REGIONAL WATER QUALITY IMPACT ASSESSMENT - ANGUS PLACE AND SPRINGVALE MINE EXTENSION PROJECTS

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EXECUTIVE SUMMARY

A daily water and salt balance model has been developed for the Coxs River and Wollondilly River catchments based on the Australian Water Balance Model (AWBM).

The objective of the model was a regional water quality impact assessment of proposed water strategies of the extensions at Angus Place Colliery and Springvale Mine within the Upper Coxs River on water quality and flow in the Coxs River and water quality and volume in Lake Burragorang.

The model was calibrated based on observed flow and salinity data within the Coxs River catchment during the period 1 January 1979 to 30 June 2014. Observation data comprised recent data from Centennial, flow and water quality data from NSW Office of Water gauging stations as well as historical water quality sampling from the period 1960 – 1992.

Modelling indicates that predicted salinity in the Coxs River between Lake Wallace and Lake Lyell will be elevated compared to the null condition, however, is well below historical observation. This is due to the closure of Wallerawang Power Station whom discharged Cooling Tower Blowdown to the Coxs River since its initial commissioning in 1957, until its closure in April 2014. Predicted salinity under the proposed water strategy is a median of 552mg/L compared to a median of 231mg/L in the null case, at the location, compared to historical average salinity of ~800mg/L. For the purpose of reference, the 95% ANZECC default trigger value for the protection of aquatic ecosystems is 235mg/L (assuming a 0.67 conversion factor on salinity, as Electrical Conductivity, of 350µS/cm).

The water quality model was constructed to encompass all catchments contributing to Lake Burragorang (Warragamba Dam). Modelling indicates the predicted salinity in Lake Burragorang will increase only slightly due to the proposal from a modelled median salinity of 85mg/L to a median salinity of 97mg/L. For the purpose of reference, the Australian Drinking Water Guideline (AWDG) is 600mg/L, based on aesthetics. The proposed water strategies have negligible impact on water volume in Lake Burragorang.

Water quality in Lake Burragorang is managed by the Sydney Catchment Authority to the ADWG for raw bulk water supply. The proposal meets this water quality standard. As well, there are site specific water quality characteristic requirements by Sydney Water for their Water Filtration Plant at Prospect. The proposal also meets these water quality requirements. The proposal therefore has a neutral impact to water quality since the predicted increase in salinity is small.

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1. Introduction

1.1 Purpose of this Report

This report was commissioned by Centennial Angus Place Pty Ltd (Angus Place) and Springvale Coal Pty Ltd (Springvale).

This work is a part of a package of works aimed at addressing queries arising from the public exhibition between 12 April 2014 and 26 May 2014 of the Environmental Impact Statements (EISs) of the proposed extensions of mining operations at Angus Place Colliery and Springvale Mine.

The objective of this report is to be a Technical Appendix to be used by Centennial during preparation of their responses to submissions made during the public exhibition period of the proposed extensions at Angus Place Colliery and Springvale Mine.

The model was constructed with view to be integrated with detailed site water balances prepared by GHD Pty Ltd, RPS and others at a later stage and to serve as a platform for water management by Centennial in the Coxs River catchment.

The model described within, will also address Conditions of Consent with respect to the Water Management Plan at the Centennial Western Coal Services Project, Condition 24 (c) (iv):

> *"to coordinate modelling programmes for validation, re-calibration and re-running of groundwater and surface water models"*

1.2 Layout of the Report

This report should be read in conjunction with the Surface Water Impact Assessment prepared for the Angus Place Mine Extension Project (RPS, 2014a) and Springvale Mine Extension Project (RPS, 2014b).

Chapter 1 – provides an introduction as to the purpose of this report

Chapter 2 – presents an extension of the description of the surface water environment to that presented in the Surface Water Impact Assessment, where relevant

Chapter 3 – presents a description of the water quality model, including construction, calibration, prediction and uncertainty analysis

Chapter 4 – presents an extension of the impact assessment to that presented in the Surface Water Impact Assessment, where relevant

Chapter 5 – presents relevant references.

2. Background

2.1 Study Area

The water quality model prepared for this impact assessment encompasses all contributing catchments to Lake Burragorang (Warragamba Dam). These catchments lie within the Upper Nepean and Upstream Warragamba Water Source of the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011 (*Water Management Act* 2000). The extent of the model is equivalent with the study area and is presented in Figure 2.1. Lake Burragorang is the primary drinking water storage dam of the Sydney Catchment Authority (SCA).

With respect to local scale, licensed discharge points of the Angus Place Colliery and Springvale Mine occur within the Wywandy Management Zone. The Wywandy Management Zone encompasses all catchments upstream of Lake Lyell, which is the lower water supply reservoir of Energy Australia's Wallerawang Power Station, now closed, and Mt Piper Power Station. Figure 2.2 presents the Wywandy Management Zone.

2.2 Surface Water Environment

As presented in the Surface Water Impact Assessment (RPS, 2014ab), the Coxs River catchment within the Wywandy Management Zone has a mixed land use comprising:

- natural vegetation
    - generally steep slopes and plateaus
- dryland farming / cleared pasture
- urban areas
    - townships of Blackmans Flat, Lidsdale, Lithgow and Wallerawang
- heavy industry
    - active and rehabilitated open cut mining areas
    - coal washery and reject emplacement areas
    - power generating facilities including dry ash placement facilities.

2.3 Water Use

The primary current and historical water use in the Wywandy Management Zone is heavy industry for power generating.

Wallerawang Power Station was commissioned in 1959, with Lake Wallace and Lake Lyell (Lilyvale Dam) commissioned in 1979. The most recent power generating units at Wallerawang Power Station, Wang C (Unit 7 and 8) were completed in 1976 and 1980. Unit 7 closed in January 2013 and Unit 8 closed in April 2014 due to dwindling energy demand. Sawyers Swamp Creek Ash Dam was constructed in about 1979 for Wallerawang Power Station. Wallerawang Power Station was converted to a dry process from a wet ash process in about 2002.

Mt Piper Power Station was built over two stages in 1992 and 1993 as well as Thompsons Creek Reservoir and associated pipeline.

It is understood that Reverse Osmosis plants (two 6ML/d plants) to treat Cooling Tower blowdown water at Mt Piper Power Station and Wallerawang Power Station were commissioned in April 2007.

The estimated demand at Wallerawang Power Station and Mt Piper Power Station was based on Water Management Licence reporting (Delta Electricity, 2006, 2007, 2008, 2009) and was 36.8ML/d at Wallerawang Power Station and is 38.9ML/d at Mt Piper Power Station. These averages were determined from average of daily take from monthly records between July 2007 and June 2009. Blowdown efficiency at Wallerawang Power Station was, on average, 32%, of daily demand. The assumed blowdown efficiency at Mt Piper Power Station is 30%.

From the 2008-09 Water Management Licence Compliance Report (Delta Electricity, 2009), accepted design efficiency was 1.65ML/GWh at Mt Piper Power Station and 1.75ML/GWh at

Wallerawang Power Station. In 2008/9, water use was 1.72ML/GWh at Mt Piper Power Station and was 1.81ML/GWh at Wallerawang Power Station.

Cooling Tower blowdown, low quality water that collates as a by-product of water use, at Wallerawang Power Station was discharged to Lake Wallace (Energy Australia LDP001 and LDP021) but the majority was discharged below Lake Wallace (Energy Australia LDP004). There is no direct discharge of Cooling Tower blowdown at Mt Piper Power Station to the surface water environment and it is understood that blowdown is recirculated on-site and ultimately disposed as brine to the adjacent Ash Placement Area.

2.4 Water Storages

There are four storages in the Wywandy Management Zone. They consist:

- Lake Wallace
    - fed by run-off from upstream catchment and pump-in from Lake Lyell
    - operational capacity of 2206ML (*modelled as 2240ML assuming full storage is 4221ML and minimum storage is 1981ML*)
    - spillway height is 871.4mAHD
    - pump-in when water level <870.5mAHD (*modelled to be 3106ML*) and pump-off at 870.8mAHD (*modelled to be 3521ML*)
    - daily environmental release requirement is 0.7ML/d from Lake Wallace, which can be met via discharge at Energy Australia LDP004 (*modelled as daily release from Lake Wallace only)*.
- Lake Lyell
    - fed by run-off from upstream catchment
    - pump-out to Lake Wallace or Thompsons Creek Reservoir
    - total capacity of 34192ML (*modelled as 34451ML*)
    - spillway height of 785.5mAHD
    - active storage capacity of 32109ML
    - minimum storage volume of 2083ML (*modelled as 2749ML*)
    - daily environmental release requirements are:
        - if total storage in Lake Wallace, Lake Lyell and Thompsons Creek Reservoir is <50,000ML for more than six months then daily release is 5ML/d (*not modelled*)
        - if total storage in Lake Wallace, Lake Lyell and Thompsons Creek Reservoir is <50,000ML (drought trigger) and daily inflow is <9ML/d then daily inflow is released (transparent flows – *modelled as described*)
        - if total storage in Lake Wallace, Lake Lyell and Thompsons Creek Reservoir is <50,000ML (drought trigger) and daily inflow is >9ML/d then 9ML/d is released (translucent flows – *modelled as described*)
        - if daily inflow <13.6ML/d then release equals daily inflows (transparent flows – *modelled as described*)
        - if daily inflow >13.6ML/d then 13.6ML/d plus 25% of daily flow greater than 13.6ML/d is released (translucent flows – *modelled as described*).
        - long term channel maintenance flow (*not modelled*).
- Thompsons Creek Reservoir
    - is an off-stream storage as very minor local catchment
    - pump-in from Lake Lyell
    - total capacity of 27,500ML (*modelled as 28,000ML*)
    - spillway height is 1032.5mAHD
    - minimum storage is 500ML (*modelled as 500ML*)
    - operationally maintained at full capacity.

- Sawyers Swamp Creek Ash Dam
  - built for wet ash disposal from Wallerawang Power Station and now operated with a negative water balance
  - total capacity of 8500L (*modelled as 8500ML*)
  - spillway height of 941.6mAHD
  - operational capacity of 1197ML (*modelled as 1197ML*).

Figure 2.3 presents the layout of the Energy Australia Coxs River Water Supply Scheme.

The pump-out capacity from Lake Lyell is 95ML/d and is understood to be able to be diverted to either Lake Wallace or the diversion value house below Thompsons Creek Reservoir.

2.5 Water Supply

There are several water sources used to meet demand at Wallerawang Power Station and Mt Piper Power Station for cooling. Energy Australia are a significant water user and therefore have a corporate licence from the NSW Office of Water. Their operating conditions are governed by their Water Access Licence Conditions including details such as environmental release requirements (NSW Office of Water, 2014ab).

The water sources for power generation comprise:

- direct supply by the Fish River Scheme from State Water Corporation
- extraction from the Coxs River (Lake Wallace, Lake Lyell and Thompsons Creek Reservoir)
- mine water make from the Springvale Delta Water Transfer Scheme (SDWTS), when operational

2.5.1 Fish River Scheme

The Fish River Water Supply Scheme was constructed in the 1950 - 60s and supplies water from Oberon Dam to several townships as well as directly to Energy Australia's Wallerawang Power Station and Mt Piper Power Station. The Fish River Scheme is now administered under the *Water Management Act* 2000 via the Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources 2012. Energy Australia's entitlement in this scheme is 8,184ML and the historical allocation is presented in Table 2.1 from July 2005. It is highlighted that there is an embargo on trading into the scheme as well as restrictions during times of drought insofar as supply to Oberon being first priority and Energy Australia and Sydney Catchment Authority (SCA) being last.

Table 2.1: Energy Australia's Historical Allocation (ML) from the Fish River Scheme

Water Year	Annual Allocation (ML)
2005/06	6367
2006/07	6590
2007/08	4367
2008/09	3356
2009/10	2856
2010/11	4932
2011/12	4141
2012/13	5873

2.5.2 Coxs River

Historically there was direct extraction from Lake Wallace to Wallerawang Power Station and from Thompsons Creek Reservoir to Mt Piper Power Station. As indicated above, with respect to operation of the Lake Lyell storage reservoir, there is transfer from Lake Lyell to Lake Wallace or Lake Lyell to Thompsons Creek Reservoir.

2.5.3 SDWTS

The Springvale – Delta Water Transfer Scheme (SDWTS) was commissioned in February 2006 and transmitted mine water make from Springvale and Angus Place via Springvale Mine directly to Wallerawang Power Station. When not required at Wallerawang Power Station, mine water make from the SDWTS was directed to Sawyers Swamp Creek via Energy Australia LDP020. In August 2012, responsibility for Energy Australia LDP020 transferred to Springvale Mine. The new LDP became Springvale LDP009. Prior to the SDWTS, mine water make at Springvale was discharged to the Wolgan River via the Newnes Plateau. Historical discharge at Angus Place was via Kangaroo Creek. Between 2006 and 2012, when the SDWTS was offline, there were periods when there was discharge to the Wolgan River. This ceased in approximately 2010. Currently all flow within the SDWTS is being directed to Sawyers Swamp Creek via Springvale LDP009.

2.6 Historical Water Quality

There has been mining activity in the Upper Coxs River catchment since the late 1800s and in recent time, since 1979, major land use activities have consisted: open cut and underground mining, power generation, dryland agriculture as well as urban development.

There are two studies of historical water quality that are of relevance to the Coxs River catchment:

- a regional water quality review undertaken by Australian Water Technologies in 1992 (AWT, 1992)
- water management licence compliance reporting by Energy Australia (then Delta Electricity) (Delta Electricity, 2009).

Figure 2.4 presents the location of the AWT water quality sites and Figure 2.5 presents the location of Energy Australia monitoring stations.

Water quality monitoring observations were extracted at selected locations from the AWT (1992) study and are presented in Figure 2.6. Table 2.2 presents a summary of observed salinity.

Table 2.2: Historical Salinity at Selected Locations (AWT, 1992).

Station ID	Easting[1]	Northing[1]	Description	Range in Salinity (mg/l)
E005	228689	6305288	Coxs River below Kangaroo Creek	87 (40 – 335, n = 8)
E015	226151	6305131	Wangcol Creek above WCSLDP006	221 (134 – 302, n = 9)
E006	227998	6304334	Wangcol Creek above Blue Lagoon	503 (101 – 6700, n = 14)
E013	228658	6300675	Coxs River above Lake Wallace	268 (154 – 536, n = 23)
E037	228588	6297735	Coxs River below Lake Wallace but above Energy Australia LDP004	281 (168 – 1005, n = 18)
E039	227015	6289786	Coxs River above Farmers Creek	121 (34 – 469, n = 9)
E070	230238	6285698	Coxs River below Lake Lyell	134 (67 – 389, n = 25)
E081	240375	6261223	Coxs River above Little River	24 (9 – 70, n = 21)
E083	246019	6248741	Coxs River above Lake Burragorang	107 (74 – 704, n = 25)

1. Eastings and Northings are in Map Grid of Australia 1994, Zone 56.

Energy Australia undertakes compliance monitoring at a number of locations. Figure 2.7 presents time-series historical salinity. Table 2.3 presents a summary of these data.

Table 2.3: Historical Salinity at Selected Locations (Delta Electricity, 2009).

Station ID	Easting[1]	Northing[1]	Description	Range in Salinity (mg/L)
WX9	228658	6300675	Coxs River above Lake Wallace	486 (302 – 687, n = unk)
COX3	228394	6297901	Lake Wallace	519 (218 – 771, n = unk)
WX13	228588	6297735	Coxs River below Lake Wallace but above Energy Australia LDP004	519 (402 – 1206, n = unk)

Station ID	Easting[1]	Northing[1]	Description	Range in Salinity (mg/L)
COX5	227753	6291380	Coxs River above Lake Lyell	737 (168 – 1240, n = unk)
COX8A	228880	6286559	Lake Lyell	427 (168 – 637, n = unk)
COX9	230238	6285698	Coxs River below Lake Lyell	402 (168 – 637, n = unk)

1. Eastings and Northings are in Map Grid of Australia 1994, Zone 56.

It is noted that Figure 2.6 has units of mS/m. The conversion factor between salinity, as EC in µS/cm, to salinity as TDS (mg/L) was assumed to be 0.67.

From Figure 2.6, historical water quality in the Coxs River above Wangcol Creek / Blue Lagoon, site E005 in the AWT (1992) study, ranged between 6mS/m (40mg/L) in 1980 and 50mS/m (335mg/L) in 1989. Current salinity at that location from monitoring at AP_COXS_DOWNSTREAM on 5 March 2014 is 610mg/L. Within Wangcol Creek, at site E006, historical water quality was 1000mS/m (6700 mg/L) in 1980 due to mining within the watercourse. In 1990, salinity at site E006 was 30mS/m (200mg/L). Current salinity at WCS_WangcolFarDownstream is 1394mg/L on 19 December 2013. Upstream of Lake Wallace, the AWT site, E013, corresponds with current monitoring at NSW Office of Water gauge 212054, water quality monitoring by Energy Australia, WX9 and monitoring by Springvale at SV_COXS_UPSTREAM. In Figure 2.6, water quality at this location was 35mS/m (235mg/L) in 1980 and was 50mS/m (335mg/L) in 1991.

Water quality in the Coxs River below Lake Wallace was monitored at AWT site E037 and corresponds with NSW Office of Water gauge, 212008, monitoring by Energy Australia, WX13 and current monitoring by Springvale at SV_COXS_DOWNSTREAM. Salinity at this location was 50mS/m (335mg/L) in 1980 and was 50mS/m (335mg/L) in 1991.

There are several other monitoring locations in the AWT study between Lake Wallace and Lake Lyell as well as below Lake Lyell through to Lake Burragorang. AWT site E039 lies on the Coxs River above Farmers Creek and observed salinity was 5mS/m (34mg/L) in 1980 and 70mS/m (469mg/L) in 1982. AWT site E070 lies on the Coxs River below Lake Lyell. Site E081 lies on the Coxs River above Little River and site E083 is on the Coxs River above Lake Burragorang. The location of all monitoring stations used in the model calibration is presented in Section 3.2.3. Salinity below Lake Lyell is observed to decrease in a downstream direction below site E070, which corresponds with NSW Office of Water gauge 212011 and Energy Australia monitoring station COX9. Water quality was 58mS/m (389mg/L) in 1981 and was 15mS/m (101mg/L) in 1991. At site E081, water quality at equivalent times were 40mS/m (268mg/L) and 17mS/m (114mg/L). At site E083, water quality at equivalent times was 23mS/m (154mg/L) and 24mS/m (161mg/L).

From Figure 2.7, water quality above Lake Wallace, at monitoring station WX9, ranges between 450µS/cm (302mg/L) in 2000 to maximum of 1025µS/cm (687mg/L) in 2009. Within Lake Wallace itself, monitoring station COX3, ranges between 650µS/cm (436mg/L) in 2000 to maximum of 1,150µS/cm (771mg/L) in 2007. Below Lake Wallace, at site WX13, historical salinity ranges between 650µS/cm (436mg/L) in 2000 to maximum in 2007 of 1150µS/cm (771mg/L). The spike in salinity in late 2000 is presumed to reflect drought conditions / low volume and therefore was ignored.

From Figure 2.7, between Lake Wallace and Lake Lyell, historical water quality at monitoring station, COX5, ranged between 400µS/cm (268mg/L) in 2000 to maximum of 1850µS/cm (1,240mg/L) in 2007. Monitoring of Lake Lyell, COX8A, presents an increasing trend from 250µS/cm (168mg/L) in 2000 to maximum of 950µS/cm (637mg/L) in 2007, followed by a drop to ~650µS/cm (436mg/L). Water quality below Lake Lyell at COX9 matches water quality within Lake Lyell. For Thompsons Creek Reservoir, there is a steady increasing trend from 250µS/cm (168mg/L) in 2000 to 650µS/cm (436mg/L) in 2009.

Historical water quality analyses indicate that the Coxs River has been impacted by industrial activity in the past. As will be presented below, the proposed water management strategies for the extension of Angus Place Colliery and Springvale Mine will not result in predicted water quality being significantly outside of that experienced historically and / or ANZECC (2000) default trigger values for 95% protection of aquatic ecosystems.

3. Modelling

3.1 Model Setup

3.1.1 Model Approach

The water quality model presented here is based on the rainfall-run-off model AWBM by Boughton (2010). The AWBM has been used extensively within Australian and is based on saturated overland flow. i.e. excess rainfall after surface storage capacity has been replenished. The structure of the AWBM is presented below.

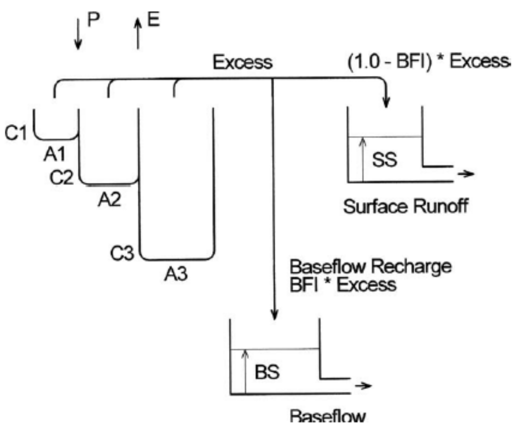

Figure: Structure of the AWBM (after Boughton, 2010).

There are three different capacities of surface storage used to represent partial areas of the catchment that runoff at different times during a storm. The surface catchment storages are depleted by evaporation and runoff is partitioned to surface runoff and baseflow based on parameter selection.

Research into the AWBM on ungauged catchments by Boughton (2010) has led to derivation of average surface storage capacity that are distributed using a fixed pattern throughout Australia. This was due to an outcome of Boughton's later research that areal distribution of rainfall was of much greater importance than variability in average surface storage capacity. As noted by Boughton (2010), small discrepancies in rainfall lead to significant variability in calibrated average surface storage capacity.

To facilitate use of the AWBM, Golder Associates Pty Ltd, the original authors of the generalised mass balance model, GoldSIM, translated the AWBM into GoldSIM and this module is available as a downloadable example from the GoldSIM website. That AWBM module was then adapted for use in this study by taking into account areal distribution of rainfall and land use through sub-catchment delineation. In total there are 281 sub-catchments in the model, from which, for the purpose of practicality, 42 different definitions of rainfall and / or land use applied via the "Clone Element" facility within GoldSIM.

Data from relevant BOM rainfall stations were manually patched such that there was a continuous daily rainfall record for each sub-catchment. Table 3.1 the list of rainfall stations used in the water quality model.

Table 3.1: Rainfall Stations in the Water Quality Model

BOM ID	Station Name	BOM ID	Station Name
63071	PORTLAND (JAMIESON ST)	68166	BUXTON (AMAROO)
63132	LIDSDALE (MADDOX LANE)	70036	LAKE BATHURST (SOMERTON)
63224	LITHGOW (BIRDWOOD ST)	70077	GOULBURN (SPRINGFIELD)
63146	CHEETHAM FLATS (JUNDAS)	70069	CROOKWELL (GUNDOWRINGA)

BOM ID	Station Name	BOM ID	Station Name
63049	LOWTHER PARK	70055	GOULBURN (KIPPILAW)
63009	BLACKHEATH (LAWRENCE ST)	70263	GOULBURN TAFE
63270	LITTLE HARTLEY (ROSCOMMON)	70269	MARULAN (JOHNNIEFELDS)
63283	HAMPTON (BINDO)	70147	GOULBURN (HILLWOOD)
63039	KATOOMBA (MURRI ST)	70119	BIG HILL (GLEN DUSK)
63036	OBERON (JENOLAN CAVES)	68008	BUNDANOON (BALLYMENA)
63227	WENTWORTH FALLS COUNTRY CLUB	68186	BERRIMA WEST (MEDWAY (WOMBAT CREEK))
67029	WALLACIA POST OFFICE	68089	JOADJA (GREENWALK)
68125	OAKDALE (COOYONG PARK)	63093	WOMBEYAN CAVES
63033	GURNANG STATE FOREST (OBERON (YOUNG ADUL	70325	WOLLONDILLY (RIVER VIEW)
68044	MITTAGONG (ALFRED STREET)	68062	HIGH RANGE (WANGANDERRY)

Evaporation in the model was based on average daily evaporation for each month at BOM Station No. 061089 (Scone SCS). Table 3.2 presents the relevant data.

Table 3.2: Mean Daily Evaporation (mm/d) (BOM Station Scone SCS (No. 061089))

	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean Daily Evap.	7.1	6.1	5.0	3.5	2.2	1.6	1.8	2.7	3.9	5.0	6.1	7.1	4.3

Salt mass flux was determined based on a simple model. For general runoff, it was assumed there were several land use types:

- Natural
- Pasture
- Urban
- Disturbed
- Channel.

For each land use type, an assumed salinity, as TDS (mg/L), was defined. Salt mass flux was then calculated based on runoff multiplied by assumed concentration plus such salt mass inflow from upstream sub-catchment plus groundwater discharge from respective LDPs (both Centennial and other operations). Salt concentration was then calculated by mass flux (kg/d) divided by water flow (ML/d). It is noted that the model approach adopted assumed concentration was 50mg/L when water flow was 0ML/d, so as to avoid a division-by-zero error.

3.1.2 Catchment Land Use

For simplicity, land uses were not changed in time during a model simulation. Land uses were different, however, in the certain sub-catchments between the calibration and prediction model to account for their change in use. For example, from an active open cut mining (Disturbed) to rehabilitated (Pasture) or from undeveloped (Natural) to open cut mining (Disturbed).

Groundwater discharge during the prediction simulation of various activities in the catchment was derived from the Western Coalfields Water and Salt Balance prepared by GHD (2014).

The layout of the model at pertinent locations is presented in Figure 3.1. Further detail of model layout is provided in the electronic deliverable, including relevant model files and GIS files.

The adopted parameters for runoff salinity and groundwater discharge through LDPs (1,200μS/cm, or 804mg/L) as well as AWBM surface storage capacities and baseflow indices are presented in Section 3.2.3.

It is noted that mine water make presented in Figure 16 of RPS (2014a) and Figure 18 of RPS (2014b) were used to define discharge to Angus Place LDP001 and Springvale LDP009. It is noted that, given each sub-catchment was implemented in the water quality model that local LDPs, such as Angus Place LDP002, Springvale LDP001 and LDP002 were assumed to be represented by catchment runoff through sediment retention structures without attenuation of flow or salinity.

Further detail on model assumptions is presented in Section 3.3.2.

3.1.3 Reservoirs

There are five reservoirs included in the model. These comprise:

- Lake Wallace (Node #074)
- Lake Lyell (Node #174)
- Thompsons Creek Reservoir (Node #272)
- Sawyers Swamp Creek Ash Dam (Node #297)
- Lake Burragorang/Warragamba Dam (Node #280).

Detail as to assumed storage capacities of these reservoirs is presented in Section 2.4.

3.1.4 Model Periods

The water quality model comprises two components:

- calibration period (1 January 1979 to 30 June 2014, 12965 days)
- prediction period (1 July 2014 to 31 December 2032, 6759 days).

The adopted timestep for the calibration and prediction simulations was 1 day.

3.2 Model Calibration

3.2.1 Observation Dataset

The water quality model was calibrated by comparing time-series flow (ML/d) and salinity, converted to TDS (mg/L), and volume (ML) to historical observation. As presented in Section 2.6, there has been some historical monitoring in the Coxs River catchment in the past and all available data is presented in the calibration simulation plots below. This includes recent water quality monitoring by Angus Place Colliery and Springvale Mine. As well, there have been daily flow measurements at several NSW Office of Water gauging sites within the catchment.

Table 3.3 presents the observation dataset including model node identifiers.

3.2.2 Calibration Parameters

There are two sets of calibration parameters in the water quality model:

- rainfall-runoff parameters
- rainfall salinity and groundwater discharge salinity.

Table 3.4 presents the calibrated values for these parameters. The results of model calibration are presented below.

3.2.3 Calibration Results

The model control file pertaining to the calibration simulation is:

- 021a_CAL-Jun14_10a.gsm

Table 3.3: Calibration Dataset

Node	Easting[1]	Northing[1]	Description	Alias_NOW[2]	Alias_Centennial	Alias_Delta[3]	Alias_AWT[4]	Flow	Salinity
RES272	221040	6296878	Thompson Creek Reservoir	NA	NA	TC1	NA	0	1
DIS105	226151	6305131	Wangcol Creek above WSLDP006	212055	WCS_WangcolNOW	NA	E015	1	1
DIS167	227998	6304334	Wangcol Creek above Blue Lagoon	NA	WCS_WangcolFarDownstream	NA	E006	0	1
NAT134	229749	6309050	Coxs River Far Upstream	NA	AP_COXS_FAR_UPSTREAM	NA	NA	0	1
PAS007	229671	6307355	Coxs River above Kangaroo Creek	NA		NA	NA	0	1
NAT011	230336	6306130	Kangaroo Creek below APLDP001	NA	AP_KANGAROO_DOWNSTREAM	NA	NA	0	1
PAS137	229483	6306289	Coxs River at confluence with Kangaroo Creek	NA	AP_KANGAROO-COXS_CONFLUENCE	NA	NA	0	1
PAS056	228689	6305288	Coxs River below Kangaroo Creek	NA	AP_COXS_DOWNSTREAM	NA	E005	0	1
PAS166	228660	6302941	Sawyers Swamp Creek at Coxs River	NA	WCS_LDP003_DOWNSTREAM	NA	NA	0	1
CHA047	228658	6300675	Coxs River above Lake Wallace	212054	SV_COXS_UPSTREAM	WX9	E013	1	1
RES074	228394	6297901	Lake Wallace	NA	NA	COX3	NA	0	1
PAS032	228588	6297735	Coxs River below Lake Wallace but above EALDP004	212008	SV_COXS_DOWNSTREAM	WX13	E037	1	1
NAT154	228152	6292169	Coxs River above Lake Lyell	212058	NA	NA	NA	1	0
NAT035	227753	6291380	Coxs River above Lake Lyell	NA	NA	COX5	NA	0	1
NAT117	227015	6289786	Coxs River aboveFarmers Creek	NA	NA	NA	E039	0	1
PAS070	230427	6289933	Farmers Creek	212042	NA	COX6	E054	1	1
RES174	228880	6286559	Lake Lyell	NA	NA	COXS8A	NA	0	1
PAS209	230238	6285698	Coxs River below Lake Lyell	212011	NA	COX9	E070	1	1
PAS221	240375	6261223	Coxs River above Little River	212045	NA	NA	E081	1	1
NAT225	246019	6248741	Coxs River above Lake Burragorang	NA	NA	NA	E083	0	1

1. Eastings and Northings are in Map Grid of Australia 1994, Zone 56; 2. NOW is NSW Office of Water; 3. Delta is Delta Electricity (Delta Electricity, 2009); 4. AWT is Australian Water Technologies (AWT, 1992).

Table 3.4: Calibrated AWBM and Water Quality Parameters

Land Use	C1 (mm)	C2 (mm)	C3 (mm)	CAve[1] (mm)	BFI[2]	Kb[2]	Ks[2]	Concn[3] (mg/L)
Natural	10.4	106.7	213	140	0.41	0.981	0	50
Pasture	11.9	122	244	160	0	1	0.5	100
Urban	2.0	20.6	41.2	27	0	1	0	250
Disturbed	4.9	50.3	100.6	66	0	1	0.5	400
Channel	2.0	20.6	41.2	27	0	1	0	100

1. Assumed pattern of distribution of partial areas is A1 = 0.134, A2 = 0.433, A3 = 0.433 for all land use classes; 2. BFI is Baseflow Index, Kb is daily baseflow recession constant and Ks is daily surface recession constant; 3. Concn is assumed run-off salinity from each land use class.

Kangaroo Creek and Coxs River above Wangcol Creek / Blue Lagoon

Water quality modelling indicates that historical discharge at Angus Place LDP001 accounts for observed increase in salinity in Kangaroo Creek and the Upper Coxs River above Blue Lagoon. The calibration simulation is presented in Figure 3.2 at monitoring station AP_KANGAROO_DOWNSTREAM (#011).

Modelling assumes water quality upstream of point of discharge of Angus Place LDP001 to Kangaroo Creek (#010 and above) is 50mg/L TDS. Modelled water quality at monitoring station AP_COXS_FAR_UPSTREAM (#134) is also 50mg/L TDS.

Review of simulated daily flows in Kangaroo Creek at point of discharge of Angus Place LDP001 (#011) during historical discharge indicates that River Flow Objective – Maintain Natural Flow Variability has been met in the past.

From Figure 3.2, there is reasonable fit between modelled and observed salinity in Kangaroo Creek.

Monitoring location AP_COXS_DOWNSTREAM (#056) corresponds with historical monitoring in the AWT (1992) study at their site, E005. The calibration simulation at Node #056 is presented in Figure 3.2.

From Figure 3.2, the assumed historical discharge from Angus Place LDP001 is conservative since the water quality model overpredicts salt concentration in the early 1980s, however, fit to recent data is reasonable.

Review of simulated daily flow in Coxs River at monitoring location AP_COXS_DOWNSTREAM indicates River Flow Objective – Natural Flow Variability has been met in the past.

Sawyers Swamp Creek

Sawyers Swamp Creek is diverted around the Sawyers Swamp Creek Ash Dam and is transmitted from #014, inclusive of point of discharge from Springvale LDP009, to #061, #098, #275, #09 and #166 before entering the Coxs River.

Water quality modelling implies increased salinity observed in Sawyers Swamp Creek above Coxs River is associated with mine water discharge at Springvale LDP009, however, the Sawyers Swamp Creek catchment is in a highly disturbed state and there are multiple potential sources of salinity and other contaminants both presently and in the past.

Monitoring location WCS_LDP003_DOWNSTREAM (#166) is located on Sawyers Swamp Creek immediately above the Coxs River. Figure 3.3 presents the calibration simulation at that location.

From the above, the calibration model overpredicts the observed salinity at WCS_LDP003_DOWNSTREAM. It is noted that discharge at Springvale LDP009 commenced in August 2012 and prior to this was associated with Energy Australia LDP020 from June 2006. The location of LDP020 changed in the past, however, was still within sub-catchment #014.

Wangcol Creek

Industrial activity within Wangcol Creek comprises Mt Piper Power Station (assumed to have commenced on 1 January 1993), Western Coal Services site (assumed to be active since commencement of calibration simulation in 1979) and Pine Dale Coal Mine (also assumed to be active since 1979).

Given that there are no licenced surface water discharge of Cooling Tower blowdown at Mt Piper Power Station, it was assumed there was a seepage to Wangcol Creek through the Ash Placement Facility at a rate of 5% of modelled water demand, at 400mg/L, from 1 January 1993 to 30 December 2006 and at 750mg/L from 1 January 2007, associated with assumed commencement of brine conditioning of ash (RO Plant Brine Stream).

As noted in Section 2.3, there was monthly water use data available for Mt Piper Power Station for the period July 2005 to June 2009. The estimated daily demand at Mt Piper Power Station is 38.9ML/d. To attempt to account for monthly variation in water demand, a month-to-month distribution of the estimated daily demand was calibrated against observation period between July 2005 and June 2009 and is presented below.

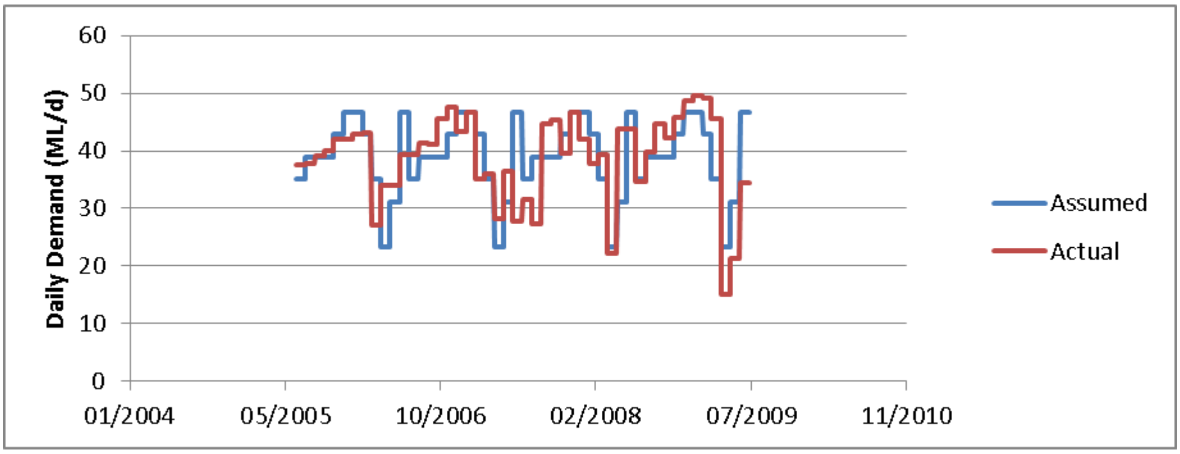

Figure: Calibrated Distribution of Daily Demand at Mt Piper Power Station (ML/d).

Table 3.5 presents the calibrated multiplication factors for Mt Piper Power Station and Wallerawang Power Station. Details of Wallerawang Power Station are presented below.

Table 3.5: Assumed Monthly Distribution of Water Demand at Mt Piper Power Station and Wallerawang Power Station

Month	MPS Daily Demand (ML/d)	Multiplication Factor[1]	WPS Daily Demand (ML/d)	Multiplication Factor[2]
January	46.7	1.20	44.1	1.20
February	42.8	1.10	36.8	1.00
March	35.0	0.90	25.7	0.70
April	23.4	0.60	29.4	0.80
May	31.2	0.80	36.8	1.00
June	46.7	1.20	40.5	1.10
July	35.0	0.90	44.1	1.20
August	38.9	1.00	47.8	1.30
September	38.9	1.00	40.5	1.10
October	38.9	1.00	33.1	0.90
November	42.8	1.10	25.7	0.70
December	46.7	1.20	36.8	1.00

1. Assumed daily demand at Mt Piper Power Station is 38.9ML/d; 2. Assumed daily demand at Wallerawang Power Station was 36.8ML/d.

It is noted that the distribution presented in Table 3.5 was used in the prediction simulation.

Figure 3.4 presents the calibration simulation at the location of the NSW Office of Water gauging station, 212055 (#105). This location was assumed to correspond with AWT (1992) monitoring site E015 and is the location of current water quality monitoring at Centennial Western Coal Services, WCS_WangcolNOW.

From Figure 3.4, there is reasonable fit between observed salinity and modelled. The staged increase in modelled salinity in January 1993 and January 2007 is due to assumed seepage from the Ash Placement facility.

Time-series water quality at monitoring location WCS_WangcolFarDownstream (#167) is also presented in Figure 3.4. This location corresponds with AWT (1992) location E006.

From Figure 3.4, the water quality model underpredicts recent observation at this location. It is noted that there is no assumed groundwater discharge from the Western Coal Services site and the recent inflow from 2011 may reflect changes in the catchment due to expansion of the Ash Placement Area at Mt Piper Power Station insofar dislocation of water previously stored within Huon Gully / Dam.

Lake Wallace

Daily demand at Wallerawang Power Station was based on data reported in the period 2005 to 2009 by Delta Electricity / Energy Australia (2006, 2007, 2008, 2009), daily consumption data from January 2006 as well as daily SDWTS consumption. From the available data between July 2005 and June 2009, average daily demand was 36.8ML/d. As for the Mt Piper Power Station, the monthly distribution of daily demand was calibrated based on available data and is presented below. Table 3.5 presents the adopted multiplication factors.

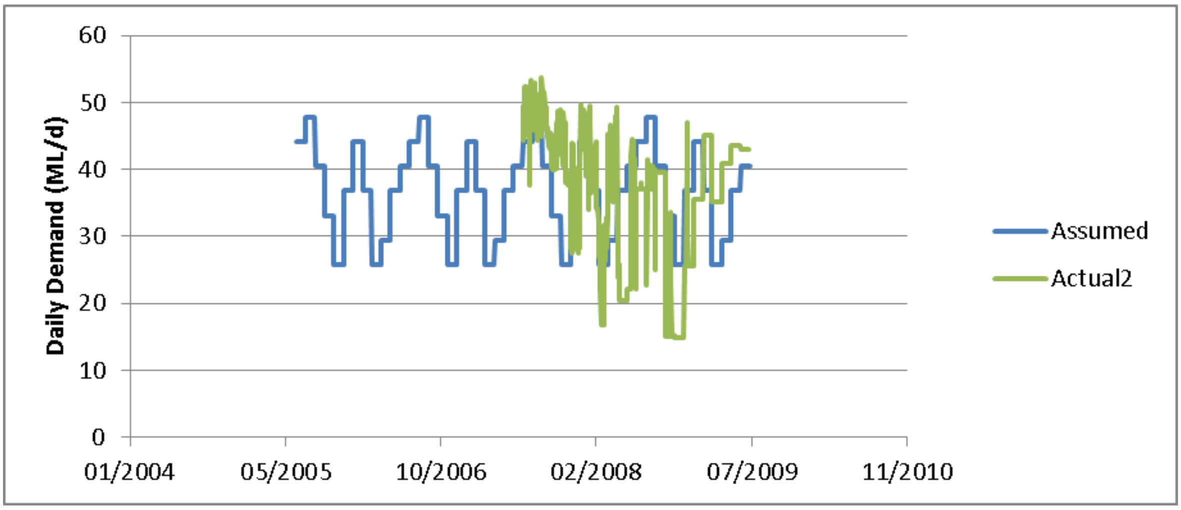

Figure: Calibrated Distribution of Daily Demand at Wallerawang Power Station (ML/d).

There is flow gauging and salinity monitoring in the Coxs River immediately upstream of Lake Wallace by the NSW Office of Water (No. 212054). This location (#047) also corresponds to historical monitoring reviewed in the AWT study, water quality monitoring by Energy Australia between 2000 and 2009 as well as recent monitoring by Springvale, SV_COXS_UPSTREAM. It is noted that this location is upstream of the confluence with Springvale Creek. Springvale Creek receives surface water discharge from Springvale Pit Top. Figure 3.5 presents results of calibration simulation at this model node.

From Figure 3.5, there is a good fit between observed salinity and flow and model simulation, in particular in the period after 1993. It is suggested in the period 1979 to 1993, the conservative assumption about mine water discharge at Angus Place may account for overprediction of salinity.

Calibration simulation results in Lake Wallace is also presented in Figure 3.5 (#074). From Figure 3.5m there is reasonable agreement between observed and modelled salinity. It is noted that the model assumes instantaneous and complete mixing within reservoirs. Also of note in Figure 3.5, the reservoir volume fluctuates between full at 4,221ML and 3,106ML. The trigger value for the Lyell to Wallace transfer to occur is 3,106ML (pump-off is 3,521ML). The transfer capacity of the Energy Australia Coxs River Water Supply System is 95ML/d.

Lake Lyell

There are several observation locations between Lake Wallace and Lake Lyell. These include:

- Coxs River immediately below Lake Wallace (#032, flow and quality)
- Coxs River between Lake Wallace and Lake Lyell (#154, flow; #035, quality; #117, quality)
- Lake Lyell (#174, quality).

Figure 3.6 presents the modelled and historical concentration and flow at these locations.

From Figure 3.6, for #032, there is reasonable fit between modelled flow and observation at NSW Office of Water Gauge 212008 and salinity, although peaks in recent water quality observations from 2010 are somewhat underestimated.

Observation at #154 is flow only and is generally consistent with historical record at NSW Office of Water Gauge 212058. Small magnitude peak flows are somewhat overestimated but larger peaks are underestimated.

The observation at #035 is quality and the water quality model underpredicts observed salinity. During available monitoring period between 2000 and 2009, salinity at #035 ranged between 200mg/L and 1,200mg/L. Calibration simulation during that period is 200 to 700mg/L, by comparison.

At #117, the calibration model underpredicts observed salinity, however, as noted above, the assumption of continuous discharge at Angus Place from 1979 is probably too conservative.

From Figure 3.6, the modelled salinity in Lake Lyell (#174) during the calibration simulation is reasonably matched with historical observation. Modelled storage volume (ML) is somewhat underpredicted, however, this is due to assumptions necessary for daily demand at Wallerawang Power Station and Mt Piper Power Station from 1993 and other input data. The results, however, are suitable for the purpose of cumulative impact assessment.

Thompsons Creek Reservoir

Figure 3.7 presents the calibration simulation of Thompsons Creek Reservoir.

From Figure 3.7, the modelled salinity in Thompsons Creek Reservoir (#272) is reasonably matched, although the model is overpredicting salinity, the increasing trend is captured. As for Lake Lyell, modelled storage volume (ML) is somewhat underpredicted.

Lake Burragorang

There are three observation locations in the water quality model between Lake Lyell and Lake Burragorang as well as Lake Burragorang itself:

- Coxs River below Lake Lyell (#209)
- Coxs River above Little River (#221)
- Coxs River above Lake Burragorang (#225)
- Lake Burragorang (#280) – whilst no observation data is available, it is useful to present the modelled historical volume and salinity.

Figure 3.8 presents the calibration simulation results at these locations.

Lake Burragorang was represented in the model as a reservoir element, with an assumed full capacity of 2,031,000ML and a minimum storage of 4,000ML. There are environmental release requirements of 22ML/d between April and October and 30ML/d between November and March. Daily consumptive demand was assumed to be 1,080ML based on SCA weekly storage reports.

From Figure 3.8, there is reasonable fit for both flow and concentration at #209. For #221, flow is reasonably matched and fit of modelled salinity to water quality data from 1980 – 1992 is also reasonable. Model node #225 corresponds with water quality observation point E083 and Figure 3.8 indicates reasonable agreement between model and observation. The large peak in observed salinity in 1988 is not replicated in the model and could potentially be low flow conditions or may be a unit transcription error. i.e. 10.5mS/m rather than 105mS/m.

The calibration simulation of water volume (ML) and salinity (mg/L) in Lake Burragorang (#280) is also presented in Figure 3.8. From Figure 3.8, storage volume in fluctuates between full and approximately 1,000,000ML, corresponding with drought periods. Modelled salinity of Lake Burragorang ranges between 74mg/L and 96mg/L, with highest salinity corresponding with drought period in the model.

3.3 Model Prediction

3.3.1 Model Setup

There are several industrial projects in the Coxs River catchment of relevance. These include:

- Centennial Neubecks Open Cut
- Energy Australia Pine Dale Stage 2
- Closure of Wallerawang Power Station
- Extension of Angus Place Colliery and Springvale Mine.

The prediction model was based on the calibration simulation and updated to account for:

- change in land use within the catchment
- updated rainfall dataset
- predicted groundwater discharge from the Western Coalfields Water and Salt Balance.

The prediction period is 19 years, being 1 July 2014 through to 31 December 2032. The historical rainfall dataset from BOM Station No. 63224, 63132 and 63071 were reviewed and 19 year total of annual rainfall depths determined from all available data and ranked. These BOM stations encompass the local catchments above Lake Wallace.

The 50th percentile median 19 year rainfall total corresponded with the period between 1987 and 2005. As will be presented below, for uncertainty analysis simulations, the 10th percentile lowest 19 year rainfall total was 1993 to 2011 and the 90th percentile highest 19 year rainfall total was 1981 to 1999.

3.3.2 Prediction Scenarios

There are two Water Management Strategies proposed with respect to extension of Angus Place Colliery and Springvale Mine. These consist:

- *Water Strategy WS1* - Angus Place discharging all mine water make at Angus Place via Angus Place LDP001 (up to 30.8ML/d) and Springvale discharging all mine water make at Springvale via Springvale LDP009 (up to 18.8ML/d)
- *Water Strategy WS2a* - Angus Place discharging to Springvale LDP009 (up to 30.0ML/d) via the existing SDWTS pipeline, to the extent available, with excess discharged through Angus Place LDP001 (up to 15.5ML/d)
- *Water Strategy WS2b* – Angus Place discharging to Springvale LDP009 (up to 43.4ML/d), with upgrade of the SDWTS pipeline to 50ML/d when combined mine water make exceeds 30ML/d, with discharge through Angus Place LDP001 at 2.0ML/d.

It is noted that mine water make presented in Figure 16 of RPS (2014a) and Figure 18 of RPS (2014b) were used to define discharge to Angus Place LDP001 and Springvale LDP009. This was a simplification of water management at Angus Place and Springvale given there is no account for the impact of underground storage due to detailed site water balances not being available to RPS. This, however, was a conservative assumption. e.g. discharge at Angus Place LDP001 of up to 15.5ML/d from mine water make (its peak in 2023), in WS2a, is compared to 6.5ML/d in Table 5.2 of the Surface Water Impact Assessments (RPS, 2014ab). A minimum discharge at 2ML/d from

Angus Place LDP001 was also assumed in WS2a and WS2b. Following upgrade of this model to incorporate detailed site water balances, modelled discharges at LDPs will be updated. Inputs presented in this assessment are conservative, however.

It is also noted that for the purpose of modelling the null case consists of both Angus Place Colliery and Springvale Mine ceasing discharge at the end of the calibration period on 30 June 2014.

3.3.3 Prediction Results

The model control files pertaining to the prediction simulations are:

- 021a_PRD-WS1_07a.gsm
- 021a_PRD-WS1_07a_NUL.gsm
- 021a_PRD-WS2a_03a.gsm
- 021a_PRD-WS2b_03a.gsm.

Kangaroo Creek and Coxs River above Wangcol Creek/Blue Lagoon

Prediction simulation of Kangaroo Creek at #011 for WS1, WS2a and WS2b is presented in Figure 3.9.

During prediction simulation of WS1 and WS2a, there is increased discharge (on a continuous basis); however, variability of flow is still evident but mine water discharge does dominate flows in Kangaroo Creek. During prediction simulation of WS2b, discharge at Angus Place LDP001 remains at 2ML/d. Under this condition, flow variability at point of discharge to Kangaroo Creek is consistent with historical and the River Flow Objective is satisfactorily met.

Flow statistics of predicted daily flow at this location are presented in Table 3.6, including for the prediction null case. As indicated above, the prediction null case comprises both Angus Place Colliery and Springvale Mine ceasing discharge on 30 June 2014.

Table 3.6: Predicted Daily Flow Statistics (ML/d) at #011 (Kangaroo Creek, downstream of point of discharge from Angus Place LDP001)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	0.1	0.0	5.4	2.0	2.0
5%	2.2	0.1	14.5	2.1	2.1
10%	2.4	0.1	14.9	2.2	2.1
20%	2.9	0.2	17.1	2.3	2.2
50%	4.1	0.5	26.1	2.9	2.5
80%	5.3	1.2	28.8	12.1	0.8
90%	6.7	2.9	29.4	15.1	4.9
95%	9.6	6.4	30.9	15.7	8.4
Maximum	853.8	458.4	473.5	460.4	460.4

Summary statistics for predicted daily salinity in Kangaroo Creek (#011) is presented in Table 3.7.

Table 3.7: Predicted Daily Salinity (mg/L) at #011 (Kangaroo Creek, downstream of point of discharge from Angus Place LDP001)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	50	50	75	55	55
5%	277	50	614	266	232
10%	429	50	703	388	356
20%	573	50	760	548	524
50%	704	50	789	698	664
80%	762	51	798	776	733
90%	780	52	800	790	759
95%	790	54	802	797	775
Maximum	804	68	804	804	804

From the above, predicted salinity in Kangaroo Creek is 804mg/L at maximum at #011. This is consistent with assumed salinity of mine water make at Angus Place. Salinity ranges between 100mg/L and 804mg/L at #011, with median being 789mg/L during WS1.

Review of predicted salinity against historical observation indicates the proposed condition is consistent with historical impact of mine water discharge. As noted above, assumed water quality of Kangaroo Creek, upstream of point of discharge is 50mg/L.

Prediction simulation of Coxs River above Wangcol Creek at #056 is presented in Figure 3.9.

A statistical summary of predicted daily flows is presented in Table 3.8.

Table 3.8: Predicted Daily Flow Statistics (ML/d) at #056 (Coxs River above Wangcol Creek/Blue Lagoon)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	0.3	0.0	6.9	2.0	2.0
5%	2.5	0.2	15.3	2.4	2.2
10%	3.0	0.4	16.2	2.6	2.4
20%	3.8	0.6	19.8	3.0	2.6
50%	5.1	1.4	27.4	5.1	3.4
80%	8.0	4.4	30.1	15.1	6.4
90%	14.4	11.4	34.8	16.9	13.4
95%	26.6	22.9	44.8	26.9	24.9
Maximum	3076.6	1613.7	1628.8	1615.7	1615.7

During prediction simulation, there is increased contribution from Kangaroo Creek to this location in WS1 and WS2a. During prediction simulation of WS2b, the impact of mine water discharge to Kangaroo Creek on flow variability at this location is small.

A statistical summary of predicted daily salinity is presented in Table 3.9.

Table 3.9: Predicted Daily Salinity (mg/L) at #056 (Coxs River above Wangcol Creek/Blue Lagoon)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	50	50	63	57	57
5%	136	50	402	127	118
10%	211	50	525	183	168
20%	339	50	666	317	289
50%	556	50	761	538	498
80%	684	55	786	738	626
90%	728	60	792	767	683
95%	759	64	798	780	732
Maximum	804	89	804	804	804

Predicted salinity in the Coxs River ranges between 100mg/L and 804mg/L, with median being 761mg/L during WS1.

Review of predicted salinity against historical observation indicates proposed condition is consistent with historical impact of discharge at Angus Place. As indicated above, salinity range of natural condition is between 50mg/L (assumed minimum) and 89mg/L, with median of 50mg/L.

Sawyers Swamp Creek

Prediction simulation in Sawyers Swamp Creek at #014 is presented in Figure 3.10 for each water management strategy. During the prediction simulation, under scenarios WS1, WS2a and WS2b, there is discharge to Springvale LDP009. Summary statistics of predicted daily flow at #014 is presented in Table 3.10.

Table 3.10: Predicted Daily Flow Statistics (ML/d) at #014 (Sawyers Swamp Creek downstream of point of discharge of Springvale LDP009)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	0.0	0.0	0.0	3.0	3.0
5%	0.0	0.0	0.0	23.3	23.3
10%	0.0	0.0	0.1	24.4	24.4
20%	0.1	0.1	0.1	25.1	25.1
50%	0.2	0.2	14.4	28.0	28.0
80%	1.0	0.4	17.9	30.1	38.1
90%	4.1	1.1	18.3	30.3	42.7
95%	16.1	2.3	18.7	30.8	43.2
Maximum	314.7	169.9	185.7	198.9	198.9

Summary statistics of predicted daily salinity is presented in Table 3.11.

Table 3.11: Predicted Daily Salinity Statistics (mg/L) at #014 (Sawyers Swamp Creek downstream of point of discharge of Springvale LDP009)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	50	50	50	160	160
5%	50	50	50	743	747
10%	50	50	50	774	775
20%	50	50	50	792	792
50%	50	50	761	799	800
80%	50	50	798	802	802
90%	634	50	801	803	803
95%	790	50	802	803	803
Maximum	819	50	804	804	804

Prediction simulation at Sawyers Swamp Creek at confluence with Coxs River (#166) is presented in Figure 3.10. Summary statistics of predicted daily flows is presented in Table 3.12.

Table 3.12: Predicted Daily Flow Statistics (ML/d) at #166 (Sawyers Swamp Creek above Coxs River)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	0.0	0.0	0.0	3.0	3.0
5%	0.0	0.0	0.1	23.4	23.4
10%	0.0	0.1	0.1	24.4	24.4
20%	0.1	0.1	0.2	25.2	25.2
50%	0.2	0.2	14.5	28.2	28.2
80%	1.2	0.6	18.0	30.2	38.3
90%	5.2	1.5	18.4	30.4	42.8
95%	16.5	3.3	18.9	31.5	43.3
Maximum	422.4	223.2	239.0	252.2	252.2

Summary statistics of predicted daily salinity is presented in Table 3.13.

Table 3.13: Predicted Daily Salinity Statistics (mg/L) at #166 (Sawyers Swamp Creek above Coxs River)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	50	50	50	154	154
5%	50	50	50	724	729
10%	50	50	50	766	767
20%	50	50	51	788	789
50%	53	51	751	799	799
80%	90	77	798	802	802
90%	605	90	800	803	803
95%	788	103	802	803	803
Maximum	818	379	804	804	804

From the above, predicted salinity at #014 and #166 is 804mg/L at maximum, consistent with the assumed salinity of mine water make at Springvale and Angus Place. The catchment upstream of point of discharge, Springvale LDP009, is relatively small; therefore the predicted median salinity is similar to the assumed salinity of mine water make. As indicated, despite the relatively small contributing catchment, there is variability in concentration at #166, albeit of limited range. Predicted median salinity at #166 of 751mg/L is within the range of modelled salinity at monitoring station WCS_LDP003_DOWNSTREAM during the calibration period.

Lake Wallace

Prediction simulation of Coxs River immediately above Lake at #047 is presented in Figure 3.11. Predicted daily flow and salinity at this location is summarised in Table 3.14 and 3.15. It is noted that WS1, WS2a and WS2b have identical daily flows at this location.

Table 3.14: Predicted Daily Flow Statistics (ML/d) at #047 (Coxs River upstream of Lake Wallace)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	2.0	4.4	13.3	13.3	13.3
5%	3.4	6.2	33.0	33.0	33.0
10%	4.5	6.7	35.1	35.1	35.1
20%	6.6	7.5	36.8	36.8	36.8
50%	41.8	10.3	47.9	47.9	47.9
80%	105.4	30.4	60.9	60.9	60.9
90%	112.2	51.5	81.9	81.9	81.9
95%	131.2	95.3	126.1	126.1	126.1
Maximum	10694.0	5576.5	5607.4	5607.5	5607.5

Table 3.15: Predicted Daily Salinity Statistics (mg/L) at #047 (Coxs River upstream of Lake Wallace)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	79	107	111	111	111
5%	156	191	358	358	358
10%	195	254	484	484	484
20%	284	397	639	639	639
50%	402	599	755	755	755
80%	514	681	780	780	780
90%	599	713	787	787	787
95%	665	731	791	791	791
Maximum	874	771	797	797	797

From the above, the predicted salinity at this location is comparable to historical salinity although median salinity at 755mg/L is higher than the median salinity of 599mg/L in the null case.

The modelled salinity in Lake Wallace is presented in Figure 3.11. When operational, Wallerawang Power Station, discharged some Cooling Tower blowdown water to the Coxs River above Lake Wallace (Energy Australia, LDP001 and LDP021), however, the majority was discharged below Lake Wallace (Energy Australia, LDP004). ‘Bleed-off’ from Sawyers Swamp Creek Ash Dam (SSCAD) is discharged to Lake Wallace (Energy Australia, LDP003) and whilst included in the water quality model, there was insufficient data of wet ash deposition (prior to 2002) and historical water level response in the dam to improve this component. During the prediction simulation, there was no ‘bleed-off’ from the SSCAD since evaporation from the surface of SSCAD exceeds direct rainfall on the dam surface and runon from the local catchment. As such, the cumulative impact assessment is conservative because there is no contribution from SSCAD via Energy Australia LDP003.

Summary statistics of prediction simulations are presented in Table 3.16 with respect to quality.

Table 3.16: Predicted Daily Salinity Statistics (mg/L) at #074 (Lake Wallace)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	100	91	79	79	79
5%	164	207	369	369	369
10%	197	235	436	436	436
20%	226	265	499	499	499
50%	309	321	604	604	604
80%	408	393	673	673	673
90%	470	433	704	704	704
95%	516	470	720	720	720
Maximum	725	552	747	747	747

From the above, the predicted salinity in Lake Wallace is up to 747mg/L under the proposed water management strategy. Comparison of predicted salinity against historical observation indicates predicted salinity is within the range experienced in the past and variability in salinity is also comparable. Median salinity, however, is higher at 604mg/L under WS1, WS2a and WS2b conditions compared to the calibration period at 309mg/L and prediction null case of 321mg/L.

Lake Lyell and above Lake Lyell

There are two monitoring locations between Lake Wallace and Lake Lyell that are of interest. The first station, #154, corresponds with NSW Office of Water Flow Gauge No. 212058. The second station, #035, corresponds with Energy Australia water quality monitoring location, COX5.

Prediction simulations (flow at #154 and salinity at #035) are presented in Figure 3.12 and summary statistics are presented in Table 3.17 (flow at #154) and Table 3.18 (salinity at #035).

Table 3.17: Predicted Daily Flow Statistics (ML/d) at #154 (Coxs River above Lake Lyell, at location of NSW Office of Water Gauge 212058)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	2.6	0.1	6.7	6.7	6.7
5%	10.0	2.2	29.9	29.9	29.9
10%	10.6	3.3	32.4	32.4	32.4
20%	11.9	5.2	36.6	36.6	36.6
50%	37.3	12.7	48.7	48.7	48.7
80%	90.2	44.5	75.9	75.9	75.9
90%	116.5	84.8	118.0	118.0	118.0
95%	156.1	161.2	192.1	191.9	191.9
Maximum	16029.0	10223.0	10254.0	10254.0	10254.0

From predicted flow chart in Figure 3.12 and tabulated statistics in Table 3.17, WS1 (WS2a and WS2b yield identical results) the proposed water management strategies lead to discernible minimum flow in the Coxs River, however, the variability in magnitude of flow is significant.

Table 3.18: Predicted Daily Salinity Statistics (mg/L) at #035 (Coxs River above Lake Lyell, at location of Energy Australia monitoring location, COX5)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	63	50	67	67	67
5%	164	100	263	263	263
10%	229	125	337	337	337
20%	337	159	418	418	418
50%	472	231	552	552	552
80%	658	315	643	643	643
90%	741	366	681	681	681
95%	786	406	705	705	705
Maximum	1893	540	740	740	740

From predicted salinity chart in Figure 3.12 at #035, expected maximum salinity and variability in salinity is consistent with historical observation, however, the median salinity in prediction simulation at 552mg/L is higher than null case at 231mg/L.

The predicted volume (ML) and salinity (mg/L) in Lake Lyell (#174) is presented in Figure 3.12. Summary statistics of predicted salinity in Lake Lyell is presented in Table 3.19.

Table 3.19: Predicted Daily Salinity Statistics (mg/L) at #174 (Lake Lyell).

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	110	127	145	145	145
5%	165	152	246	246	246
10%	185	170	271	271	271
20%	235	186	303	303	303
50%	355	223	422	422	422
80%	437	251	500	500	500
90%	499	262	522	522	522
95%	559	270	539	539	539
Maximum	830	462	566	566	566

From the above, the prediction simulation indicates salinity in Lake Lyell is higher due to proposed water management strategy at Angus Place and Springvale, however, concentration is comparable to historical range and variability.

The prediction simulation indicates a positive difference in stored volume in Lake Lyell (#174) due to the proposed water management strategy.

Thompsons Creek Reservoir

The predicted volume (ML) and salinity (mg/L) in Thompsons Creek Reservoir is presented in Figure 3.13. Summary statistics of predicted salinity is presented in Table 3.20.

Table 3.20: Predicted Daily Salinity Statistics (mg/L) at #272 (Thompsons Creek Reservoir)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	110	237	314	314	314
5%	110	243	318	318	318
10%	110	245	343	343	343
20%	110	254	365	365	365
50%	274	276	477	477	477
80%	423	307	536	536	536
90%	491	313	575	575	575
95%	561	344	588	588	588
Maximum	914	471	613	613	613

The predicted salinity in Thompsons Creek Reservoir (#272) is higher due to the proposed water management strategy but is only marginally higher than the modelled calibration values.

Similar to the predicted impact in Lake Lyell, there is a minor positive difference to predicted storage volume (ML) in Thompsons Creek Reservoir due to the proposal.

Lake Burragorang and above Lake Burragorang

Figure 3.14 presents the modelled flow and predicted salinity at #225 which lies on the Coxs River immediately above Lake Burragorang. Table 3.21 presents summary statistics of flow and Table 3.22 presents summary statistics of salinity at this model node.

From Figure 3.14, the proposed water management strategy has minimal impact on predicted flow. The difference in predicted salinity is more significant.

Table 3.21: Predicted Daily Flow Statistics (ML/d) at #225 (Coxs River immediately above Lake Burragorang)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	9.0	2.7	9.0	9.0	9.0
5%	16.5	13.9	29.0	29.0	29.0
10%	21.1	19.6	33.2	33.2	33.2
20%	30.0	29.4	41.3	41.3	41.3
50%	72.5	75.7	86.9	86.9	86.9
80%	289.9	312.1	335.0	335.0	335.0
90%	704.9	735.1	788.6	788.6	788.6
95%	1603.0	1701.7	1830.4	1830.4	1830.4
Maximum	93964.0	65977.0	68789.0	68789.0	68789.0

Table 3.22: Predicted Daily Salinity Statistics (mg/L) at #225 (Coxs River immediately above Lake Burragorang)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	51	50	52	52	52
5%	63	63	80	80	80
10%	70	67	90	90	90
20%	80	74	106	106	106
50%	101	90	153	153	153
80%	155	106	252	252	252
90%	209	118	315	315	315
95%	269	129	358	358	358
Maximum	576	217	503	503	503

From Table 3.22, the median salinity under the proposed water management strategy is 153mg/L compared to the null case of median of 90mg/L. The predicted median salinity is higher than the calibration period and, in general, the predicted range is at the upper end of historical observation. Predicted salinity at this location, however, is below the default ANZECC 95% trigger value of 234mg/L (350µS/cm).

The modelled volume (ML) and salinity (mg/L) in Lake Burragorang is presented in Figure 3.14. Table 3.23 presents summary statistics of modelled daily salinity.

Table 3.23: Predicted Daily Salinity Statistics (mg/L) at #280 (Lake Burragorang)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	75	73	74	74	74
5%	77	75	77	77	77
10%	79	77	78	78	78
20%	80	81	85	85	85
50%	83	85	97	97	97
80%	86	87	104	104	104
90%	92	94	108	108	108
95%	94	95	109	109	109
Maximum	97	97	112	112	112

From the above, the proposed discharge by the extensions at Angus Place and Springvale to the Coxs River lead to a marginal increase in salinity in Lake Burragorang compared to the null case. In the null case, median salinity is 85mg/L and is 97mg/L under WS1, WS2a and WS2b. There is a small positive impact to volume in Lake Burragorang due to the proposal.

3.4 Uncertainty Analysis

There are two uncertainty analysis conditions presented:

- Low Rainfall Condition
- High Rainfall Condition

3.4.1 Low Rainfall Condition

Model Setup

The uncertainty analysis simulation was based on the prediction simulation with rainfall dataset updated. All other parameters in the model were left unchanged. As presented in Section 3.3.1, historical annual rainfall totals at BOM Stations 63224, 63071 and 63132 were reviewed and the 19 year total rainfall depth derived. For the low rainfall condition, the lowest 10th percentile rainfall total coincided with the period 1993 to 2011.

The calibrated AWBM parameters and run-off salinity concentrations presented in Table 3.3 were retained for the uncertainty analysis simulation.

Uncertainty Results

The model control files pertaining to the uncertainty analysis simulation were:

- 021a_UNC-LowRf_WS1_01a.gsm
- 021a_UNC-LowRf_WS1_01a_NUL.gsm
- 021a_UNC-LowRf_WS2a_01a.gsm
- 021a_UNC-LowRf_WS2b_01a.gsm

Results from uncertainty analysis are presented at selected locations.

Kangaroo Creek

Figure 3.15 presents modelled flow and salinity in Kangaroo Creek at #011, downstream of point of discharge from Angus Place LDP001. Table 3.24 presents the summary statistics of daily flows at this location. Table 3.25 presents the summary statistics of daily salinity.

Table 3.24: Uncertainty Simulation (Low Rainfall) Daily Flow Statistics (ML/d) at #011 (Kangaroo Creek downstream of Angus Place LDP001)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	0.1	0.0	5.6	2.0	2.0
5%	2.2	0.1	14.2	2.1	2.1
10%	2.4	0.1	14.7	2.1	2.1
20%	2.9	0.2	16.0	2.2	2.2
50%	4.1	0.4	26.4	2.7	2.4
80%	5.3	0.9	28.7	12.3	2.9
90%	6.7	2.1	29.4	14.9	4.1
95%	9.6	4.6	30.3	15.7	6.6
Maximum	853.8	206.6	221.6	208.6	208.6

Table 3.25: Uncertainty Simulation (Low Rainfall) Daily Salinity Statistics (mg/L) at #011 (Kangaroo Creek downstream of Angus Place LDP001)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	50	50	102	59	59
5%	277	50	667	333	280
10%	429	50	738	478	422
20%	573	50	771	600	567
50%	704	50	791	711	680
80%	762	51	798	778	744
90%	780	52	801	790	768
95%	790	54	802	795	782
Maximum	804	74	804	804	804

From Figure 3.15, simulated salinity during WS1 is higher than the equivalent peak under median rainfall conditions, however, is not significantly outside the range of historical observation. The median simulated salinity is 791mg/L. This is compared to 789mg/L during the prediction, as presented in Table 3.7. The maximum simulated salinity is 804mg/L compared to prediction simulation of 804mg/L.

Sawyers Swamp Creek

Figure 3.16 presents the modelled flow and simulated salinity at #14, immediately downstream of point of discharge of Springvale LDP009 under each water management strategy.

Table 3.26 presents summary statistics with respect to daily flow. Table 3.27 presents summary statistics with respect to simulated water quality.

Table 3.26: Uncertainty Simulation (Low Rainfall) Daily Flow Statistics (ML/d) at #014 (Sawyers Swamp Creek downstream of Springvale LDP009)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	0.0	0.0	0.0	3.1	3.1
5%	0.0	0.0	0.0	23.8	23.8
10%	0.0	0.0	0.1	24.4	24.4
20%	0.1	0.1	0.1	25.2	25.2
50%	0.2	0.1	14.2	27.5	27.5
80%	1.0	0.3	17.8	30.1	38.1
90%	4.1	0.8	18.3	30.3	42.6
95%	16.1	1.7	18.7	30.7	43.0
Maximum	314.7	76.5	93.3	106.3	106.3

Table 3.27: Uncertainty Simulation (Low Rainfall) Daily Salinity Statistics (mg/L) at #014 (Sawyers Swamp Creek downstream of Springvale LDP009)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	50	50	50	261	261
5%	50	50	50	759	761
10%	50	50	50	782	783
20%	50	50	50	794	795
50%	50	50	782	800	800
80%	50	50	799	802	802
90%	634	50	801	803	803
95%	790	50	802	803	803
Maximum	819	50	804	804	804

From Figure 3.16, Table 3.26 and Table 3.27 there is no significant difference compared to predicted flow or predicted concentration since catchment area contributing to #014 is small. Median salinity in uncertainty analysis simulation at #014 is 782mg/L compared to 761mg/L during prediction simulation.

Lake Lyell and Above Lake Lyell

Figure 3.17 presents the simulated concentration at #035, which lies on the Coxs River upstream of Lake Lyell. Model node #035 corresponds to location of Energy Australia monitoring location COX5.

Table 3.28 presents a statistical summary of simulated salinity at this location.

Table 3.28: Uncertainty Simulation (Low Rainfall) Daily Salinity Statistics (mg/L) at #035 (Coxs River above Lake Lyell)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	63	50	105	105	105
5%	164	116	325	325	325
10%	229	135	381	381	381
20%	337	163	454	454	454
50%	472	231	566	566	566
80%	658	389	642	642	642
90%	741	485	677	677	677
95%	786	519	710	710	710
Maximum	1893	622	762	762	762

From Figure 3.17, simulated salinity is marginally higher than the prediction simulation. From Table 3.28, median salinity is 566mg/L. This is compared to a median salinity of 552mg/L, as presented in Table 3.18.

The simulated volume (ML) and salinity (mg/L) in Lake Lyell is presented in Figure 3.17, with a statistical summary of daily salinity presented in Table 3.29.

Table 3.29: Uncertainty Simulation (Low Rainfall) Daily Salinity Statistics (mg/L) at #174 (Lake Lyell)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	110	175	247	247	247
5%	165	185	317	317	317
10%	185	190	345	345	345
20%	235	202	375	375	375
50%	355	225	457	457	457
80%	437	374	529	529	529
90%	499	407	554	554	554
95%	559	431	565	565	565
Maximum	830	477	616	616	616

From Figure 3.17, simulated peak salinity of 616mg/L is higher than the peak of 566mg/L in the prediction simulation. Median simulated salinity in Table 3.29 is also marginally higher than median prediction simulation presented in Table 3.19.

From Figure 3.17, simulated periods of low storage volume correspond with higher salinity, as would be expected.

Lake Burragorang and Above Lake Burragorang

Simulated daily flow and daily salinity upstream of Lake Burragorang at #225 is presented in Figure 3.18.

Table 3.30 presents summary statistics with respect to daily flow and Table 3.31 presents summary statistics with respect to salinity.

Table 3.30: Uncertainty Simulation (Low Rainfall) Daily Flow Statistics (ML/d) at #225 (Coxs River immediately upstream of Lake Burragorang)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	9.0	2.9	9.0	9.0	9.0
5%	16.5	15.0	26.1	26.1	26.1
10%	21.1	20.2	31.6	31.6	31.6
20%	30.0	28.5	40.5	40.5	40.5
50%	72.5	66.2	78.7	78.7	78.7
80%	289.9	229.0	251.6	251.6	251.6
90%	704.9	591.9	642.4	642.4	642.4
95%	1603	1,345	1,416	1,416	1,416
Maximum	93964	53,590	53,627	53,627	53,627

Table 3.31: Uncertainty Simulation (Low Rainfall) Daily Salinity Statistics (mg/L) at #225 (Coxs River immediately above Lake Burragorang)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	51	51	52	52	52
5%	63	66	95	95	95
10%	70	71	104	104	104
20%	80	77	120	120	120
50%	101	93	170	170	170
80%	155	112	262	262	262
90%	209	140	331	331	331
95%	269	183	378	378	378
Maximum	576	363	513	513	513

From Table 3.31, median salinity at #225 is 170mg/L and is higher compared to equivalent median in the prediction simulation. As indicated in Table 3.31, the median salinity in the simulated null case is also slightly higher compared to Table 3.22. From Figure 3.18, simulated salinity is above the range of historical observation, as presented in Figure 3.8.

Figure 3.18 presents the simulated volume and salinity in Lake Burragorang and Table 3.32 presents summary statistics of daily salinity.

From Figure 3.18, the simulated salinity ranges between 79mg/L and 105mg/L and is 79mg/L and 88mg/L at equivalent times in the null case.

Table 3.32: Predicted Daily Salinity Statistics (mg/L) at #280 (Lake Burragorang)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	75	79	79	79	79
5%	77	79	84	84	84
10%	79	80	88	88	88
20%	80	81	91	91	91
50%	83	85	95	95	95
80%	86	87	100	100	100
90%	92	89	102	102	102
95%	94	90	103	103	103
Maximum	97	92	105	105	105

From Table 3.32, median salinity in the simulation is 85mg/L and is 95mg/L in the null case. The median salinity in this uncertainty analysis simulation in Table 3.32 is consistent with the median salinity in the prediction simulation and is also the case with respect to the null case.

The results of uncertainty analysis imply simulated salinity in Lake Burragorang is not particularly sensitive to assumed rainfall condition.

3.4.2 High Rainfall Condition

Model Setup

The uncertainty analysis simulation was based on the prediction simulation, with rainfall dataset updated. As indicated above for the low rainfall condition simulation, the 19 year rainfall totals from historical annual rainfall record of stations 63224, 63071 and 63132 were reviewed and the 90th percentile total determined. This corresponded with the period 1981 to 1999. The daily record from 1 July 1981 to 31 December 1999 was then transcribed into the model.

Uncertainty Results

The model control file pertaining to uncertainty analysis simulations are:

- 021a_UNC-HighRf_WS1_01a.gsm
- 021a_UNC-HighRf_WS1_01a_NUL.gsm
- 021a_UNC-HighRf_WS2a_01a.gsm
- 021a_UNC-HighRf_WS2b_01a.gsm

It is noted that the locations of presentation of simulation results in this uncertainty analysis simulation correspond with the locations for the low rainfall conditions such that they can compared.

Kangaroo Creek

Figure 3.19 presents the simulated daily flow and salinity at #011 which lies on Kangaroo Creek downstream of point of discharge from Angus Place LDP001. Table 3.33 presents summary statistics with respect to flow and Table 3.34 presents summary statistics with respect to daily salinity at this location.

Table 3.33: Uncertainty Simulation (High Rainfall) Daily Flow Statistics (ML/d) at #011 (Kangaroo Creek downstream of Angus Place LDP001)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	0.1	0.0	6.0	2.0	2.0
5%	2.2	0.1	14.2	2.1	2.1
10%	2.4	0.1	14.8	2.1	2.1
20%	2.9	0.2	16.1	2.2	2.2
50%	4.1	0.5	26.5	2.7	2.5
80%	5.3	1.5	28.9	12.8	3.5
90%	6.7	3.6	29.5	15.8	5.6
95%	9.6	8.0	32.3	17.5	10.0
Maximum	853.8	851.2	866.2	853.2	853.2

Table 3.34: Uncertainty Simulation (High Rainfall) Daily Salinity Statistics (mg/L) at #011 (Kangaroo Creek downstream of Angus Place LDP001)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	50	50	65	53	53
5%	277	50	607	286	202
10%	429	50	698	444	318
20%	573	50	754	584	483
50%	704	50	787	697	652
80%	762	51	797	761	728
90%	780	52	800	778	758
95%	790	53	801	787	776
Maximum	804	68	804	804	804

From Table 3.34, simulated median salinity is 787mg/L compared to median salinity in null case of 50mg/L. As presented in the prediction simulation in Figure 3.9, discharge at Angus Place does dominate daily flows and daily salinity in Kangaroo Creek since contributing catchment of Kangaroo Creek is only of moderate size.

Sawyers Swamp Creek

Figure 3.20 presents the results of uncertainty analysis simulation at #014, which lies on Sawyers Swamp Creek, immediately downstream of point of discharge of Springvale LDP009. Table 3.35 presents a statistical summary of daily flows at this model node and Table 3.36 presents a statistical summary of daily salinity at this location.

Table 3.35: Uncertainty Simulation (High Rainfall) Daily Flow Statistics (ML/d) at #014 (Sawyers Swamp Creek downstream of Springvale LDP009)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	0.0	0.0	0.0	3.2	3.2
5%	0.0	0.0	0.0	23.6	23.6
10%	0.0	0.0	0.1	24.3	24.3
20%	0.1	0.1	0.1	25.1	25.1
50%	0.2	0.2	14.2	27.6	27.6
80%	1.0	0.6	18.1	30.3	38.3
90%	4.1	1.3	18.7	30.8	43.0
95%	16.1	3.0	19.9	32.0	43.5
Maximum	314.7	314.8	331.6	344.5	344.5

Table 3.36: Uncertainty Simulation (High Rainfall) Daily Salinity Statistics (mg/L) at #014 (Sawyers Swamp Creek downstream of Springvale LDP009)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	50	50	50	115	115
5%	50	50	50	732	740
10%	50	50	50	768	772
20%	50	50	50	789	791
50%	50	50	753	799	799
80%	50	50	796	802	802
90%	634	50	799	803	803
95%	790	50	801	803	803
Maximum	819	50	804	804	804

From Figure 3.20, discharge from Springvale LDP009 does dominate flows in Sawyers Swamp Creek with respect to each water management strategy. Simulated median salinity at #014 is 753mg/L and is 50mg/L in the null case. Assumed salinity of mine water discharge is 804mg/L for comparison. As indicated in Section 3.3.3, due to the small size of Sawyers Swamp Creek catchment upstream of this location, median simulated salinity is close to assumed salinity of mine water make.

Lake Lyell and Above Lake Lyell

Figure 3.21 presents simulated salinity at #035. #035 lies on the Coxs River above Lake Lyell and corresponds with Energy Australia monitoring location, COX5. Table 3.37 presents a statistical summary of daily salinity at this location.

Table 3.37: Uncertainty Simulation (High Rainfall) Daily Salinity Statistics (mg/L) at #035 (Coxs River above Lake Lyell)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	63	50	69	69	69
5%	164	88	231	231	231
10%	229	98	303	303	303
20%	337	120	395	395	395
50%	472	216	533	533	533
80%	658	347	622	622	622
90%	741	412	660	660	660
95%	786	448	688	688	688
Maximum	1893	546	767	767	767

From Figure 3.21, simulated salinity in this uncertainty analysis is marginally lower compared to prediction simulation presented in Figure 3.11. This is due to higher runoff from the catchment given the higher rainfall condition. From Table 3.37, median salinity is 533mg/L and is 216mg/L in the null case.

The simulated volume and salinity in Lake Lyell is presented in Figure 3.21. A statistical summary of daily salinity is presented in Table 3.38.

Table 3.38: Uncertainty Simulation (High Rainfall) Daily Salinity Statistics (mg/L) at #174 (Lake Lyell)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	110	109	141	141	141
5%	165	129	203	203	203
10%	185	135	237	237	237
20%	235	148	273	273	273
50%	355	218	420	420	420
80%	437	321	470	470	470
90%	499	334	487	487	487
95%	559	372	504	504	504
Maximum	830	469	598	598	598

From Figure 3.21, the minimum salinity is 141mg/L and maximum is 598mg/L and is 112mg/L and 469mg/L in the null case at equivalent times. In Table 3.38, median salinity in the uncertainty analysis simulation is 420mg/L and is marginally lower than the prediction simulation at 422mg/L, reflecting greater runoff from the Coxs River catchment.

Lake Burragorang and Above Lake Burragorang

Figure 3.22 presents the simulated flow and salinity at #225 which lies on the Coxs River upstream of Lake Burragorang. Table 3.39 presents a statistical summary of flow at this location and Table 3.40 presents a statistical summary of salinity.

Table 3.40 indicates the median salinity is 142mg/L in this uncertainty analysis simulation and is 89mg/L in the null case. By comparison, the median salinity presented in Table 3.22 for prediction simulation is 153mg/L. As noted in Section 3.3.3, simulated range of salinity is at the upper end of historical observation at this location.

Table 3.39: Uncertainty Simulation (High Rainfall) Daily Flow Statistics (ML/d) at #225 (Coxs River immediately upstream of Lake Burragorang)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	9.0	5.8	9.0	9.0	9.0
5%	16.5	16.0	25.3	25.3	25.3
10%	21.1	21.0	31.5	31.5	31.5
20%	30.0	32.9	43.5	43.5	43.5
50%	72.5	87.9	98.6	98.6	98.6
80%	289.9	364.9	397.3	397.3	397.3
90%	704.9	830.0	899.6	899.6	899.6
95%	1603.0	1,920.0	2,048.5	2,048.5	2,048.5
Maximum	93964	94,117	94,154	94,154	94,154

Table 3.40: Uncertainty Simulation (High Rainfall) Daily Salinity Statistics (mg/L) at #225 (Coxs River immediately above Lake Burragorang)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	51	51	52	52	52
5%	63	58	77	77	77
10%	70	63	86	86	86
20%	80	70	100	100	100
50%	101	89	142	142	142
80%	155	113	227	227	227
90%	209	139	286	286	286
95%	269	177	329	329	329
Maximum	576	348	460	460	460

Figure 3.22 presents simulated volume and salinity in Lake Burragorang and Table 3.41 presents summary statistics of daily salinity.

Table 3.41: Uncertainty Simulation (High Rainfall) Daily Salinity Statistics (mg/L) at #280 (Lake Burragorang)

Percentile	CAL	NUL	WS1	WS2a	WS2b
Minimum	75	74	78	78	78
5%	77	75	79	79	79
10%	79	76	80	80	80
20%	80	78	81	81	81
50%	83	82	88	88	88
80%	86	91	102	102	102
90%	92	92	104	104	104
95%	94	93	104	104	104
Maximum	97	95	107	107	107

From Figure 3.22, the higher rainfall condition leads to higher storage levels in Lake Burragorang, as would be expected. Simulated salinity under the proposed water management strategies, has minimum of 78mg/L and maximum of 107mg/L, with minimum and maximum in null case at equivalent times 74mg/L and 95mg/L. Median salinity in Table 3.41 is 88mg/L and is 82mg/L in the null case.

The results of uncertainty analysis indicates simulated salinity in Lake Burragorang is not particularly sensitive to assumed rainfall condition.

4. Impact Assessment

4.1 Impact to Flow

4.1.1 Kangaroo Creek and Coxs River above Wangcol Creek / Blue Lagoon

The daily rainfall / runoff model developed as part of this impact assessment indicates that mine water discharge at Angus Place through Angus Place LDP001 does dominate flows in Kangaroo Creek in WS1 and WS2a, however, is commensurate with historical flows under WS2b (discharge at Angus Place LDP001 at 2ML/d).

In the Coxs River, upstream of Wangcol Creek / Blue Lagoon, continuous discharge under WS1 is substantial compared to the null case, however, peak flows in the null case do exceed average daily flow which implies some variability in flow is maintained. Under WS2a, the impact of mine water discharge at Angus Place is reduced and is not significant under WS2b.

4.1.2 Sawyers Swamp Creek

At node #014, which lies on Sawyers Swamp Creek, immediately downstream of point of discharge from Springvale LDP009, predicted flow under WS1, WS2a and WS2b are significant compared to the null case. As indicated in Section 3.2.3, this is due to the small catchment upstream of this location on Sawyers Swamp Creek due to the catchment diversion because of the SSCAD.

At the downstream end of Sawyers Swamp Creek, above the Coxs River, at node #166, runoff from the null case is small compared to the predctions under the proposed water management strategies. In context, however, the Sawyers Swamp Creek catchment is already in a highly disturbed state due to the presence of historical open cut mining at Kerosene Vale, the SSCAD and Dry Ash Emplacement Facility. As indicated in Section 2.5.3, with the construction of the SDWTS in 2006, excess mine water was discharged to Sawyers Swamp Creek when not required at Wallerawang Power Station.

4.1.3 Downstream Impacts

At node #047, which lies on the Coxs River above Lake Wallace, whilst there is continuous discharge that leads to predicted median flows exceeding predicted median flows in the null case, peak flows (flood flows) at this location are substantial in comparison.

A similar conclusion is drawn for node #154, which lies on the Coxs River between Lake Wallace and Lake Lyell.

At node #255, which lies on the Coxs River immediately upstream of Lake Burragorang, the impact of the proposed water management strategy is essentially indiscernible compared to the null case.

Table 4.1 presents a summary of the model results from the top of the catchment downstream through to Lake Burragorang. The model results presented in Table 4.1 were obtained from detailed results presented in Section 3.0.

Table 4.1: Summary of Predicted Daily Flows (ML/d) in the Coxs River catchment.

Location	Node	NUL[1]	WS1[1]	WS2a[1]	WS2b[1]
Kangaroo Creek and Coxs River above Wangcol Creek/Blue Lagoon					
Kangaroo Creek downstream of Angus Place LDP001	#011	0.5(0.0-458)	26.1(5.4-474)	2.9(2.0-460)	2.5(2.0-460)
Coxs River above Wangcol Creek/Blue Lagoon	#056	1.4(0.0-1613)	27.4(6.9-1629)	5.1(2.0-1616)	3.4(2.0-1616)
Sawyers Swamp Creek					
Sawyers Swamp Creek downstream of Springvale LDP009	#014	0.2(0.0-170)	14.4(0.0-186)	28.0(3.0-199)	28.0(3.0-199)
Sawyers Swamp Creek above Coxs River	#166	0.2(0.0-223)	14.5(0.0-239)	28.2(3.0-252)	28.2(3.0-252)

Location	Node	NUL[1]	WS1[1]	WS2a[1]	WS2b[1]
Lake Wallace					
Coxs River above Lake Wallace	#047	10.3(4.4-5,577)	47.9(13.3-5,607)	as per WS1	as per WS1
Lake Wallace	#074	n/a	n/a	as per WS1	as per WS1
Lake Lyell and above Lake Lyell					
Coxs River above Lake Lyell	#154	12.7(0.1-10,223)	48.7(6.7-10,254)	as per WS1	as per WS1
Lake Lyell	#174	n/a	n/a	as per WS1	as per WS1
Thompsons Creek Reservoir					
Thompsons Creek Reservoir	#272	n/a	n/a	as per WS1	as per WS1
Lake Burragorang and above Lake Burragorang					
Coxs River above Lake Burragorang	#225	75.7(2.7-65,977)	86.9(9.0-68,789)	as per WS1	as per WS1
Lake Burragorang	#280	n/a	n/a	as per WS1	as per WS1

1. The format of presented model results is median (minimum to maximum);

4.2 Impact to Quality

4.2.1 Kangaroo Creek and Coxs River above Wangcol Creek / Blue Lagoon

Modelling indicates that predicted salinity in Kangaroo Creek is dominated by the assumed salinity of mine water discharge at Angus Place. Predicted salinity of a maximum of 804mg/L in the Coxs River above Wangcol Creek / Blue Lagoon is within the range of historical observation due to discharge at Angus Place in the past. Modelled salinity upstream of point of discharge in Kangaroo Creek is 50mg/L and in the Coxs River above the confluence with Kangaroo Creek, fluctuates between 50 and 75mg/L.

4.2.2 Sawyers Swamp Creek

Modelling indicates that the predicted salinity in Sawyers Swamp Creek is also dominated by the assumed salinity of mine water discharge at Springvale Mine via Springvale LDP009.

4.2.3 Downstream Impacts

In the Coxs River, at #047, which lies immediately upstream of Lake Wallace, the predicted median salinity is 755mgL; however, as presented in Figure 3.11, there is reasonable modelled day to day variability. For comparison, in the null case, the median salinity is 599mg/L. The predicted salinity in Lake Wallace (#074) is 604mg/L (median) and is 321mg/L (median) in the null case.

Further downstream, in Lake Burragorang, the predicted impact of the proposed water management strategies is an increase in median salinity from 85mg/L to 97mg/L.

Table 4.2 presents a summary of the model results from the top of the catchment downstream through to Lake Burragorang. The model results presented in Table 4.2 were obtained from detailed results presented in Section 3.0.

Table 4.2: Summary of Predicted Daily Salinity (mg/L) in the Coxs River catchment.

Location	Node	NUL[1,2]	WS1[1]	WS2a[1]	WS2b[1]
Kangaroo Creek and Coxs River above Wangcol Creek/Blue Lagoon					
Kangaroo Creek downstream of Angus Place LDP001	#011	50(50-68)	789(75-804)	698(55-804)	664(55-804)
Coxs River above Wangcol Creek/Blue Lagoon	#056	50(50-89)	761(63-804)	538(57-804)	498(57-804)
Sawyers Swamp Creek					
Sawyers Swamp Creek downstream of Springvale LDP009	#014	50(50-50)	761(50-804)	799(160-804)	800(160-804)
Sawyers Swamp Creek above Coxs River	#166	51(50-379)	751(50-804)	799(154-804)	799(154-804)
Lake Wallace					
Coxs River above Lake Wallace	#047	599(107-771)	755(111-797)	as per WS1	as per WS1
Lake Wallace	#074	321(91-552)	604(79-747)	as per WS1	as per WS1
Lake Lyell and above Lake Lyell					
Coxs River above Lake Lyell	#035	231(50-540)	552(67-740)	as per WS1	as per WS1
Lake Lyell	#174	223(127-462)	422(145-566)	as per WS1	as per WS1
Thompsons Creek Reservoir					
Thompsons Creek Reservoir	#272	276(237-471)	477(314-613)	as per WS1	as per WS1
Lake Burragorang and above Lake Burragorang					
Coxs River above Lake Burragorang	#225	90(50-217)	153(52-503)	as per WS1	as per WS1
Lake Burragorang	#280	85(73-97)	97(74-112)	as per WS1	as per WS1

1. The format of presented model results is median (minimum to maximum); 2. It is noted that minimum salinity in water quality model was 50mg/L.

SCA has adopted a risk assessment based approach to water quality management. As part of that management framework, SCA have developed a Pollution Source Assessment Tool. The outcomes of that work identified the five most significant pollution sources in the catchment which, in general, relate to faecal contamination and/or nutrients (Phosphorous and Nitrogen). They include the following:

- grazing
- intensive animal production
- on-site wastewater management systems
- sewage collection systems
- urban stormwater.

As outlined in SCA's Annual Water Quality Monitoring Report 2012-2013 (SCA, 2013), water quality management is focussed on:

- Australian Drinking Water Guidelines (health-related)
- Raw Water Supply Agreements (in this case Prospect Water Filtration Plant).

The relevant target water quality parameters are reproduced from SCA (2013) in Table 4-1 and Table 4-2 respectively.

From the above, there is no target for salinity since the ADWG do not have a health-based water quality criteria. There is also no target for salinity for the Prospect Water Filtration Plant with respect to Raw Water Supply Agreement. As identified in the SSTV Assessment, other water quality characteristics meet the ADWG and the Raw Water Supply Agreement specifications. The predicted minor increase in salinity in Lake Burragorang due to the proposal is therefore considered to have a neutral effect with respect to the Neutral or Beneficial Effect test criteria.

Table 4.3: SCA Target Health-Related Water Quality Characteristics for Lake Burragorang

Table 4.1 Health-related water quality characteristics

	Specific Water Characteristic	ADWG (2011) Health Guideline
SYNTHETIC ORGANICS – RADIOLOGICAL - PESTICIDES	Amitrole	0.0009 mg/L
	Atrazine	0.02 mg/L
	Chlorpyrifos	0.01 mg/L
	2,4-D	0.03 mg/L
	2,4,5-T	0.1 mg/L
	Diazinon	0.004 mg/L
	Diquat	0.007 mg/L
	Diuron	0.02 mg/L
	Glyphosate	1.0 mg/L
	Heptachlor	0.0003 mg/L
	Hexazinone	0.4 mg/L
	Triclopyr	0.02 mg/L
	Gross alpha	0.5 Bq/L
	Gross beta	0.5 Bq/L
	Benzene	0.001 mg/L
	1,2-Dichloroethane	0.003 mg/L
	1,2-Dichloroethene	0.06 mg/L
	Hexachlorobutadiene	0.0007 mg/L
	Vinyl chloride	0.0003 mg/L
CHEMICAL/BIOLOGICAL/ORGANIC	Arsenic	0.01mg/L
	Barium	2 mg/L
	Boron	4 mg/L
	Iodide	0.5 mg/L
	Mercury	0.001 mg/L
	Molybdenum	0.05 mg/L
	Selenium	0.01 mg/L
	Silver	0.1 mg/L
	Tin	N/A
	Beryllium	0.06 mg/L
	Escherichia coli	Seek advice from NSW Health and liaise with customers if the thresholds for these analytes in Raw Water Quality Incident Response Plan are exceeded
	Enterococci	
	Clostridium perfringens	
	Cryptosporidium	
	Giardia	
	Toxin producing cyanobacteria	
	Toxicity	
	Cyanobacteria biovolume	

Footnotes

1 Section shaded **yellow** contains health related water quality characteristics – these characteristics must not exceed Australian Drinking Water Guidelines (NHMRC, 2011) in raw water supplied for treatment.

2 Section shaded **blue** contains characteristics for which drinking water guidelines exist although these are not applicable for raw water. However, SCA must endeavour to supply the best quality raw water available so that it can be treated to meet Australian Drinking Water Guidelines.

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Table 4.4: SCA Target Raw Water Supply Agreement Water Quality characteristics for Lake Burragorang

Table 4.2 Raw water supply agreements – Site specific standards

PARAMETER	Prospect WFP	Warragamba WFP Orchard Hills WFP	Macarthur WFP Value of Parameter Based on Demand Range (ML/d)				Illawarra WFP	Woronora WFP	Nepean WFP	Cascade WFP	Kangaroo Valley WFP	Wingecarribee † WFP
			185-<265	125-<185	80-<125	<80						
Turbidity (NTU^)	40	40	10	25	50	60	10	10	150	15	20	40
True colour (CU^)	60	60	40				50	70	60	60	70	70
Iron (mg/L^)	3.5	3.5	0.6	0.8	1.1	1.3	1.1	1	5	3	1.1	1.1
Manganese (mg/L^)	1.4	1.4	0.2	0.25	0.3	0.35	0.4	0.1	1.5	0.3	NA	NA
Aluminium (mg/L^)	2.6	2.6	0.4	0.5	0.75	0.95	1.4	0.4	1.0	0.2	NA	NA
Hardness (mg/L as $CaCO_3$)	25 – 70	25 - 70	6 – 30	6.0 – 32.2			0 – 30	2 – 30	2 – 35	0 – 40	0 – 36.5	0 - 36.5
Alkalinity (mg/L as $CaCO_3$)	15 – 60	15 - 60	0 - 15				0 – 10	0 – 15	0.5 – 25	0 – 30	0 - 29	0 - 35
pH (pH units)	6.3 – 7.9	6.3 - 7.9	5.7 – 7.7				6.2 – 7.2	5.1 – 7.5	4.8 – 7.7	6.0 – 7.9	6.5 – 8.5	6.5 – 8.5
Temperature (°C)	10 – 25	10 - 25	8 - 25				10 – 25	10 – 25	10 – 25	10 – 25	NA	NA
Algae (ASU)	1000*	2000	**see note				5000	5000	2000	2000	5000	5000

* Maximum for Prospect WFP is 1000 ASU, except if turbidity is greater than 10NTU or true colour is greater than 30 CU, then the maximum algae criterion will be 500 ASU.
** Algal limits for Macarthur WFP (average of 3 samples): 500 ASU small individual cells (<10μm) of filamentous or colony-forming species or 100 ASU large cells (>10μm) of branching or gelatinous species.
^ Upper limits are shown for these parameters.
† Same arrangement for Goulburn-Mulwaree Council for water supplied via the Goulburn pipeline

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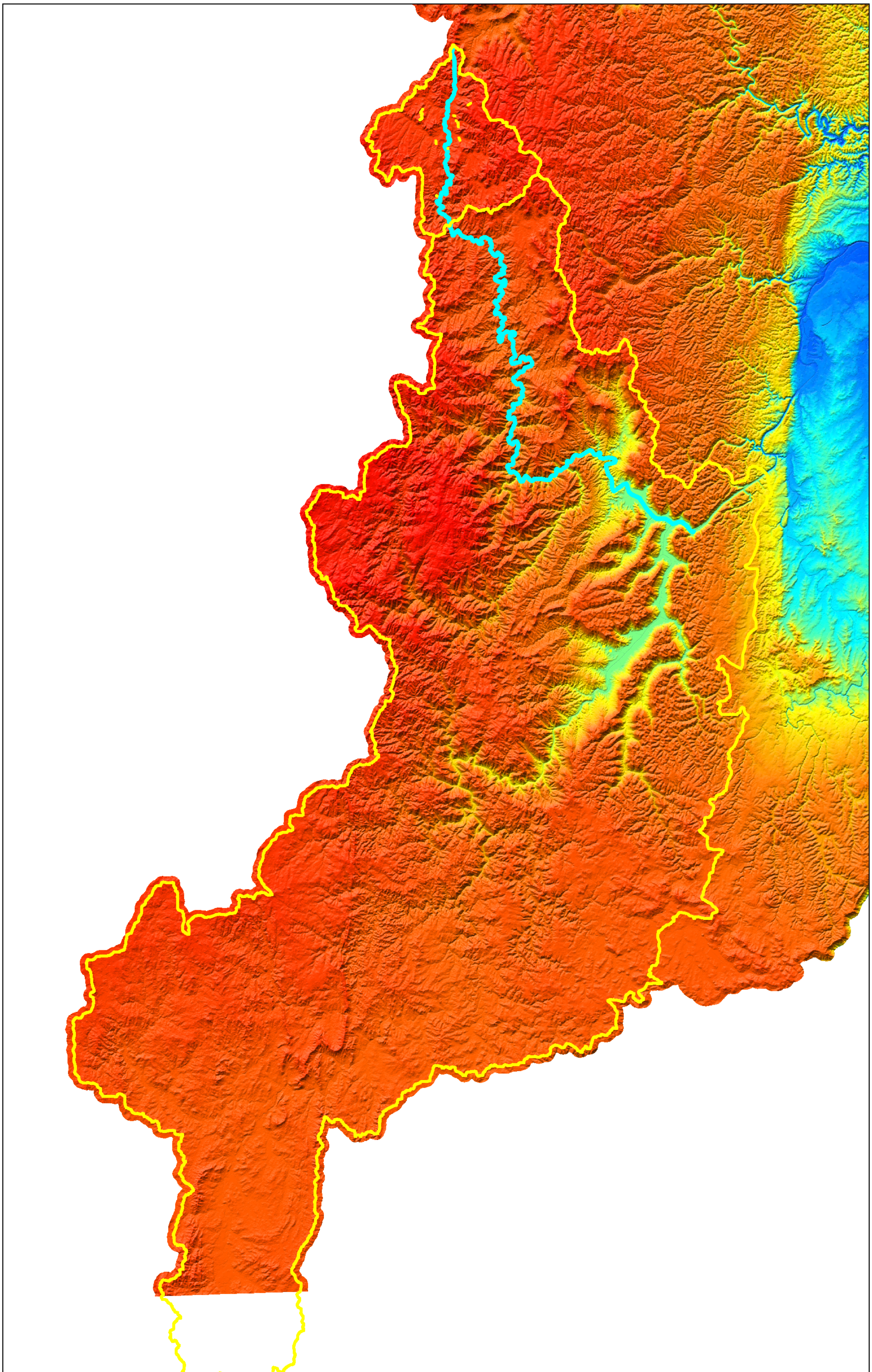
FIGURES



RPS

STUDY AREA FIGURE 2-1

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