total P and total N concentrations are also elevated relative to default guidelines values at most sites upstream and downstream of the DCM. There is however no apparent trend over time in either of these parameters. It is anticipated that these elevated concentrations are related to non-mining activities (e.g. agriculture).

Based on the available water quality monitoring data, no change in water quality of the Karuah River on the Mammy Johnsons River, has been observed since the approval of the DEP.

Associate Professor Barry Noller of the University of Queensland was commissioned by DCPL to review the potential impacts of rainfall runoff from DCM irrigation areas on salinity and aquatic ecosystems of the Mammy Johnsons River (Noller, 2010). Ecotoxicity tests were conducted on MWD and Coal Shaft Creek water samples as part of the review. Associate Professor Noller (2010) concluded:

> *The acute and chronic testing indicated no toxicity to a range of sensitive aquatic test species at any dilution (i.e. up to 100% of Main Water Dam water). The acute and chronic testing of Coal Shaft Creek samples also indicated no toxicity to a range of sensitive aquatic test species at any dilution. Based on these results it is considered that the risk of change to aquatic ecosystem assemblages in Coal Shaft Creek is low.*
>
> *…*
>
> *As the water quality of the Mammy Johnsons River is of better quality than Coal Shaft Creek and a high level of dilution would occur in the Mammy Johnsons River, it is considered that the risk of change to aquatic ecosystem assemblages in the Mammy Johnsons River would be even lower than the risk described above.*

2.5 Flooding

The Mammy Johnsons River flows through a relatively confined strata bound valley. The valley has variable areas of fringing floodplain comprising gently sloping pockets of alluvium. In the vicinity of the Coal Shaft Creek confluence, floodplains have formed on both sides of Mammy Johnsons River which in places extend some 600 m from the river banks. In other areas the floodplains are less well developed and are absent in some areas where the Mammy Johnsons River is locally confined by hills. There are no official records of flooding along the lower reaches of Mammy Johnsons River and there is no known flood study having been conducted along this section of the river.

The proposed DCM (including the Modification) is located predominantly in the upper reaches of Coal Shaft Creek. Coal Shaft Creek commands a relatively small (approximately 6 km^2) catchment upstream of the DCM and has been extensively diverted around the DCM. The diversion has been designed to safely pass flows up to the 1 in 100 year average recurrence interval (ARI) and the majority of the diversion would be retained during the DCM life.

The Mammy Johnsons River in the vicinity of the DCM is located at approximately 45 m AHD, while the extent of the floodplain is at approximately 52 m AHD. The Modification surface development area ranges from approximately 100 to 140 m AHD and is therefore very unlikely to be exposed to flooding in Mammy Johnsons River.

2.6 Karuah River Water Sharing Plan

The Mammy Johnsons River and its tributaries fall within Management Zone Four of the *Water Sharing Plan for the Karuah River Water Source, 2003* made under section 50 of the *Water Management Act, 2000*.

The vision for the *Water Sharing Plan for the Karuah River Water Source, 2003* is:

> *… to achieve a progressive, discernible and sustainable improvement in the quality of the Karuah River and its tributaries to deliver greater benefits in health, biodiversity, recreational attractiveness and economic productivity, achieved through implementation of a balanced water management plan.*

The plan defines access conditions for water extraction and rules for extracting water, including limiting the long-term average extraction of water and the amount of water that can be extracted on a daily basis from different flow classes.

DCPL hold Approval Number 20WA202053 under the *Water Sharing Plan for the Karuah River Water Source, 2003* for the Coal Shaft Creek Diversion.

3.0 SURFACE WATER MANAGEMENT

3.1 Existing Water Management System

Water management at the DCM is conducted in accordance with the Water Management Plan incorporating the Site Water Balance, Surface Water Management Plan (including the Irrigation Management Plan) and Groundwater Management Plan.

Water management at the DCM in also conducted in accordance with EPL 11701.

The existing water management system at the DCM is based on the management of four separate components namely upslope diversions/runoff, mine-water, effluent/waste water and water carrying sediments from areas disturbed by DCM activities. It includes the following:

- water management storages including the Main Water Dam (MWD) and Auxiliary Dams (Nos. 1, 2 and 3[4]);
- diversion of runoff from catchment areas upstream of the mine disturbance area;
- runoff control on disturbed and rehabilitated areas at the mine;
- runoff control on infrastructure areas;
- sedimentation control;
- open pit dewatering;
- disposal of excess water through on-site irrigation; and
- sewage treatment and disposal of effluent.

The existing/approved DCM water management schematic is shown on Figure 6.

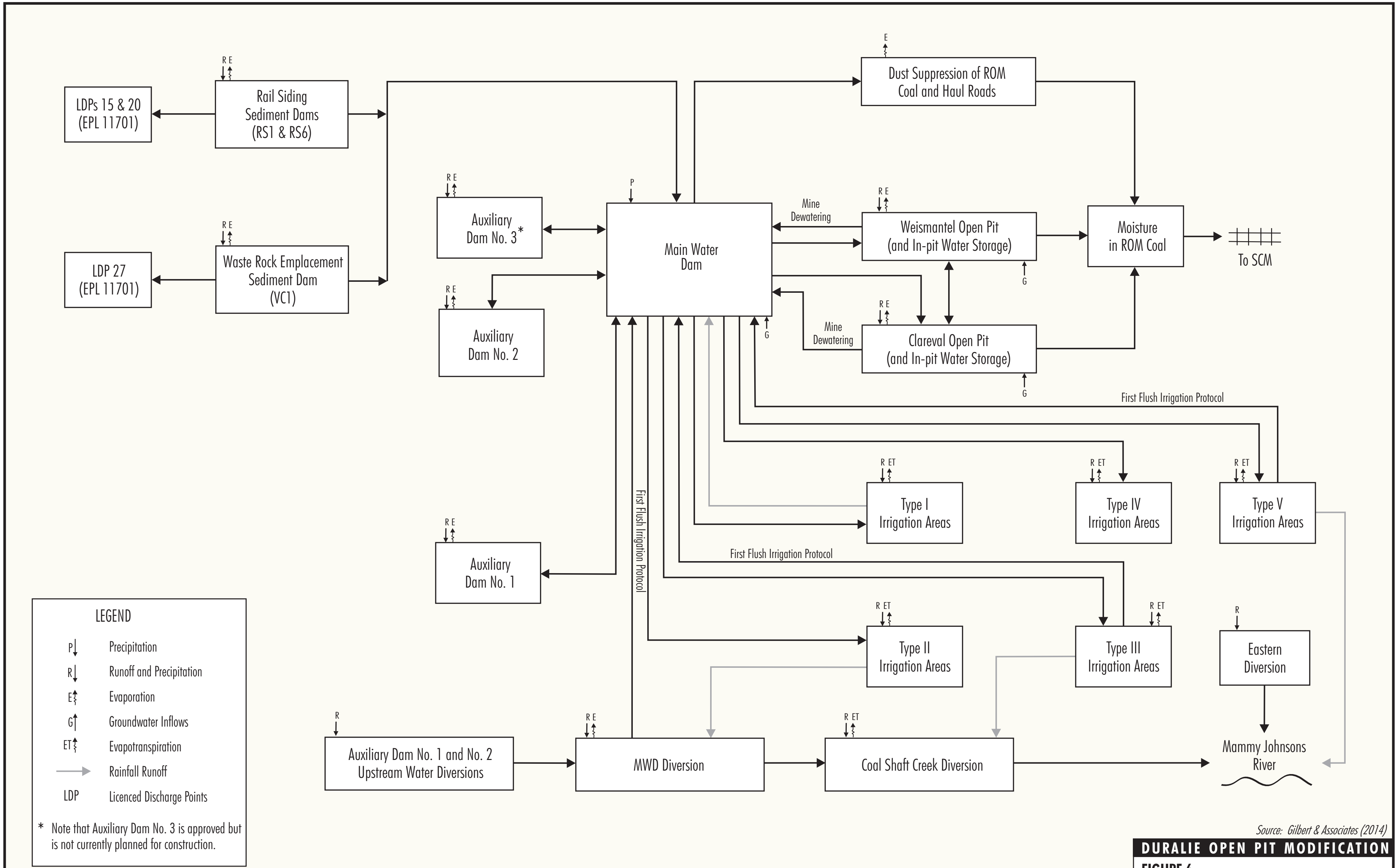
3.1.1 Water Management Storages

Water collected for storage on-site includes incident rainfall on mine disturbance areas, first-flush capture waters and groundwater inflows into the DCM. Water pumped from sumps in the open pits is stored in the MWD which has a capacity of approximately 1,405 megalitres (ML).

The MWD is operated to maintain freeboard below its spill level. This has been achieved by irrigation of excess water, cessation of mine dewatering operations during periods of low freeboard levels in the MWD and by maintaining freeboard in MWD by transferring excess water to the Auxiliary Dams (1 and 2). During time of excessive water build up in site dams the excess water would be pumped to the Weismantel open pit to prevent spill from the MWD to the environment.

The MWD is also used to store water pumped from selected sediment dams and runoff from the main infrastructure area.

[4] Has not yet been constructed.



Source: Gilbert & Associates (2014)

DURALIE OPEN PIT MODIFICATION

FIGURE 6
Water Management Schematic

DURALIECOAL

GCL-14-23_Mod 2_SWA_001A

The key existing/approved DCM water storage structures are summarised in Table 7 below.

Table 7
Existing/Approved Water Storages – Duralie Coal Mine

Storage	Capacity (ML)	Function
Main Water Dam	1,405	Main containment storage for mine and disturbed area runoff and water source for irrigation.
Auxiliary Dam 1	462	Supplementary storage for containment of water pumped from the Main Water Dam
Auxiliary Dam 2	2,724	Supplementary storage for containment of water pumped from the MWD.
Auxiliary Dam 3	110	Supplementary storage for containment of water pumped from the MWD. Has not been constructed.
VC1	8.9	Receives runoff from overburden emplacement areas. Runoff is transferred to the MWD.
RS1	10	Receives runoff from overburden emplacement areas. Runoff is transferred to the MWD.
RS6	3.7	Receives runoff from coal loading area. Water is transferred to the MWD.

The capacity and function of these storages would not change as a result of the Modification.

3.1.2 Runoff Control Structures

The main runoff water control structures at the DCM are:

- MWD diversions – Two diversion drains were approved as part of the original DCM and have been constructed around the MWD (northern and southern drains), to the south of the open pit and current waste rock emplacement area). The MWD diversions intercept runoff from the catchments upstream of the MWD and divert the up-catchment runoff water to Coal Shaft Creek (northern drain) and Mammy Johnsons River (southern drain). The MWD diversion is also a component of the irrigation first flush protocol and is discussed further below. No changes are required to the MWD diversions as a result of the Modification.
- Coal Shaft Creek diversion – The Coal Shaft Creek diversion channel allows for the flow of up-catchment runoff reporting to Coal Shaft Creek to traverse the DCM site and avoid the open pit, waste rock emplacement and infrastructure areas. The diversion is required until the watercourse is re-established at the cessation of mining. The diversion was approved by Approval Number 20WA202053 under the *Water Sharing Plan for the Kuruah River Water Source* and has a design capacity to safely pass the 100-year ARI peak flow event. There are no changes required to the Coal Shaft Creek diversion as a result of the Modification.
- Eastern diversion – A diversion drain located along the ridgeline to the east of the existing open pit to intercept runoff from upslope catchments and divert it to Mammy Johnsons River. This structure was also part of the original DCM approvals and will not change as a result of the Modification.
- Northern diversions – Diversion drains located on the western side of the Clareval and Weismantel open pits to intercept runoff from upslope catchments and divert it to the Unnamed Tributary.

- A series of temporary diversion dams were also approved as part of the original DCM approval. These dams have been constructed in accordance with the original approval to divert water (via pumping) to the Coal Shaft Creek diversion and would not be changed as a result of the proposed Modification.

3.1.3 Sedimentation Control

Erosion and sediment control structures are currently in use at the DCM. All erosion and sediment control structures are designed and operated in accordance with the Surface Water Management Plan.

3.1.4 Open Pit Dewatering

Water reporting to the open pit is pumped via in-pit sumps to the MWD. DCPL holds an existing Bore Licence (20BL168404), that allows for up to 300 ML of groundwater to be extracted from "works" in any 12 month period.

3.1.5 On-site Irrigation System

Irrigation at the DCM is conducted in accordance with the Irrigation Management Plan. Irrigation is conducted over pasture/woodland and waste rock emplacement areas. Five irrigation areas are currently approved, as follows:

- Type I – Irrigation areas located between the MWD diversions and the water storage inundation area of the MWD.
- Type II – Irrigation areas located upslope of the MWD diversions within ML 1427.
- Type III – Irrigation areas located upslope of the northern extent of the Weismantel open pit, including the upper reaches of Coal Shaft Creek (irrigation in these areas has not yet commenced).
- Type IV – Irrigation areas located on partially rehabilitated and rehabilitated areas of the waste rock emplacement.
- Type V – Irrigation areas located on inactive (but not yet top-soiled or rehabilitated) areas of waste rock emplacement. Drainage from waste rock areas that haven't been rehabilitated returns to the open pit workings.

Irrigation is currently undertaken in Type I, II, IV and V areas.

3.1.6 First Flush Protocol

The Irrigation Management Plan includes a first flush protocol. The first flush protocol is designed to collect initial (or "first flush") rainfall runoff from irrigation areas which drain to Coal Shaft Creek or Mammy Johnsons River (i.e. Type II and Type III only) following prolonged dry spells, if this runoff contains high salinity as a result of salt build-up in irrigated soils.

Sensors measuring EC have been installed in the southern and northern drains of the MWD diversion to monitor runoff from the Type II irrigation areas. The first flush system for the Type II irrigation areas is designed to operate as follows:

- When EC readings in the MWD diversion drain sumps are equal to or greater than 1,326 µS/cm, or if the EC reading at Site 11 in the Mammy Johnsons River is equal to or greater than 400 µS/cm, motorised butterfly valves in pipelines at the downstream end of the MWD diversion northern and southern drains open, directing runoff from the irrigation areas to the MWD.
- When the EC readings in the MWD diversion drain sumps are below 1,326 µS/cm and the EC reading in the Mammy Johnsons River (at Site 11) is below 400 µS/cm, the valves close, allowing the runoff in the MWD diversion to report to the Coal Shaft Creek diversion and Mammy Johnsons River downstream of the DCM.

A field EC meter will be used following rainfall events for checking EC levels in the northern diversion dam as part of the first flush system for Type III irrigation areas. The first flush system for the Type III irrigation areas will generally operate the same as the Type II irrigation areas, as described below:

- When the EC reading in the northern diversion dam is equal to or greater than 1,326 µS/cm, a valve in the base of the diversion dam is opened, directing runoff from the irrigation areas to the Weismantel open pit sumps where it is then pumped to the MWD.
- When the EC reading in the northern diversion dam is below 1,326 µS/cm, the EC reading in the Mammy Johnsons River (at Site 11) is equal to or greater than 400 µS/cm and the dam is not full (i.e. there is a low risk of spill to the Coal Shaft Creek diversion), no action is taken and the EC levels are checked following the next rainfall event.
- When the EC reading in the northern diversion dam is below 1,326 µS/cm, the EC reading in the Mammy Johnsons River (at Site 11) is equal to or greater than 400 µS/cm and the dam is near capacity (i.e. there is a high risk of spill to the Coal Shaft Creek diversion), a valve in the base of the diversion dam is opened, directing runoff from the irrigation areas to the Weismantel open pit sumps where it is then pumped to the MWD.
- When the EC reading in the northern diversion dam is below 1,326 µS/cm and the EC reading in the Mammy Johnsons River (at Site 11) is below 400 µS/cm, the water contained in the northern diversion dam is pumped to the Coal Shaft Creek diversion.

There would be no changes required to the irrigation system or the first flush protocol as a result of the Modification.

3.1.7 Water Management System Performance

A key objective of the water management system is to contain and re-use water captured on-site. The existing water management system has operated effectively to contain and re-use water captured in the open pits and MWD on-site.

3.2 Proposed Modifications to DCM Water Management System

Changes associated with the Modification of relevance to water management are:

- minor changes to the open pit extents and overburden emplacement areas and their catchments; and
- changes to the mining sequence.

Under the proposed Modification mining would continue in the Clareval open pit through until its completion in 2017. After which mining would recommence in the Weismantel open pit through the approved DCM mine life. The Weismantel open pit would initially be inactive and available for secure storage of excess water through to mid-2017. Once mining is completed in the Clareval open pit (2017), it would be available for secure storage of excess water. Any excess water in the Weismantel open pit would be removed to the Clareval final void, in advance of recommencement of mining in the Weismantel open pit in early 2018.

The storage capacity of the Weismantel final void has been estimated at approximately 12,400 ML. The storage capacity of the Clareval final void has been estimated to be approximately 38,000 ML.

3.2.1 Water Management System Inflows

The sources of water from within mining related areas would remain unchanged for the Modification and would include:

- rainfall within the open pits;
- groundwater seeping into the open pits;
- rainfall induced runoff and seepage from active sections of the waste rock emplacement;
- rainfall induced runoff from the main infrastructure area;
- rainfall induced runoff from haul roads;
- rainfall induced runoff from areas stripped of topsoil (typically exposing clays);
- rainfall induced runoff from areas yet to adequately revegetated within sediment dam catchments; and
- direct rainfall falling on sediment dams and water management storages.

Rainfall induced runoff from active mining areas would vary with climatic conditions and the extent of disturbance throughout the DCM life. Runoff to active mining areas would be minimised through the maintenance of existing upslope diversions including the Coal Shaft Creek diversion and the MWD and associated auxiliary dam diversions. Sediment laden runoff generated during rainfall events from the waste rock emplacement, main infrastructure and rail siding area and the haul road would be captured in open pits or sediment dams (Section 3.1).

The open pit workings would become sinks for incident rainfall, infiltration through mine waste rock emplacements and rainfall runoff. Sumps would be excavated in the floor of the active open pits as part of routine mining operations to facilitate efficient dewatering operations and to minimise interruption to mining.

Groundwater inflows to the open pits have been modelled by HydroSimulations (2014).

3.2.2 Water Storages

No change to the existing/approved DCM water storages is proposed in the Modification.

Water would be transferred between the storages and the open pits to minimise the disruption to mining and to maintain storm runoff storage capacity needed to achieve a low (negligible) risk of off-site release. The performance of the water management system and risks of off-site releases have been assessed as part of the water management system modelling discussed in Section 4.0. The MWD would continue to be managed and operated to maintain freeboard for storm runoff and a consequent low (negligible) risk of off-site spill (refer Section 4.3).

3.2.3 Water Consumption

There would be no change to water consumption rates as a result of the proposed Modification. Water would be required for washdown of mobile equipment, dust suppression on haul roads and on run-of-mine (ROM) coal stockpiles and conveyor systems.

The water consumption requirements and the water balance of the system would fluctuate with climatic conditions and as the extent of the mining operation changes over time. Fluctuations in water consumption have been accounted for in the site water balance model (Section 4).

3.3 Waste Rock Drainage Management

Management of potentially acid forming (PAF) materials at the DCM is currently conducted in accordance with the Potentially Acid Forming Material Management Plan component of the Surface Water Management Plan. PAF management at the DCM includes the following components:

- PAF material identification and separation procedures;
- PAF material storage procedures; and
- monitoring of surface water and groundwater to determine the effectiveness of PAF material controls.

Open pit surface water monitoring results indicate the existing operational controls have been successful in controlling the release of acid from PAF material.

4.0 SIMULATED PERFORMANCE OF WATER MANAGEMENT SYSTEM

A water balance model of the DCM water management system has been developed to simulate the behaviour of the water management system over the remaining life of mining operations. The model structure is generally as per the existing/approved water management schematic in Figure 6.

4.1 Model Description

4.1.1 General

The model is based on the model developed for the Duralie Extension Project (Gilbert & Associates, 2010). It simulates daily changes in stored volumes of water at DCM in response to inflows (rainfall and groundwater) and outflows (evaporation, dust suppression use, irrigation loss and spill [if any]). Modelling includes simulation of storage in the MWD, open pits, in-pit waste rock emplacements (pore water storage), auxiliary dams and the minor dams (RS6 and VC1) (refer Figure 6). For each storage, the model simulates:

> *Change in Storage = Inflow – Outflow*
>
> Where:
>
> > *Inflow* includes rainfall runoff (for surface storages), seepage (from waste emplacements), groundwater inflow (for open pits), first flush capture and all pumped inflows from other storages.
> >
> > *Outflow* includes evaporation, seepage and all pumped outflows to other storages or to a water use.

Infiltration through waste rock emplacement areas is assumed to report to the open pits, however runoff from rehabilitated waste emplacement areas at the southern end of the waste rock emplacement is assumed to report to a 60 ML capacity collection dam at the south-west corner of the waste emplacement.

4.1.2 Rainfall

The model operates on a daily time step and has been developed to simulate the remaining life of the DCM. The model utilises a long term (10,000 year) stochastic rainfall data set as input.

The model was run repeatedly, simulating 1,000 possible mine life “sequences”, each 4.5 years in length, to generate water balance, storage spill and open pit inundation performance statistics.

4.1.3 Irrigation Area First Flush Protocol Capture

The model simulates capture of first flush runoff from relevant irrigation areas by simulating the actual protocols used on site (refer Section 3.1.6).

The model simulation is based on the relationships developed for the Duralie Extension Project site water balance model (Gilbert & Associates, 2010). These relationships have been updated to incorporate recent monitoring data.

4.1.4 Operational Protocols

The following operational protocol for managing the containment of mine water and disturbed area runoff on site have been developed by DCPL and tested in the model:

- No pumping from either open pit to the MWD when the volume held in the MWD is above 1,200 ML.
- Pumped transfer from the MWD to the Weismantel open pit or Clareval final void at 24 megalitres per day (ML/day) when the volume held in the MWD rises above 1,200 ML.
- The following key triggers for transfer between the MWD and Auxiliary Dams Nos. 1 and 2 to minimise the risk of disruption to mining:

	Auxiliary Dam No. 1	**Auxiliary Dam No. 2**
Trigger volume in MWD for pumping to begin to the auxiliary dams from MWD (pending Auxiliary dam freeboard requirements below).	900 ML	900 ML
Trigger volume in MWD for pumping to begin from auxiliary dams to MWD	800 ML	800 ML
Auxiliary dam minimum freeboard for pumping from MWD	43 ML	130 ML
Transfer rate from MWD to auxiliary dams	10 ML/day	10 ML/day
Transfer rate from auxiliary dams to MWD	58 ML/day	58 ML/day

- Transfer from Auxiliary Dam No. 1 to the MWD (at 58 ML/d rate) occurs when either:
  - MWD volume falls below 800 ML; or
  - Remaining Auxiliary Dam No. 1 freeboard is less than 43 ML and the MWD volume is less than 1,295 ML (water below inlet of pipeline to pit).
- Transfer from Auxiliary Dam No. 2 to the MWD (at 58 ML/d rate) occurs when either:
  - MWD volume falls below 800 ML; or
  - Remaining Auxiliary Dam No. 2 freeboard is less than 130 ML and the MWD volume is less than 1,295 ML (water below inlet of pipeline to pit).

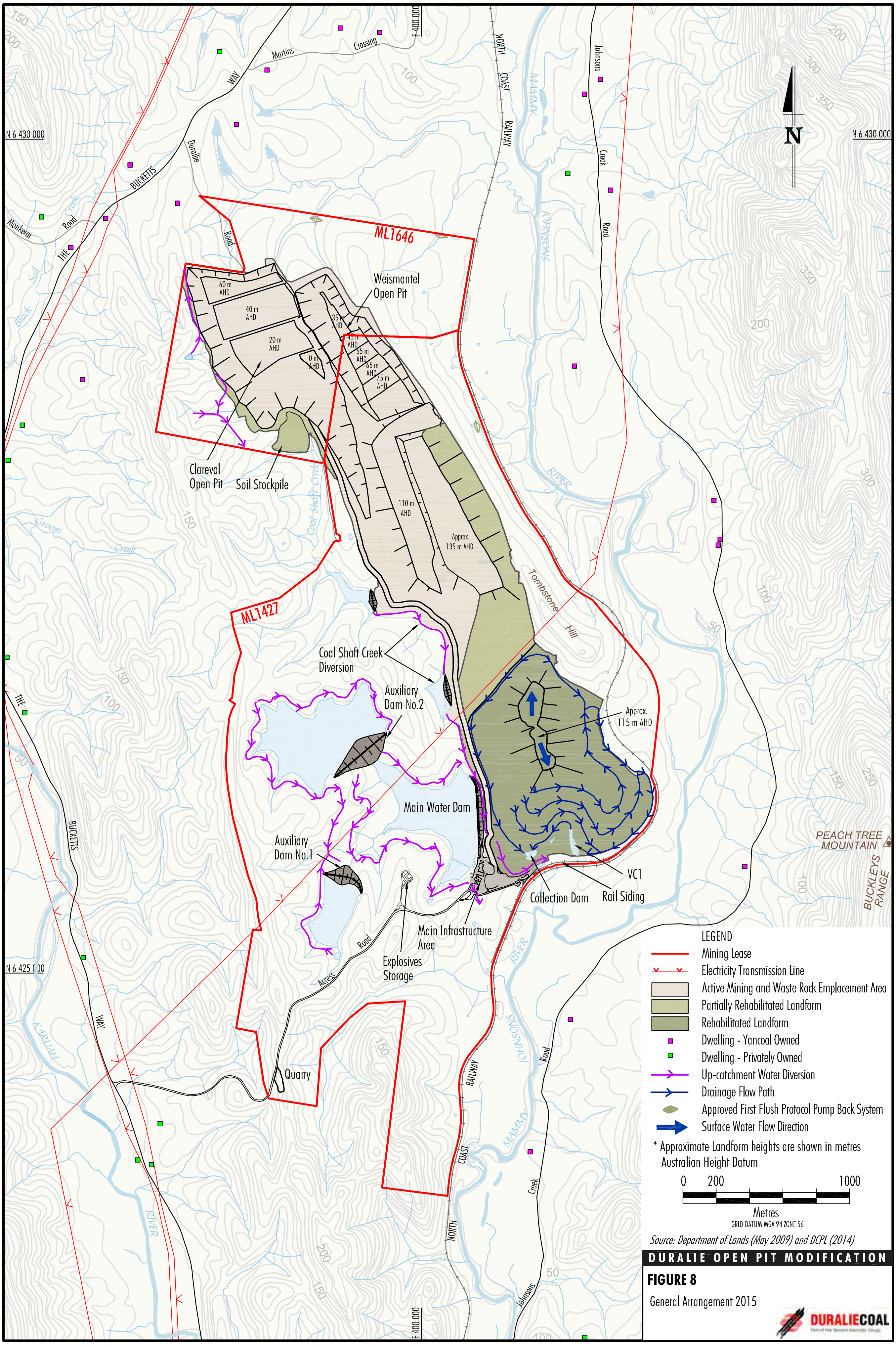
4.1.5 Other Data

Other key data and assumptions used in the model include the following:

- Average monthly pan evaporation data taken from Data Drill (refer Table 2).
- Future mine catchment areas measured from "snapshot" plans provided by DCPL (refer Figures 7 to 9 below).
- Rainfall events in excess of the 100 year ARI design capacity of the MWD diversion and Coal Shaft Creek diversion would result in overtopping of the diversions and flow into the MWD, Clareval or Weismantel open pits. Inflow estimates are included in the model.
- Progressive development of additional Type IV irrigation areas and commissioning of new Type V irrigation areas early during the Project life.

FIGURE 7
General Arrangement
(Existing - 2014)

GCL-14-23_Mod2_SWA_110A

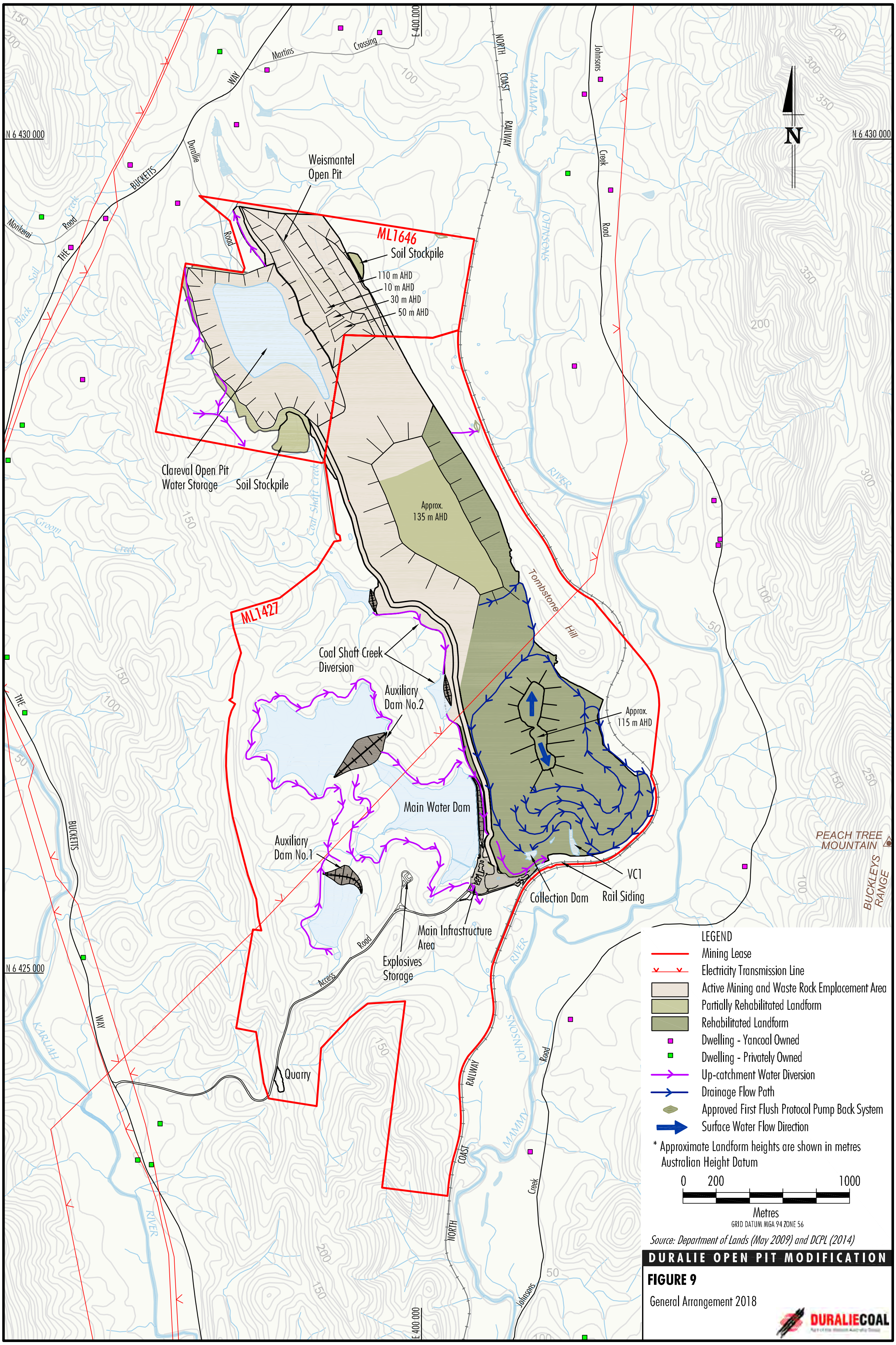


DURALIE OPEN PIT MODIFICATION

FIGURE 8

General Arrangement 2015

GCL-14-23_Mod2_SWA_107C



GCL-14-23_Mod2_SWA_108C

- Commissioning of the Weismantel open pit as a water containment storage from 2014 to mid-2017.
- Use of the Clareval final void for water storage after completion of mining in 2017

4.2 Model Calibration

The model is based on the model developed for the Duralie Extension Project which included a model calibration process (Gilbert & Associates, 2010). A recent review (Gilbert & Associates Pty Ltd, 2014) found close correspondence between monitored and model predicted storage volumes.

4.3 Simulated Performance

4.3.1 Main Water Dam

The MWD receives runoff from the residual catchment between the storage area and the MWD diversions, direct rainfall, water pumped from the open pits and other dams at DCM, seepage from the MWD diversion and Auxiliary Dam 2, and first flush capture from the Type II irrigation area.

The simulated storage volume envelope curves for the MWD are shown on Figure 10. The figure shows the maximum simulated storages volumes derived from all 1,000 model run simulations and the 90th percentile, 50th percentile and 10th percentile exceedance probability curves. The curves can be interpreted to show, at all times during the DCM mine life, the maximum simulated storage volumes in any simulation and the percentages of simulations that had storage volume was below the MWD capacity (i.e. 1,405 ML).

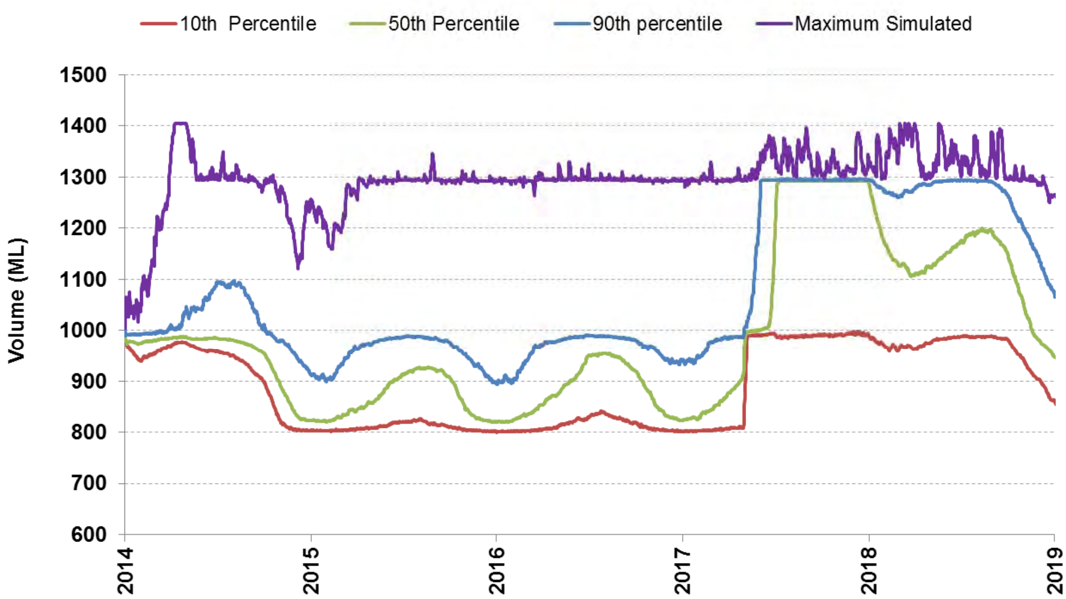


Figure 10 Simulated Storage Volume Exceedance Probability Envelope Curves – Main Water Dam

4.3.2 Open Pits

Simulated storage volume envelope curves for the Weismantel and Clareval open pits are shown on Figures 11 and 2, respectively. The simulated build-up water in the inactive Weismantel open pit prior to mid-2017 is apparent after which excess water is stored in the completed Clareval open pit. The build-up of water in both pits is relatively low compared to the available capacity.

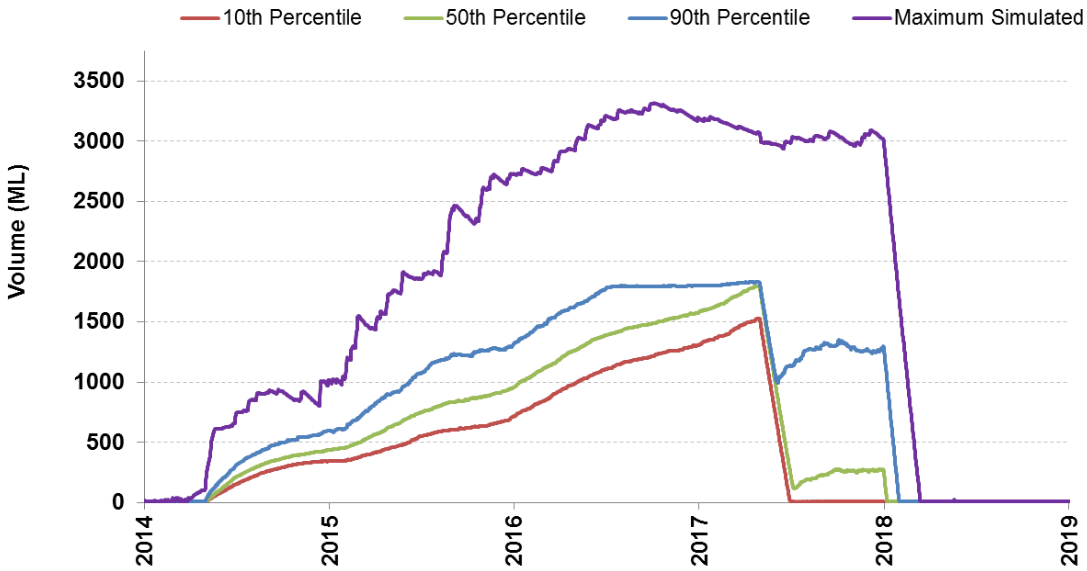


Figure 11 Simulated Storage Volume Exceedance Probability Envelope Curves – Weismantel Open Pit

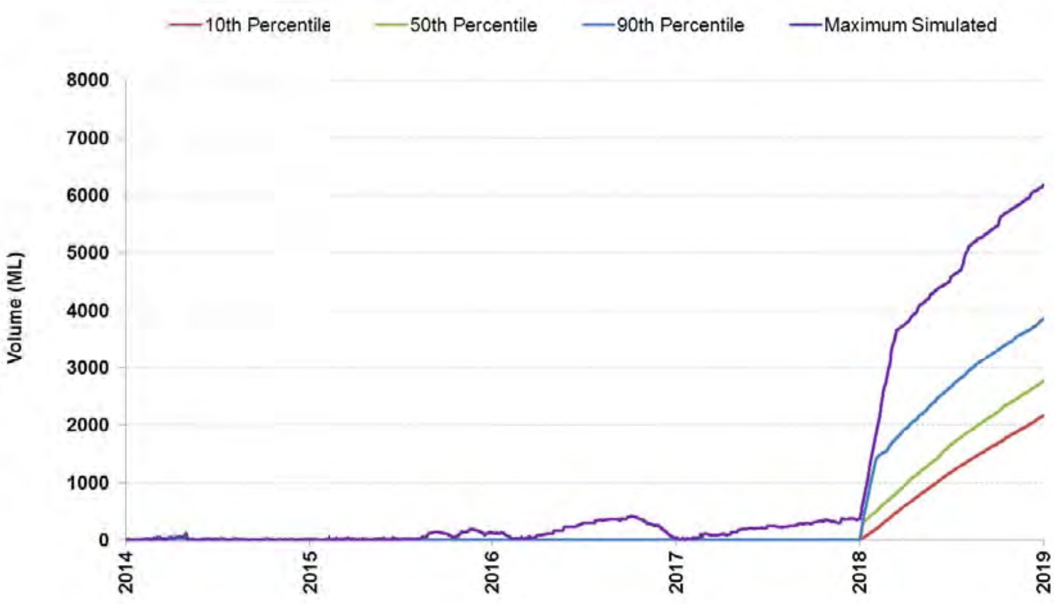


Figure 12 Simulated Storage Volume Exceedance Probability Envelope Curves – Clareval Open Pit

4.3.3 Overall System Performance

DCPL would maintain their policy of no release of mining-related water off-site. The policy of no uncontrolled release would be achieved through:

- the use of controlled irrigation of excess water;
- transfer of water between the MWD and auxiliary dam water storages and the open pits;
- maintaining adequate freeboard for large rainfall events; and
- ensuring adequate pump capacity is installed to transfer water between the water storages and to the open pits.

The water balance simulation modelling showed that there were no simulated releases of water from the MWD or the auxiliary dams in any of the 1,000 sequences simulated. This reflects a negligible risk (expected to be less than 0.1% over the mine life) of uncontrolled spill risk if the assumed operational conditions are adhered to and is consistent with the approved DCM.

During times of excess water in the surface water management storages water would be transferred to the inactive open pit. There would be a period when water in the inactive Weismantel open pit would need to be removed to enable recommencement of mining. Under the proposed water management system if there is insufficient capacity to store water within the above ground (non-open pit storages), the consequent risk of disruption to mining operations is an operational risk and would not result in off-site release/spill.

The DCM is operated with the operational risk of disruption to mining as a result of exceedance of the design capacity of the water management systems. The operational risk to the DCM as a result of the water management system has been assessed using the water balance modelling in conjunction with 1,000 sequences each 4.5 years in length and has been determined to be an economically and operationally acceptable risk.

4.4 Salinity Balance – Main Water Dam and Auxiliary Dams

A salt balance has been incorporated into the water balance simulation model. The balance involves tracking the movement of salt[5] into and out of the MWD and auxiliary dams and estimating changes in salt concentration EC) in these dams over the remaining DCM life over the 1,000 climatic sequences modelled. Salt loads and concentrations are calculated by applying salt concentrations to the salt sources (inflows) to the MWD and auxiliary dams based on DCM records for these sources. Salt outflows (with irrigation water and other water outflows) were calculated by multiplying the outflows by the salt concentration of the three storages which was tracked on a daily basis via the salt load and water volume in the storages. The adopted salt concentrations in the inflows to the storages are summarised in Table 8 below and have generally been based on DCM monitoring data.

Table 8
Assumed Electrical Conductivity in Inflows to the MWD

Salt Inflow Source	Electrical Conductivity (µS/cm)
Internal catchment runoff	100*
Seepage	2,300
Weismantel open pit	4,000
Clareval open pit	4,000
First flush return (Type II and V Irrigation Areas)	1,500
Runoff from Active Waste Emplacement Areas	1,440

* Assumed value - the majority of runoff comprises direct rainfall on the stored water surface.

The simulated salinity (EC) probability envelope curves for the MWD are shown on Figure 13 below.

[5] Because the bulk of the available data on salinity is in the form of field measurements of electrical conductivity, which is an indirect measure of total dissolved solids, the model has been set-up to simulate changes in electrical conductivity.

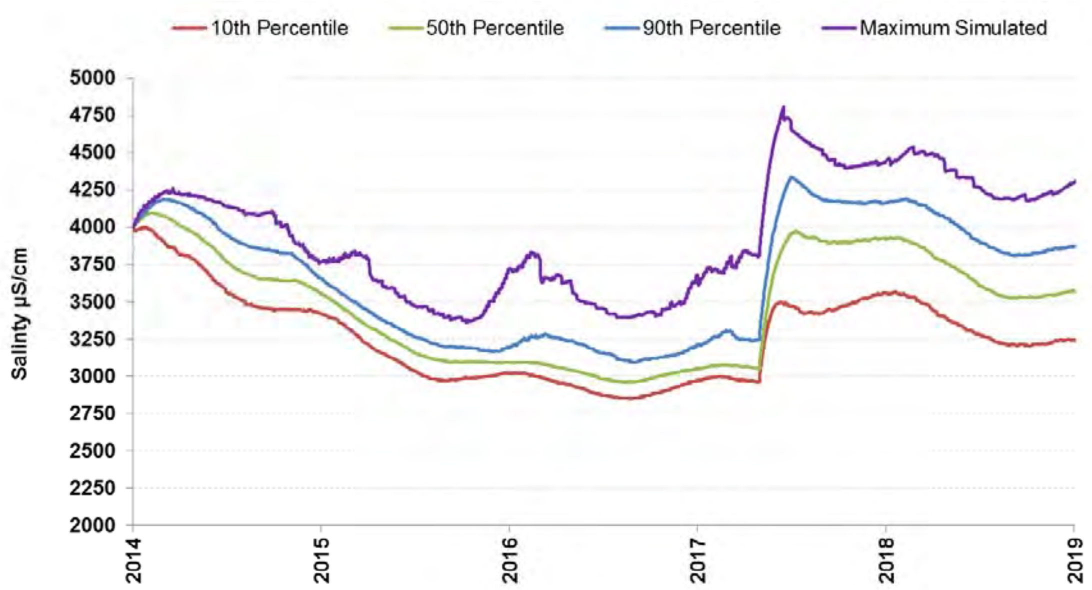


Figure 13 Simulated Salinity Exceedance Probability Envelope Curves - Main Water Dam

The simulated salinity (EC) of water in the MWD ranges between approximately 2,500 and 4,200 µS/cm.

4.5 Water Management Implications

The Modification would not require any significant changes to the existing/approved water management system. The Modification would have the following implications for how stored water is managed and the timing of future proposed works:

- Access to inactive and completed open cut voids over the remaining mine life increases the flexibility for containing water on-site and reducing risk of off-site spill and disruption to mining.
- There is some risk of delays to recommencement of mining in the Weismantel open pit early in 2018 if high rainfall conditions have resulted in a significant build up in site water inventories prior to commencement of dewatering of the inactive Weismantel open pit ahead of its recommissioning. This risk can however be managed by tracking water inventories in the period leading up to the change-over and by commencing proactive dewatering and enhanced irrigation operations to reduce water inventories early.

5.0 ASSESSMENT OF POTENTIAL OPERATIONAL SURFACE WATER IMPACTS

The potential operational impacts of the Modification on local and regional surface water resources are:

- Minor changes to flows in local creeks due to expansion and subsequent capture and re-use of drainage from mine catchment areas.
- Changes to the potential for export of contaminants (principally sediments and soluble salts) in mine area runoff and accidental spills from containment storages (principally sediments, soluble salts, oils and greases), causing degradation of local and regional watercourses.
- Changes to flows in the Mammy Johnsons River as a result of runoff and flow changes in contributing catchments and groundwater drawdown.

Given the large distance to the nearest coal mining (Stratford Coal Mine) and coal seam gas activity (Gloucester Gas Project), no quantitative cumulative impact assessment is deemed necessary.

5.1 Impacts on Flow Regime in Local Creeks

The effect of runoff capture on flows in local drainages as a result of the expanded area affected by mining as part of the Modification is summarised in Table 9.

Table 9
Changes to Contributing Catchment of Local Creeks

Catchment	Total Pre-mining Catchment Area (km^2)	Area Captured in Water Management System (km^2)	
		Maximum under approved DCM	Maximum under Modification
Coal Shaft Creek	9	5.2	5.2
Unnamed Tributary	2.9	0.8	0.9

Given that there is no change to the Coal Shaft Creek catchment and negligible change to the Un-named Tributary catchment the impact of the Modification on the flow regimes of these watercourses would be negligible.

The catchments of Coal Shaft Creek and the Unnamed Tributary would be progressively reinstated as the waste rock emplacements are rehabilitated and become free draining. Following the completion of rehabilitation post-mining, only the catchment areas of the final voids (approximately1.2 km^2) would remain excised from these catchments.

5.2 Release of Contaminants in Drainage Off-site

The risk of spill from the MWD and the open pits has been evaluated as part of the site water balance. There were no spills simulated during the 1,000 climatic sequences simulated and subject to adherence with the operational protocols and other assumptions inherent in the modelling there is a negligible risk (expected to be less than 0.1%) of spill occurring from the MWD or the auxiliary dams over the DCM life to downstream receiving waters including Mammy Johnsons River. The Modification would therefore not change the risk of spill compared to the approved DCM.

Surface runoff from disturbed areas at the DCM would continue to be captured on-site in accordance with the Surface Water Management Plan and, therefore, there would be no change to approved impacts associated with the potential release of this surface runoff from disturbed areas.

There are no changes proposed to the approved irrigation system or management regime as a result of the Modification. Horizon Soil Survey and Evaluation (2014) prepared an Irrigation Area Management Review for the Modification and is included in Attachment B. Horizon Soil Survey and Evaluation (2014) concluded that irrigation at the DCM appears to be sustainable and the predicted irrigation water salinities for the Modification (Section 4.4) would not cause soil structural degradation or plant growth in irrigation areas.

Given the above, and that DCPL would continue to manage irrigation in accordance with the Irrigation Management Plan, the Modification is not expected to change potential surface water impacts associated with irrigation area runoff.

5.3 Impacts on Mammy Johnsons River

Changes to flows and flow regimes in the Mammy Johnsons River may potentially occur as a result of:

- runoff and flow changes in contributing catchments; and
- groundwater migration as a result of irrigation and on-site water storage (including in-pit water storage).

The catchment areas of Coal Shaft Creek and the Unnamed Tributary to Mammy Johnsons River contribute approximately 3.2% of the total catchment area of Mammy Johnsons River. The DCM currently excises approximately 6 km^2 of the Mammy Johnsons River. The loss of a further 0.1 km^2 total catchment as part of the Modification represents approximately 0.1% of the total catchment of Mammy Johnsons River. The cumulative loss (with the existing DCM) of 8 km^2 total catchment represents approximately 2% of the total catchment of Mammy Johnsons River. Following the completion of rehabilitation post-mining, the size of the Mammy Johnsons River that is excised would reduce to approximately 1.2 km^2 which represents less than 0.05% of the total catchment of Mammy Johnsons River. Given the change in the Mammy Johnsons River catchment would be negligible, the impact of the Modification on the Mammy Johnsons River flow regime would also be negligible.

The Groundwater Review (Appendix A of the Environmental Assessment) concluded that the impact on flows in the Mammy Johnsons River as a result of the Modification is considered to be negligible.

The Modification is not expected to change the potential water quality impacts on the Mammy Johnsons River. As described in Section 5.2, surface runoff from disturbed areas at the DCM would continue to be captured on-site in accordance with the Surface Water Management Plan and, therefore, there would be no change to approved impacts associated with the potential release of this surface runoff from disturbed areas. In addition, the Modification is not expected to change potential surface water impacts associated with irrigation area runoff.

The migration of groundwater as a result of irrigation and on-site water storage is expected to be minor, and would have a negligible impact on water quality in the Mammy Johnsons River.

The implementation and adherence to these measures would result in the Modification having a negligible risk of water quality impacts on the Mammy Johnsons River.

6.0 POST-MINING WATER MANAGEMENT

The post-mining water management strategy is shown on Figure 14.

The final water management strategy for the DCM would be finalised in consultation with the NSW Division of Resource and Energy.

6.1 Final Void Water Management

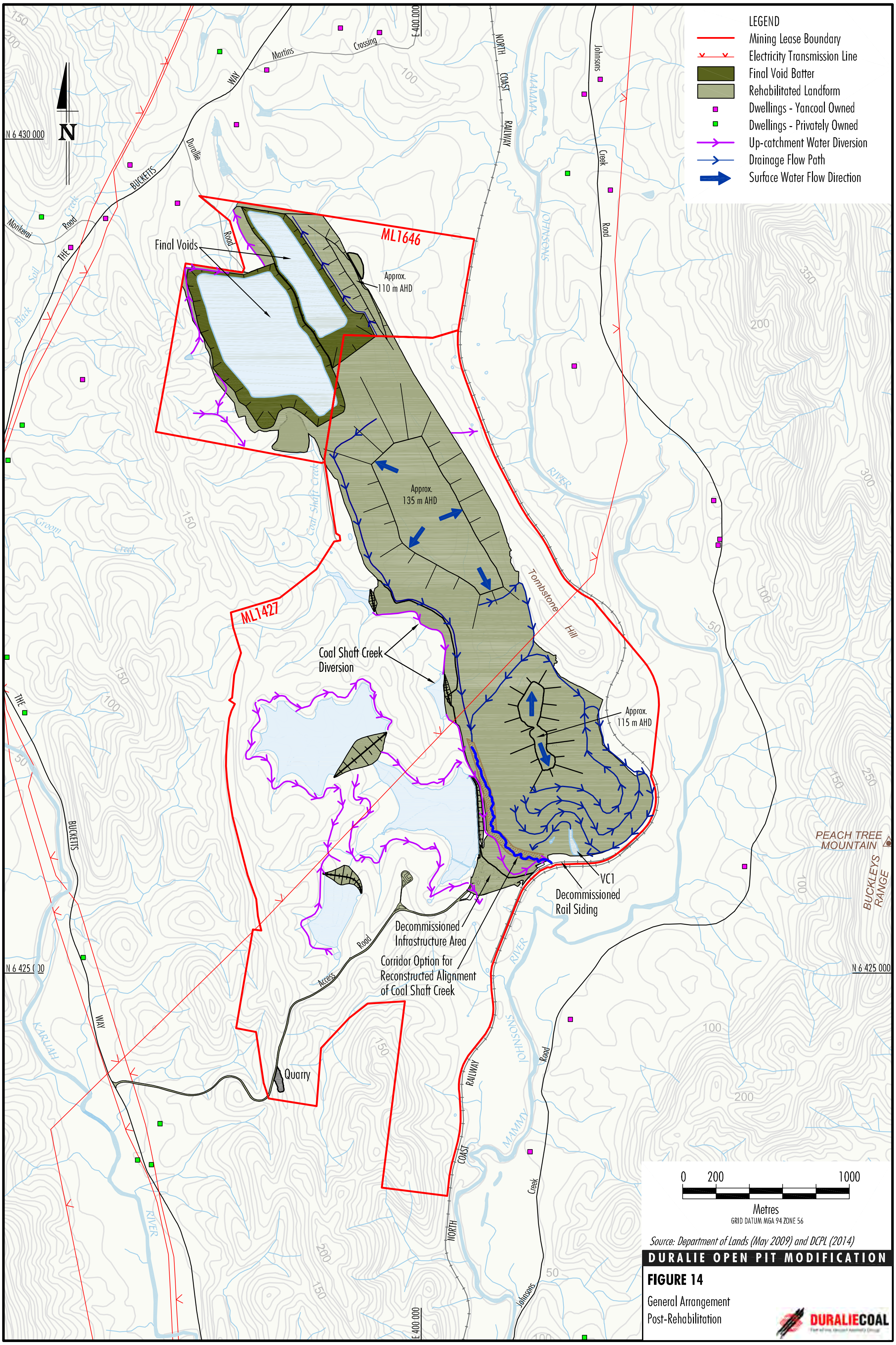
The surface catchment area of the final voids would be reduced to a practicable minimum (refer Figure 14) by the use of upslope diversions, contour drains around their perimeter and maximising backfilling of voids.

Inflows to the final open pit voids comprise incident rainfall over the void lake surface, runoff and seepage from the sides of the voids and their adjacent contributing catchment and seepage from coal seam groundwater and waste rock emplacement infiltration. A final void water balance model has been developed for the combined final voids to predict the long-term behaviour of the final void water bodies.

Post recovery groundwater seepage rates (including overburden infiltration) to the voids were advised by HydroSimulations (2014). The seepage rates were estimated for different final void water levels (reducing with rising water level).

The post-closure water balance and salinity of the final voids were investigated by running the water and salt balance model for a period of 300 years post closure. The model was configured to simulate conditions post closure. Model results for the Weismantel final void are shown in Figure 15 below in terms of predicted final void water levels and salinity versus time.

The model predictions show that the final water level would stabilise in both final voids at levels below the spill level which is about 88 m AHD. The long term water level in the Weismantel final void is predicted to be about 76 to 79 m AHD which is some 7 to 10 m below the level at which water is predicted to spill over into the adjoining Clareval void (i.e. 86 m AHD). The long term water level in the Clareval final void is predicted to be around 60 m AHD as a result of relatively higher evaporative area of the Clareval final void. It is likely that there would be some groundwater flow between the voids, given the different water levels, which would result in some lowering of longer term levels in the Weismantel final void and correspondingly higher long term water levels in the Clareval final void. The final void water levels would however remain significantly below spill level. The salinity of water in both voids is predicted to increase slowly over time.



Source: Department of Lands (May 2009) and DCPL (2014)

DURALIE OPEN PIT MODIFICATION

FIGURE 14

General Arrangement
Post-Rehabilitation

DURALIECOAL

GCL-14-23_Mod2_SWA_109E

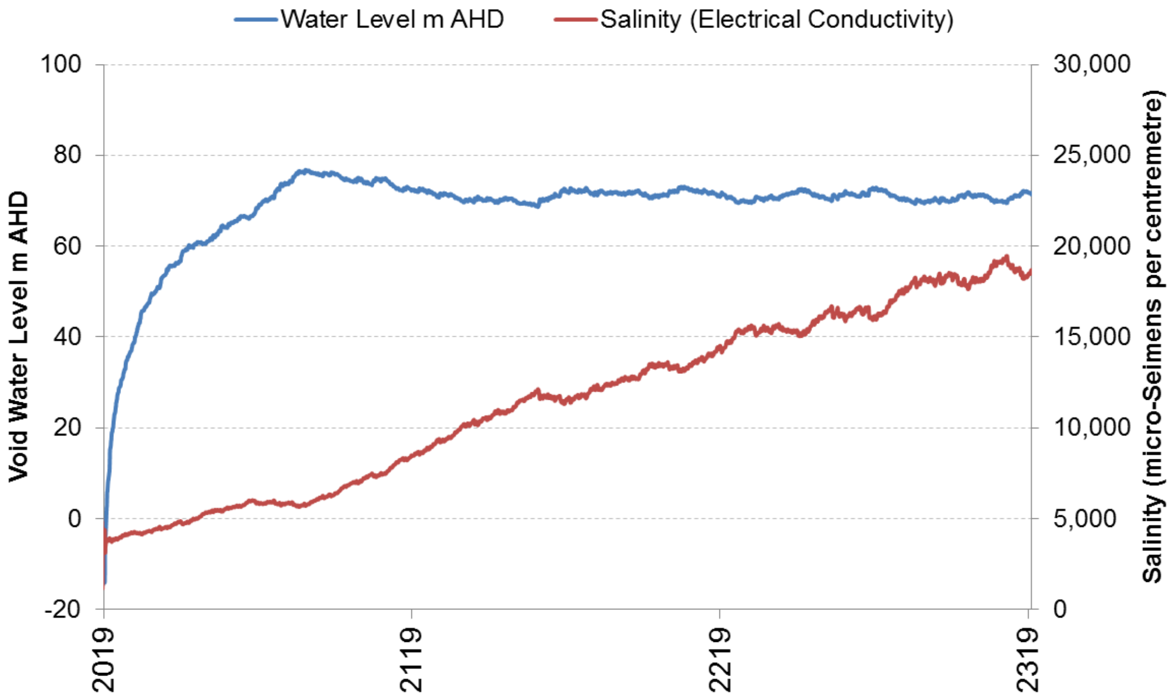


Figure 15 Simulated Water Levels and Salinity – Weismantel Final Void Post Closure

Model results for the Clareval final void are shown in Figure 16 below in terms of predicted final void water levels and salinity versus time.

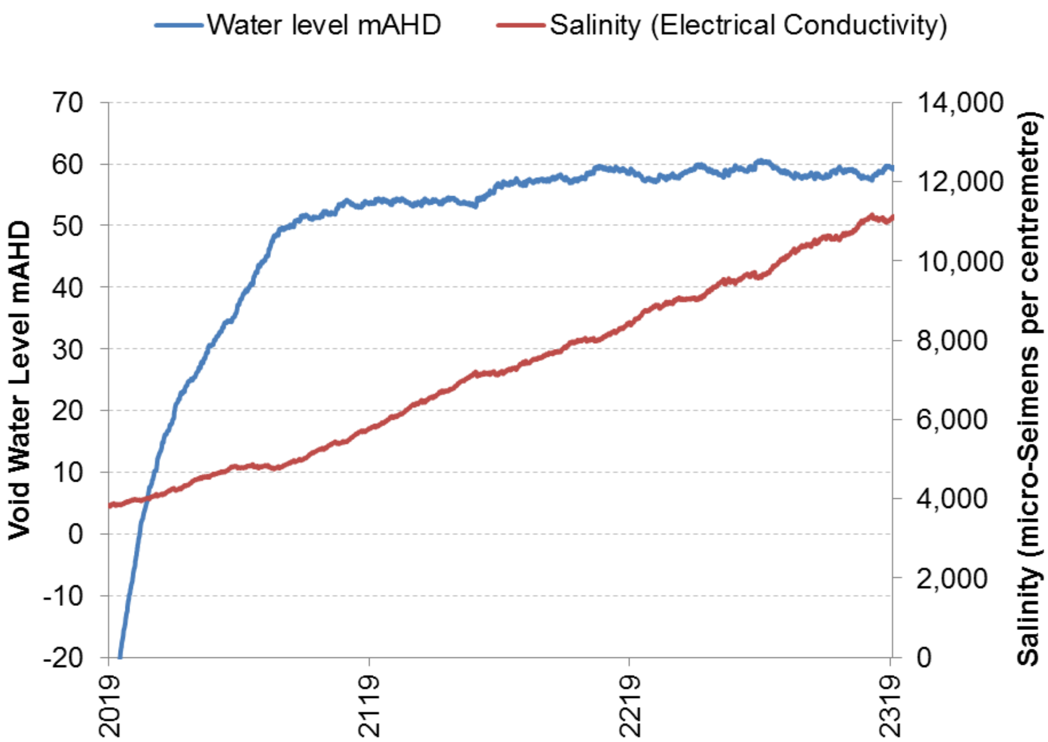


Figure 16 Simulated Water Levels and Salinity – Clareval Final Void Post Closure

6.2 Coal Shaft Creek

Following the completion of mining activities at the DCM, a final alignment of Coal Shaft Creek would be established, stabilised and revegetated prior to ML relinquishment.

The approved design for the post-mining alignment of Coal Shaft Creek would comprise a reworked section of the existing Coal Shaft Creek diversion channel, a drop-down section outside the in-pit waste rock emplacement, and a reconstruction of the creek within a corridor within the in-pit waste rock emplacement at the southern end of the Weismantel open pit extent.

There are no changes proposed to the final alignment or configuration of Coal Shaft Creek as result of the Modification.

6.3 Erosion and Sediment Control

Erosional stability would be a key requirement of site rehabilitation and closure works design. The operational sediment and erosion control works would be retained and maintained during the revegetation establishment phase. Following the establishment of self-sustaining stable final landforms, key elements of the operational sediment control structures would either be left as passive water control storages or would be removed if they could not be left without an ongoing maintenance commitment.

7.0 EFFECTS OF CLIMATE CHANGE ON PREDICTED SURFACE WATER IMPACTS

The potential effects of climate change on predicted DCM surface water impacts were considered by Gilbert & Associates (2010) and it was concluded that:

- There would be reduced rainfall in all seasons with particularly large reductions in winter and spring by 2100.
- There would also be a tendency for reduced overall runoff particularly in winter and spring.

Overall, it was concluded that (Gilbert & Associates, 2010):

> *The implications of climate change predictions on water management are unlikely to be significant over the Project life because they are small compared to the natural climatic variability. In the long-term however they have implications on the final void behaviour. In this regard the currently most accepted scenarios would see a reduction in overall rainfall and an increase in evaporation. This would translate to reduced surface water runoff inflows to the void and reduced incident rainfall over the void surface. There would also be increased evaporation loss from the void surface and as a consequence lower average water levels in the void.*

It is considered that this conclusion is relevant to the Modification and no additional climate change analysis was deemed necessary.

8.0 RECOMMENDED MONITORING

DCPL has an established system for monitoring the DCM water management system and potential impacts to local and regional surface water resources. There is no requirement to change the currently approved monitoring as a result of the Modification.

9.0 REFERENCES

ANZECC/ARMCANZ (2000a). “Australian Water Quality Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy”, Australian and New Zealand Environment and Conservation Council, October.

BoM (2014). “Climate Data Online”, Accessed May 2014, Website: <http://www.bom.gov.au/climate/averages/>.

Duralie Coal Pty Limited (2014). “Duralie Open Pit Modification Environmental Assessment”.

Gilbert & Associates (2010). “Duralie Extension Project Surface Water Assessment”, January.

Gilbert & Associates Pty Ltd (2014) “Duralie Coal Mine 2013 Annual Water Balance Review”.

Horizon Soil Survey and Evaluation (2014). “Irrigation Area Management Review”, Report prepared for DCPL.

HydroSimulations (2014). “Duralie Coal Modification”, Report prepared for DCPL.

Noller, B. (2010). “Duralie Coal Mine – Assessment of Potential Impacts of Rainfall Runoff from Irrigation Areas on Salinity and Biota in the Mammy Johnsons River”, Report prepared for DCPL.

Woodward-Clyde (1996a). “Duralie Coal Project Environmental Impact Statement”, September 1996. Report prepared for DCPL.

Attachment A

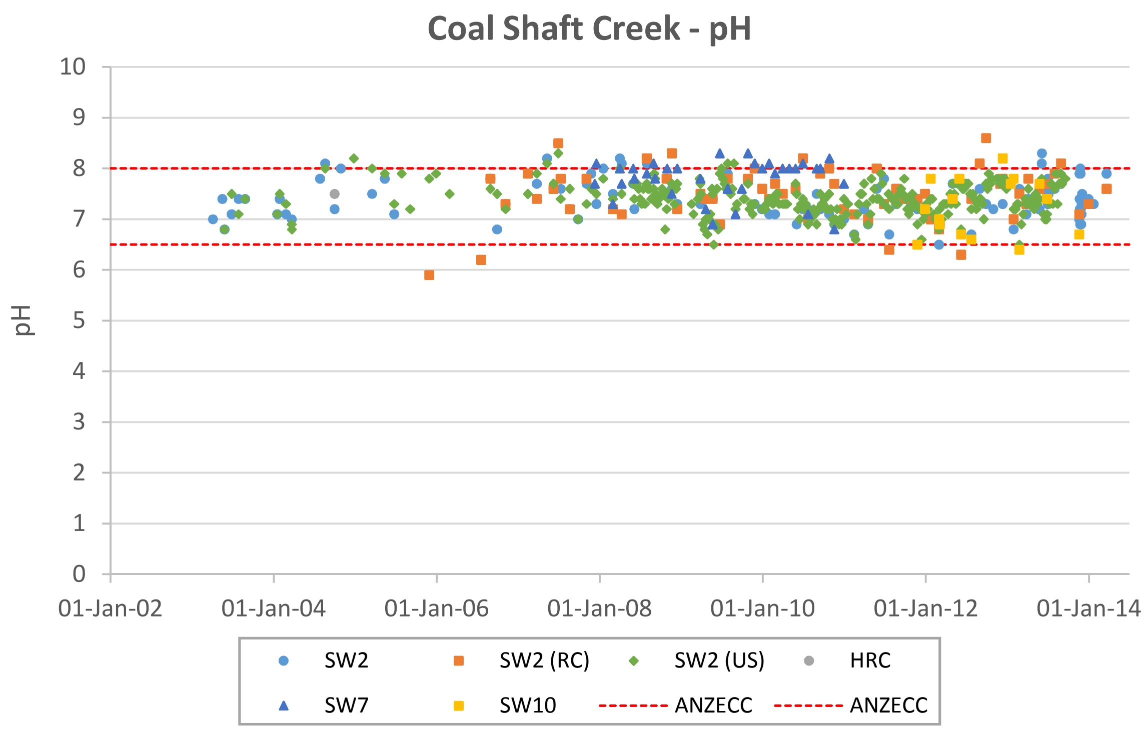
Water Quality Monitoring Data

pH Monitoring Results

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

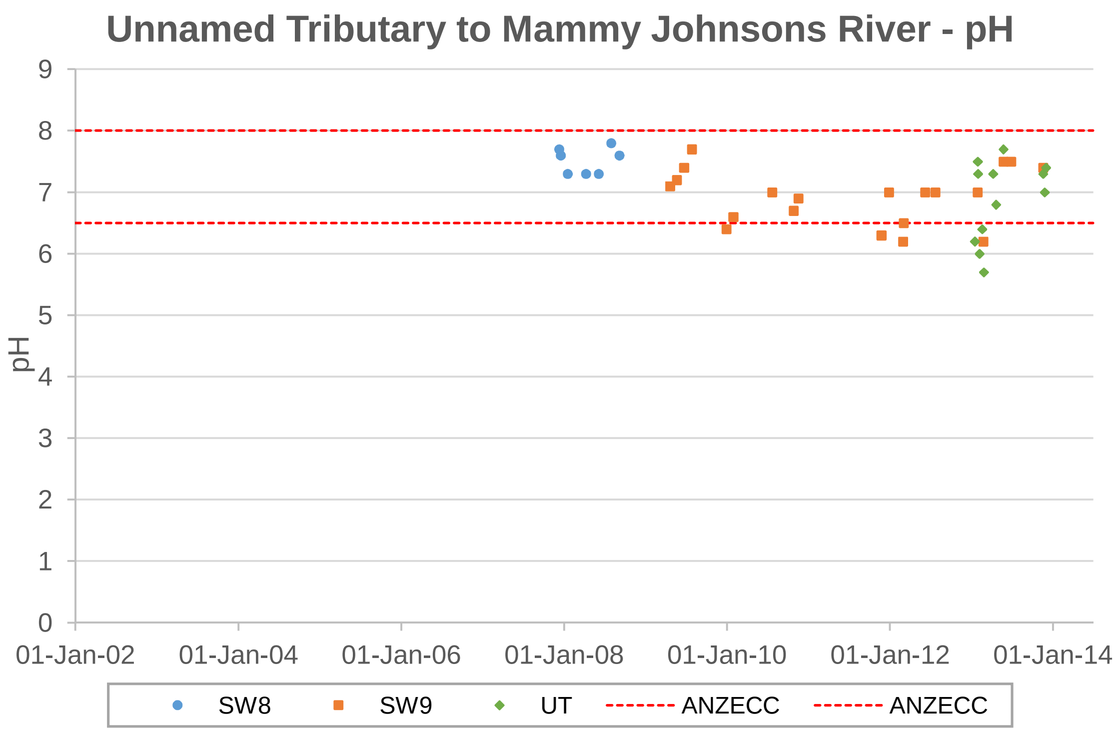
Table A-1
Summary of pH Monitoring Results

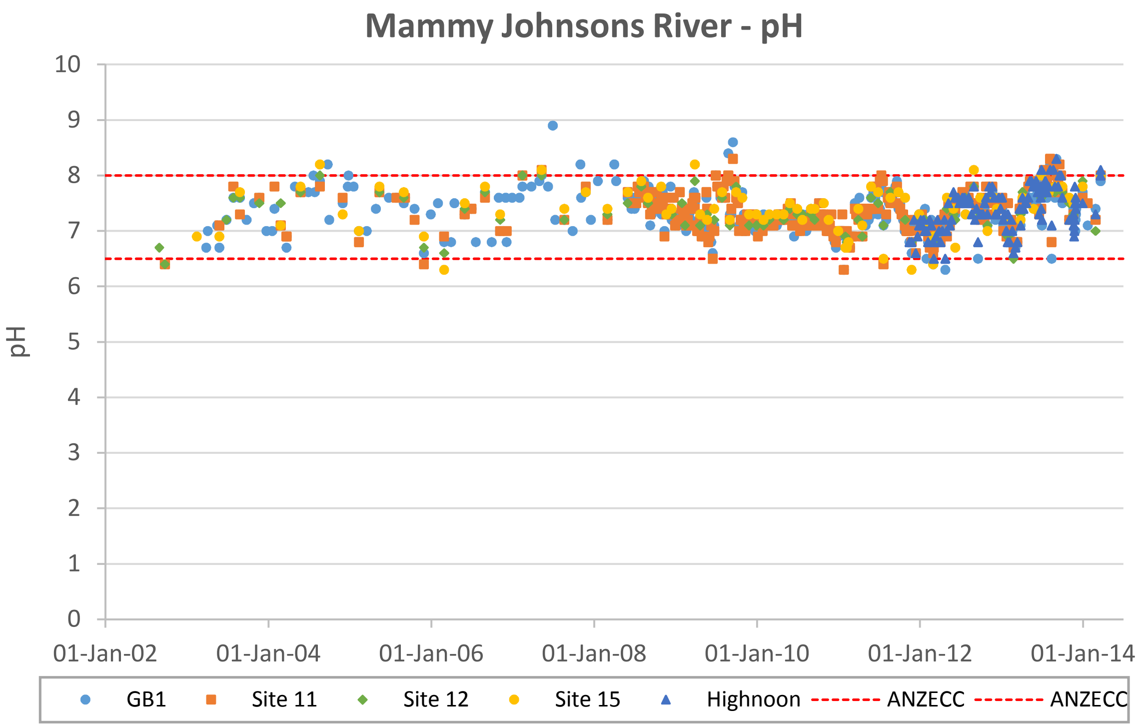
Site	No. of Samples	Minimum	Median	Maximum	Percentage Exceedance (%)
SW2 (RC)	65	5.9	7.5	8.6	16.9
Unnamed Tributary	12	5.7	7.2	7.7	33.3
GB1	386	6.3	7.3	8.9	3.1
Highnoon	127	6.5	7.4	8.3	4.7



pH Monitoring Results (Continued)

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).



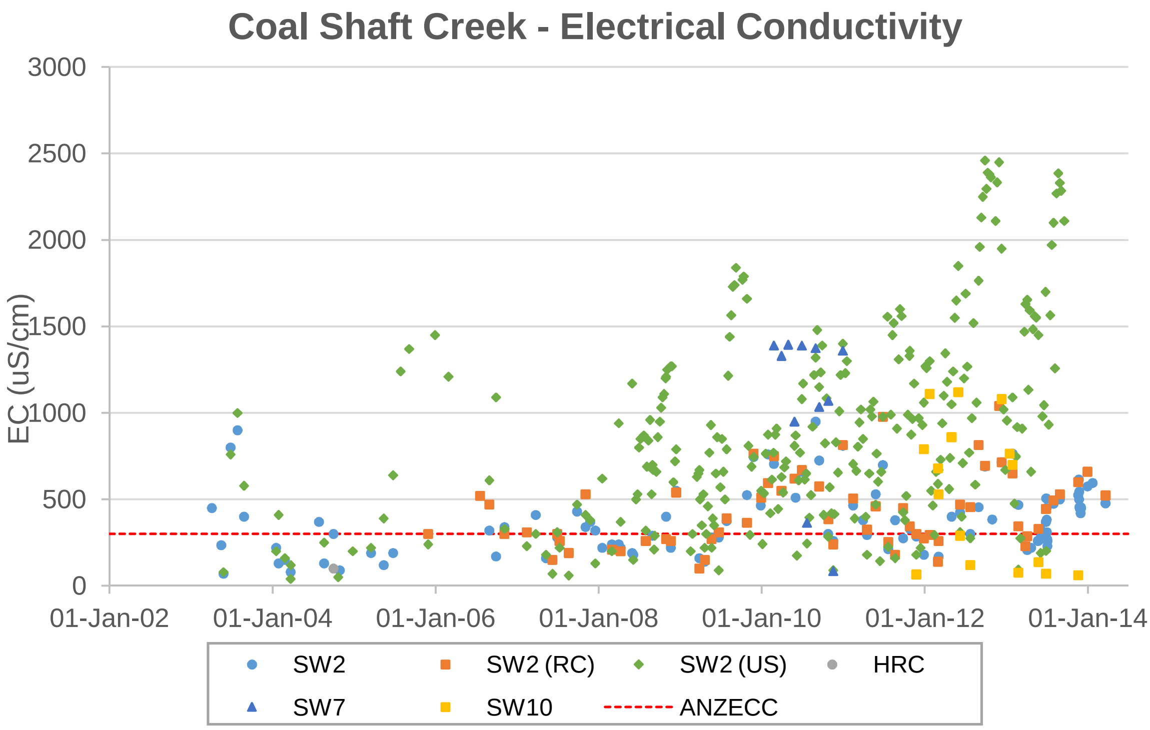


Electrical Conductivity Monitoring Results

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

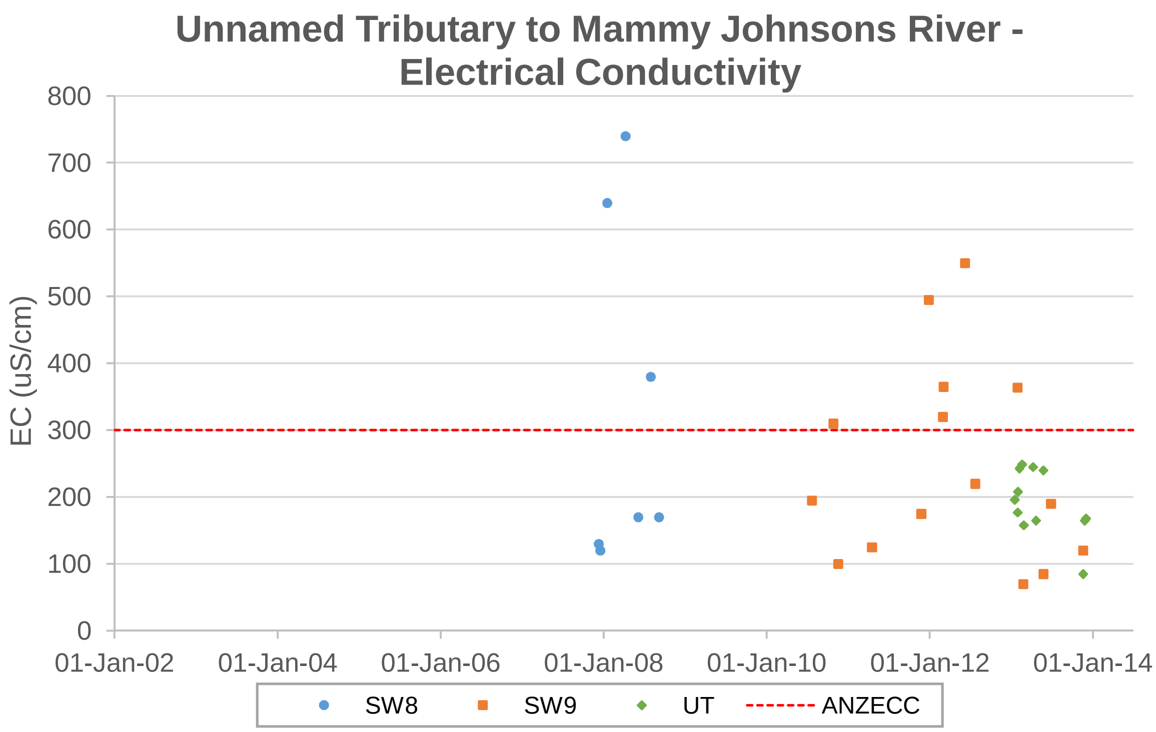
Table A-2
Summary of EC Monitoring Results

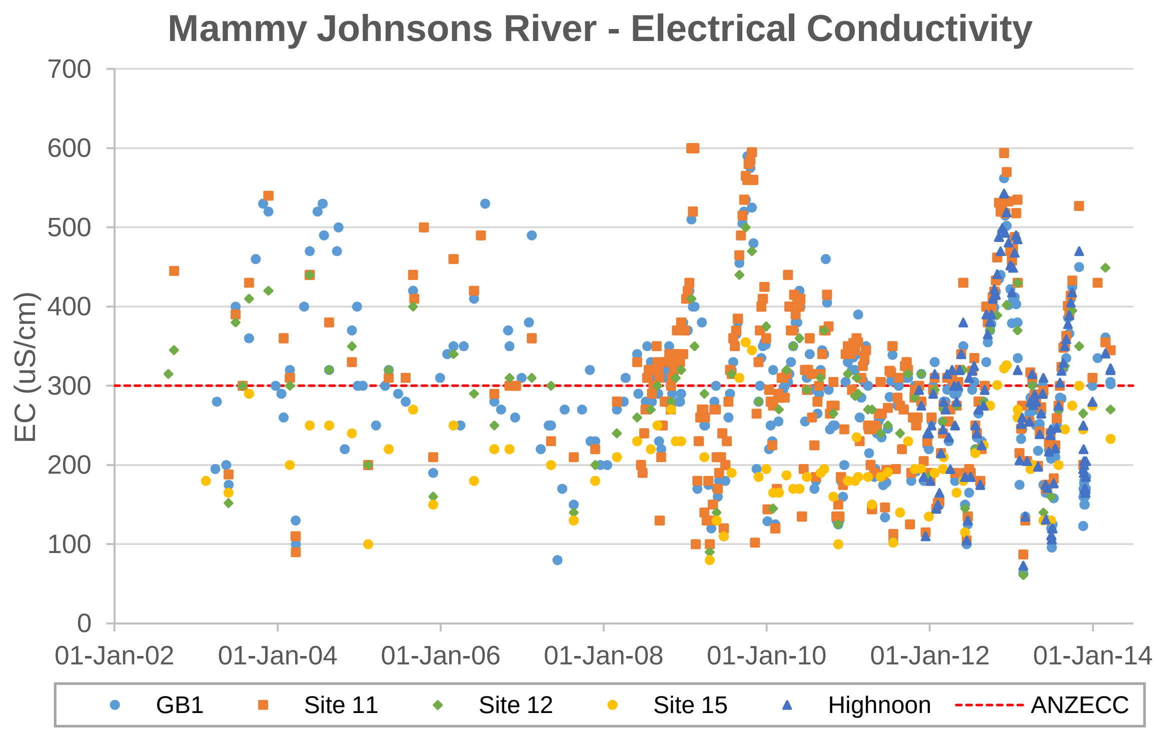
Site	No. of Samples	Minimum	Median	Maximum	Percentage Exceedance (%)
SW2 (RC)	63	100	385	1040	61.9
Unnamed Tributary	12	85	187	249	0.0
GB1	387	63	285	590	40.1
Highnoon	127	73	270	543	36.2



Electrical Conductivity Monitoring Results (Continued)

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).



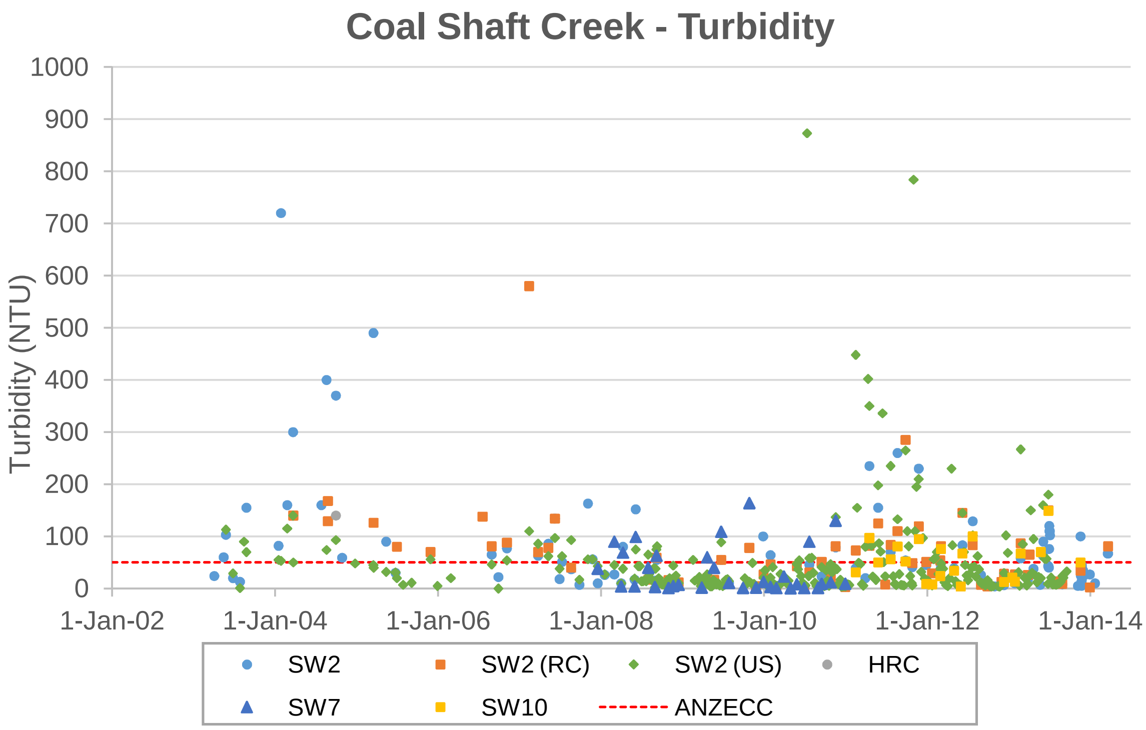


Turbidity Monitoring Results

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

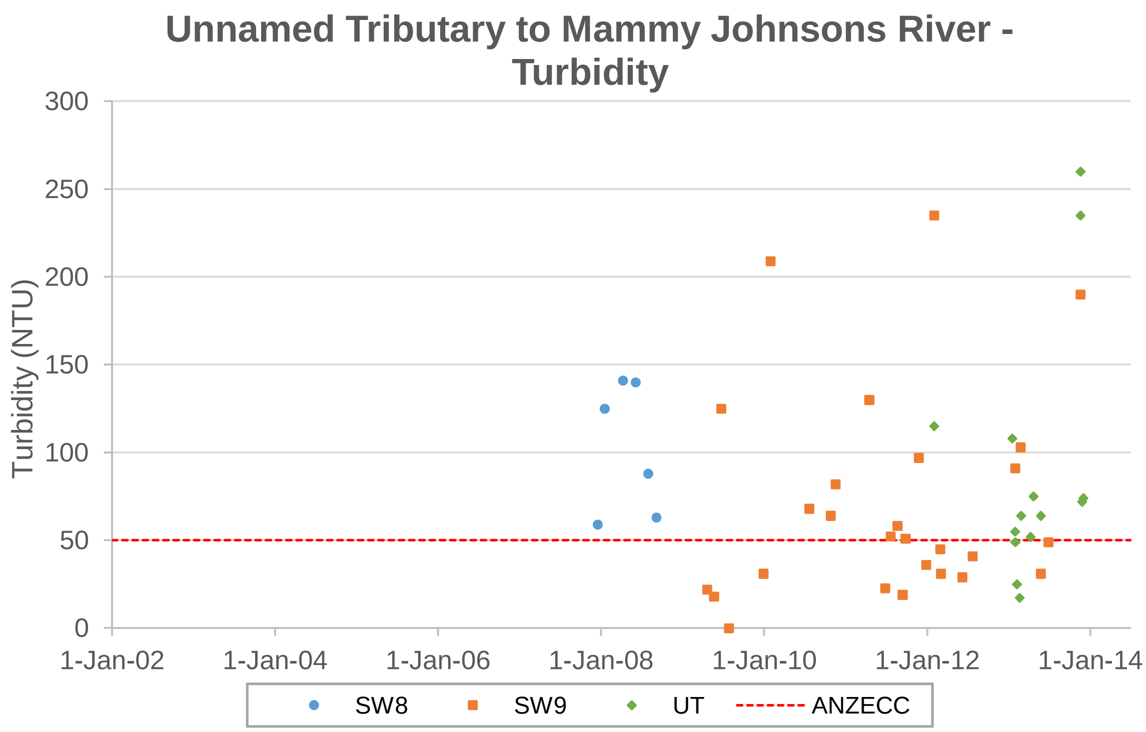
Table A-3
Summary of Turbidity Monitoring Results

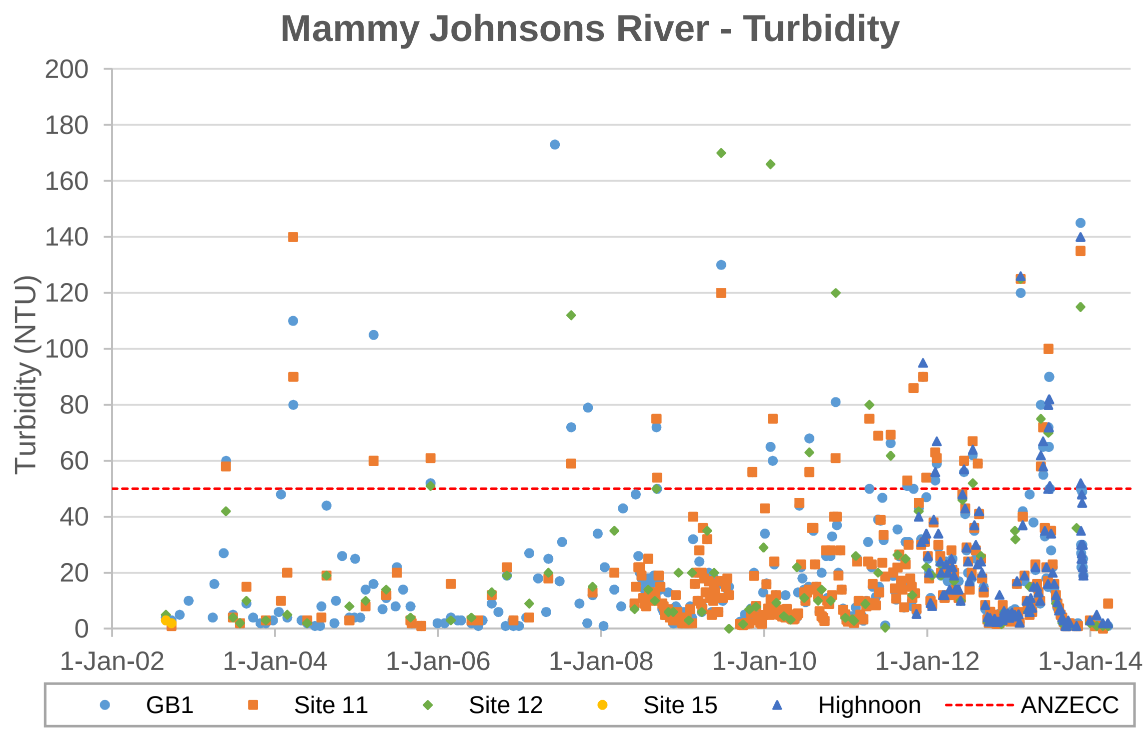
Site	No. of Samples	Minimum	Median	Maximum	Percentage Exceedance (%)
SW2 (RC)	65	1.6	51	580	52.3
Unnamed Tributary	14	17.3	68	260	78.6
GB1	387	1	12	173	8.5
Highnoon	127	1	19	140	15.0



Turbidity Monitoring Results (Continued)

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).



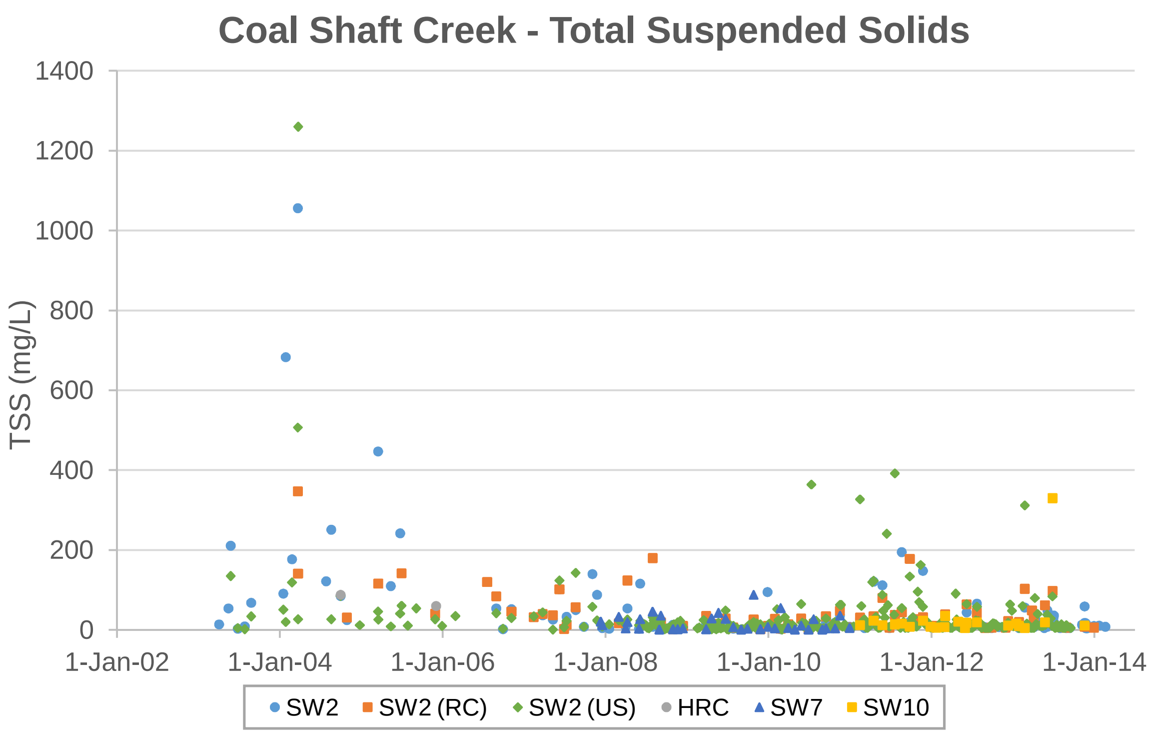


Total Suspended Solids Monitoring Results

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

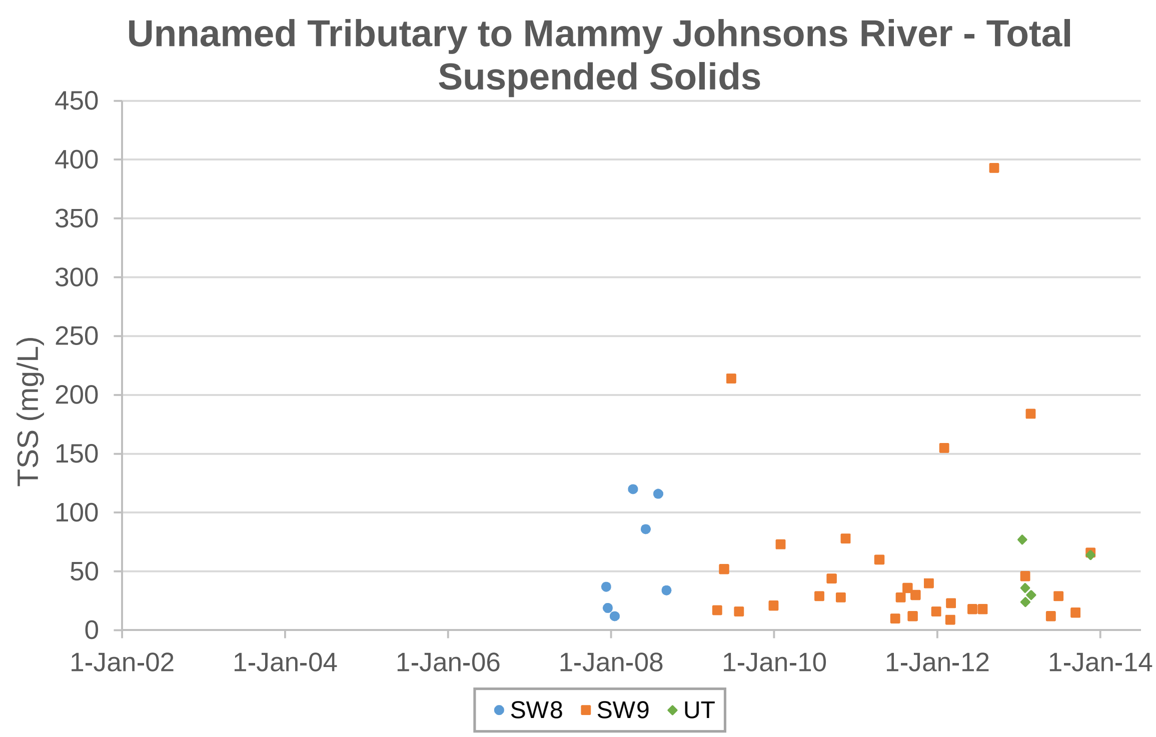
Table A-4
Summary of Total Suspended Solids Monitoring Results

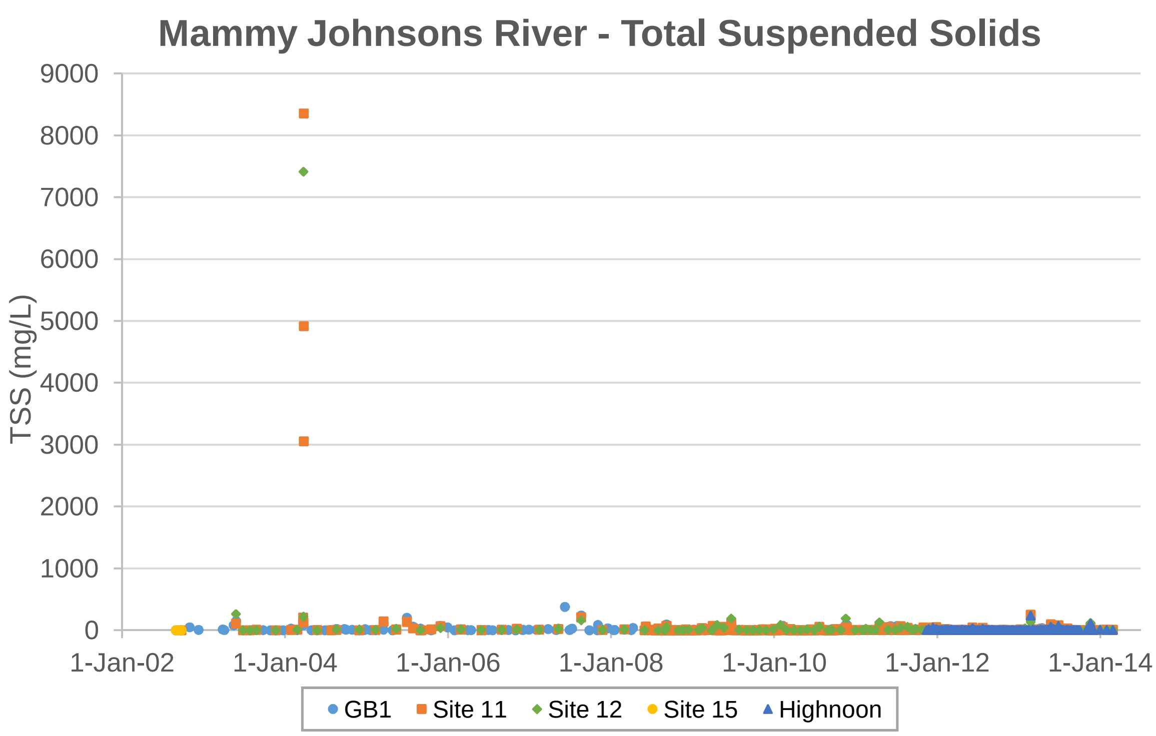
Site	No. of Samples	Minimum	Median	Maximum
SW2 (RC)	70	2	28.5	347
Unnamed Tributary	5	24	36	77
GB1	388	1	6	380
Highnoon	125	5	7	240



Total Suspended Solids Monitoring Results (Continued)

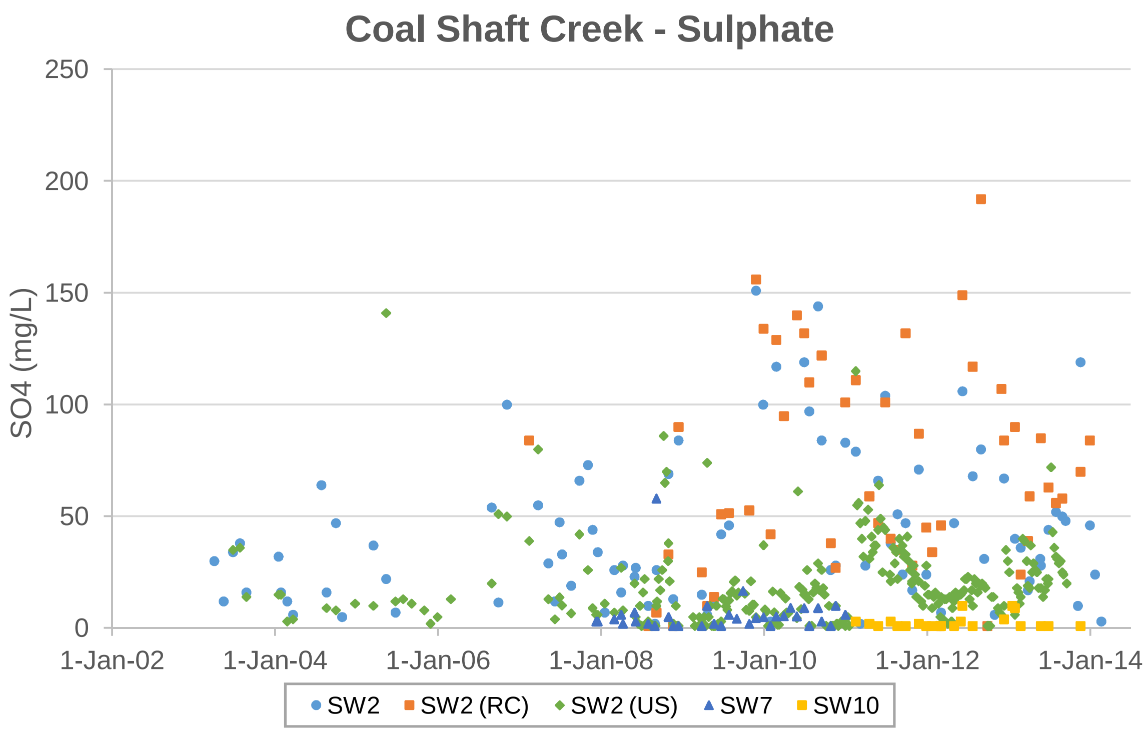
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

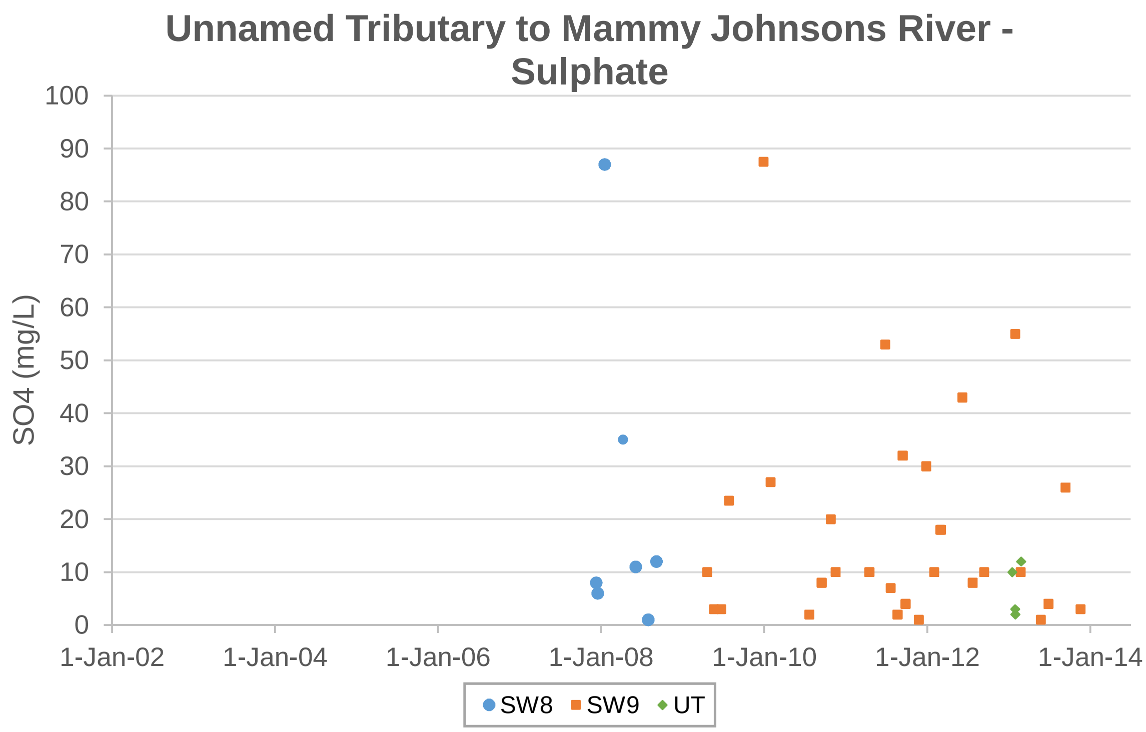




Sulphate Monitoring Results

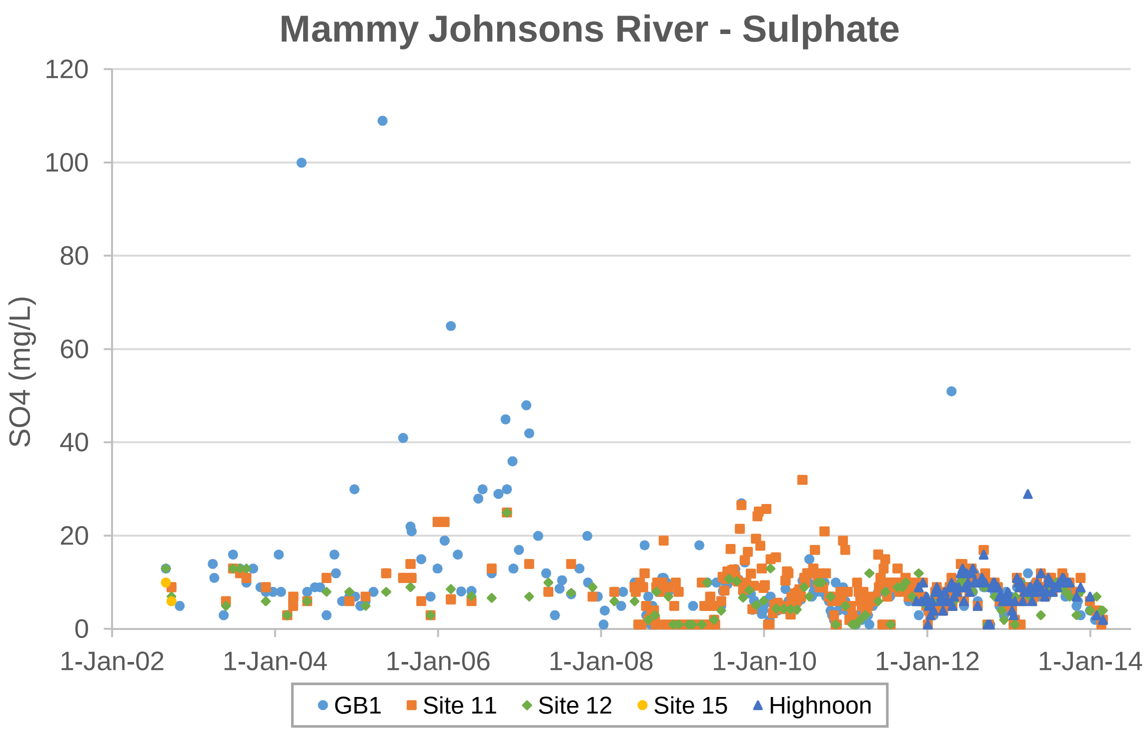
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).





Sulphate Monitoring Results (Continued)

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

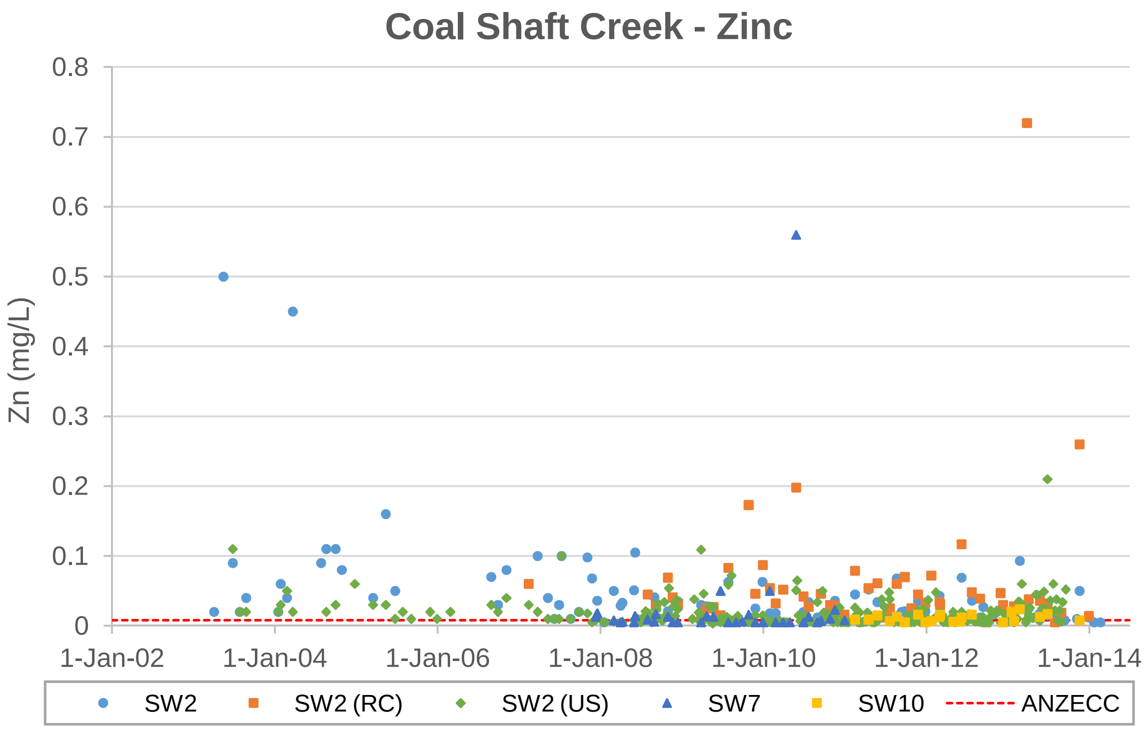


Zinc Monitoring Results

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

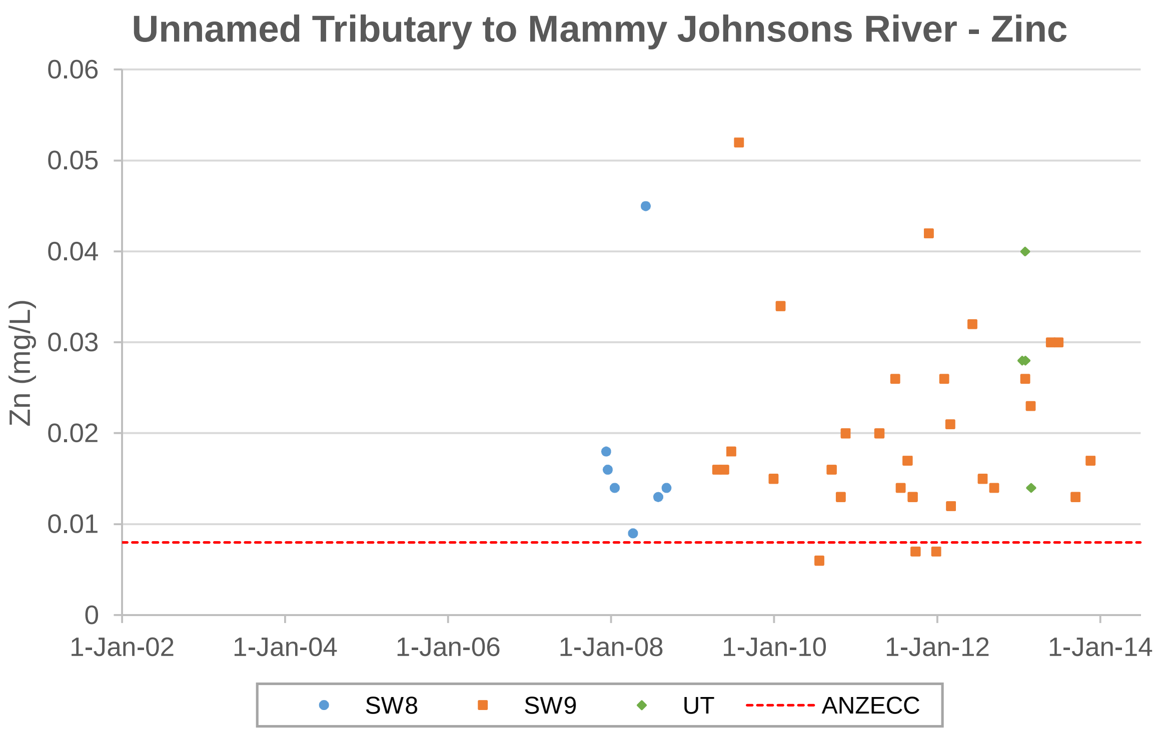
Table A-5
Summary of Zinc Monitoring Results

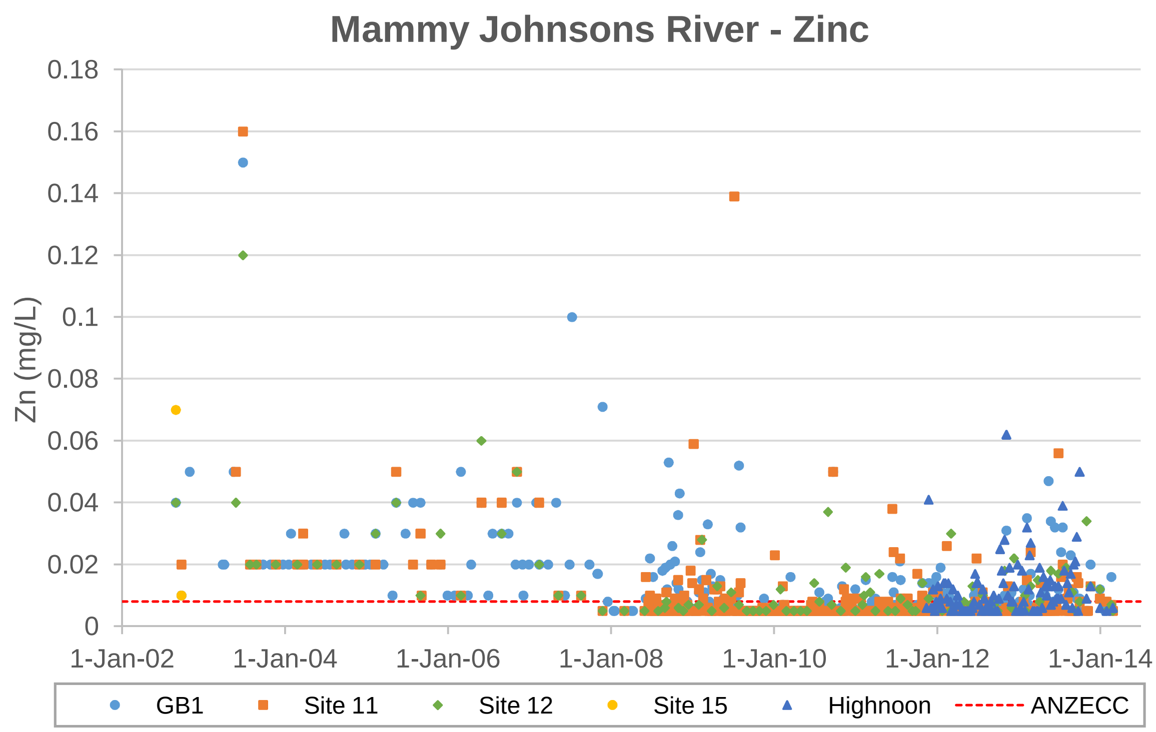
Site	No. of Samples	Minimum	Median	Maximum	Percentage Exceedance (%)
SW2 (RC)	53	<0.005	0.038	0.720	96.2
Unnamed Tributary	4	0.014	0.028	0.040	100
GB1	362	<0.005	0.007	0.150	42.8
Highnoon	103	<0.005	0.009	0.062	52.4



Zinc Monitoring Results (Continued)

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).



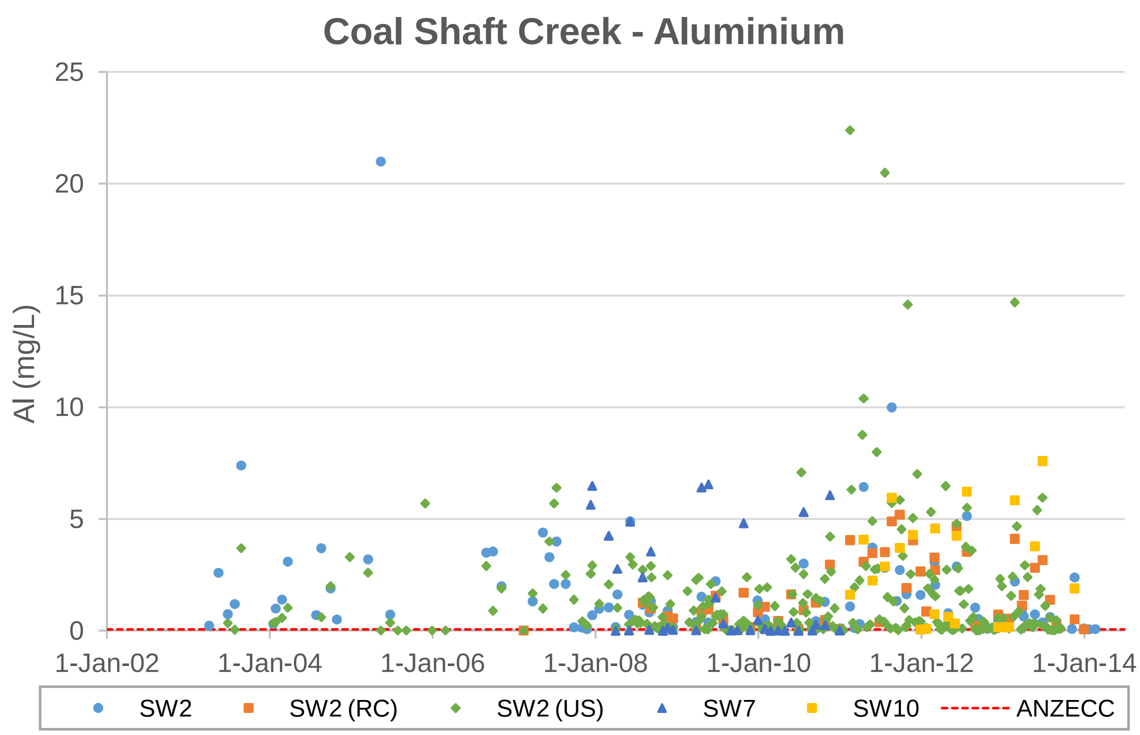


Aluminium Monitoring Results

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

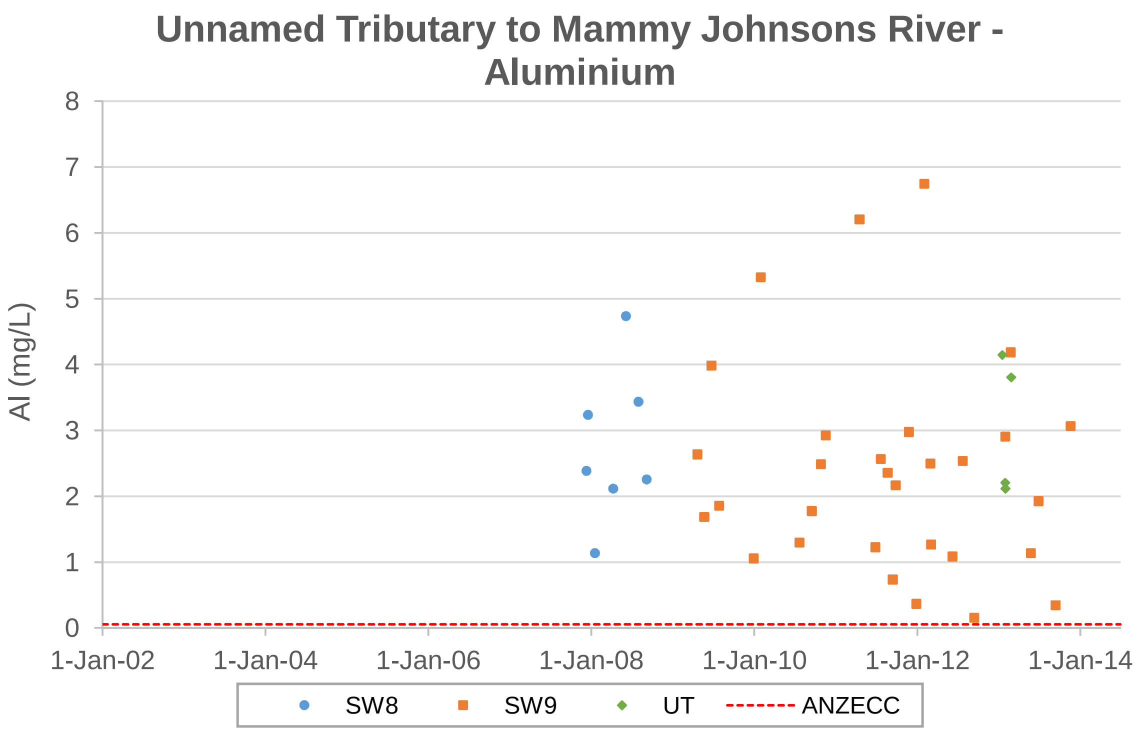
Table A-6
Summary of Aluminium Monitoring Results

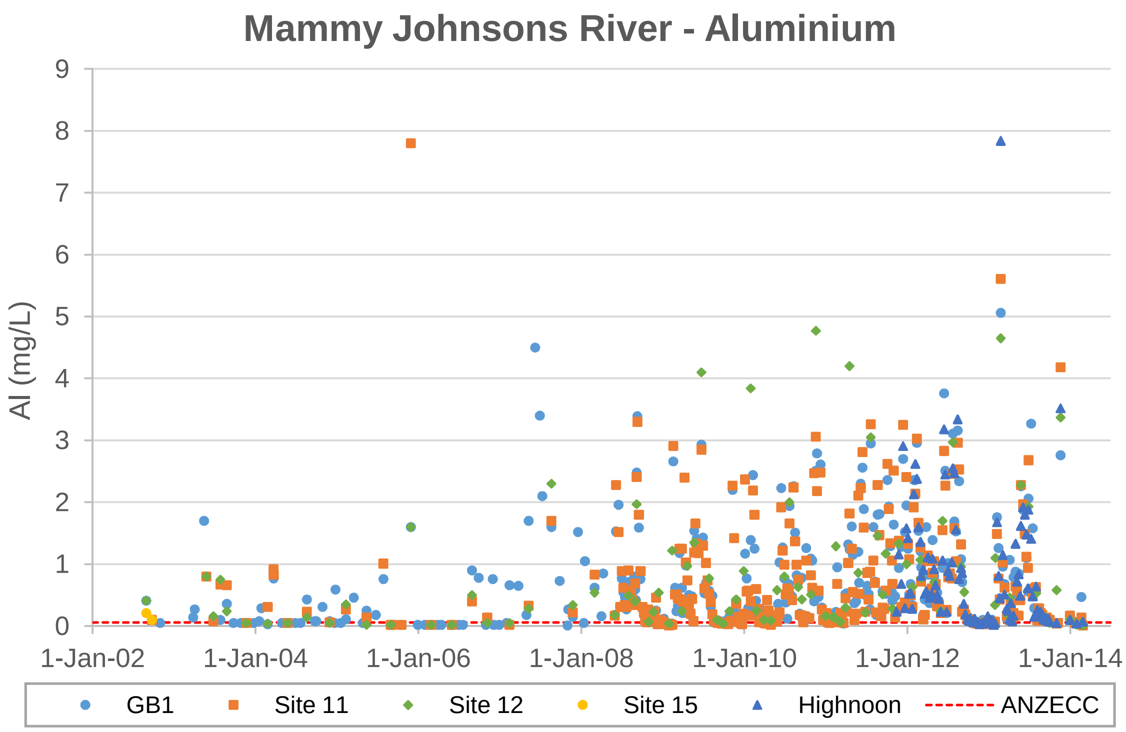
Site	No. of Samples	Minimum	Median	Maximum	Percentage Exceedance (%)
SW2 (RC)	53	0.01	0.36	5.06	85.9
Unnamed Tributary	4	2.12	3.01	4.15	100
GB1	362	<0.02	0.43	5.06	85.6
Highnoon	103	0.02	0.50	7.84	92.2



Aluminium Monitoring Results (Continued)

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).



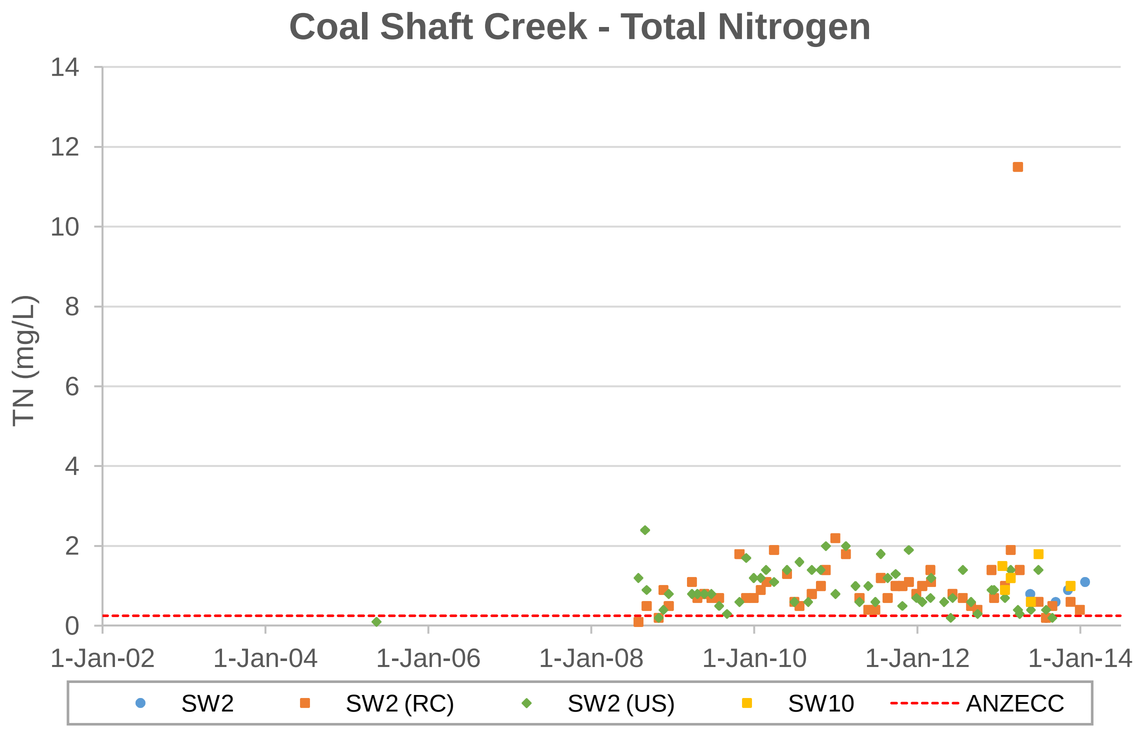


Total Nitrogen Monitoring Results

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

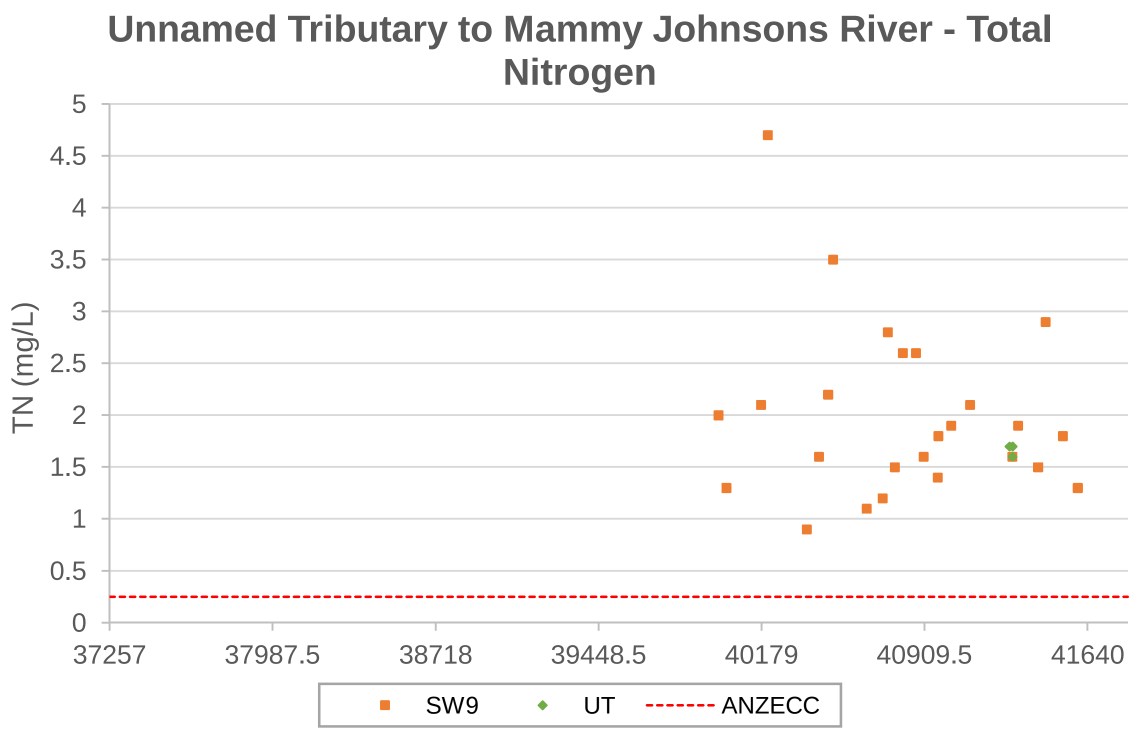
Table A-7
Summary of Total Nitrogen Monitoring Results

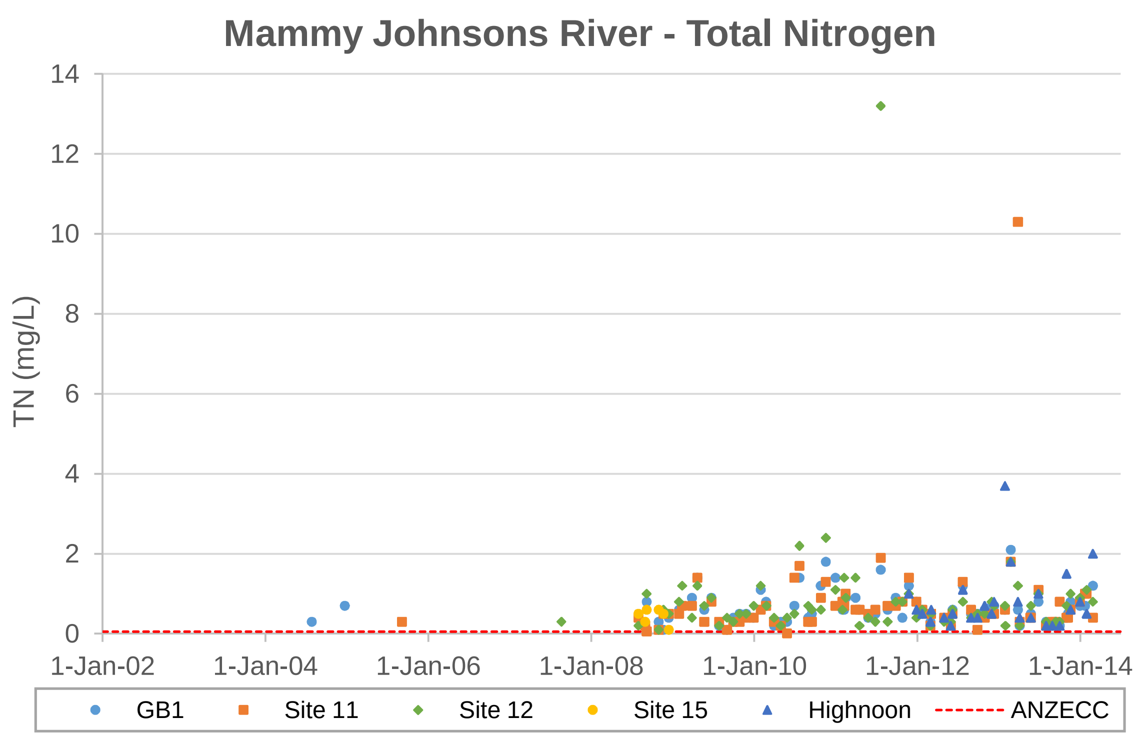
Site	No. of Samples	Minimum	Median	Maximum	Percentage Exceedance (%)
SW2 (RC)	52	0.1	0.8	11.5	94.2
Unnamed Tributary	3	1.6	1.7	1.7	100
GB1	73	<0.1	0.6	2.1	87.7
Highnoon	28	0.2	0.55	3.7	85.7



Total Nitrogen Monitoring Results (Continued)

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).



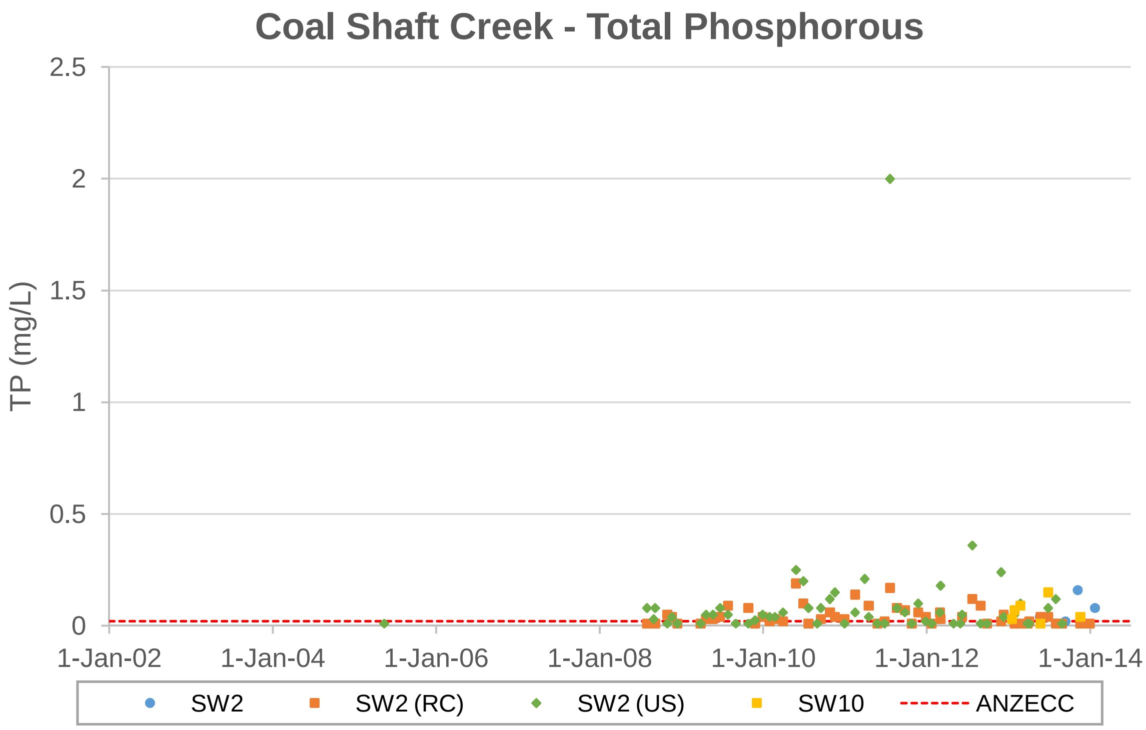


Total Phosphorous Monitoring Results

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

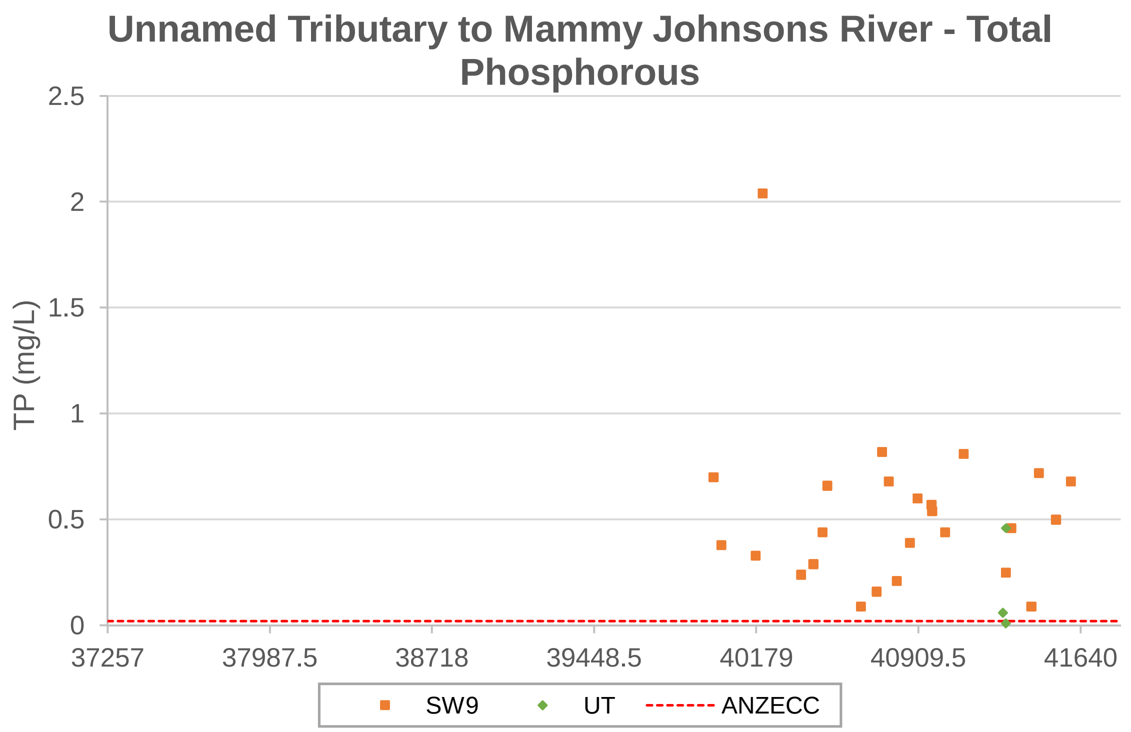
Table A-8
Summary of Total Phosphorous Monitoring Results

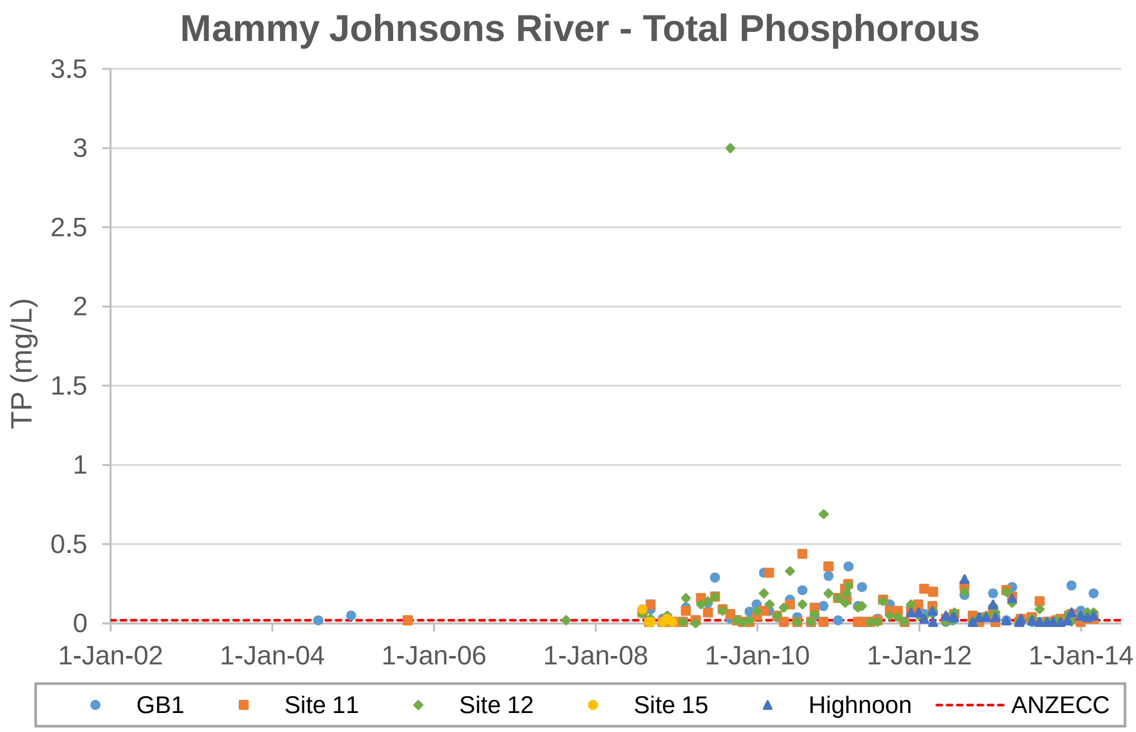
Site	No. of Samples	Minimum	Median	Maximum	Percentage Exceedance (%)
SW2 (RC)	52	<0.01	0.03	0.19	57.7
Unnamed Tributary	3	<0.01	0.06	0.46	66.7
GB1	73	<0.01	0.05	0.36	67.1
Highnoon	28	<0.01	0.04	0.28	64.3



Total Phosphorous Monitoring Results (Continued)

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).



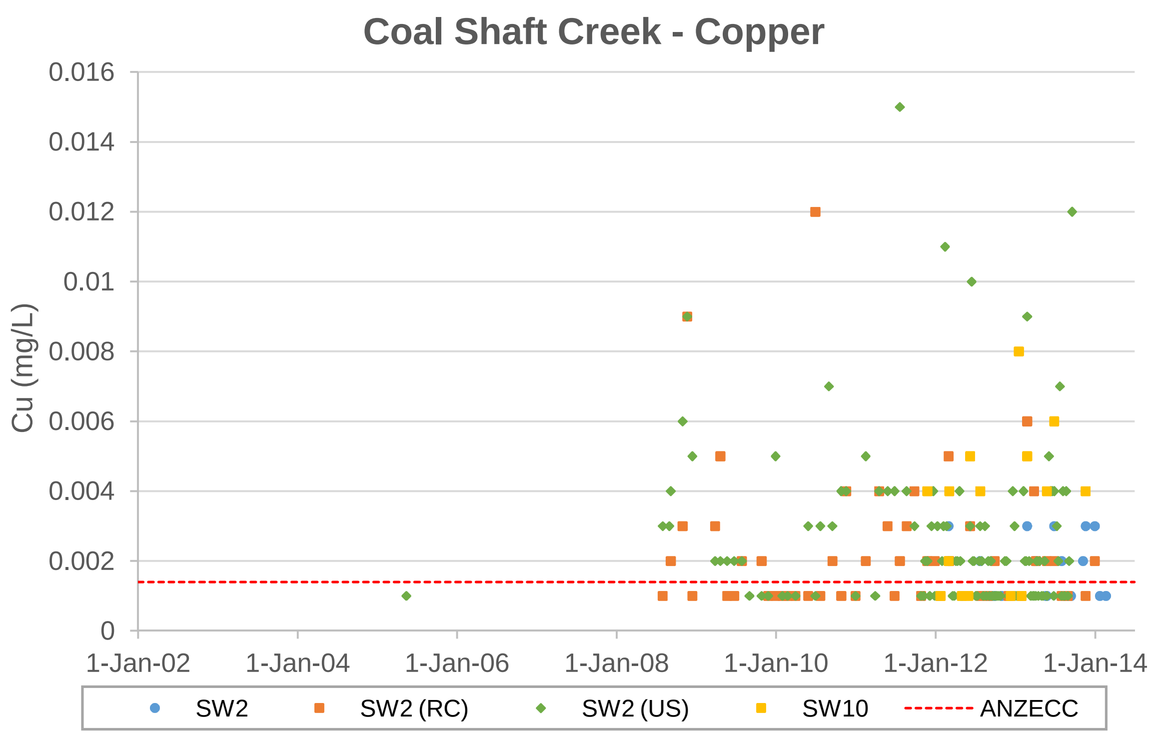


Copper Monitoring Results

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

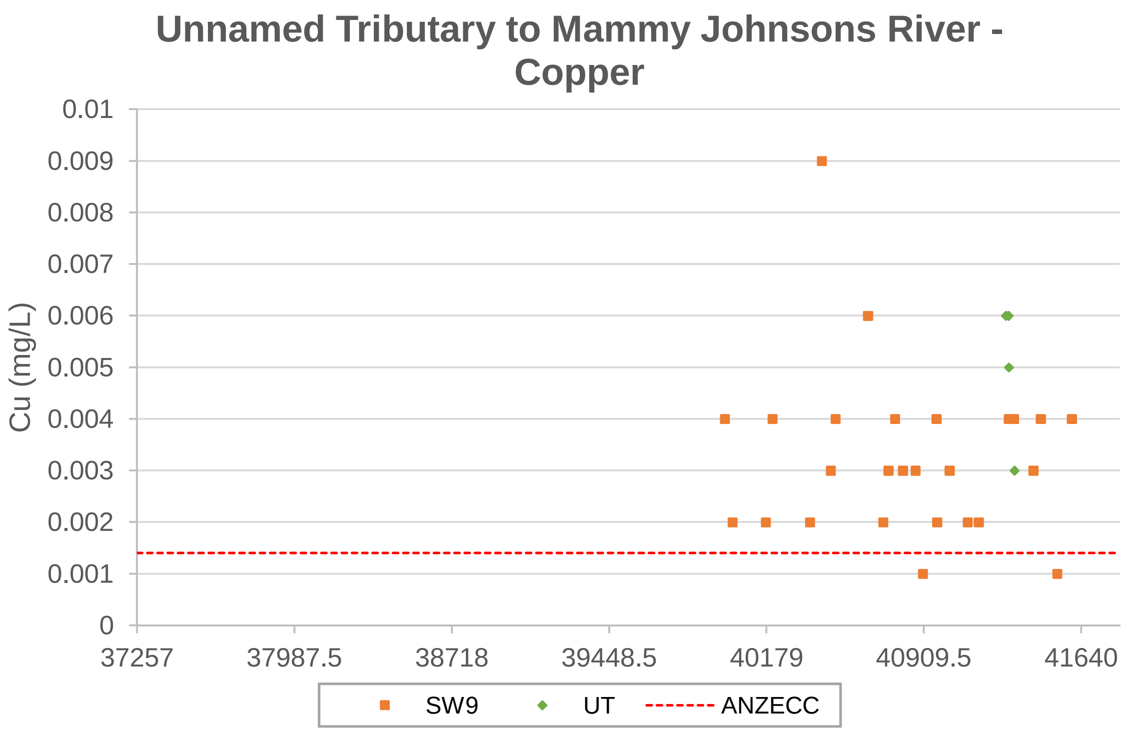
Table A-9
Summary of Copper Monitoring Results

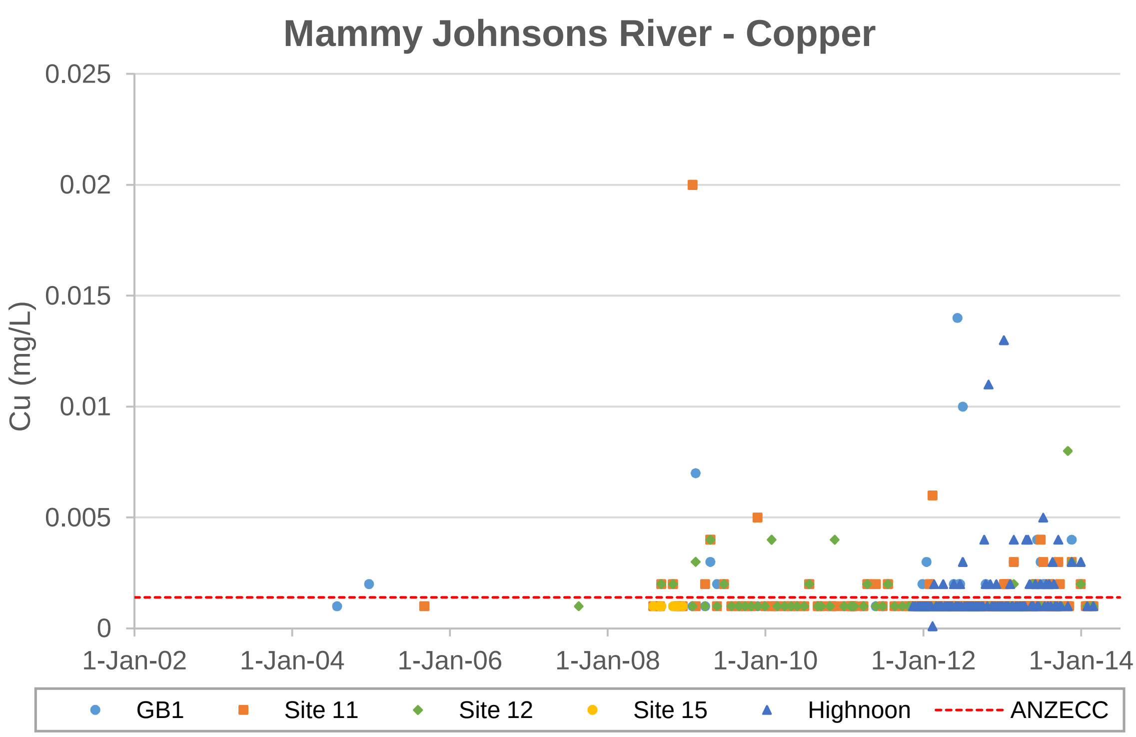
Site	No. of Samples	Minimum	Median	Maximum	Percentage Exceedance (%)
SW2 (RC)	52	<0.001	0.002	0.012	53.8
Unnamed Tributary	4	0.003	0.006	0.006	100
GB1	148	<0.001	0.001	0.014	20.3
Highnoon	103	<0.0001	0.001	0.013	26.2



Copper Monitoring Results (Continued)

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).



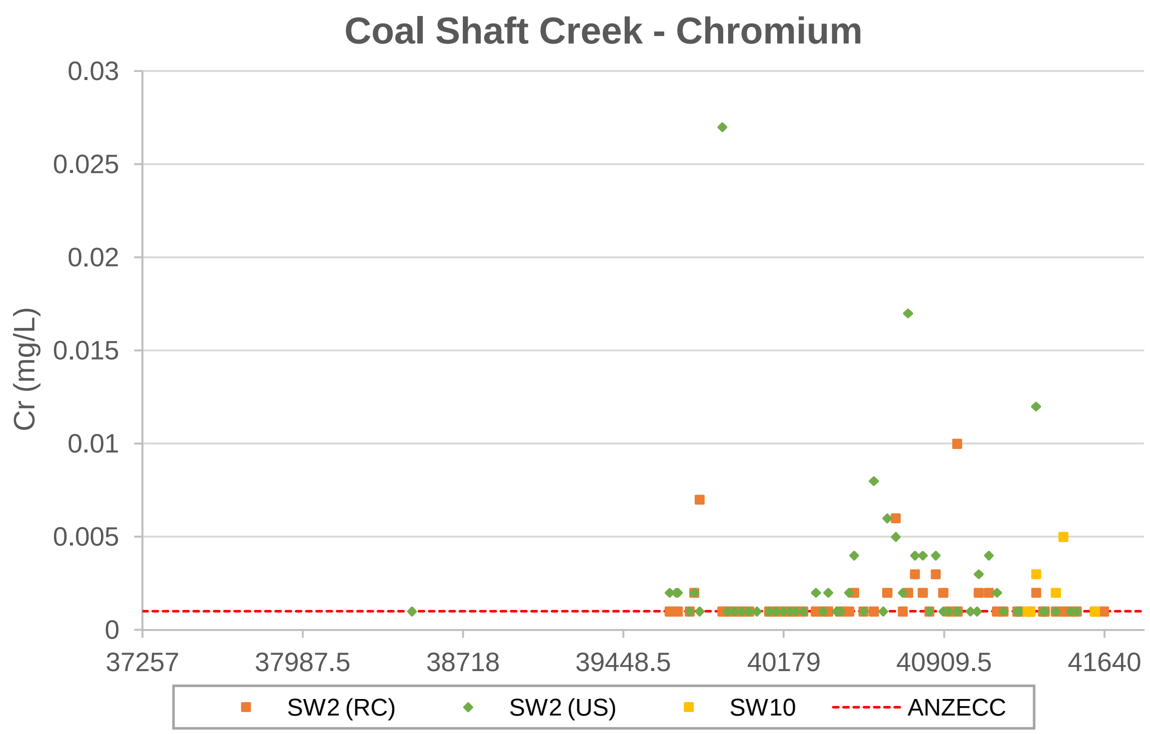


Chromium Monitoring Results

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

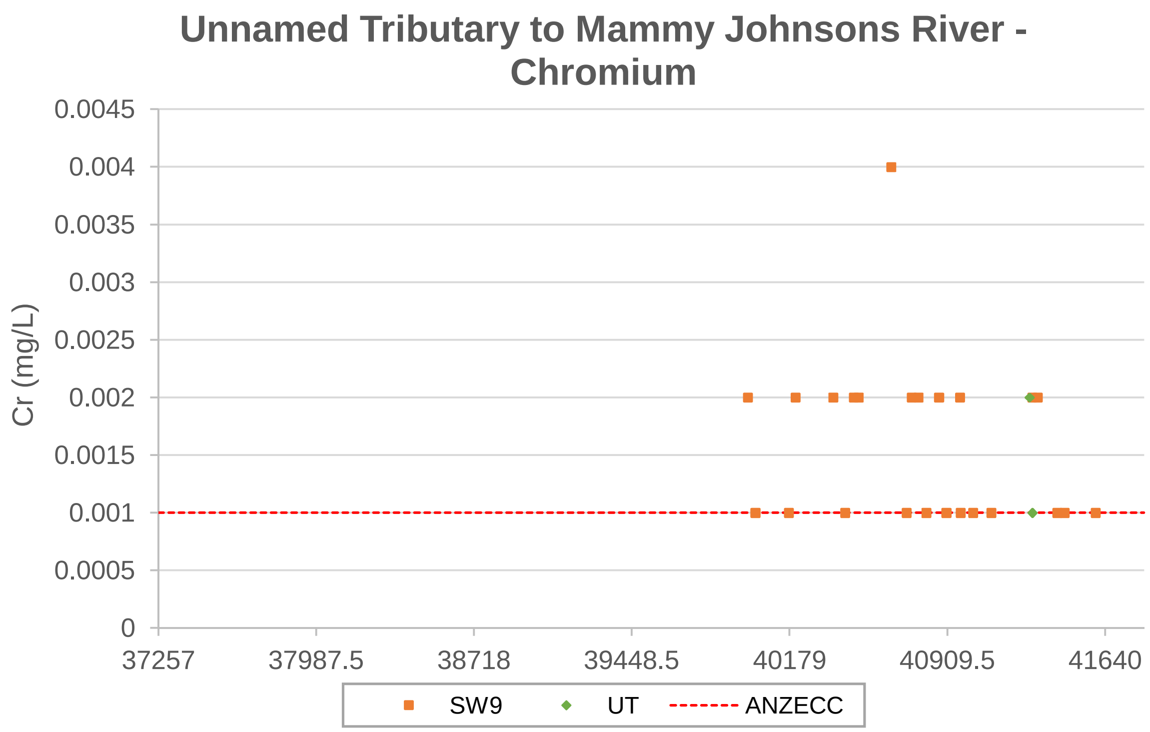
Table A-10
Summary of Chromium Monitoring Results

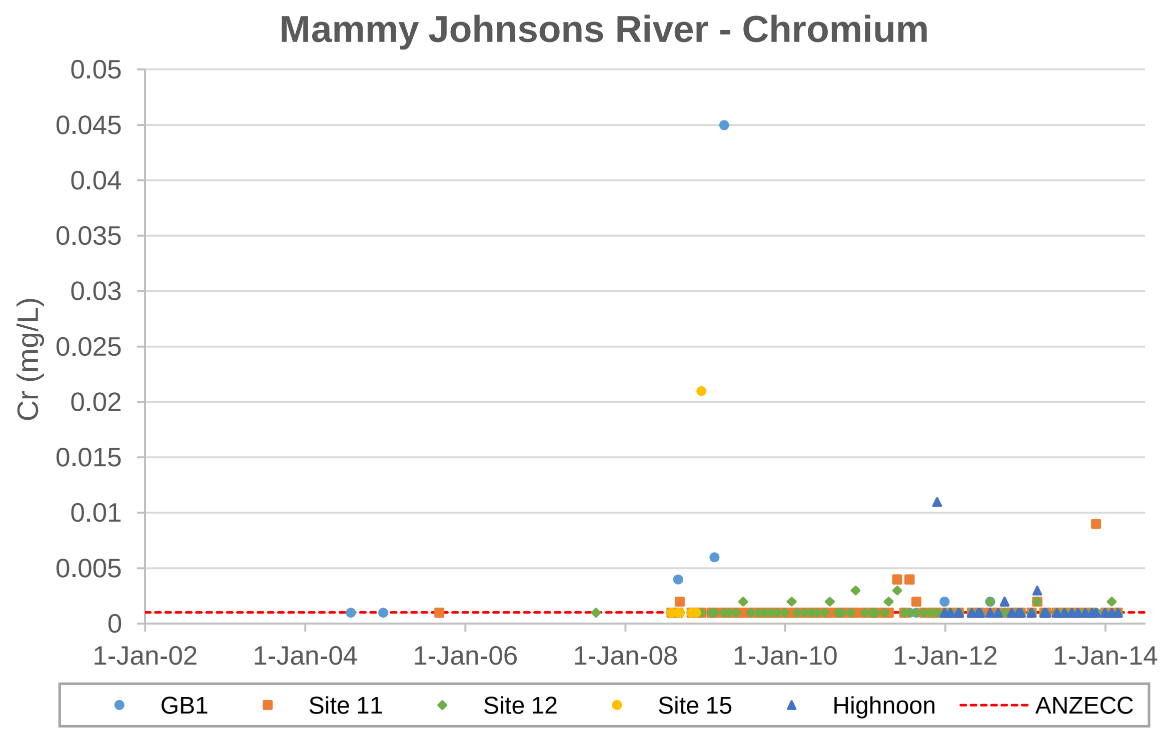
Site	No. of Samples	Minimum	Median	Maximum	Percentage Exceedance (%)
SW2 (RC)	52	<0.001	0.001	0.010	26.9
Unnamed Tributary	3	0.001	0.001	0.002	33.3
GB1	71	<0.001	0.001	0.045	9.9
Highnoon	28	<0.001	0.001	0.011	10.7



Chromium Monitoring Results (Continued)

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).





Attachment B
Irrigation Area Management Review

Irrigation Area Management Review

Duralie Coal Mine (ML1427 & 1646), Bucketts Way, GLOUCESTER NSW

Prepared for

Duralie Coal Pty Ltd

Project J000037

HORIZON SOIL SURVEY

Document History

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Duralie Coal Mine, ML1427 & 1646, Bucketts Way, Gloucester, NSW

Local Authority: Gloucester Shire Council

Proponent: Duralie Coal Pty Ltd

1. Introduction

The Duralie Coal Mine (DCM) is located approximately 10 kilometres (km) north of the village of Stroud and approximately 20 km south of Stratford in the Gloucester Valley in New South Wales (NSW). Duralie Coal Pty Ltd (DCPL) is the owner and operator of the DCM. DCPL is a wholly owned subsidiary of Yancoal Australia.

This Irrigation Area Management Review for the Duralie Open Pit Modification (the Modification) has been prepared to support an application to modify the Project Approval (08_0203) under Section 75W of the NSW *Environmental Planning and Assessment Act 1979*.

To reflect the results of ongoing mine exploration and mine planning, the following changes to the currently approved DCM are proposed for the Modification:

- Increase in the maximum depth of the Clareval open pit.
- A minor increase in the extent of surface development of the DCM of approximately 2.5 hectares (ha), resulting from:
  - a reduction in low wall angles of the Clareval open pit and the removal of a pillar between the Clareval and Weismantel open pits to improve geotechnical stability; and
  - associated relocation of the upstream diversion to the west of the Clareval open pit.
- Revised mining sequence (i.e. progression of mining in the Clareval and Weismantel open pits).
- Increased height of the central portion of the waste emplacement (i.e. the backfilled open pit) from the currently approved elevation of approximately 110 metres Australian Height Datum (m AHD) to approximately 135 m AHD.

The Modification would result in no change to the following elements of the currently approved DCM relevant to the Irrigation Area Management Review:

- Mine life.
- Use of irrigation areas for the disposal of excess water.
- First flush protocol and controlled release of water in accordance with the concentration limits of Environment Protection Licence 11701.
- Waste rock geochemistry management measures.
- Rehabilitation of surface disturbance areas.

The scope of the Irrigation Area Management Review is to (based on our proposal dated the 16 May 2014):

- summarise the existing irrigation system
- summarise existing irrigation water quality and irrigation area monitoring results
- review potential irrigation impacts associated with ongoing irrigation (assuming the current irrigation water chemistry & simulated salinity from the updated mine water balance)
- review existing irrigation area management measures and monitoring program.

2. Duralie Coal Mine Irrigation System

Excess water within the DCM water management system is stored in the Main Water Dam (**MWD**) prior to disposal through an on-site irrigation system. Details of the irrigation system and its management are provided in the Irrigation Management Plan (**IMP**) (DCPL, 2013a).

2.1 Irrigation areas

The five types of irrigation area delineated in the **IMP** are:

- *Type I* – Irrigation areas between the **MWD** diversions and the water storage inundation area of the **MWD**. Heavily irrigated area that drains to the **MWD**.
- *Type II* – Irrigation areas located upslope of the **MWD** diversions within Mining Lease (ML) 1427. A first flush containment protocol diverts saline drainage to the **MWD**.
- *Type III* – Irrigation areas located upslope of the northern extent of the open pits, including the upper reaches of Coal Shaft Creek. A first flush containment protocol would divert saline drainage from the Northern Diversion Dam to the **MWD**.
- *Type IV* – Irrigation areas located on partially rehabilitated and rehabilitated areas of the waste rock emplacement. A first flush containment protocol diverts saline drainage from rehabilitated waste rock emplacement areas from collection dams to the **MWD**.
- *Type V* – Irrigation areas located on inactive (but not yet top-soiled or rehabilitated) areas of waste rock emplacement. Drainage from waste rock emplacement areas that haven't been rehabilitated returns to the open pit.

Fixed sprays, travelling irrigators and evaporators are used to irrigate water from the **MWD** at the DCM.

Type III irrigation areas have not been commissioned at the **DCM** to date (DCPL, 2013a). **Figure 1** shows the existing and approved irrigation areas at the **DCM**.

Land use in the irrigation areas is a mixture of pasture and woodland with the exception of *Type IV and V* irrigation areas on waste rock emplacements.

Woodlands include the following species: Spotted Gum (*Corymbia maculata*), Narrow-leaved Ironbark (*Eucalyptus crebra*), Thin-leaved Stringybark (*Eucalyptus eugenioides*), Red Ironbark (*Eucalyptus fibrosa*), White Stringybark (*Eucalyptus globoidea*), Hill Banksia (*Banksia spinulosa*), Grey Box (*Eucalyptus molucanna*), Mugga Ironbark (*Eucalyptus siderophloia*) and Forest Red Gum (*Eucalyptus tereticornis*) (Cenwest Environmental Services and Resource Strategies 2010).

The major native grass species present within the DCM area are Blady Grass (*Imperata cylindrica var. major*), Kangaroo grass (*Themeda australis*), *Aristida sp.*, Common couch (*Cynodon dactylon*), Tufted hedgehog grass (*Echinopogon caespitosus var. caespitosus*) and Wiry Panic (*Entolasia stricta*). Giant Parramatta Grass (*Sporobolus fertilis*) is a significant weed species (Cenwest Environmental Services and Resource Strategies 2010).

2.2 Irrigation management

In accordance with the **IMP**, the irrigation system is operated to maximise evapotranspiration and plant growth and to avoid surface runoff, due to irrigation. Irrigation water is applied to maintain a 10 millimetres (mm) soil moisture deficit before, during and immediately following irrigation application. Soil moisture deficit is measured using soil moisture sensors. The irrigation system is operated such that soil moisture levels are maintained below field capacity to ensure that saturation only occurs during rainfall (DCPL, 2013a).

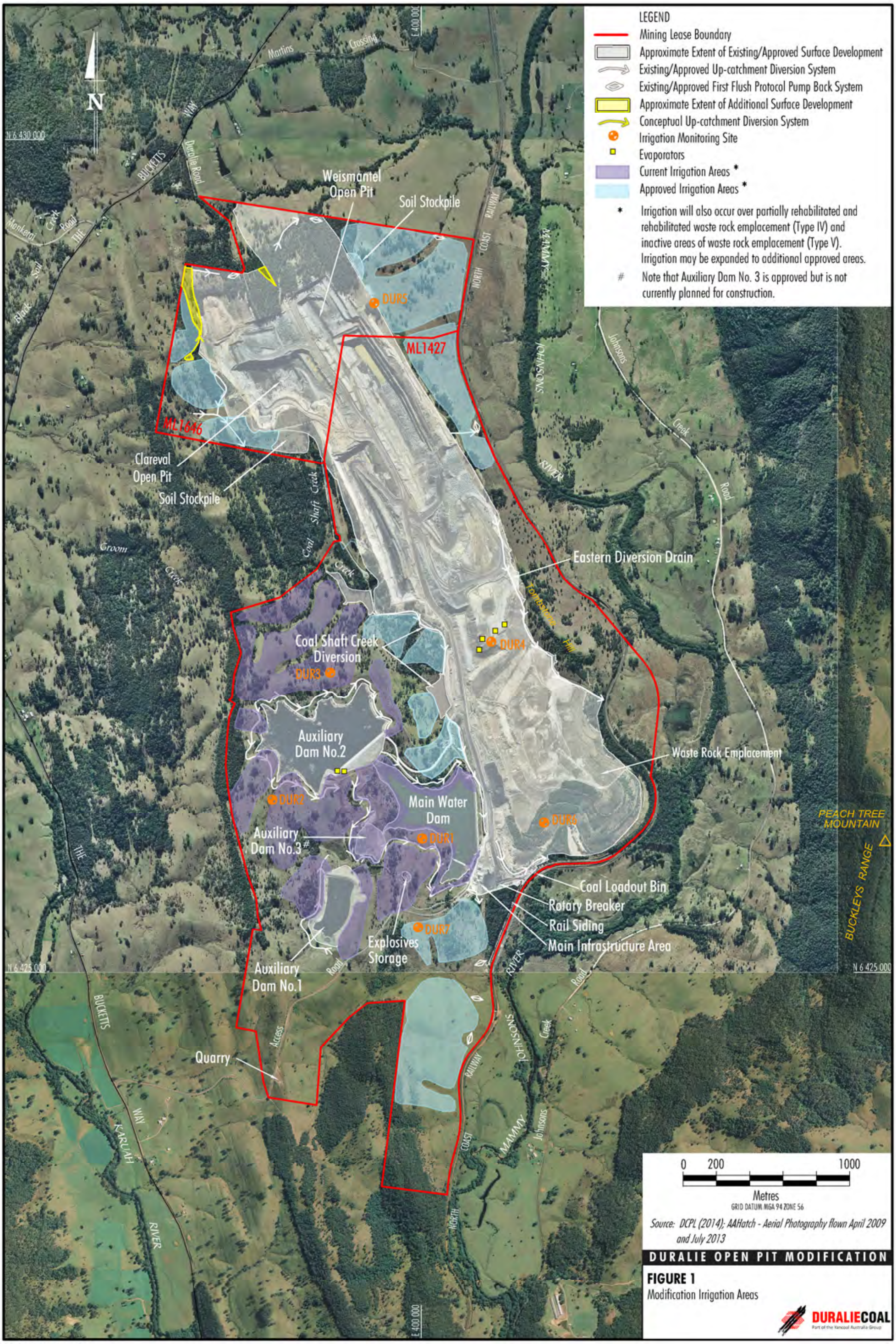

FIGURE 1
Modification Irrigation Areas

GCL-14-23_Mod 2_IR_101A

Irrigation system operation since 2010 that was documented in a spreadsheet provided by DCPL (Duralie Irrigation Run Times & Volumes 2010 to present.xls) is summarised in **Table 1**. Irrigation was mainly applied during the summer months when evaporative demand was increased. Irrigation rates were 3 to 10% higher than summer potential evaporation rates and which provides for leaching of salts below the root zone.

Table 1 Irrigation system operation (Type I 2.8ha, and II 55.7 ha totalling 58.5 ha)

Statistic	*2010*	*2011*	*2012*	*2013*	*2014*	*Average*
Total mm	594	591	543	828	325	576
Irrigation days	220	86	125	145	44	124
mm/d	3	7	4	6	7	5

Note:

mm/d = millimetres per day.

The Surface Water Management Plan (**SWMP) (DCPL, 2013b)** has environmental performance indicators for investigating potential adverse impacts to mitigate against significant impact to soil properties, or suitability of soil in irrigated pasture areas for future agricultural use (i.e. grazing on native pasture). The irrigation performance indicators for investigating potential adverse impacts in Section 9 of **SWMP** include (DCPL, 2013b):

- **MWD** water:
  - pH between 6.0 and 8.5.
  - electrical conductivity (EC) greater than 2.5 deciSiemens per metre (dS/m)[1].
  - residual sodium carbonate (RSC) greater than 1.5 milliequivalents per litre (meq/L).
  - sodium adsorption ration (SAR) greater than 6.0.
- Irrigation areas:
  - soil pH between 5.5 and 7.5.
  - soil EC increases above 2.5 dS/m.
  - soil SAR greater than 6.0.
  - leaf scorching.

3. Irrigation Water Monitoring

A summary of sodicity (SAR), salinity (EC) and pH monitoring for the **MWD** (SW3) since 2011 is provided in **Table 2**. As water collected in the open pits is the dominant input to the **MWD** water, salinity (EC) and pH monitoring from the Weismantel and Clareval open pits is also summarised in **Table 2**.

The average salinity in the **MWD** increased from 2.5 dS/m to 4.0 dS/m between 2010 and 2014. The average salinity increased from 3.3 dS/m to 4.0 dS/m between 2013 and 2014. The pH in the **MWD** has remained neutral at approximately 7.6. Average sodicity (SAR) increased from 1.9 in 2011 to 5.7 in 2014. The maximum sodicity in the **MWD** increased from 2.2 to 5.8 from 2011 to 2014.

[1] 1 dS/m = 1,000 microSiemens/centimetre.

Table 2 Summary statistics of sodicity (SAR), salinity (EC) and pH in the MWD and open pits from 2011-2014

Storage/Analyte	*Statistic*	*2011*	*2012*	*2013*	*2014*
		MWD (SW3)			
SAR	Mean	1.9	2.2	4.9	5.7
	Median	1.9	2.2	5.4	5.7
	Minimum	1.7	2.1	2.1	5.6
	Maximum	2.2	2.4	6.1	5.8
EC (dS/m)	Mean	2.1	2.6	3.3	4.0
	Median	2.1	2.6	3.2	4.0
	Minimum	1.9	2.2	2.7	4.0
	Maximum	2.5	2.8	3.9	4.0
pH	Mean	7.6	7.7	7.5	7.6
	Median	7.6	7.8	7.4	7.6
	Minimum	7.0	7.0	6.9	7.6
	Maximum	8.4	8.3	8.0	7.6
	N	12	12	12	2
		Weismantel Open Pit (SW4)			
EC (dS/m)	Mean	3.7	4.3	4.1	
	Minimum	2.4	3.7	2.9	
	Maximum	4.6	4.7	4.7	
pH	Mean	6.4	6.6	6.3	
	Median	6.5	6.5	6.5	
	Minimum	5.0	6.2	3.2	
	Maximum	7.2	7.7	7.0	
	N	36	22	17	0
		Clareval Open Pit			
EC (dS/m)	Mean	3.3	3.7	3.9	3.9
	Minimum	0.6	2.1	2.3	3.1
	Maximum	4.4	4.9	5.4	4.6
pH	Mean	6.7	7.0	6.7	7.1
	Minimum	3.2	3.3	2.7	6.9
	Maximum	7.7	8.2	8.0	7.2
	N	18	26	27	4

The average salinity in the Weismantel open pit increased from 3.7 dS/m to 4.1 dS/m between 2011 and 2014, while average salinity in the Clareval open pit varied between 3.3 and 3.9 dS/m. The pH in the Weismantel open pit water was more variable (range 3.2 to 7.0) in 2013 than in previous years. The pH in the Clareval open pit was highly variable (e.g. 2.7 to 8.0 in 2013) in most years.

There was a steadily increasing salinity (EC) trend associated with increasing calcium (Ca), sulfate (SO_4), and sodium (Na) concentrations in the **MWD** (**Figure 2**). Major ion profiles (**Figure 3**) show SO_4 and Ca activities increasing proportionally more than other ions in solution.

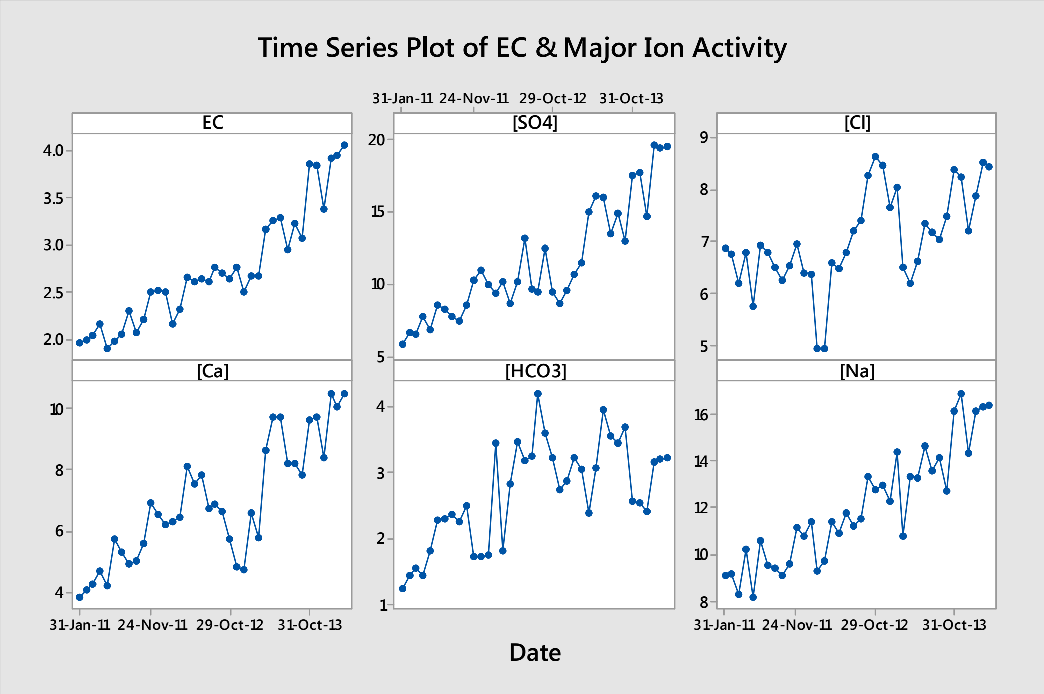

Figure 2 Time series graphs of salinity (EC dS/m) and major ions in the MWD

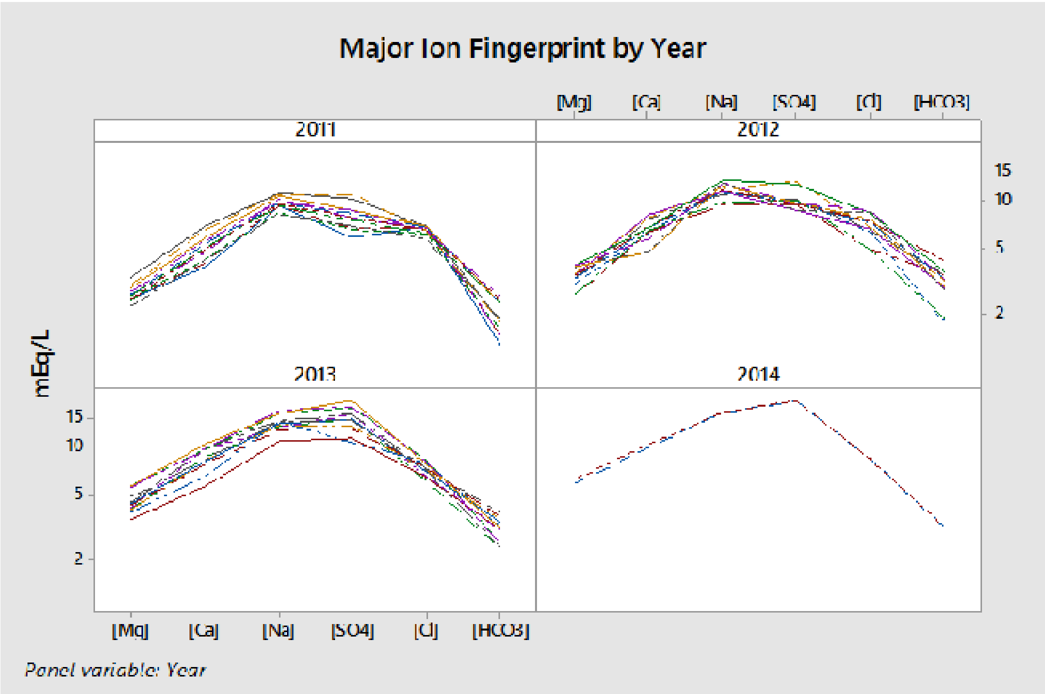

Figure 3 Major ion composition in the MWD fingerprint diagrams by year

The average salinity in the **MWD** has exceeded the **SWMP** irrigation performance indicator for investigating potential adverse impacts (**Section 2.2**) in 2013 and 2014. The maximum sodicity (SAR) monitoring result also exceeded the **SWMP** irrigation performance indicator for investigating potential adverse impacts (**Section 2.2**) in 2013. In accordance with the **SWMP**, an *assessment of performance measure* to determine whether there has been significant impact on soil properties, or to the suitability of soil in irrigated areas for future agricultural use (i.e. grazing on native pasture) has been conducted (**Section 4**).

4. Irrigation Area Monitoring

Annual irrigation area soil monitoring (*soil salinity, permeability and cumulative contaminant loading*) and irrigation area vegetation monitoring (*species composition, growth rates, grazing levels, harvesting, rotation of irrigation areas*) is conducted in accordance with the **SWMP**. The 2013 and 2014 monitoring rounds found there was no measurable impairment of agricultural land values associated with operation of the irrigation system (Hollingsworth, 2013, Hollingsworth, 2014).

Soil and vegetation conditions are monitored at five irrigation sites and at two reference sites (**Figure 1**) representing natural soil variation (**Table 3)**. Standards methods are used in the monitoring program (Muir, Schmidt, Tindall, Trevithick, Scarth and Stewart, 2011, NCST, 2009).

4.1 Soil chemistry

The soil reference site (*DUR7*) is located in a volcanic geological unit (Pea – alkaline, olivine basalt and albatite) to the west of the DCM (**Figure 1**). The soils formed on these parent materials have relatively high pH, cation exchange capacity (CEC) and fine texture (clay loam to light medium clay) in the surface.

Soil reference site *DUR5* has been established to represent soils formed on sedimentary rocks (Pldy – sedimentary sandstones and conglomerate) to the east of the DCM (**Figure 1**). The soils formed on these parent materials have relatively low pH, CEC and coarse texture (sandy clay loam) in the surface.

The surface soils (0 to 0.1 metres [m]) formed on volcanic rocks (Dermosols at sites *DUR1, DUR2, DUR3* and *DUR7)* were finer textured than those formed on sedimentary rocks (Kurosols and Anthroposols at sites *DUR4, DUR5* and *DUR6*). These differences in soil type and texture were associated with higher soil fertility parameters for soils of volcanic than sedimentary origin (**Table 4**).

The soil fertility parameters for surface soils (0 to 0.1 m) in irrigated pastures were similar in most respects to the background conditions at reference site *DUR7*. The irrigated pasture sites were located on volcanic rock derived soils. Relatively low soil fertility parameters at irrigated waste rock emplacement sites (*DUR4* – waste rock emplacement; *DUR6* – rehabilitated waste rock emplacement) were similar to the background conditions at reference site *DUR5*, formed on sedimentary geology.

Saturated soil extract salinity (EC_{se}) under irrigation (for both waste rock emplacements and pastures) was elevated by an order of magnitude above background (reference sites). However, soil salinity did not exceed levels expected to reduce pasture productivity.

There is no evidence in **Table 4** that exchangeable sodium percentage (ESP) has increased under irrigation. There was no increase in a field measurement of soil dispersibility under irrigation. Total soil nitrogen (N) concentration appeared to increase under irrigation and this was associated with higher organic carbon concentrations rather than dissolved sources of N.

Table 3 Survey site classification

Site	Irrigation Area Type	Land use	Soil classification
DUR1	I	Improved pasture	**Soil map unit:** Stroud Road **ASC:** Haplic Massive Black Vertosol, slightly gravelly medium fine medium fine deep **Principal Profile Form:** Um4.2 **Great Soil Group:** Black earth **Land class:** V
DUR2	II	Improved pasture	**Soil map unit:** Stroud Road **ASC:** Humose Mesotrophic Black Dermosol, thick moderately gravelly clay-loamy clayey deep **Principal Profile Form:** Ug5.13 **Great Soil Group:** Black earth **Land class:** V
DUR3	III		**Soil map unit:** Stroud Road **ASC:** Humose Mesotrophic Black Dermosol, thick moderately gravelly clay-loamy clayey deep **Principal Profile Form:** Gn2.24 **Great Soil Group:** Black earth **Land class:** V
DUR4	V	Waste rock emplacement	**Soil map unit:** Gloucester River **ASC:** Spolic Anthroposol Thin Moderately gravelly Loamy Loamy Thin **Principal Profile Form:** U **Land class:** VII
DUR5	reference	Improved pasture	**Soil map unit:** Gloucester River **ASC:** Humose Mesotrophic Grey Kurosol Thick Moderately gravelly **Principal Profile Form:** Dg4 **Great Soil Group:** Gleyed Podzolic **Land class:** V
DUR6	IV	Rehabilitated waste rock emplacement	**Soil map unit:** Gloucester River **ASC:** Spolic Anthroposol Thin Moderately gravelly Clay-loamy Clayey Deep **Principal Profile Form:** U **Great Soil Group:** Gleyed Podzolic **Land class:** VII
DUR7	reference	Native pasture	**Soil map unit:** Stroud Road **ASC:** Humose Mesotrophic Black Dermosol, thick moderately gravelly clay-loamy clayey deep **Principal Profile Form:** Ug5.13 **Great Soil Group:** Black earth **Land class:** V

Table 4 Soil (0-10 centimetres) chemistry by geology, soil type and land use

	Reference sites				*Irrigation areas*			
	Volcanic rocks		Sedimentary rocks		Volcanic rocks I II & III		Sedimentary rocks IV & V	
	Dermosols (Site DUR7)		Kurasols (Site DUR5)		Pasture (Sites DUR1-3)		Waste rock (Sites DUR4 & 6)	
Analyte	2013	2014	2013	2014	2013	2014	2013	2014
pH	6	6	6	5	6-7	6	5-6	4-5
$EC_{1:5}$ (dS/m)	0.02	0.03	0.03	0.02	0.2-0.4	0.3	0.03-2	0.02-3
EC_{se} (dS/m)[1]	0.03	0.03	0.03	0.02	0.2-0.6	0.4-0.5	0.03-1.7	0.02-5
CEC (cmol(+)/kg)	27	22	5.5	4.0	10-30	10-20	10-13	13-14
CCR[2] ccmol(+)/kg clay	0.5	0.5	0.2	0.2	0.5	0.5	0.9	0.9
ESP (%)	0.6	2	1.2	2	0.4-1.9	2-2.5	0.6-1.0	0.6-0.7
Ca/Mg	2	2	2	2	3	3	3-15	5-9
Organic C (%)	5.2	3	4.2	2	4-5	3	n.d.-4.6	n.d.
N (%)	0.26	0.17	1.61	0.11	0.2-0.9	0.2-0.3	0.2-0.6	0.01-0.04
Tot.P (mg/kg)	400	300	250	100	150-700	150-170	100-140	30-80
Ext.P (mg/kg)	6		20	4	n.d.-20	10	n.d.-3	n.d.-5
Ext.K (mg/kg)	n.d.	n.d.	n.d.	n.d.	n.d.-500	n.d.	n.d.	n.d.
Trace elements								
Cu (mg/kg).	2	1	n.d.	n.d.	n.d.-2	n.d.-1	n.d.	n.d.
Fe (mg/kg).	100	150	220	140	100-200	100-200	100	70-90
Mn (mg/kg).	20	12	50	3	30-50	10	10-50	10-50
Zn (mg/kg).	n.d.	2	4	1	2-3	2	n.d.-2	1-10

Note:

[1] EC_{se} calculated from $EC_{1:5}$ accounting for anions other than Cl and clay content using relationships in Table 8.1 in Shaw (1999).

[2] CCR: CEC/clay ratio, measure of clay mineralogy for sodicity soil stability assessment.

cmol/kg = centimol per kilogram.

C = carbon.

P = phosphorous.

K = potassium.

Cu = copper.

Fe = iron.

Mn = manganese.

Zn = zinc.

mg/kg = milligrams per kilogram.

The ranges in screened metal and metalloid contaminants that occurred at measurable levels are presented in **Table 5.** There is no clear evidence that the concentrations of these elements has increased. When there are four repeated annual monitoring measurements then trends may be able to be discriminated using control charts (ANZECC&ARMCANZ, 2000).

Table 5 Soil metals & metalloids properties by soil type and land use

Analyte	*Reference sites*				*Irrigation area land use*			
	Volcanic rocks		Sedimentary rocks					
	Dermosols (Site DUR7)		Kurasols (Site DUR5)		Pasture (Sites DUR1-3)		Waste rock (Sites DUR4 & 6)	
	2013	2014	2013	2014	2013	2014	2013	2014
Metals and metalloids (Total.)								
As	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.-16	n.d.-10	n.d.-6
Ba	130		70	60	40-130	130	60-80	30-50
Be	1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cd	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cr	40	40	5	8	n.d.-60	2-30	8	8-10
Co	60	55	6	6	n.d.-60	n.d.-24	5-10	4-6
Cu (mg/kg)	27	25	5	n.d.	5-31	n.d.-16	5-10	6-9
Pb (mg/kg)	6	6	7	11	6-8	9-11	8-11	8-9
Mn (mg/kg)	2660	2310	125	148	30-250	100-540	170-290	110-260
Ni (mg/kg)	15	15	5	5	210-220	2-10	5-10	5-10
Se (mg/kg)	-	n.d.	-	n.d.	-	n.d.	-	n.d.
Va (mg/kg)	240	260	36	48	8-220	10-260	20-35	15-25
Zn (mg/kg)	60	60	10	10	7-55	15-30	20-50	30-40

4.2 Soil salinity and sodicity

Salinity profiles were higher at the surface under irrigation at sites DUR1 and DUR2 and at depth at reference sites DUR5 and DUR7 **(Figure 4**). Elevated surface salinity reflects saline irrigation inputs. Cl is a conservative tracer and profiles indicate the amount of input water (rainfall + irrigation) relative to drainage below the root zone.

Bulges in the Cl profiles identify the depth of the solute front under irrigation. The Cl profile bulge for irrigated sites (DUR1 irrigation area Type I and DUR2 irrigation area Type II) in **Figure 4** identify a solute front at approximately 0.3 m depth. The Cl profiles steadily decline below this depth. This pattern of relatively high Cl concentration near the soil surface and tapering chloride profiles with depth contrasted with the appropriate reference site DUR7.

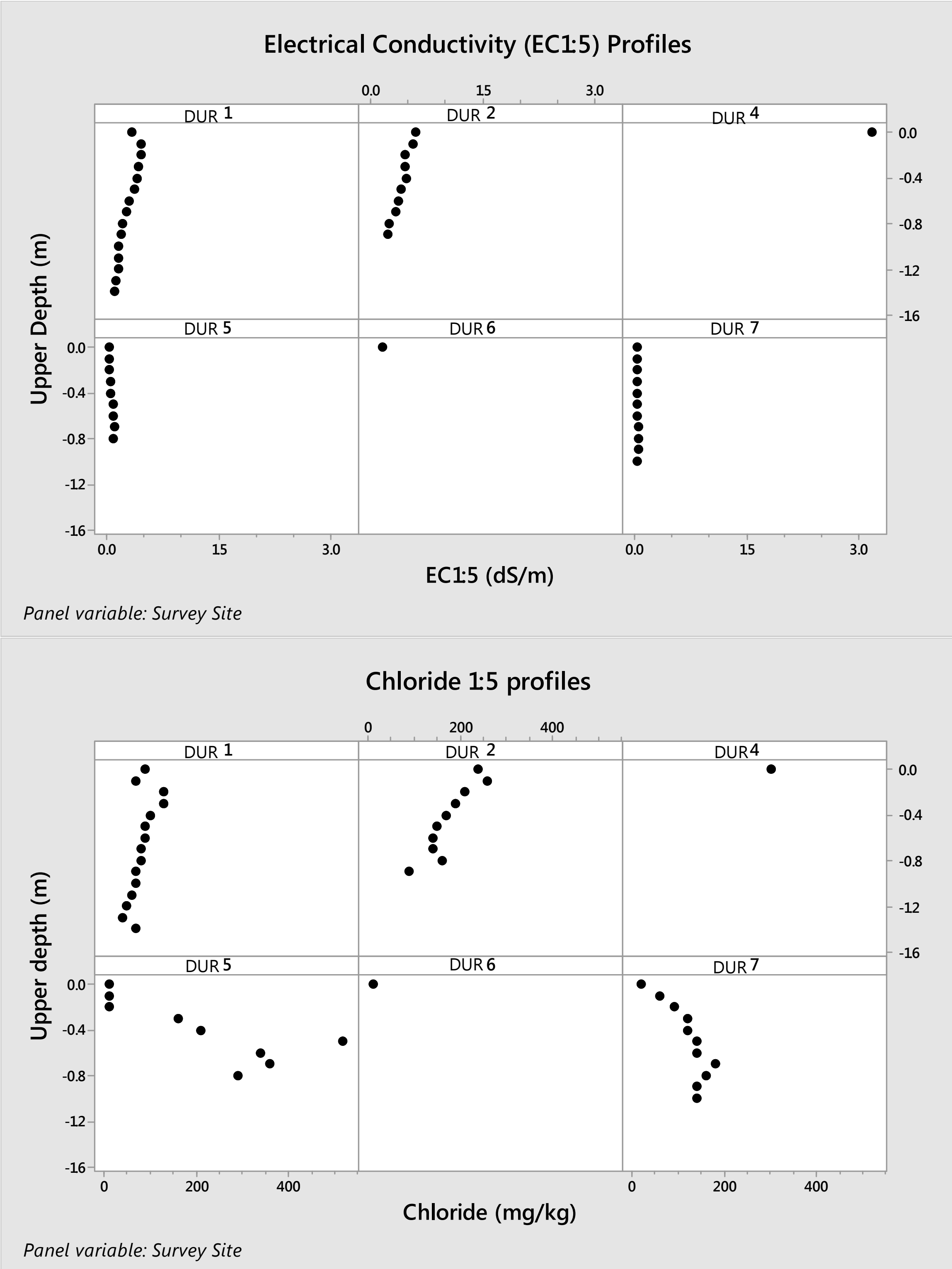

Figure 4 Soil electrical conductivity and chloride profiles at each site

The Cl profile at the reference site, DUR7, for these soils increased steadily to 0.3 m depth (20 to 120 milligrams per kilogram [mg/kg] Cl) and was relatively constant below this depth. The pattern of increasing Cl concentration is consistent with soil evaporation and plant root water extraction from pasture to 0.3 m and little root water extraction leading to further concentration of Cl in the soil water solution below this depth.

Cl at the base of irrigated profiles DUR1 and DUR2 was 50 and 100 mg/kg, which was lower than the reference site (DUR7) 140 mg/kg. This indicates a greater proportion of input water leaching from the root zone at the irrigated sites and augmented input with sources other than rainfall, such as groundwater interflow.

Throughflow (a component of interflow groundwater) was observed during the 2013 survey campaign at these sites (Hollingsworth, 2013). Interflow is likely to be a significant component of the water balance on footslopes of rolling hills — the landscape position at the irrigated sites. The reference site is on a hill slope where augmented water input from interflow is likely to be less significant.

Soil salinity levels in the irrigation area profiles were less than 0.5 dS/m. Relatively high EC of 3 dS/m on waste rock under the evaporators (DUR4 in **Figure 4**) reflected the higher salinity under the evaporators.

4.3 Soil permeability

Soil permeability measurements (**Table 6**) indicate that the profiles in the irrigation areas are moderately permeable although saturated conditions can persist in the winter.

Table 6 Soil permeability measurements

Soil type	*Site*	*Saturated hydraulic conductivity (Ksat) (m/day)*				
		Rep1	**Rep2**	**Rep3**	**Mean**	**SD**
Stroud	DUR1	8.4	0.5	0.5	3.1	3.7
Road	DUR2	0	0	0	0	0
	DUR3	n.s.	n.s.	n.s.	n.s.	n.s.
	DUR4	0.3	1.0	0.5	0.5	0.3
Gloucester	DUR5	0.1	1.9	0.2	0.7	0.8
River	DUR6	31	22	5.0	19	11
	DUR7	0.5	70	1.7	24	32

Note:

n.s. – not sampled

4.4 Salt balance

Leaching fractions (**LF**) at the base of the sampled soil profiles were calculated from soil chloride profiles in **Figure 4** using **Equation 1**.

$$LF = \frac{EC_i}{EC_d} = \frac{D_d}{D_i} = \frac{Cl_i}{Cl_d} \qquad \textbf{Equation 1}$$

where *i* is input and *d* is drainage.

Using **Equation 2**, soil $EC_{1:5}$ was converted to EC_{se} to assess salinity impact for low tolerance pastures (1.9 dS/m in **Table 8**).

We used published (Shaw, 1999) conversion to estimate EC_{se} and in the salt balance and to calculate **LF**.

$$EC_{se} = EC_{1:5}\left(\frac{500+6ADMC}{SP}\right)^b \qquad \textbf{Equation 2}$$

Air dry moisture content (ADMC) and saturation percentage (SP) were estimated from the CEC using published linear relationships in Shaw (1999) Table 8.1. The exponent, *b*, relates to the proportion of soluble chloride salts in relation to $EC_{1:5}$.

$$\boldsymbol{b = \frac{EC_{1:5}}{EC_{Cl}} = 6.64.Cl\%} \qquad \textbf{Equation 3}$$

The **LF** or deep drainage at the base of the sampled soil profiles under irrigation was calculated from salinity profiles using a mass balance approach (Department of Natural Resources, 1997).

$$\boldsymbol{LF = \frac{EC_i}{EC_d} = \frac{D_d}{D_i} = \frac{Cl_i}{Cl_d}} \qquad \textbf{Equation 4}$$

where *i* is input and *d* is drainage. Using **Equation 2**, soil $EC_{1:5}$ was converted to EC_{se} to assess salinity impact for low tolerance pastures, 1.9 dS/m (Shaw, 1999). EC_i was calculated from the weighted average of rainfall plus irrigation, assuming under the **IMP** that all the irrigation water infiltrates and a runoff coefficient of 30% applied to rainfall.

The **LF** results for reference and irrigated monitoring sites are summarised in **Table 7**. The solute peak under irrigation had moved to approximately 0.3 m depth (**Figure 4**). **LF**s were estimated at the base of the soil profiles. The **LF** at irrigated monitoring sites was higher than one indicating a throughflow water balance component in addition to rainfall and irrigation at these footslope locations. The **LF** at the reference sites (on hillslopes) was less than one consistent with evaporative concentration of Cl from rainfall with depth in the soil profile.

Table 7 Salt balance

Analyte	*Reference*		*Irrigated*	
	Dermosols Site DUR7	**Kurasols Site DUR5**	**Type I Site DUR1**	**Type II Site DUR2**
EC_{se} (dS/m)	0.03	0.02	0.4	0.5
EC_{iw} (dS/m)	0.03	0.03	1.8[2]	1.8[2]
Cl_i (mg/kg)	15[1]	15[1]	110[2]	110[2]
Cl_d (mg/kg)	90[3]	160[3]	130[3]	210[3]
LF (Cl_i/Cl_d)	0.15	0.1	1.3	2.7
D_i (mm)	740[4]	740[4]	1320[5]	1320[5]
D_d[6] (mm)	110	74	1720	3560

Note:

[1] Published rainfall (Shaw and Thorburn, 1985).

[2] Weighted average of rainfall and irrigation water

[3] Measured at base of profile

[4] 1050mm rainfall x 0.3 runoff coefficient = 740mm infiltration.

[5] 580 mm irrigation (see Table 1) + 740 mm rainfall = 1320 mm.

[6] $D_d = D_i$*LF.

4.5 Vegetation

The summary of vegetation cover and condition, according to the type of irrigation area with grazing and irrigation pressure is presented in **Table 8**. There were high levels of vegetated cover for the irrigated pastures and reference sites. Grazing pressure rather than irrigated land use appeared to affect biomass at the pasture monitoring sites. Grazing pressure has varied between nil (*Type I* management area, high irrigation pressure) and moderate (*Type II* management area, moderate irrigation pressure).

Table 8 Vegetation cover summary

Irrigation management	*Ref. site*	*Type I*	*Type II*	*Ref. site*	*Type IV*
Site	**DUR7**	**DUR1**	**DUR2**	**DUR5**	**DUR6**
Cover and species composition	**2014**	**2014**	**2014**	**2014**	**2014**
Estimated biomass (kg/ha)	2550	4250	2550	4250	4250
Vegetation cover	100%	100%	100%	100%	83%
Kangaroo grass	52%	21%	27%	13%	
Cocksfoot		57%	19%	11%	
Parramatta grass		6%		2%	
Lambs tongue		2%	6%	68%	
Paspalum		5%	6%	2%	
Sedge		3%	25%		
Imperata	22%		3%		
Purpletop				3%	
Hedgehog grass	2%		10%		
Aristida	3%			2%	
Barbed wire grass	6%				
Weeping grass	5%		3%		
Whisky grass	5%				
Rhodes grass	5%				92%
Rock					17%
Midstorey cover					
Overstorey cover					44%
Acacia irrorata					44%
Callitris sp.					2%
Pasture height (m)	1	1	0.5	1	1
Grazing summary	nil	nil	light	nil	nil

Note:
kg/ha = kilograms per hectare.

5. Existing Irrigation Impacts

5.1 Irrigation water

A detailed summary of irrigation water quality monitoring results at the **DCM** is provided in **Section 3**. An increase in salinity and sodicity of the irrigation water has been observed since March 2013. This water quality is not currently a risk to soils or plant growth in the irrigation areas at the DCM (**Section 5.2**).

5.2 Irrigation area

Although surface soil salinity measured on a 1:5 soil:water extract is higher by an order of magnitude in irrigation areas than reference site conditions, this does not translate directly into salinity impact on the pasture. The dominance of Ca and SO_4 in the irrigation water chemistry moderates the more serious salinity effects on soil structure and plant growth that would occur from increasing Na and Cl.

The estimated salinity of the EC_{se} was less than 0.6 dS/m and would need to increase three fold before guidelines for salinity impact (1.9 dS/m) were exceeded. Salinity levels that may reduce pasture productivity have not been reached except under evaporators on irrigated waste rock emplacement (*Type V*).

The sodicity of the irrigated soils has not increased. The low sodicity (SAR) of the irrigation water (**Table 2**) explains the lack of detrimental effect from irrigation of saline water on soil sodicity.

Metal and metalloid concentrations in the **MWD** were too low, apart from Al, to warrant site-based risk assessment of cumulative contaminant loading limit in the irrigation management system. Al load is not soluble at circumneutral pH and has no detrimental effect on pasture production. The applied Al may already be in a fine particulate form (fine enough to pass the field filtering <0.45 µm). We have not reviewed field filtering protocols in the water sampling and laboratory analysis procedures to verify the cause of elevated Al.

Major nutrient and micronutrient levels are relatively low, especially in the waste rock emplacement and the soils formed on sedimentary parent materials. Fertility monitoring and fertiliser application may increase pasture production and consequently pasture water use. Irrigation at the DCM may have however increased surface soil organic matter content, soil organic carbon and soil nitrogen levels by encouraging pasture growth during periods of natural water stress.

Measured surface soil hydraulic conductivity was moderate to high across all of the soils that were tested. Although the land has been extensively cleared for pasture for a long period of time and this may have led to loss of subsoil porosity. Rejuvenating pastures with deep ripping along the contour could increase infiltration, deep drainage and the fraction of irrigation water leaching salts out of the root zone.

The salt balance (**Table 7**) for *Type I* (DUR1) and *Type II* (DUR2) irrigation sites indicated that the leaching fraction of applied water was higher than the reference sites. The irrigated sites are located on lower slopes while the reference sites are on mid to upper slopes. In addition to vertical drainage there is significant lateral groundwater movement as interflow in the lower slope areas that could account for **LF** values higher than one in irrigated pasture areas.

High levels of vegetated cover observed in the irrigated pastures and reference sites (Section 4.5) indicated that irrigation has not significantly impaired pasture growth. The pasture vegetation in *Type I* and a minor part of *Type II* irrigation areas is vigorous due to low grazing pressure. Increasing the higher grazing pressure or slashing these areas may increase dry matter production and pasture water use.

6. Ongoing Irrigation Impacts and the Modification

Management of the existing irrigation system at the DCM is generally consistent with the **IMP** and appears to be sustainable based on irrigation monitoring results (**Sections 4 and 5**). The salinity and sodicity of the irrigation water has however been increasing since March 2013 (**Section 3**).

As the Modification does not propose any changes to the existing/approved irrigation system, this assessment of potential irrigation impacts focuses on the potential impacts associated with the changing irrigation water quality.

6.1 Irrigation water

Continued deterioration in the irrigation water quality may reduce the sustainability of the irrigation system. Increasing irrigation water salinity may be due to a combination of salt concentration under the evaporators on the waste rock emplacement in the Weismantel open pit and mineral weathering processes including any influence of lime application to manage potentially acid forming (**PAF**) material in the waste rock emplacement (Environmental Geochemistry International, 2011).

The observed larger increases in Ca^{2+} and SO_4^{2-} compared to other major ions in the irrigation water is consistent with mineral weathering processes including the influence of the lime application for **PAF** management. Otherwise, if enhanced evaporation from the use of the evaporators was solely responsible for salinity increases, then uniform increases in major ion activities, including Cl^- concentrations may be expected to have occurred.

Gilbert & Associates (2014) has prepared a **MWD** salt balance simulation for the Modification over median, unusually wet and unusually dry periods. The predicted maximum EC values under these weather conditions are:

- Median Rainfall Sequence: 3.4 dS/m.
- Wet (1/10 wet) Rainfall Sequence: 3.1 dS/m.
- Dry (1/10 dry) Rainfall Sequence: 3.8 dS/m.

The predicted irrigation water salinity has been considered in this assessment of potential irrigation impacts.

6.2 Irrigation area

The rates of water applied matched potential evapotranspiration rates plus a fraction for soil leaching. The irrigation management system does not appear to cause waterlogging or runoff. Soil hydraulic conductivity and sodicity are the dominant controls on leaching rates in clay soils and leaching requirements are strongly influenced by the salt concentration and sodicity of the irrigation water.

As described in Section 5.1, the current salinity and sodicity levels of the irrigation water are not currently a significant risk to soil degradation or plant growth in the irrigation areas. However, if the current increasing salinity trend continues the sustainability of the irrigation system may be reduced. A sustainable irrigation water salinity for a specified **LF** can be calculated as:

$$\boldsymbol{EC_{iw}} = \mathbf{2.2} \times (\boldsymbol{EC_{se} x LF}) \qquad \textbf{Equation 5}$$

where EC_{iw} is the weighted average of water inputs as rainfall and irrigation.

The maximum EC_{se} in the root zone was estimated as 0.4 to 0.5 dS/m (**Table 4**) with current irrigation water quality – approximately one third of the soil salinity guideline for moderately sensitive crops, i.e. 1.9 dS/m (Shaw, 1999). From **Table 7**, the **LF** for irrigated soils were estimated as 1.3 and 2.7 for irrigated sites DUR1 and DUR2 respectively. **LF** higher than one reflected water inputs from groundwater throughflow in the footslope locations at these sites. Based on these estimates average **LF** at the irrigated sites DUR1 and DUR2 was 2. Using these figures in **Equation 5,** $EC_{iw} = 2.2 \times (1.9 \times 2) = 8.4$ *dS/m*. Consequently, input water quality (rainfall + irrigation) may need to deteriorate from 1.8 dS/m (**Table 7**) to 8.4 dS/m before soil salinity would be a constraint to pasture growth.

Assuming that the amount of irrigation remains the same in proportion to infiltration (irrigation:infiltration, 580 mm/740 mm) and rainfall salinity is 0.03 dS/m (Shaw, 1999) then irrigation water salinity could rise above 8.4 dS/m before detrimental effects on pasture growth would be likely to occur. Consequently, irrigation area management may need to be reviewed if irrigation water salinities continue to increase above approximately 9 dS/m. Irrigation with water at a salinity of 9 dS/m and the current SAR (approximately 6) would not cause soil structural degradation. This sustainable irrigation water salinity is higher than the predicted irrigation water salinities predicted by Gilbert & Associates (2014).

Notwithstanding the above, land management intervention could be considered in the event that irrigation water salinity increases above 9 dS/m or salinity in the surface 0-100mm of soil increases above 1.9 dS/m. **LF** may be increased to ensure that salts are leached below the root zone. This can be achieved either through enhanced drainage or higher application or both, as irrigation water salinity increases. Managing the irrigation rate and soil permeability to increase the proportion of irrigation water leaching below the root zone (leaching fraction) may be used to maintain sustainable irrigation from the **MWD** at **DCM**.

High sodicity and salinity can reduce pasture productivity, and in extremity cause plant death. Physiological drought conditions result from excess salts accumulating in the soil and increasing the osmotic pressure of the soil solution. Plants can wilt due to insufficient water absorption by the roots compared to the amount lost from transpiration, even though the soil water content is in the plant available range of matric potentials. Sodicity degrades soil structure, causing dispersion leading to reduced infiltration, thereby reducing water supply and plant growth and increasing soil erodibility.

Na^+ and Cl^- dominate major ion chemistry in meteoric water (derived from evaporation and rainfall). Other ions such as SO_4^{2-} and Ca^{2+} may be dominant in connate water and drainage associated with pyrite weathering and carbonate neutralising reactions in weathering rocks in the waste rock emplacement and open pit. SO_4^{2-} has no major impact on the soil other than contributing to the total salt content. Irrigation with water high in sulfate ions reduces phosphorus availability to plants and high levels may acidify the soil.

At current or increasing salinity levels, irrigation water sodicity (SAR) would need to increase threefold to 15 before soil stability issues would occur. The major ion chemistry of the irrigation water makes it unlikely that further increases in salinity and sodicity would induce soil structural problems.

7. Irrigation Management Review

It is recommended that the management and monitoring of irrigation impacts at the **DCM** continue to be conducted in accordance with the **IMP**, including:

- Continued operation of the irrigation system such that soil moisture levels are maintained below field capacity such that saturation will only occur during rainfall. Under such conditions evapotranspiration and plant growth will be maximised and surface runoff, due to irrigation, will be avoided (Section 4 of the **IMP**).
- Soil characteristics (salinity, permeability, cumulative contaminant loading), irrigation area (signs of waterlogging and erosion), vegetation and irrigation water monitoring (Section 6 of the **IMP**).

We would question the pasture growth rate monitoring requirement in Section 6 of the **IMP**. Measuring pasture growth rates from an annual survey is neither practical nor relevant. Meaningful pasture growth rate measurements are made at a higher frequency to reflect changes in environmental growth factors, namely temperature, light and rainfall during the year, and enclosures to exclude grazing and manage harvesting are required. A monitoring program to describe pasture condition in terms of biomass, species mix and ground cover, is more achievable and relevant to assess impact on land use from irrigation with water from the **MWD**.

In addition to the above, it is also recommended that the following additional measures be undertaken for the Modification:

- An investigation be undertaken to confirm the cause of the consistent increase in irrigation water salinity so water management can be modified (if required) to prevent salinity increasing to levels likely to impair sustainable irrigation.
- In the event that the salinity of the irrigation water is likely to increase above 9 dS/m, or soil salinity (EC_{se}) increases above 1.9 dS/m in the surface soil, irrigation area management will need to be reviewed. In this situation, irrigation rate and soil permeability may need to be modified to increase the proportion of irrigation water leaching below the root zone (leaching fraction). Deep ripping may increase soil permeability and improve salt leaching. Revegetation or pasture improvement may improve water disposal by evapotranspiration
- Once the results from four annual monitoring campaigns are available, control charting to monitor soil chemistry against background or reference site conditions as presented in ANZECC & ARMCANZ monitoring guidelines (ANZECC & ARMCANZ, 2000) is a robust way to assess trend and sustainable land management.
- Modifying Section 6 of the **IMP** so that pasture condition monitoring rather than pasture growth rate monitoring is specified to support a practical and effective monitoring program.

8. Conclusions

Management of the existing irrigation system at the DCM is generally consistent with the **IMP** and appears to be sustainable based on irrigation monitoring results.

Soil salinity has increased in irrigation areas relative to the non-irrigated reference sites. The size of the increase is unlikely to cause measureable decrease in pasture productivity in the short or long term. However, the effect of irrigation with saline water from the **MWD** on pasture condition should continue to be monitored.

Soil permeabilities and application rates in the irrigation areas were adequate to maintain leaching of salts applied in irrigation out of the root zone. The soils are not dispersive. There may be a general lack of soil porosity to depth that promotes waterlogging. The lack of soil porosity at depth may be due to over-clearing for pasture.

There does not appear to be a detrimental effect on ground cover or pasture composition in the irrigated pastures compared with the non-irrigated reference sites.

As the Modification does not propose any changes to the existing/approved irrigation system, this assessment of potential irrigation impacts focused on the potential impacts associated with the changing irrigation water quality.

It is expected that predicted irrigation water salinities for the Modification (Gilbert & Associates 2014) would not cause soil structural degradation or plant growth in irrigation areas. Notwithstanding the above, in the event that the salinity of applied irrigation water increases above 9 dS/m, or soil salinity (EC_{se}) increases above 1.9 dS/m in the surface soil, deep ripping of the irrigation areas may improve salt leaching. However, the irrigated water supply from the **MWD** should be managed to prevent this situation developing.

The recommendations outlined in **Section 7** should be implemented for the Modification.

9. References

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10. Limitations

Horizon Environmental Soil Survey and Evaluation (HESSE) has prepared this report for a project at **DCM**, Gloucester, NSW in accordance with HESSE's proposal dated 16 May 2014 and Gloucester Coal Group of Companies Purchase Order 151236. The report is provided for the exclusive use of Gloucester Coal Group of Companies for this project only and for the purpose(s) described in the report. It should not be used for other projects. In preparing this report HESSE has necessarily relied upon information provided by the client and/or their agents.

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