APPENDIX F

Surface water assessment

Cobbora Coal Project – Surface Water Assessment

January 2013

Cobbora Holding Company Pty Limited

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Executive summary

This report assesses the potential surface water impacts associated with the proposed Cobbora Coal Project (the Project). Parsons Brinckerhoff has prepared this report for Cobbora Holding Company Pty Limited (CHC) for the purpose of informing the environmental assessment for the Project.

The Project comprises a new open-cut coal mine that will supply thermal coal, primarily to power stations in NSW. In addition, some coal will be produced for a combination of export and spot domestic markets. The Project is located approximately 5 km south of Cobbora, 22 km south-west of Dunedoo, 64 km north-west of Mudgee and 60 km east of Dubbo in the central west of NSW.

The Project's main elements are an open-cut mine, a coal-handling and preparation plant (CHPP), a train-loading facility and rail spur, a mine infrastructure area, and supporting infrastructure, including access roads, water supply and storage, and electricity supply. It is envisaged that construction activities will commence in mid-2013, with coal supplied to customers from the first half of 2015. The mine life will be 21 years.

The scope of the surface water assessment was developed to address the Director General's Requirements, as they apply to surface water. The assessment has therefore focussed on the following three key technical areas:

- site water management
- flood impacts
- downstream water quality and flow impacts.

A brief summary of the findings from each technical area is provided below.

Site water management

The proposed water management system has been designed to segregate clean runoff and mine water, and provide flexibility to ensure the site can operate over the proposed 21 year mine-life under a range of climatic conditions.

Clean water from undisturbed catchments will be diverted around the mine to Sandy Creek and Laheys Creek as much as practical. This will assist to maintain flows in the creek system. Runoff from disturbed areas, such as overburden emplacement areas, will be directed to a number of sedimentation dams strategically placed throughout the mine to allow settling. Captured water will be either reused on-site to satisfy site water demands or returned to Sandy Creek and Laheys Creek when water quality criteria have been met.

Runoff and groundwater seepage captured in-pit will be pumped to mine water dams. Infrastructure runoff from the CHPP, mine infrastructure area, coal stockpiles and rail loading facilities will be captured in storage dams. This water will be used to meet site demands as a priority over raw water and will not be released to the creek system under any circumstances.

Water balance modelling predicted that during mining the surface water flows downstream of the site will slightly decrease for dry years, but will generally increase for median and wet years. During median and wet years more water captured in sedimentation dams will be released to downstream creeks because it will not be required to supplement on-site demands. Post mining the catchment changes due to the rehabilitated landform will result in increases in downstream flows for dry, median and wet years.

The final landform has been designed to backfill two mining voids and minimise the size of the third void. Due to economic constraints on the Project, a void lake is unavoidable in the south eastern end of mining area B. This void will not overtop and will act as a groundwater sink which will therefore not impact on the surface water environment.

The water balance modelling suggests that site demands cannot be met just by harvesting on-site runoff. Water deficits will occur throughout the life of the mine under all climatic conditions, and imported water will be required to make-up this deficit. The requirement for imported water peaks in Year 20, when production rates and demands are high but groundwater make is relatively low.

CHC's current water entitlements of 3,311 ML/a from the Cudgegong/Macquarie Regulated River system are adequate to meet requirements for a 10th percentile dry rainfall year, assuming most of its allocation of high security entitlements is available. If extremely dry conditions (i.e. beyond the 10th percentile) are experienced, there would be a nominal water shortage and the mine would have to rely on a hierarchy of additional water supply or consumption strategies.

Flood impacts

A detailed flood investigation, including hydrologic and hydraulic modelling gave an understanding of the existing flooding behaviour of Sandy Creek and Laheys Creek and how it affects the main mining area. The modelling also determined how the proposed mine and associated infrastructure will affect flood behaviour in the catchment. Areas outside the mine, such as Flyblowers Creek, north of Sandy Creek catchment and the proposed rail spur waterway crossings, were assessed separately using other methods.

It was found that flows in Laheys Creek would increase slightly due to the progressive diversion of the northern part of the catchment (which naturally flows into Sandy Creek) into Laheys Creek. However, this will be counteracted by the loss of catchment area to the mine, so changes in peak flows will be minimal.

The northern boundary of the mine is approximately 2 km from the Talbragar River, and the catchment containing the mine is up to 45 m above the banks of the river. For all events analysed, including the 2,000-year average recurrence interval (ARI) event, flood levels in the Talbragar River will not be affected by the mine due to the distance and difference in elevation between the mine and the river.

Overall, the hydraulic modelling shows no significant change in flood levels along Sandy Creek and Laheys Creek, both upstream and downstream of the main mining area, and no impacts on flooding in land outside of CHC's ownership. Therefore, no mitigation measures are required in the Sandy Creek catchment to reduce flooding impacts.

However, there would be an impact on Flyblowers Creek, north of Sandy Creek. During Years 12–20, mitigation measures would be required to reduce the peak flow in Flyblowers Creek. A dry detention basin with a capacity of 70 ML is recommended. The detention basin can be accommodated within the Project Application Area, and should be close to the disturbed area. With this detention basin, peak flows reaching the Golden Highway should be close to those of the existing scenario, thereby avoiding adverse impacts on the highway.

In the rail corridor, the proposed rail spur will cross local waterways at 21 locations, including Fords Creek, Lambing Yard Creek and Tallawang Creek. Because some of the rail spur will be located on embankments up to 6 m high, local flooding impacts upstream of the embankments could be significant. Therefore, waterway crossings, cross-drainage culverts and rail corridor longitudinal drainage will need to be detailed at the design stage so that local flooding can be managed and impacts to the local environment and rail infrastructure minimised.

Downstream water quality and flow

Potential water quality and flow impacts on local watercourses were assessed against customised water quality and flow objectives developed from relevant Australian guidelines.

Water quality was assessed with a mass-balance model to predict potential changes in local watercourses over several operational stages of the mine. These changes were generally localised to Sandy Creek, with elevated levels of nutrients and TDS predicted in Years 1 to 16 of the Project. Impacts on the Talbragar River were minor due to the larger catchment size and greater flows providing dilution of impacts.

The flow assessment demonstrated that Sandy Creek and Laheys Creek do not significantly influence flows in the Talbragar or Macquarie Rivers, due to their relatively small catchment areas and annual flow contributions. Impacts of the Project on local flows were found to be minor in the Talbragar River system but the mining operation will modify the flow regime such that low flows will increase in the Sandy Creek system, where semi-permanent pools along the creek were likely to receive more regular surface water flow and therefore less frequent drying. However, some pools that are potentially groundwater dependent will be adversely affected by groundwater drawdown during mining. Of a total of 14 refuge pools assessed within or adjacent to the main mining areas, two will definitely be adversely affected by the drawdown – one on Sandy Creek and one on Laheys Creek – while there is potential for a further two on Sandy Creek to be affected. Groundwater levels will fully recover at these sites within 50 years post mining; therefore, the groundwater inflows to the affected pools will recover in the long term.

The potential cumulative impacts of the Project on water quality and flows in the Talbragar River will be negligible, because existing mines upstream of the Talbragar River have already augmented water quality and flows in the river.

1. Introduction

The Cobbora Coal Project (the Project) is a new open-cut coal mine proposed by Cobbora Holding Company Pty Limited (CHC). The Project is located approximately 5 kilometres (km) south of Cobbora, 22 km south-west of Dunedoo, 64 km north-west of Mudgee and 60 km east of Dubbo in the central west of NSW (see Figure 1.1).

A Major Project application under Part 3A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) was submitted to the NSW Department of Planning in January 2010. The Director General’s Environmental Assessment Requirements (DGRs) for the Project were issued in March 2010 and revised requirements were subsequently provided that responded to project changes and altered Government policies.

This report describes the surface water assessment that Parsons Brinckerhoff undertook for the Project’s environmental assessment report.

1.1 Cobbora Coal Project

1.1.1 General overview of Project

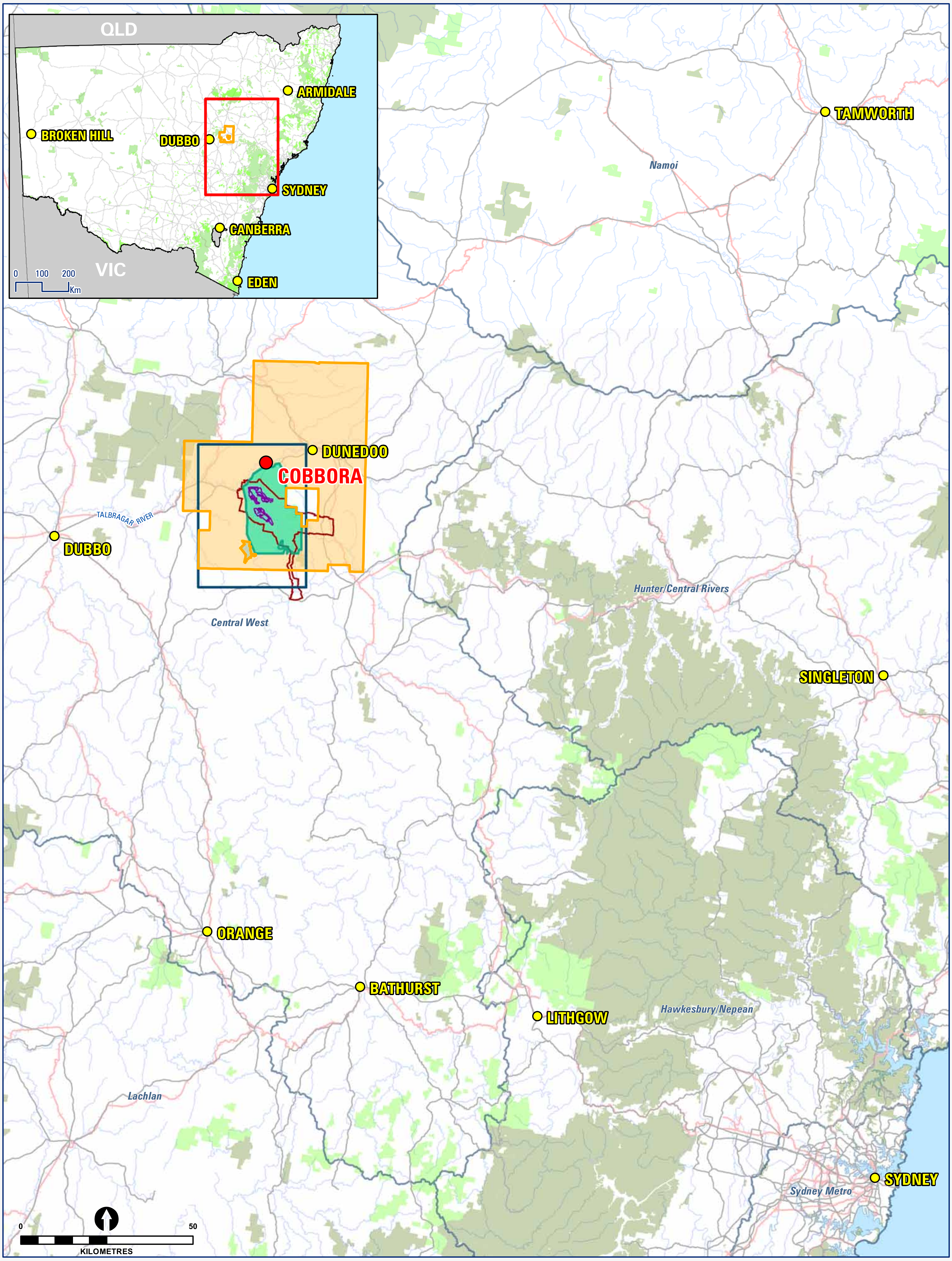
The Project will be developed near Dunedoo in the central west of New South Wales (NSW). The Project Application Area is approximately 274 square kilometres (km^2). The primary purpose of the Project is to provide coal for five major NSW power stations.

The mine will extract around 20 million tonnes per annum (Mt/a) of run-of-mine (ROM) coal. From this, approximately 9.5 Mt/a of product coal will be sold to Macquarie Generation, Origin Energy and Delta Electricity under long-term contract. In addition, approximately 2.5 Mt/a will be produced for export or the spot domestic market.

The Project's key elements are:

- an open-cut mine
- a coal-handling and preparation plant (CHPP)
- a train-loading facility and rail spur
- a mine infrastructure area
- supporting infrastructure, including access roads, water supply and storage, and electricity supply.

Construction is expected to commence in mid-2013, with coal being supplied to customers from the first half of 2015. The mine life will be 21 years.



- Assessment area
- Project application area (approximate) (as of February 2012)
- Drainage
- Railway
- Main roads
- Exploration licence (7394)
- Exploration licence (6093)
- National parks & state forests
- Proposed maximum mine pit area based on RevD mine plans

Figure 1-1 Site location

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1.1.2 Open-cut mine

Multiple open-cut mining pits will be developed in three mining areas:

- mining area A north of the infrastructure area
- mining area B south of the infrastructure area
- mining area C north-east of the infrastructure area.

There will be three out-of-pit waste rock emplacements:

- AC-OOP between mining areas A and C
- B-OOP E adjacent to mining area B on the east side of Laheys Creek
- B-OOP W adjacent to mining area B on the west side of Laheys Creek.

Over the mine life, operations will encompass approximately 4,350 hectares (ha), including associated infrastructure (e.g. haul roads), out-of-pit waste rock emplacements and rehabilitated areas. The mining areas and out-of-pit waste rock emplacements have been designed and placed to maximise the efficient extraction of the coal resource, while avoiding or minimising impacts on creeks and ecologically significant vegetation.

1.1.3 Coal-handling and preparation plant

The CHPP will treat ROM coal so that product coal meets customers' sizing and coal quality requirements. Subject to the level of impurities (rejects) in the coal and washability characteristics, the ROM will be either crushed and bypassed or treated (washed) in the preparation plant. The rejects will typically include waste rock from above, below and within the coal seam, as well as mineral matter dispersed throughout the coal.

The CHPP will be typical of those used by most coal mines in NSW and will be capable of treating up to 20 Mt/a of ROM coal. The CHPP will separate washed product coal from rejects in a series of coal-cleaning circuits (including heavy media separation). The CHPP will include a truck dump station, crushing plants, coal stockpiles and infrastructure to move and stockpile coal. Rejects from the CHPP will be returned back to the operating mine.

1.1.4 Train-loading facility and rail spur

Coal will be transported by rail to the Project's customers, including Bayswater and Liddell power stations in the Upper Hunter Valley, and Eraring, Vales Point and Munmorah power stations on the NSW Central Coast. Coal will also be transported to other domestic customers or to a ship-loading facility in Newcastle for export.

Product coal will be loaded onto trains from an overhead train-loading bin located on a rail spur balloon loop. Approximately four trains will be loaded each day. The rail spur will be approximately 28 km long (including the loop) and will join the Dunedoo-Gulgong rail line near Tallawang. A locomotive-provisioning facility will be located adjacent to the balloon loop.

1.1.5 Mine infrastructure area

An infrastructure area will be located adjacent to the mining areas. It will include workshops, hardstand and lay-down areas, bulk storage buildings, bulk fuel storage and a fuelling station, office buildings, an operations building and change-house, parking, an explosives magazine and vehicle washdown bays.

1.1.6 Supporting infrastructure

1.1.6.1 Access road

The main access to the mine will be from the Golden Highway to the north of the operations, via a road diversion that will replace an existing section of Spring Ridge Road. There will be limited light vehicle access from the south via Spring Ridge Road. Internal roads will connect the mine entrance to the workshop, administration buildings and the mine infrastructure area. Internal roads will also connect the various mine areas.

1.1.6.2 Water supply

The Project will require water, primarily for the CHPP and for dust suppression. Water will be sourced by extracting surface water, by pumping groundwater that enters the mine area, and by harvesting and reusing water on-site in accordance with the relevant permits and licences. The primary source of external water will be the Cudgegong River. Water will be supplied via approximately 26 km of pipeline from a pump station on the Cudgegong River to a primary raw-water dam south-east of the mining area. Pre-existing high-security water access licences (WALs) have been purchased to allow up to 3.311 gigalitres (GL) of water to be extracted from the river.

1.1.6.3 Electricity supply

The Project will require 20 megawatts (MW) of electrical power. The mine will be connected to the grid at a small switching yard adjacent to the Castlereagh Highway. A power line, generally running parallel to the rail spur, will deliver electricity to a substation in the mine infrastructure area. An 11 kV powerline will supply the Cudgegong River pump station from the existing grid approximately 2 km south of the pump station site.

1.1.7 Workforce and operating hours

The proposed mine construction workforce will average approximately 350 persons, peaking at approximately 550 persons between the third quarter of 2013 and the second quarter of 2016.

The operational workforce is estimated to be 300 persons during the first two years of full production in 2016 and 2017. This will increase steadily over the next 10 years to peak at approximately 590 persons between 2027 and 2030.

Mine construction is expected to occur up to 10 hours a day. However, construction may occur up to 24 hours a day at times, such as during major concrete pours. Mining will occur up to 24 hours a day, 7 days a week, 52 weeks a year.

1.2 Scope of assessment

Parsons Brinckerhoff was commissioned by CHC to assess potential surface water impacts from the construction and operation of the Project, as described in Section 1.1 of this report.

The key objectives of the assessment were:

- to identify and assess potential impacts on surface water from the development of the Project
- to satisfy the DGRs relevant to surface water impacts
- to inform the wider community about the Project and its potential impacts on the local and regional surface water environment.

To achieve these objectives, the surface water impact assessment had to:

- cover a geographical area where any impacts may potentially occur
- address all surface water issues identified in the DGRs
- describe government legislation and policy relevant to surface water aspects of the Project
- describe assessment methods used, including any fieldwork
- provide the results of fieldwork and any modelling
- describe the existing surface environment, including regional and local hydrology, regional and local catchments, flooding, local water bodies, surface water quality and other surface water users
- describe the proposed water management system and mine water balance, including proposed site water demands, water disposal methods, water supply infrastructure and water storage structures
- describe the potential impacts on surface water during construction, operation and post-closure, including flooding, interception of surface water and disposal of excess water. This includes an assessment of potential cumulative impacts
- recommend measures to avoid or mitigate impacts
- recommend an appropriate surface water monitoring program.

This report has been prepared to meet the objectives and satisfy the list of requirements described above.

1.3 Report structure

The structure of this report is as follows:

- **Section 1** introduces the surface water assessment, providing an overview of the Project, and the objectives and scope of the surface water assessment.

- **Section 2** summarises the DGRs relating to surface water for the Project and the relevant legislation, policies and guidelines.
- **Section 3** describes the existing surface water environment, including local and regional hydrology, regional and local catchments, flooding, local water bodies, surface water quality and other surface water users.
- **Section 4** details the proposed water management system and mine water balance, including site water demands, water disposal methods, water supply infrastructure and water storage structures.
- **Section 5** discusses the Project's potential impacts on surface water during construction, operations and post closure, including flooding, interception of surface water, surface water extraction and disposal of excess water. This includes an assessment of potential cumulative impacts.
- **Section 6** describes recommended mitigation measures and response plans.
- **Section 7** outlines a recommended surface water monitoring program, including monitoring requirements, procedures and recommendations.
- **Section 8** provides the conclusions of the surface water assessment.
- **Section 9** provides the list of references used in the assessment.

1.4 Terms of engagement

This commission was carried out under the contract between Parsons Brinckerhoff and Cobbora Holding Company. It assesses existing conditions and proposes measures to mitigate impacts from the proposed mine on surface water. As further information becomes available and detailed designs are carried out, those mitigation measures can be optimised.

The investigations had the benefit of two years of site-specific monitoring data, together with more than a century of nearby weather information. The nature and extent of that monitoring are described in the report. The monitoring and measurements of site conditions are believed to be representative of conditions during those two years and were performed in a professional manner, in accordance with generally accepted practices and using a degree of skill and care ordinarily exercised by reputable environmental consultants under similar circumstances. The recommended monitoring program will add further information that will increase the understanding of surface water regimes at the site.

In preparing the report, Parsons Brinckerhoff received information from a variety of reputable sources, including CHC, other specialist consultants, published papers and other environmental assessments. While it reviewed the data before using it, the information was accepted in good faith and it was not verified in detail for accuracy or completeness.

The report is for the use of Cobbora Holding Company and regulators in the determination of a development application for the Cobbora Coal Project and no responsibility will be taken for its use by other parties. If any other party seeks to rely on this report, they should seek their own independent advice to ensure that it is relevant to their own needs. Any losses or damage that they suffer as a result of failing to make their own enquiries will not be the responsibility of Parsons Brinckerhoff.

2. Planning and legislation

2.1 Director General's requirements

On the 14 October 2011, the Director General of the NSW Department of Planning and Infrastructure (DP&I) issued a set of requirements for the Project in accordance with the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). The Director General Requirements (DGRs) included specific requirements from the NSW Office of Water (NOW).

The DGRs relating to surface water are listed in Table 2-1 and include the section of this report where they are addressed.

Table 2-1 Director General's requirements

Director General's requirements		Sections
General requirements	▪ A description of the existing environment, including sufficient baseline data.	3, Appendix A
	▪ An assessment of the potential impacts of the Project, including any cumulative impacts, taking into consideration any relevant guidelines, policies, plans and statutory provisions.	5
	▪ Description of the measures that would be implemented to avoid, minimise and, if necessary, offset potential impacts of the Project, including detailed contingency plans for managing any significant risks to the environment.	6 & 7
Key issues	▪ Detailed modelling of the potential surface water impacts of the Project.	5
	▪ A detailed site water balance, including a description of site water demands, water disposal methods (inclusive of the volume and frequency of any water discharges), water supply infrastructure and water storage structures.	4.1 and 4.2, Appendix E
	▪ A demonstration that water supplies for the construction and operation of the mine can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant water sharing plan (WSP) and/or requirements of the *Water Act 1912* for water sources outside of any relevant WSP.	4.3
	▪ A description of the measures proposed to ensure the Project can operate in accordance with the proximity and water source protection criteria of the relevant WSP.	4.3
	▪ Identification of any licensing requirements under the *Water Act 1912* or *Water Management Act 2000.*	4.4, Appendix F
	▪ A detailed assessment of the potential impacts on: ‣ the quality and quantity of existing surface water resources ‣ affected, licensed water users and basic landholder rights ‣ the riparian, ecological, geomorphological and hydrological values of water courses resulting from any proposed diversion works, including environmental flows.	5, Appendices B and C
	▪ A detailed description of the proposed water management system and water-monitoring program for the Project and other measures to mitigate surface water impacts.	7
	▪ A detailed flood impact assessment identifying the impact of the Project on flooding and the measures proposed to mitigate potential flood impacts.	5.2, Appendix D

2.2 Relevant legislation

The two key pieces of legislation for water management in NSW are the *Water Act 1912* and the *Water Management Act 2000*.

2.2.1 Water Act 1912

The *Water Act 1912* (WA 1912) has historically been the main legislation managing NSW water resources. While some provisions of WA 1912 are still in force, WA 1912 is being progressively phased out and replaced by the *Water Management Act 2000 (*WMA 2000*)*.

Water sharing plans (WSPs) are statutory plans under WMA 2000 that apply to individual water source areas and contain rules for sharing and managing the water resources of NSW. These plans are progressively being developed for all water source areas across NSW.

CHC has obtained external water for the Project by purchasing regulated river (high-security) WALs from the Macquarie and Cudgegong Regulated Rivers Water Source. These licences are described in detail in Section 4.3.

The mine is located in the Sandy Creek catchment, a sub-catchment of the Talbragar River. This system is not yet covered by a WSP for surface water; however, CHC holds WA 1912 entitlements in this catchment. Further information regarding these entitlements is provided in Section 4.3. A WSP is currently being developed for the Macquarie-Bogan Unregulated and Alluvial Water Sources that will cover the Project Application Area. This WSP is expected to commence during 2012. Refer to Section 2.3.2 for further information.

The existing conditions of CHC's current WA 1912 licences will be carried over when the licence is converted under WMA 2000*,* which will come into effect at the commencement of the WSP.

2.2.2 Water Management Act 2000

The *Water Management Act 2000* (WMA 2000) and associated WSPs are the major water management and planning instruments in NSW. WMA 2000 established a new statutory framework for managing water in NSW, although WA 1912 continues to apply in areas not yet covered by WSPs.

For the purposes of this Project, WMA 2000 requires any development taking or using water to:

- assess whether the development will adversely impact the river or aquifer and its dependent ecosystems
- protect basic landholder rights.

WMA 2000 outlines the requirements for taking and trading water through WALs, water supply works and water use approvals.

CHC currently holds WMA 2000 entitlements from the Macquarie and Cudgegong Regulated Rivers Water Source. These entitlements are a key component for ensuring the Project has an adequate and secure water supply. Further information regarding these entitlements is provided in Section 2.3.1 and Section 4.3.

2.2.3 Dams Safety Act 1978

The *Dams Safety Act 1978* is the key instrument in NSW for the safe management of dams. The Act authorises the Dams Safety Committee to be the statutory body representing the Crown in administering the Act.

The Dams Safety Committee is therefore responsible for determining appropriate dam safety arrangements for dams. In particular it focuses on 'prescribed' dams, which are listed under Schedule 1 of the Act.

The final configuration of the mine and associated dams will be determined during detailed design, but some of the water management system dams are likely to meet the criteria for 'prescribed' dams under the Act. They will therefore need to be referred to the Dams Safety Committee before they can be built.

2.2.4 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) is the main environmental protection legislation that controls how developments operate in NSW. The Act and associated Regulations are administered by the NSW Office of Environment and Heritage.

The Project is likely to require the periodic release of treated water to Sandy Creek and Laheys Creek during mining operations. These releases will need to be licensed under the POEO Act.

2.3 NSW water policies, guidelines and plans

2.3.1 Water Sharing Plan for the Macquarie and Cudgegong Regulated Rivers Water Source

The Macquarie and Cudgegong Rivers are managed as one water source in the Central West Water Management Area prescribed under WMA 2000. Water access and trading rules for these rivers are provided in the Water Sharing Plan (WSP) for this water source.

This WSP commenced on 1 July 2004 and will apply until 2014. The plan provides water for the environmental needs of the Macquarie and Cudgegong Regulated Rivers Water Source and directs how water available for extraction is to be shared. The WSP also sets rules that affect the management of WALs, water accounts, water trading, dam operations and flow management.

CHC holds water entitlements to extract 3,311 ML or 3.311 GL of regulated river (high-security) water, together with water supply works approvals to extract from the Cudgegong River. Further details of these WALs are provided in Section 4.3.

2.3.2 Draft Water Sharing Plan for the Macquarie-Bogan Unregulated and Alluvial Water Sources

A draft WSP for the Macquarie-Bogan Unregulated and Alluvial Water Sources is currently being developed. The draft WSP area is understood to comprise 30 surface water and four groundwater sources in the Macquarie–Bogan River catchment.

The Project lies within the Lower Talbragar River Water Source. This flows into the Macquarie Regulated River. There are 14 licensed water entitlements on the Lower Talbragar covering 897 ML/a. About 92% of the total entitlement is for irrigation and the remaining 8% is for stock and domestic purposes.

Given the non-perennial nature of the stream, the proposed access rules include a 'cease to pump' condition on licences — that is, pumping is not permitted from natural pools when the water level in the pool is lower than its full capacity as defined in the draft WSP. Water requirements for persons entitled to basic landholder rights (i.e. domestic and stock rights) are estimated to total 308 ML/a for the Lower Talbragar River Water Source.

CHC does not currently hold any licences to extract water from the main stream of the Lower Talbragar River, but it does hold two WA 1912 entitlements that authorise extraction from existing water supply dams. The existing licence conditions for these dams will be carried over when the licences are converted under WMA 2000 when the WSP begins.
Further details about the existing dam licences are provided in Section 4.3.

The draft WSP for the Macquarie-Bogan Unregulated and Alluvial Water Sources was placed on public exhibition from 1 September to 21 October 2011. A final WSP is expected to come into effect sometime during 2012. This will specify water access and management arrangements for the nominated water sources and replace any WA 1912 entitlements. Trading will also be permitted within this water source and from the Upper Talbragar River Water Source in accordance with the WSP trading rules.

2.3.3 Other relevant policies, plans and guidelines

The following policies, plans and guidelines have been reviewed in preparing this report:

- Draft Murray Darling Basin Plan (Murray Darling Basin Authority 2011).
- Australia and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000).
- Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (NSW EPA 2004).
- Australian Rainfall and Runoff — A Guide to Flood Estimation (Engineers Australia 2001).
- Australian Runoff Quality (Engineers Australia 2006).
- Managing Urban Stormwater — Soils and Construction, Volume 1 (Landcom 2004).
- Managing Urban Stormwater — Soils and Construction, Volume 2E, Mines and Quarries (DECCW 2008).
- Central West Catchment Action Plan 2006–2016 (Central West Catchment Management Authority 2007).
- Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region (DIPNR 2005).
- Strategic Water Management in the Minerals Industry – A Framework (MCMPR 2006).
- Water Management — Leading Practice Sustainable Development Program for the Mining Industry Department of Resources, Energy and Tourism 2008).
- Macquarie-Bogan Water Quality and River Flow Objectives (Department of Environment, Climate Change and Water 2006).

3. Existing environment

This section summarises baseline surface water conditions that have been used to assess potential impacts from the Project. Further details of how baseline conditions were defined are contained in Appendix A.

3.1 Assessment area

For the purpose of the downstream water quality and flow impact and water balance assessments (Appendices B, C and E respectively), the relevant assessment area was limited to include potential surface water receptors defined as those watercourses that drain the proposed mining areas and/or could be impacted by proposed mining activities. These receptors generally included Sandy Creek and Laheys Creek, and the downstream system of the Talbragar River through to the Macquarie River and Macquarie Marshes.

For the purposed of the flood impact assessment (Appendix D), the relevant assessment area was expanded to include additional surface water receptors that could potentially be affected by the construction of ancillary mine infrastructure (e.g. road, pipeline and rail crossings). These receptors included Flyblowers Creek, Tallawang Creek, Fords Creek, Lambing Yard Creek and Tucklan Creek.

3.2 Regional context

The Project is located approximately 5 km south of Cobbora in the central west of NSW. Figure 3-1 shows its location in relation to regional surface water resources.

Rivers in the greater Cobbora area include the Talbragar River and Cudgegong River, which are tributaries of the Macquarie River. The Macquarie River is formed near Bathurst, at the junction of the Fish River and Campbells River, and extends north-west to the Barwon River upstream of Brewarrina. The river flows through the Macquarie Marshes, which are one of the largest semi-permanent wetlands in south-eastern Australia, covering more than 150,000 ha.

Cudgegong River rises in the Great Dividing Range above Rylstone and drains an area of 3,880 km^2. It is a major tributary of the Macquarie River and flows into Windamere Dam upstream of its confluence with the Macquarie River. A section of the Cudgegong River is located within the Project Application Area and is located approximately 17 km south of the proposed mining area.

Talbragar River is the closest major water body to the proposed mining area. It separates from the Coolaburragundy River at Dunedoo and runs south-west, joining the Macquarie River just north of Dubbo.

3.3 Topography and land use

The topography of the assessment area covered by the Project is gently undulating to hilly, with elevations varying between 320 and 620 m Australian Height Datum (AHD). It is mostly cleared and used for farming, including grazing sheep and cattle, cultivating cereal crops and forestry.

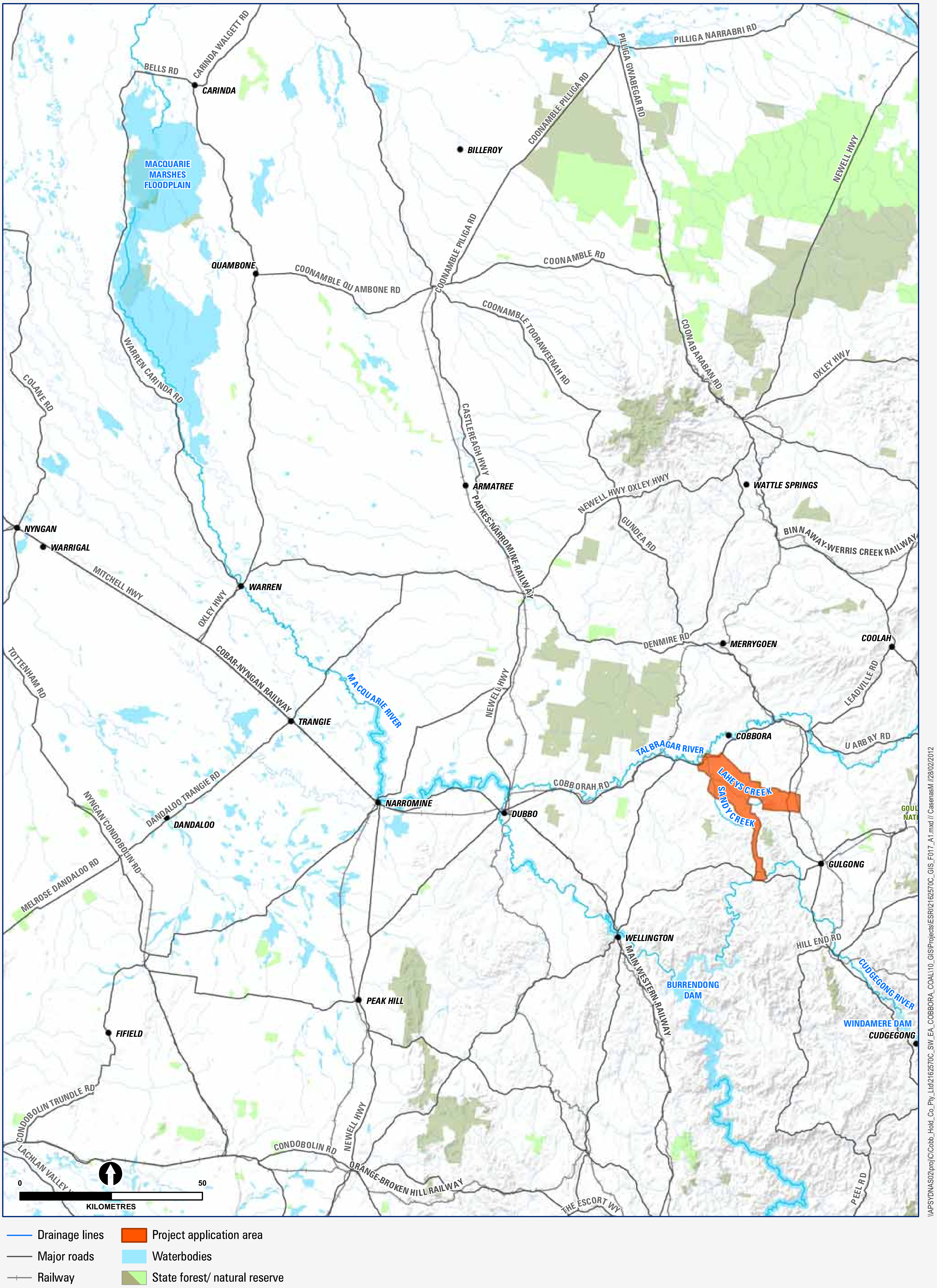


Figure 3-1 Existing water resources environment

3.4 Soils

The predominant soil type in the assessment area is unit Qb17, which occurs in undulating country with gravelly or stony ridges comprising hard and friable neutral red soils. Along the Talbragar River, the soil unit is Gb11, occurring on river terraces and floodplains and comprising dark porous loamy soils with some cracking clays.

3.5 Dryland salinity

The *Salinity Risk Assessment of the Central West Catchment* (Humphries 2000) describes the salinity hazard rating of the Lower Talbragar River catchment as 'very high'. However, the Sandy Creek sub-catchment has relatively low salinity compared to more salinised catchments to the west. The Project targets only Triassic and Permian strata within the sub-catchment and not the Lachlan Orogen metasediments, which are generally associated with saline soils. The salinity risk is therefore much lower in this particular part of the catchment.

3.6 Climate

3.6.1 Local weather stations

There are no Bureau of Meteorology (BoM) weather stations operating in the assessment area. However, there are two nearby weather stations that have been used to understand local weather patterns and generate a long-term dataset. These include BoM Station 064009 at Dunedoo Post Office and BoM Station 062013 at Gulgong Post Office. The closest station with long-term evaporation observations is the Wellington Research Centre (BoM Station 065035), about 60 km south-west of the assessment area.

Two additional meteorological gauging stations were installed by CHC in the assessment area between 2009 and 2011. These have been used to supplement long-term records obtained from the BoM stations, and provide rainfall information specific to the assessment area. The locations of these weather stations are shown in Figure 3-2.

3.6.2 Rainfall and evaporation

Annual rainfall is very similar at both BoM gauging stations. Average annual rainfall at Gulgong and Dunedoo between 1961 and 1990 was approximately 667 mm/a and 630 mm/a respectively.

A cumulative rainfall departure assessment for the Dunedoo station shows that this area recorded frequent below-average rainfall from 1910 to 1945 and frequent above-average rainfall after 1945. Since 2000, annual rainfall has continued to be above long term averages.

Rainfall is generally greater in the summer months than in winter, and evaporation is higher than rainfall. This is typical of Australian environments. The winter months of June and July are the exception, where rainfall and evaporation are comparable.

3.6.3 Climate change

Climate change is projected to have a marked impact on many climate variables, including temperature and rainfall, as the century progresses. However, the predicted changes over the lifetime of the Project are low, with approximately 1% change in average annual rainfall and approximately 1ºC change in average annual temperature. The Project will therefore not need to implement adaptation strategies to account for climate change.

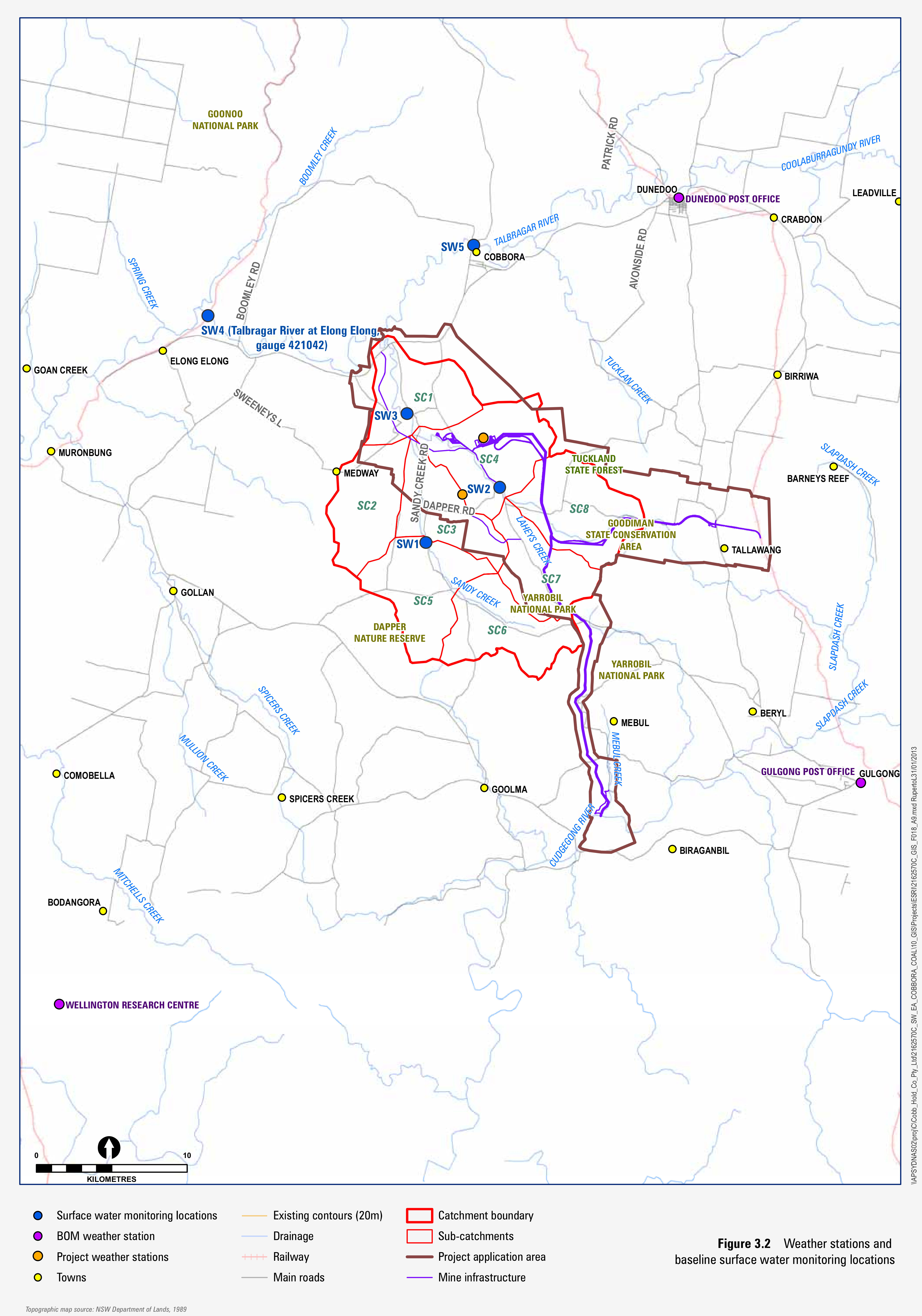


Figure 3.2 Weather stations and baseline surface water monitoring locations

3.7 Local surface water bodies

The proposed mining area is predominantly located in the Sandy Creek catchment, a sub-catchment of the Talbragar River. Sandy Creek, Laheys Creek (a tributary of Sandy Creek) and Blackheath Creek (a tributary of Laheys Creek) flow in a general north-westerly direction through the proposed mining area.

The Talbragar River, Sandy Creek and Laheys Creek are naturally ephemeral waterways that cease to flow during dry periods. There are no headwater storages to regulate flows, so all flows directly reflect rain events, groundwater baseflows and evapotranspiration processes.

Flyblowers Creek is a small creek catchment located north-west of the Sandy Creek catchment. This creek flows into the Talbragar River upstream of Sandy Creek and downstream of Tucklan Creek.

Fords Creek is a tributary of Laheys Creek and lies in the upper catchment. Fords Creek flows west and captures runoff from the forested areas near the Goodiman State Forest. Many small drainage channels and gullies drain into it. The proposed rail corridor runs along Fords Creek and crosses a number of these channels and gullies.

The remainder of the Project Application Area covers catchments of minor tributaries and small creeks in the south and part of the tributary system draining to Tallawang Creek in the east. Tallawang Creek flows south into the Wyaldra Creek, which eventually flows into the Cudgegong River west of Gulgong.

Two farm dams have been constructed on Blackheath Creek, a tributary of Laheys Creek. These were constructed by the landowner approximately 30 years ago to service the property's irrigation needs and are generally referred to as the west 'Woolandra' farm dams. The larger of the two dams has a capacity of approximately 1,470 ML. The upstream smaller dam (referred to as the 'sausage dam') receives inflow from groundwater springs higher in the catchment and has a capacity of approximately 15 ML.

Tucklan Creek flows in a northerly direction from the site into the Talbragar River, approximately 10 km upstream of the Sandy Creek – Talbragar River confluence. Tucklan Creek has a similar catchment area to Laheys Creek, but only approximately 1 km of its headwaters lie within the assessment area. No infrastructure will be constructed in the Tucklan Creek catchment. It was therefore not necessary to consider Tucklan Creek further in this assessment.

3.8 Baseline hydrologic conditions

3.8.1 Stream gauge information

There are no NSW Office of Water (NOW) gauging stations currently in operation within the assessment area or the broader Sandy Creek catchment. However, Station 421042 is located on the Talbragar River at Elong Elong, approximately 10 km north-west and downstream of the assessment area (shown on Figure 3-2 as SW4). Additional stream flow records are available from discontinued NOW stream gauges on the Talbragar River at Cobbora (close to SW5 on Figure 3-2) and on Sandy Creek at Medway (close to SW3 on Figure 3-2).

The Talbragar River is characterised by a seasonal discharge pattern, with lower flows during summer and autumn, and floods throughout winter and spring.

Based on available recorded data from NOW, the median annual discharge at Elong Elong is 21,509 ML/a, with a maximum recorded annual discharge of 264,366 ML in 1998 and a minimum recorded annual discharge of 653 ML in 2005.

The flow duration curve developed from the Elong Elong gauge shows that although the highest recorded mean daily flow was 40,835 ML/d (in December 2010), for 50% of the time flows were less than 11.9ML/d and for 32% of the time there was no flow.

The flow record from Sandy Creek at Medway shows that for the period of record (1966–1985), the highest mean daily flow was 8,937 ML/d, which occurred in February 1971. The flow duration curve for Sandy Creek at Medway shows that for 50% of the time flows were less than 0.04 ML/d and for 46% of the time there was no flow. Refer to Appendix A for further details.

3.8.2 Water level gauging

As part of Parsons Brinckerhoff's ongoing baseline surface water monitoring program, four water level gauging stations have operated on the Talbragar River, Sandy Creek and Laheys Creek since November 2009 at locations SW1, SW2, SW3 and SW5 (see Figure 3-2). These data have been used in the water quality impact assessment (Appendix B) to identify the flow regimes that occurred during the surface water quality sampling program.

3.8.3 Baseline flood hydrology

3.8.3.1 Flood history

Limited flooding information is available for the assessment area and no flood studies have been carried out for the Talbragar River, Sandy Creek or Laheys Creek. Consultation with local councils indicated that major floods in the Talbragar River coincide with floods in the Macquarie River. The coincidence of high flows in both the Macquarie and Talbragar Rivers, however, rarely imposes a flood risk to Dubbo, which is located near the confluence.

The February 1955 flood was the only known occasion where both rivers flooded together and the Talbragar River 'backed up' the Macquarie River, causing extensive inundation in central and northern Dubbo.

The Dubbo Local Flood Plan suggests that the Talbragar River floods 'every few years', with only the events of 1870, 1920, 1926, 1950 and 1955 known to have broken banks and entered the surrounding floodplain. The 1955 flood is believed to be the most severe and was estimated to have a 200-year average recurrence interval (ARI). In contrast, the floods of 1920 and 1950 (the next highest) only resulted in backwater flooding in low spots along the Talbragar River.

3.8.3.2 Design flood estimation

To estimate baseline design flood conditions, a combination of flood frequency analysis and hydrologic and hydraulic modelling was undertaken. The relatively long 41 year flow record for Elong Elong was the key dataset used to estimate peak flows at Medway on Sandy Creek, by using a method that correlated flow records to transpose flood frequency analyses at Elong Elong to Medway. The flood frequency analyses for the two gauge sites are given in Tables 3-1 and 3-2.

Table 3-1 Flood frequency analysis results for the Talbragar River at Elong Elong

Storm event	Estimated flow (m^3/s)	Estimated 95%ile lower bound flow (m^3/s)	Estimated 95%ile upper bound flow (m^3/s)
2 year ARI	43	27	68
5 year ARI	169	104	306
50 year ARI	893	469	2113
100 year ARI	1234	624	3103

Table 3-2 Design flood flow estimates for Sandy Creek

Event	Estimated range of Sandy Creek peak flow (m^3/s)			WBNM modelled peak flow (m^3/s)
	Estimated flow	95%ile lower bound flow	95%ile upper bound flow	
2 year ARI	17	11	28	29
5 year ARI	74	44	137	78
100 year ARI	599	291	1,584	429

Refer to Appendix D for further details on how the Sandy Creek analysis and design flow estimates were developed.

3.8.3.3 Hydraulic model

A hydraulic model for Sandy Creek was developed to assess baseline and future flood conditions near the mine. The model determined flood levels, extents and velocities in the watercourses. It was also used in the preliminary design of access and haul road crossings, and flood protection levees for mine infrastructure.

The model simulated flood conditions for the 2, 5, 100 and 2000 year ARI events, with the 2000 year ARI event included as an upper limit for assessing flood risk.

3.8.3.4 Baseline flood behaviour

The baseline 100 year ARI flood extent is illustrated in Figure 3-3. Overall, the 100 year ARI flood is contained within channel in the upper tributaries of Sandy Creek and Laheys Creek. Once the catchment flattens out in the middle to lower reaches of Sandy Creek and Laheys Creek, there is some floodplain flow in the left and right overbanks due to the meandering nature of these watercourses.

Existing 2 year and 5 year ARI events are mainly conveyed in-channel for the middle to lower reaches, with higher flows going out of bank in localised areas. The 2000 year ARI event produces mainly overbank flow, but flows are still contained by the shape of the valley in the lower reaches.

3.9 Baseline water quality

Baseline surface water quality was assessed by:

- defining objectives and guidelines
- reviewing and analysing baseline water-sampling data

- comparing baseline water quality against relevant guidelines
- assessing surface water quality processes in the assessment area.

Baseline water sampling data were reviewed for gauge locations SW1, SW2, SW3, SW4 and SW5 (see Figure 3-1). Samples were collected and analysed each month from August 2009 to September 2011 (inclusive). They were analysed for physical parameters (electrical conductivity, pH, turbidity, temperature, dissolved oxygen), major ions, nutrients and a suite of metals.

3.9.1 Objectives and guidelines

ANZECC (2000) guidelines and DECCW (2006) water quality objectives were used to assess baseline water quality conditions. The ANZECC guidelines were also used to develop customised or project-specific water quality objectives to assess the Project's potential impacts on surface water quality (see Appendix B for details).

To determine baseline water quality, parameters were assessed against the 'Condition 2' category, defined as '*slightly to moderately disturbed systems*', as the Talbragar River, Sandy Creek and Laheys Creek catchments are dominated by agriculture and pastoralism.

3.9.2 Flow ranges during water quality monitoring

Appendix A contains a detailed analysis of the flow conditions that occurred during the surface water quality monitoring carried out between August 2009 and June 2011.
In summary, the following observations were made:

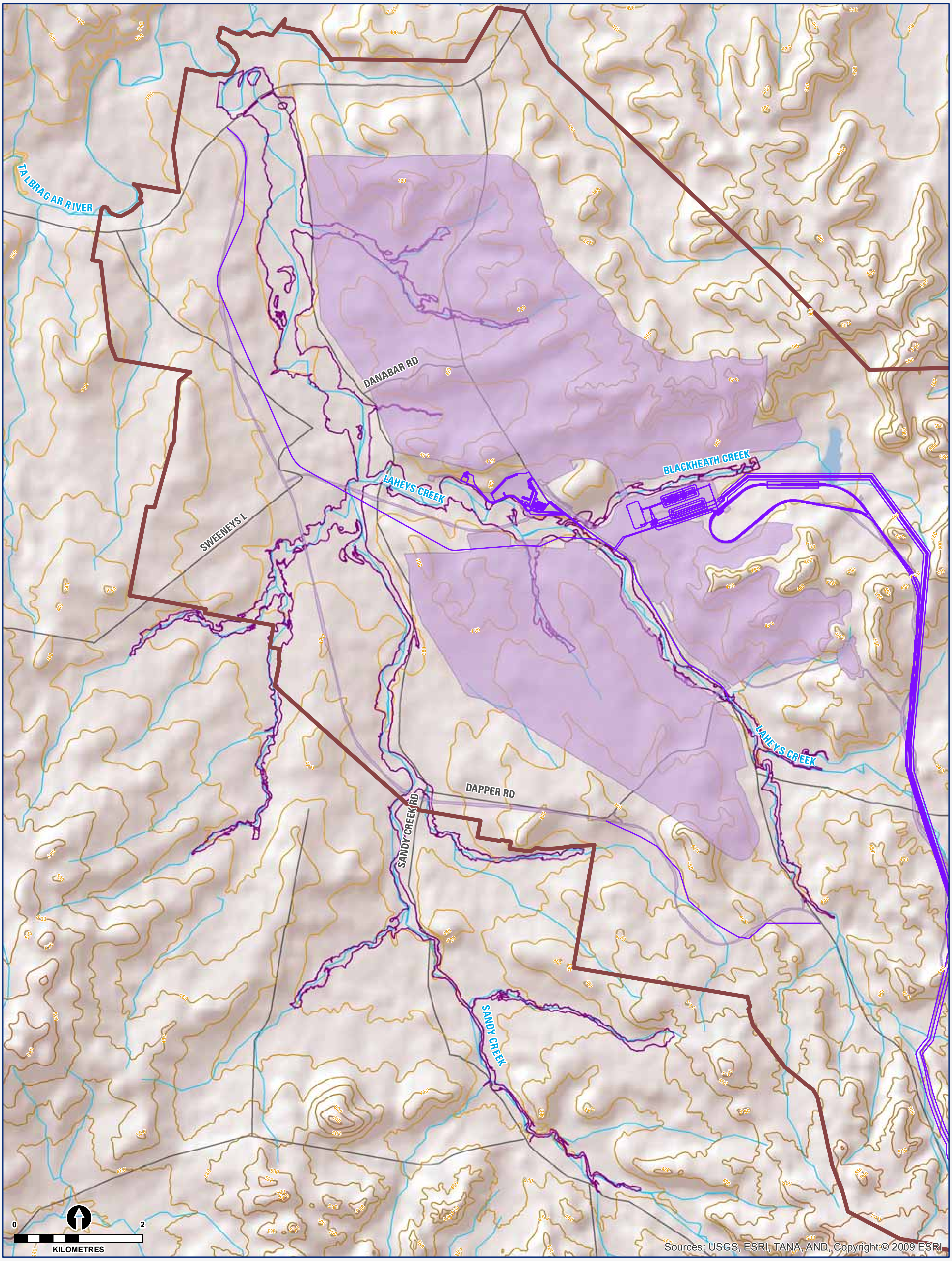
- Samples taken were predominantly collected during 'nil' or 'low' flow conditions. 'Medium' and 'high' flow conditions were not represented as frequently as the lower flows.
- Due to the ephemeral nature of Sandy Creek and Laheys Creek, low flow is the normal catchment condition and therefore the sampling undertaken to date is representative of average conditions in these creeks.

3.9.3 Surface water quality monitoring findings

Surface water quality monitoring results were compared against ANZECC water quality guidelines and water quality objectives. Full details are provided in Appendix A.
The following sections summarise baseline water quality findings.

3.9.3.1 Salinity

Salinity in upstream locations of Sandy Creek (SW1) and Laheys Creek (SW2) were relatively high. This is likely to be due to saline soils and the effect of evaporation in isolated, semi-permanent pools, increasing the concentration of dissolved ions.



- 100 year existing flood extent
- Elevation (m)
- Mine infrastructure
- Drainage lines
- Roads
- Project application area
- Maximum mine footprint

Figure 3.3 Existing 100 year ARI flood extent (Sandy Creek catchment)

3.9.3.2 Nutrients

Elevated nutrients were also found and are likely to have been caused by local land uses and river flows. The land surrounding Sandy Creek and Laheys Creek and the Talbragar River is mainly used for cattle and sheep grazing on improved pastures, and dryland cropping.

Sediment sources will also contribute to the nutrient load in these watercourses and include overland erosion, especially along tracks which provide a conduit for surface water runoff, bank erosion during high-flow conditions and re-suspension of in-channel bed sediments. Watercourse crossings provide a mechanism to deliver and re-suspend sediment in creeks, with plumes of sediment caused by vehicle traffic.

Ephemeral streams such as Laheys and Sandy creeks also retain large amounts of particulate organic matter in the dry channel that may be carried downstream during storms.

3.9.3.3 Metals

Some metals were above the protection threshold for 99% of species in aquatic ecosystems, including aluminium, arsenic, boron, copper, manganese, nickel and zinc. Except for aluminium and boron, these metals also exceeded the threshold for the protection of 95% of species. This is commonly associated with *slightly to moderately disturbed ecosystems*, which is the existing condition of the assessment area.

Because there are no industrial discharges upstream of the site, these levels are naturally occurring, reflecting local soils and geology. In semi-permanent pools like those recorded in Laheys Creek and Sandy Creek, toxicants can also accumulate.

3.10 Baseline geomorphology

A rapid walkover survey has been used to characterise current geomorphological condition in Sandy Creek, Laheys Creek and the Talbragar River using the RiverStyles^{TM} procedure. Full details of the assessment are provided in Appendix A.

Talbragar River, Sandy Creek, Laheys Creek and other minor catchments near the site are dominated by valley fills of Quaternary alluvium. The alluvium is characterised by gravels and sands interspersed with clays, and varies in thickness from 0 to 28 m. These soils retain runoff and release it slowly, particularly when vegetation is intact. They are also long-term sediment stores.

In the Sandy Creek upper catchment, alluvial deposits are interspersed with short, bedrock-controlled sections where the longitudinal creek bed profile drops down, providing an overall stepped, longitudinal profile. The upstream Sandy Creek reach is confined with bedrock control as it steps down from the Tannabutta Group (shale, slate and thick-bedded volcaniclastic sandstone) that rims the catchment.

Downstream of those sections in Sandy Creek and Laheys Creek, water floods out into the broader valley floors of the higher order watercourses. Energy conditions are generally low in the broad valley floors where flows are dispersed. Many of these valley floors have been altered to allow cultivation and cropping. They have been channelised, often by excavation at a valley margin to reduce saturation and increase agricultural productivity.
The downstream reaches of Sandy Creek and Laheys Creek are alluvial discontinuous with either chain-of-ponds or valley fill features.

The Talbragar River is in a broad valley floor with a valley fill that has been altered by cultivation. The channel has moderate sinuosity and gravel/sand bed. However, channel development is still minimal and flows are largely unconfined. The Talbragar River is an alluvial continuous channel with channelised fill.

3.11 Groundwater – surface water interaction

A key feature of groundwater – surface water interaction in the catchments is the presence of ecological refuge pools that persist during prolonged dry periods, several of which have been observed on Sandy and Laheys Creeks. Pools that persist during sustained dry periods are likely to be groundwater fed rather than reliant on surface water runoff. Other pools that dry out shortly after rainfall events are likely to be surface water fed and do not receive significant groundwater inflow. It is also likely that some pools and habitats are reliant on a combination of surface and groundwater inflows; however, given that the creeks are ephemeral, groundwater inflows will govern levels in persistent pools rather than short duration surface water inflows.

14 pool sites that have been documented in the aquatic ecology assessment (Cardno 2012) were reviewed against the groundwater modelling results and the following characteristics were identified:

- Pool site 3 on Sandy Creek downstream of its confluence with Laheys Creek is potentially groundwater dependent.
- Pool site 5 on Sandy Creek downstream of its confluence with Laheys Creek is likely to be groundwater dependent.
- Pool site 6 on Sandy Creek upstream of its confluence with Laheys Creek is potentially groundwater dependent.
- Pool sites 10 and 13 on Laheys Creek upstream of its confluence with Blackheath Creek are potentially groundwater dependent.
- Pool site 14 on Fords creek is likely to be groundwater dependent.
- The remaining eight pools are not groundwater dependent.

Refer to Appendix A for details of the locations of these pools and the method of assessment.

4. Water management system

This section summarises the Project's proposed mine water balance and surface water management system, including predicted site water demands and proposed mine water storages and associated structures. It also describes the proposed water supply and licensing strategy for the Project. Please refer to Appendix E for a more detailed description of the above.

4.1 Water management strategy

The water management strategy proposed for the mine aims to segregate water according to its quality to minimise the volume of stored water affected by mining. This will allow treatment to settle suspended sediment and to divert clean water away from mining activities.

Five water classifications have been nominated for the mine site:

- **Clean water** — runoff from undisturbed areas that are expected to have pre-mining water quality and that can be diverted to the creek system.
- **Overburden water** — runoff from overburden emplacements, topsoil stockpiles and other disturbed areas. This water contains elevated suspended solids, which will be settled in sedimentation dams before release to the creek system or on-site reuse.
- **Pit water** — runoff from the open pits and groundwater seepage into the mine. This water can potentially contain suspended solids, salts and heavy metals etc. This water will be stored on-site and will be reused.
- **Infrastructure water** – runoff from the areas around the CHPP, stockpiles and infrastructure. This water will be directed to the process water circuit.
- **Process water** —water that is utilised in the CHPP, including return water from the reject emplacement areas and refuse disposal ponds. This water is continuously recycled within the system.

A brief summary of the water management systems being proposed to manage water at the mine is provided below. Refer to Appendix E for additional details on these systems.

4.1.1 Clean water system

The clean water system will generally comprise the following components:

- Clean water catch drains to divert minor catchments around the mine site, where practical.
- Clean water highwall dams and levees upslope of active mine pits to reduce peak flow rates and velocities from undisturbed catchments.
- A pump and pipeline system to pump clean water stored in clean water highwall dams to the creek system.
- A raw water dam to store water imported to the mine from the Cudgegong/Macquarie Regulated River system.

- A pump and pipeline system from the raw water dam to deliver stored water to either the process water dam (CHPP), truck fill stations (dust suppression) or water treatment plant (potable water).

- Flood mitigation works, such as levees along the edge of mining areas.

4.1.2 Overburden water system

The overburden water system will generally comprise the following components:

- A drainage system to convey runoff from the overburden emplacements, topsoil stockpiles and other disturbed areas to sedimentation dams.

- Several sedimentation dams strategically located throughout the mine site to capture water from the above sources.

- A pump and pipeline system to transfer water stored in sedimentation dams to either the mine water system for reuse at the mine site or to the creek system at nominated licensed points.

4.1.3 Pit, infrastructure and process water systems

For the purpose of this assessment, the pit, infrastructure and process water systems have been combined into a single system, referred to as the mine water system.

The mine water system will generally comprise the following components:

- Small sumps in the pit floor to collect and contain local surface water runoff from the pit floor, high wall, low wall and end walls, as well as groundwater seepage.

- Pit dewatering pumps and associated dewatering pipelines to transfer pit water to the nearest mine water dam, if necessary via a small staging dam.

- Treated effluent from the on-site wastewater treatment plant.

- A drainage system to convey runoff from disturbed areas to the nearest water storage dam.

- Mine water dams to store and contain water from the above sources.

- A return water pump and pipeline system from each dam to deliver stored water to either the CHPP (coal washing), mine infrastructure area (for vehicle wash, workshop and dust-suppression sprayers), and truck fill stations (for haul road dust suppression).

It is important to note that there will be no releases of water captured in the mine water system to the natural creek system. This system will be used as a priority to meet on-site water demands and imported raw water will only be used when there is a water deficit or high quality water is required for uses such as potable applications.

During extended wet periods, surplus mine water will be stored in-pit once the mine water dams have reached their capacity. The scale of the mine with multiple pits allows pit water to be pumped between individual open cuts. This gives good flexibility, allowing the mine to continue to operate without flooding active workings or relying on unscheduled releases of surplus water.

4.1.4 Staging of water management system

The water management system will evolve as the Project expands, to be compatible with the mine landform and schedule.

Development of the water management system concepts over the mine's 21-year life have been illustrated through snapshots at five mine stages, corresponding to Year 1, 4, 12, 16 and 20 mine landforms. For the purpose of the surface water assessment, the five mine stages selected provide a reasonable representation of how the mine will be developed. The five mine stages also illustrate the design flow paths of different classes of water and locations of water management dams during respective stages of the mine's development.

12 mine water dams, 39 sedimentation dams, one raw water dam and 10 clean water / highwall dams are proposed to manage the surface water runoff and water supply of the mine over its 21-year life.

Detailed mine stage plans and schematic diagrams showing the general connectivity between water sources, demands and storages are provided in Appendix E.

4.2 Site water balance model

A water balance model has been developed to simulate the Project's water management system. It was used to assess the performance of the system and estimate potential annual runoff volumes and water requirements. The water balance model has also been used to assess the potential for dam overflows during a range of climatic conditions.

4.2.1 Modelling approach

The water balance model was developed using GoldSim software, a widely used and industry standard platform for mine site water balance studies.

Separate GoldSim models were developed for Year 1, 4, 12, 16 and 20 mine landforms to assess the site water balance over the life of the mine. The site water balance was simulated for each mine year using 111 years of climate data based on a daily time step. The climate data were statistically analysed to present potential water balances for 10th (dry), 50th (median) and 90th (wet) percentile years. Each year of the mine was modelled for 111 years of climatic data, with water stored in all dams carried forward from one year to the next.

Treated water stored in sedimentation dams that cannot be reused or stored on-site would be returned to the creek system in accordance with relevant licensing requirements.

Catchment boundaries for the water management system were delineated using conceptual mine staging plans and reasonable assumptions about the likely destination of runoff across the site. The model was also based on other assumptions in relation to dam sizes, stage-storage relationships, pump rates and general system operating rules. Please refer to Appendix E for further details on model setup and assumptions.

4.2.2 Water inputs

The water balance model was configured for the following water inputs:

- surface water runoff
- groundwater seepage to the open pits
- imported water.

Surface water runoff includes runoff from undisturbed, disturbed and rehabilitated catchments. The Australian Water Balance Model (AWBM) was incorporated into the GoldSim model to generate a daily time series of runoff from undisturbed, disturbed and rehabilitated catchments.

Groundwater includes natural groundwater seepage into the pits without pre-mining dewatering. Groundwater seepage rates over the life of the mine have been referenced from the Project's groundwater assessment report (Parsons Brinckerhoff 2013).

Raw water will be imported to meet part of the demands of the mine and provide a high quality source for potable water. This water will be pumped from the Macquarie and Cudgegong Regulated River system and stored in a raw water dam. CHC currently holds 3,311 unit shares of high security WALs from this system, which equates to 3,311 ML/a of imported water. Refer to Section 4.3 for further details.

For the purposes of this assessment, the existing west 'Woolandra' farm dams have been included in the baseline model, that is, their combined runoff capture capacity contributes to reductions in flow in the downstream waterways. However, these farm dams have been excluded from the water balance model and proposed water management system for the Project. It is assumed that runoff from their catchments will be returned to Laheys Creek.

Treated wastewater effluent was not included in the water balance model, as the quantity will be nominal and relatively insignificant when compared to other sources.

The water balance presented in this report assumes full availability of high-security WALs. Further optimisation to minimise water consumption from the Macquarie and Cudgegong Regulated River system may be possible and will be assessed during detailed design.

4.2.3 Water demands

Water demands for the Project comprise:

- CHPP make-up water
- mine infrastructure areas, such as workshops and vehicle washdown areas
- haul road dust suppression
- potable water
- miscellaneous uses, such as construction water.

Water demands for the Project are summarised in Table 4-1. The peak demand is estimated to be 4,340 ML/a.

Table 4-1 Water demand summary

Year	Product coal (Mt/a)	CHPP make-up water (ML/a)	Mine infrastructure area demand (ML/a)	Haul road dust suppression (ML/a)	Potable water demand (ML/a)	Total site demand (ML/a)
Construction (peak)	—	—	—	—	46.5	46.5
1	0.7	134	9	376	5	524
4	11.2	2092	140	968	10	3,210
12	12.0	2524	150	1,651	15	4,340
16	12.0	2524	150	1,603	15	4,292
20	12.0	2524	150	1,371	10	4,055

Refer to Appendix E for further details on how water demands for each activity were estimated.

4.2.4 Results of water balance modelling

Site water balances were obtained by assuming that runoff captured in sedimentation dams will be available for reuse. The water balance shows that the mine will generally need imported water to meet its total water demands. The estimated imported water requirements for typical dry (10th percentile), median (50th percentile) and wet (90th percentile) rainfall years are summarised in Table 4-2.

Table 4-2 Summary of imported water requirement for dry-, median- and wet-year climate conditions

Year	Total site demand (ML/a)	Groundwater seepage (ML/a)	Imported water for a dry year (ML/a)	Imported water for a median year (ML/a)	Imported water for a wet year (ML/a)
1	524	131	120	160	0
4	3,210	1,069	1,820	1,300	360
12	4,340	2,446	2,600	1,840	380
16	4,292	2,403	2,520	1,780	400
20	4,055	1,163	3,240	2,540	400

It is estimated that 2,545 ML/a of imported water will be required for a typical 10th percentile dry year and 385 ML/a for a typical 90th percentile wet year between years 4 and 20. By reusing water captured by the sedimentation dams, the Project's peak imported water demand is expected to reduce by 125 ML/a for the modelled dry year. The requirement for imported water peaks to about 3,240 ML/a in Year 20, but remains within the 3,311 ML/a WAL limit for the 111 years simulated.

The model predicts that the pit dewatering system will generally be able to maintain dry pits, but during extended wet periods in-pit flooding may restrict mining area access to a single ramp. The model also predicts that there will be no releases of mine water from the water management system over the life of the Project. Mine runoff will be reused on-site and stored in-pit during extended wet periods until the mine water dams have regained their capacity to store water.

4.3 Water supply

The water balance modelling predicts that make-up water will need to be sourced from an external supply source. This external supply is referred to as imported water in Section 4.2 and is discussed in more detail below. CHC has obtained entitlements to this imported water to ensure it has an adequate supply to construct and operate the mine.

4.3.1 The Macquarie and Cudgegong Regulated Rivers Water Source

In NSW, there currently is an embargo on new WALs. Water for any new developments must therefore be sourced by the purchase of existing WALs from willing sellers via the water trading market. That means that new users can only gain access to water by purchasing entitlements from existing licence holders. This approach is consistent with the objectives of the National Water Initiative.

To provide the necessary level of water security for the Project, CHC purchased regulated river (high-security) WALs from the Macquarie and Cudgegong Regulated Rivers Water Source. CHC began buying WALs in late 2009 in accordance with the WSP and obtained 3,311 ML of regulated river (high-security) WALs from willing sellers in the system. This included 1,000 ML of authorising extraction from upstream of Burrendong Dam on the Cudgegong River and 2,311 ML from downstream of Burrendong Dam on the Macquarie River.

Purchase of this water was conditional upon receiving approval from the NSW Office of Water (NOW) for:

- Changing the extraction zone from downstream to upstream of Burrendong Dam, but still within the same water source.
- Works Approval for a pump site on the Cudgegong River some 2 km upstream from Yamble Bridge.

Changes to the extraction zone and the water supply works were subject to a detailed impact assessment by NOW, as required by WMA 2000, prior to its determination. Each of these approvals is discussed further below.

4.3.1.1 Approval to change water extraction zone

There are two extraction zones in the Macquarie and Cudgegong Regulated Rivers Water Source — upstream of Burrendong Dam on the Cudgegong River and downstream of the dam on the Macquarie River.

A change of extraction zone is permitted if the environmental and third-party user impacts are not significant and if the total extraction potential in the upstream zone does not exceed 40,000 ML. Potential extraction in this case was less than 27,000 ML.

WMA 2000 requires that the impact will not be significant. This involves an assessment by NOW on the potential environmental and third party impacts, including hydrological changes. For an approval to be granted, the Minister needs to be satisfied that the transfer of entitlement will not have adverse consequences.

Applications to change the authorised extraction zone were submitted in June 2010. Following NOW’s determination that the impact will not be significant, the change of extraction zone for WALs associated with 2,311 ML was approved by the Minister under Section 71S of WMA 2000 in June 2011.

NOW also confirmed that as the extraction zone for the other 1,000 ML is located upstream of Burrendong Dam, it did not require further assessment by NOW nor approval from the Minister.

On this basis, CHC now holds 3,311 ML of regulated river (high security) WALs in the extraction zone upstream of Burrendong Dam in the Cudgegong River.

Access to this water is determined by the WSP for the regulated Macquarie and Cudgegong Rivers Water Source and will vary from year to year, depending on water in storage, climatic conditions and the associated Available Water Determination. Water availability under these types of WALs is generally very secure with the full allocation being available every year in all but the driest year on record.

The average long-term extraction factor for high-security WALs for the Macquarie Regulated River Valley published in the document *Water availability in New South Wales Murray-Darling Basin Regulated Rivers* (DWE 2009) is 0.95. This suggests a high degree of certainty about the availability of high-security WAL allocations in this system.

Regulated river (high security) WALs have priority of allocation over regulated river (general security) WALs. High security entitlements, however, cannot carryover water from one year to the next, but as specified in the WSP, 100% is allocated to high security prior to general security water being made available each year.

In all but the driest year on record, the Project will have access to 3,311 ML of water from its high security entitlements. Under extreme prolonged dry weather conditions, however, town water supply and domestic/stock uses will always take priority over other consumptive uses.

High security WALs associated with the Project do not receive an allocation before all town water supply requirements are met. This means that critical human water needs must be fully catered for before any water is allocated for other uses.

State Water is responsible for ensuring water is delivered to the authorised extraction points, in accordance with the WSP. State Water will generally require four day forward orders on water from CHC to ensure there is sufficient water in the system to deliver it to the authorised extraction point.

4.3.1.2 Authorised water extraction point and extraction strategy

CHC required a Works Approval to build a pumping station at Lot 39 DP 750780 to extract water from the water source. Development consent for these works is required under Section 92 of WMA 2000 and the Determining Authority is NOW.

A development application was submitted by CHC in early 2010. The application was advertised and placed on public exhibition in accordance with statutory requirements, closing on 28 June 2010. No objections were lodged with NOW about the application.

NOW assessed the potential impacts of the proposed Works Approval. The site was also inspected by NOW to confirm potential impacts. The Works Approval was granted in September 2011.

A condition of the Works Approval is that CHC must provide an Extraction Strategy Agreement to State Water Corporation before the start of each water year. The main purpose of the Agreement is to assist State Water Corporation in river operational efficiencies by “mopping-up” operational surplus flows. Operational surpluses mean flows higher than the Yamble Bridge target averaging 25 ML/day.

Operational surplus arises primarily from rain-rejection of ordered water, but can also result from operator error and infrastructure failure, such as pump breakdowns. The preference of upstream licence holders to extract entitlements primarily during off-peak power periods is another significant and typically more regular source of operational surplus.

Given the strategic location of CHC's pump site in the Cudgegong River System, which is about 2 km upstream of Yamble Bridge, and that CHC will be the last major water user prior to the Cudgegong River entering the upper reaches of Burrendong Dam, CHC has a unique ability to assist river operators minimise operational surplus. Any reductions in the operational surplus will benefit the Cudgegong River delivery and water supply operations and in turn enhance the security of supply from Windamere Dam to downstream users.

CHC and State Water Corporation are have developing a Framework for Extraction Strategy Agreement in order to meet the imported water requirements of the Project as well as assist with operational efficiencies of the system. The Agreement includes a statement of intent, purpose, water order requirements, infrastructure capacity, communications protocol, information exchange, real-time monitoring and end of year reporting.

The extraction agreement allows CHC to extract river water in accordance with its Works Approval. The following conditions apply:

- Extraction not permitted when flow <25 ML/day at downstream Yamble Bridge NOW gauging station.
- Maximum pump rate 24 ML/day.
- Access not permitted to water comprising bulk transfer from Windamere Dam to Burrendong Dam.
- CHC will submit water orders to State Water Corporation as required by Water Supply Works Approval (which requires not less than 4 days notice).

The Cudgegong River at Yamble Bridge adjusted flow record has been provided by State Water, and is and is analysed in Appendix E. It is understood that State Water has made the following adjustments to the flow record:

- Daily flow records include a 'surplus' component which is the result of incomplete extraction of water orders by irrigators sourced from Windamere Dam.
- Daily flow adjusted when appropriate to remove bulk transfer flow from Windamere Dam to Burrendong Dam.
- State Water deemed that pre-1995 flow record not representative of current regulated river management (i.e. catchment-wide irrigation developments in infancy, pre-dates presence of 'surplus' flows); as such the adjusted record is for period 1995 to 2011.

Appendix E includes a water balance sensitivity analysis of the constraints posed by the extraction agreement. Suitable water supply security options are available to manage mine water requirement shortfalls should they be identified. These options are discussed in Section 6.2.1.

4.3.2 Existing water entitlements

A full listing of all water entitlements held by CHC is provided in Appendix F. This table includes both surface water and groundwater entitlements held under WMA 2000.

Further information regarding each of the surface water entitlements listed in Appendix F is provided below. For information regarding the groundwater entitlements, refer to the relevant section in the Project's groundwater assessment report (Parsons Brinckerhoff 2013).

4.3.2.1 Approvals under the Water Management Act 2000

CHC has approval to extract water from an existing set of pumps upstream of Lot 39 DP 750780, near Gulgong at Lot 3 DP 1171470 (80WA702573). This approval is associated with the 1,000 ML of water that CHC purchased in the extraction zone upstream of Burrendong Dam as part of the high security WAL. CHC holds water entitlements as part of a Joint Water Supply Works Approval. CHC will make an application to NOW under s.71W of WMA 2000 to change the nominated works to the authorised Project extraction point at Lot 39 DP 750780.

The pipeline from the authorised extraction point to the Project site is described in more detail in the main Environmental Assessment volume.

4.3.2.2 Water Access Licences under the Water Management Act 2000

Macquarie and Cudgegong Regulated Rivers Water Source

CHC holds a total of 3,311 shares of regulated river (high security) WALs to extract from the zone upstream of Burrendong Dam in the Macquarie and Cudgegong Regulated River Water Source.

Lower Talbragar River Water Source

Three licensed dams in the Lower Talbragar River Water Source are located on land owned by CHC .The licences have recently been converted to annual volumetric entitlements with unregulated access as per a requirement of the WSP for the Macquarie Bogan Unregulated and Alluvial Water Sources, which came into effect in October 2012. Conditions on water access under each of these licences are outlined below:

80AL718189 (WAL 34444) — Lot 1 DP 209396 'Rockleigh'

The current conditions attached to this licence allow CHC to divert from this structure up to 43 ML of water per year for the purpose of 'irrigation'. The licence conditions allow CHC to divert up to twice this amount in any one year (up to 86 ML), provided the total diversions do not exceed three times the licensed volume in any three year period. This means the maximum that can be diverted in a three year period is 129 ML.

In accordance with the WSP for the Macquarie Bogan Unregulated and Alluvial Water Sources, this access licence can be then used for any purpose, including mining. CHC is required to apply for a change of purpose to 'mining' in accordance with Section 92 of WMA 2000.

80AL718191 (WAL 34440) — Lot 22 DP 754289 and Lot 41 DP 754289

This licence incorporates two separate dams. The larger Woolandra West Dam (Lot 41 DP 754289) has a capacity of 1,470 ML at the headwaters of Blackheath Creek. The smaller Woolandra East Dam (Lot 22 DP 754289) has a capacity of 548 ML at the headwaters of a Tucklan Creek tributary.

The current licence allows CHC to divert from the structures up to 1,737 ML of water per year for the purpose of 'irrigation'. CHC can divert up to twice this amount in any one year (up to 2,538 ML), provided the total diversions do not exceed three times the licensed volume in any three year period. The maximum that can be diverted in a three year period is 3,807 ML.

In accordance with the WSP for the Macquarie Bogan Unregulated and Alluvial Water Sources, this access licence can be then used for any purpose, including mining. CHC is required to apply for a change of purpose to 'mining' in accordance with Section 92 of WMA 2000.

4.3.3 Basic water rights — harvestable rights dams

Harvestable rights allow landholders in most rural areas to collect a proportion of the runoff on their property and store it in one or more farm dams up to a certain size, without requiring a licence. This harvestable right water is generally intended for essential stock and household use but can be used for any purpose.

The harvestable right is the total amount of water that owners are entitled to capture and store, pursuant to the harvestable rights order made under Part 1 of Chapter 3 of the *Water Management Act 2000*. The maximum harvestable right dam capacity (MHRDC) is the total dam capacity allowed under the harvestable right for a property.

This MHRDC is determined via a runoff coefficient provided by NOW and the property's area. For the project site the MHRDC is 0.065 ML/ha (NOW 2008). Therefore based on a property area of 32,538 ha (as of January 2013), there is the potential to construct dams of capacity up to 2,115 ML.

A desktop mapping assessment by CHC identified 811 unlicensed farm dams located on the CHC property area. The total capacity of the existing unlicensed farm dams is estimated at 1,545 ML.

The capacity of harvestable right currently not accounted for by unlicensed dam capacity is estimated at 570 ML. NOW has advised that water storages with a combined capacity less than unused MHRDC do not require a water access licence. It appears that CHC has sufficient unused MHRDC to establish Clean Water Dam 9 (44 ML) and Clean Water Dam 10 (357 ML). Additional storage capacity would require licensing.

4.3.4 Water source protection criteria of the WSP

The WSP for the Macquarie and Cudgegong Regulated River Water Source includes specific environmental water rules to protect the water source and its dependent ecosystems.

These are designed to:

- Ensure there is no erosion of the long-term average volume of water available to the environment during the life of the Plan.
- Provide more natural flows in the upper reaches of the Cudgegong River immediately below Windamere Dam.
- Establish an environmental water allowance, which is to be released:
  - to provide more natural flows downstream of Burrendong Dam during autumn, winter and spring months, and
  - when needed for specific environmental purposes in the Macquarie River or Macquarie Marshes.

As outlined in Section 4.3, CHC has entitlements to extract from the Macquarie and Cudgegong Regulated Rivers Water Source. These were subject to detailed review and assessment by NOW prior to determination.

On the basis of NOW's positive determination and subsequent approval by the Minister, the environmental and source protection criteria set for the Macquarie and Cudgegong Regulated River Water Source will be met by the Project.

4.4 Licensing requirements

CHC proposes to construct Raw Water Dam 1 (RWD1) to store water extracted from the Macquarie and Cudgegong Regulated River Water Source. The dam will also capture run off generated from a 50 ha catchment area. This raw water dam will require a water access licence in accordance with WMA 2000. CHC will consult with NOW to obtain the necessary licences and approvals prior to construction.

CHC consulted with NOW regarding the licence requirements for clean water dams CWD1 to CWD10 which capture run off from undisturbed areas upslope of mining areas. As discussed in Section 4.3.3, CWD9 and CWD10 will not require a water access licence as they will be established under harvestable right.

The water balance modelling (Section 4.2) included groundwater seepage into mining areas during the life of mine. Seepage is predicted to depressurise coal measures close to the mine, causing lowering of the local water table and an increase to the rate which surface water recharges underlying aquifers. CHC will be required to net-off incidental take of both groundwater and surface water by purchasing corresponding water entitlements for the Project. Further information on this requirement is provided in the groundwater assessment report (Parsons Brinckerhoff 2013).

By utilising the account management provisions of the Water Sharing Plan for the NSW Murray-Darling Basin Porous Rock Groundwater Sources in respect to Available Water Determinations, carryover and account limits, required aquifer access licence (AAL) entitlement is 1,924 unit shares (equates to 1,924 ML when the Available Water Determination is 1 ML). Entitlements will be purchased from the Gunnedah Oxley Basin MDB Groundwater Source in accordance with the Water Sharing Plan. CHC currently holds 1,024 unit shares of AAL. An additional 150 unit shares of AAL have been identified for purchase, with settlement expected in early 2013. CHC will attempt to secure the remaining 750 unit shares of AAL from the water market. There is also a large volume of "unassigned water" within the Gunnedah Oxley Basin MDB Groundwater Source with the current level of entitlement, plus estimated basic rights, accounting for only 11% of the long-term average annual extraction limit. The potential exists for issue of new entitlement through a Controlled Allocations Order under section 65 of the WMA 2000.

A portion of AAL will be held post-mining to account for longer-term impacts to groundwater resulting from recharge to the void lake. Parsons Brinckerhoff (2013) estimates the maximum post-mining impact to be 270 ML/a.

The total combined of induced loss of enhanced in-pit recharge and flows in the Lower Talbragar River Water Source peaks at 799 ML/a. The total surface water entitlement required to meet these impacts is 799 unit shares of WAL. Entitlements have been purchased in the Lower Talbragar River Water Source in accordance with the WSP for the Macquarie Bogan Unregulated and Alluvial Water Sources. CHC currently holds 1,780 unit shares of WAL for existing licensed dams which historically stored water for irrigation purposes. CHC will consult with NOW to establish changes to licensing arrangements, including change of use for mining purposes. No further purchase of WAL is proposed for the Project.

A portion of WAL will be held post-mining to account for ongoing impacts to surface water due to modified recharge characteristics of the rehabilitated land surface. Parsons Brinckerhoff (2013) estimates the maximum post-mining impact to be 280 ML/yr.

No further licencing requirements under the WMA 2000 have been identified to source surface water for the site.

The water management system described in Section 4.2 includes the return of treated water from sedimentation dams to Sandy Creek and Laheys Creek. These are likely to be regulated by an Environment Protection Licence (EPL) issued by the NSW Office of Environment and Heritage (OEH) under the provisions of the *Protection of the Environment Operations Act 1997*.

Preliminary locations of up to three licensed points have been identified in Section 7. The final number and location of these points may be refined during detailed design in consultation with OEH.

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5. Potential impacts

This section discusses the potential surface water impacts of the Project during the construction, operational and post-mining phases of the Project.

5.1 Construction phase

In general, construction phase impacts associated with mining infrastructure have been assessed with operational impacts of the Project. Key construction impacts are related to erosion and sedimentation issues, which have been considered in the site water management and water quality assessments.

The Project includes a number of watercourse crossings where access roads, haul roads and rail lines cross natural creeks and drainage lines. Preliminary design of major crossings was undertaken as part of the flood impact assessment (Appendix D). These designs determined clearances above flood levels, afflux criteria and main dimensions and invert levels of bridge and culvert openings.

During the construction of these crossings, there is potential for significant erosion unless appropriate mitigation measures are implemented. Typical construction activities will generally include the following:

- Temporary obstruction of main flow channels and/or temporary diversions to build bridge piers and abutments, or install culverts.
- Excavation in channels and floodplains to construct foundations for culverts, bridge piers and abutments.
- Placement and compaction of fill over channels and across floodplains to raise road and rail embankments at crossing structures.

If not properly controlled, these activities could have the following potential impacts:

- Disturbance of creek beds and floodplain soils which could lead to erosion of the disturbed areas and/or sedimentation in downstream channels where the eroded material will be deposited.
- During rainfall or high flow events, construction materials could be carried into creeks.
- Obstruction of flow channels or floodplains with temporary works could reduce flow conveyance leading to elevated flood levels upstream during floods. This could flood upstream land or infrastructure during construction.

Mitigation measures while constructing watercourse crossings are discussed in Section 6.1.

5.2 Operational phase

5.2.1 Water quality

The methodology used to assess water quality involved the following key tasks (refer to Appendix B for details):

- Potential surface water users and water quality objectives (WQOs) relevant to the system were reviewed.

- Project-specific or customised WQO trigger levels were developed based on published guidelines.
- Potential water quality changes downstream of the Project were assessed quantitatively using a mass-balance water quality model.
- Suitable mitigation measures were identified to minimise potential impacts.
- Potential cumulative impacts on water quality in the Talbragar River were assessed.

The assessment referred to the *Macquarie-Bogan River Water Quality and River Flow Objectives* (DECCW 2006) and ANZECC (2000) Guidelines.

Data collected by the surface water monitoring program (see Appendix A) were compared against ANZECC water quality triggers to characterise baseline water quality. These were found to exceed ANZECC guidelines for a number of water quality parameters. For this reason, and due to the ephemeral nature of the affected watercourses, it was necessary to develop customised or project-specific WQO trigger levels to assess future water quality.

A mass-balance water quality model determined customised WQO trigger levels and assessed potential impacts from sedimentation dams on water quality in Sandy Creek and the Talbragar River.

The key findings of the water quality impact assessment were:

- Change in ionic concentrations in the Talbragar River for TDS only due to mining. The increased concentrations of TDS remain below trigger levels defined by the customised WQOs in the Talbragar River.
- In Sandy Creek, all parameters were below customised WQO trigger levels, apart from TDS and TN.
- In Sandy Creek, water quality remains acceptable for irrigation.
- In Sandy Creek, water quality remains acceptable for contact recreation and livestock, apart from elevated TDS levels.
- In Sandy Creek, water quality remains acceptable for aquatic ecosystems apart from elevated TN levels at years 12 and 20.

Model predictions for TN and TP levels in Sandy Creek were based on groundwater bore concentrations, in the absence of measured data from surface runoff. Since the Project will change the existing land use from livestock pasture to mining, nutrient loads are likely to significantly reduce over the life of the mine. These parameters should therefore be viewed as conservative and are expected to decrease over time.

A cumulative assessment considered combined water quality impacts from the Project and Ulan Coal Mine, which is upstream of the confluence of Sandy Creek and the Talbragar River. Ulan Coal Mine is committed to meeting prescribed discharge limits for TDS to ensure there are no adverse impacts on the river. The Project assessment predicted a maximum 5% increase in TDS values in the Talbragar River above the baseline case, which is still well below the default WQO trigger level set for the Macquarie-Bogan catchment. The cumulative impact of the Project on the Talbragar River will therefore be acceptable.

5.2.2 Downstream flow impacts

Downstream flows are summarised in this section. Refer to Appendix C for full details of this assessment. The flow impact assessment involved the following tasks:

- Estimation of baseline catchment flows to understand the contribution of the Sandy Creek catchment to downstream flows in the Talbragar and Macquarie Rivers.
- Identification of River Flow Objectives for the wider Macquarie-Bogan catchment.
- Development and analysis of flow duration curves for Sandy Creek at Medway gauge and the Talbragar River at Elong Elong gauge.
- Analysis of the mine water balance model outputs to understand the impact of mining on flow regimes in Sandy Creek and the Talbragar River.
- Assessment of the potential cumulative impacts on flow in the Talbragar River.

The water balance for the Project (Appendix E) indicates that annual average flows will be similar to, but slightly less than baseline conditions, with a worst-case decrease of around 5% during average and dry years (with increases in annual flow volumes during wet years). Flow impacts were assessed at the confluence of Sandy Creek and Talbragar River and further downstream near the Elong Elong gauge.

Estimates in Sandy Creek were based on flows produced by the AWBM model developed for the mine water balance. For the baseline scenario, baseline flows were calibrated with data recorded at the Medway gauge on Sandy Creek. During mining, flows were taken from the water balance model outputs and assigned to specific reporting points on Sandy Creek and the Talbragar River, following the procedure described in Appendix C.

Key findings of the assessment were:

- In terms of annual average flow volume, there is a reduction in the yield of the Sandy Creek system during dry rainfall years of up to 6% but an increase in yield during median and wet years. A 6% yield reduction in Sandy Creek equates to approximately a 0.6% reduction in yield in the Talbragar River at Elong Elong based on the mean flow relationship between the Medway and Elong Elong gauges (see Figure 3.1).
  This impact in the Talbragar catchment reduces further downstream as the influence of the Sandy Creek sub-catchment is reduced.
- While there is a potential decrease in the annual yield from the Sandy Creek system in low rainfall years, the modelling shows that the periodic releases of water from the mine will modify the flow duration statistics in the receiving creeks such that there is a minor increase in flows within the ranges defined by the NOW flow objectives.
- Groundwater drawdown will also affect the semi-permanent pools. Groundwater modelling suggests that there will be no adverse impacts related to groundwater drawdown at Year 1. However, from Year 4 onwards drawdowns will result in loss of groundwater inflow and potential loss of persistent groundwater fed pools at one site on Sandy Creek and one on Laheys Creek. Two other sites on Sandy Creek may also be affected; however, the magnitude of drawdown at these other locations is relatively low and within the margin of error of the groundwater modelling and the ground level data. Groundwater levels will fully recover at these sites within 50 years post mining; therefore, the groundwater inflows to the affected pools will recover in the long term.

The mine will contribute more surface water to the Talbragar River during median and wet years, but there will be minor reductions in annual flow volumes of at most 0.6% in dry years at the Elong Elong gauge. Given the minor changes caused by of the Project and the management actions proposed at Ulan Mine to release treated surplus mine water, it can be concluded that the cumulative impact of the Project on Talbragar River flows will be negligible.

5.2.3 Flood impacts

Appendix D gives full details of the flood impact assessment. This was based on the catchment breakdown prescribed by the Year 20 mine plan, which is the critical case for flooding. At Year 20, approximately 1,270 ha of catchment area is lost to the pits or diverted to catchments outside Sandy Creek.

Instead of this water flowing west into Sandy Creek, it is diverted north to a small tributary which joins the Talbragar River less than 1 km upstream of Sandy Creek.

Hydraulic models were constructed using the HEC-RAS software to represent baseline conditions and mining operations at Year 20. Of the eight existing sub-catchments delineated for the flood model, only four will have changed catchment characteristics. Most of these changes will be in two of the catchments.

Impervious areas will increase in most of the affected sub-catchments. The percentage changes in peak flood flows just upstream of the confluence of Sandy Creek and the Talbragar River are presented in Table 5.1.

Table 5-1 Percentage change in peak flood event flows

Event	Peak flow (m^3/s)	Percentage Change (%)
2 year ARI	31	+7
5 year ARI	83	+6
100 year ARI	432	+1
2000 year ARI	1,355	0

Flyblowers Creek, a minor tributary of the Talbragar River, will also be affected by the Project. During Years 12 to 20, a portion of the upper eastern Sandy Creek catchment will be diverted north into the eastern arm of Flyblowers Creek. This diverted catchment reaches 86 ha at Year 12 of the mine plan.

The hydrological assessment found that peak flows in this tributary will increase by around 30% across a range of ARIs (2 year, 5 year and 100 year) due to the diverted catchment. This could affect the existing watercourse crossings at Spring Ridge Road and a further 1.2 km downstream at the Golden Highway.

While Spring Ridge Road will be closed as a result of the mining development, flood mitigation is required so that land not owned by the mine is not impacted and flows at the Golden Highway are not significantly modified. Measures to mitigate flows in this tributary are proposed in Section 6.2.

The hydraulic model at Year 20 found that much of the mine workings and infrastructure are located significant distances away from creek lines and generally out of the wider floodplain. Therefore, there are only isolated effects on flood behaviour.

The 100 year ARI flood extent in Year 20 is illustrated in Figure 5-1. This shows that mining infrastructure has relatively little interaction with the floodplain. However, there are some parts of the mine that are located on the edge or just inside the 100 year ARI flood envelope. These include part of the workshop area, northern access road and the out of pit emplacements along the upper reaches of Laheys Creek near mining area B.

Parts of the mine footprint are within the 2000 year ARI flood. These are the northern bank of the mid reaches of Laheys Creek adjacent to the workshop area; the western edge of Laheys Creek along mining area B; and the southern edge of Blackheath Creek near the CHPP.

Appendix D demonstrates that flooding behaviour is relatively unaffected by the mine. In some localised areas, there is a small increase in flood levels – in particular Laheys Creek and the lower reaches of Blackheath Creek – but flood levels in the lower reaches of Sandy Creek are similar to baseline and worst-case developed conditions.

Overall, flooding behaviour in the upper and lower reaches of Sandy Creek do not change. There is slightly more out of channel flow in the mid to lower reaches near the junction with Laheys Creek but this impact diminishes further downstream.

Average peak velocities for Sandy and Laheys Creeks for the worst-case developed scenario are generaly similar to the range of baseline flow velocities. There are localised areas where velocities higher than 3 m/s occur in the Laheys Creek channel, but these are near proposed structures and standard mitigation measures will be required to either reduce velocities or provide erosion protection to ensure channel stability.

5.2.4 Project water demand

The water balance confirms that an external water source is needed for the Project (Section 4.2.4). Site runoff and groundwater inflows generated during mining will not be sufficient to meet the water demands of the Project under normal climatic conditions.

As outlined in Section 4.3.1, CHC has 3,311 shares of regulated river (high security) WALs to extract from the zone upstream of Burrendong Dam. These entitlements and associated extraction points were assessed by NOW during the WAL application process and were found to have no significant impact on the Macquarie and Cudgegong Regulated Rivers Water Source and associated downstream users.

It is estimated that 3,240 ML/a of imported water will be required for a 10th percentile dry rainfall year at Year 20 of the mine plan. The water balance indicates that imported water entitlements will be sufficient for of the past 111 years modelled.

In Year 20 there is a low probability that current entitlements may not be adequate to meet demands for a very dry year (i.e. drier than those experienced in the last 111 years). If very dry climatic conditions are experienced in the final years of mining, greater water economies or alternate water supply sources would be required to maintain mining operations at full production. A conservative sensitivity test of lowest recorded river flows coinciding with the peak demand year 20 was undertaken which concluded that there is a 21% probability of a water deficit at year 20 under these conditions. However, the peak predicted deficit of 334ML is only 13% of the estimated CHPP demand for year 20.

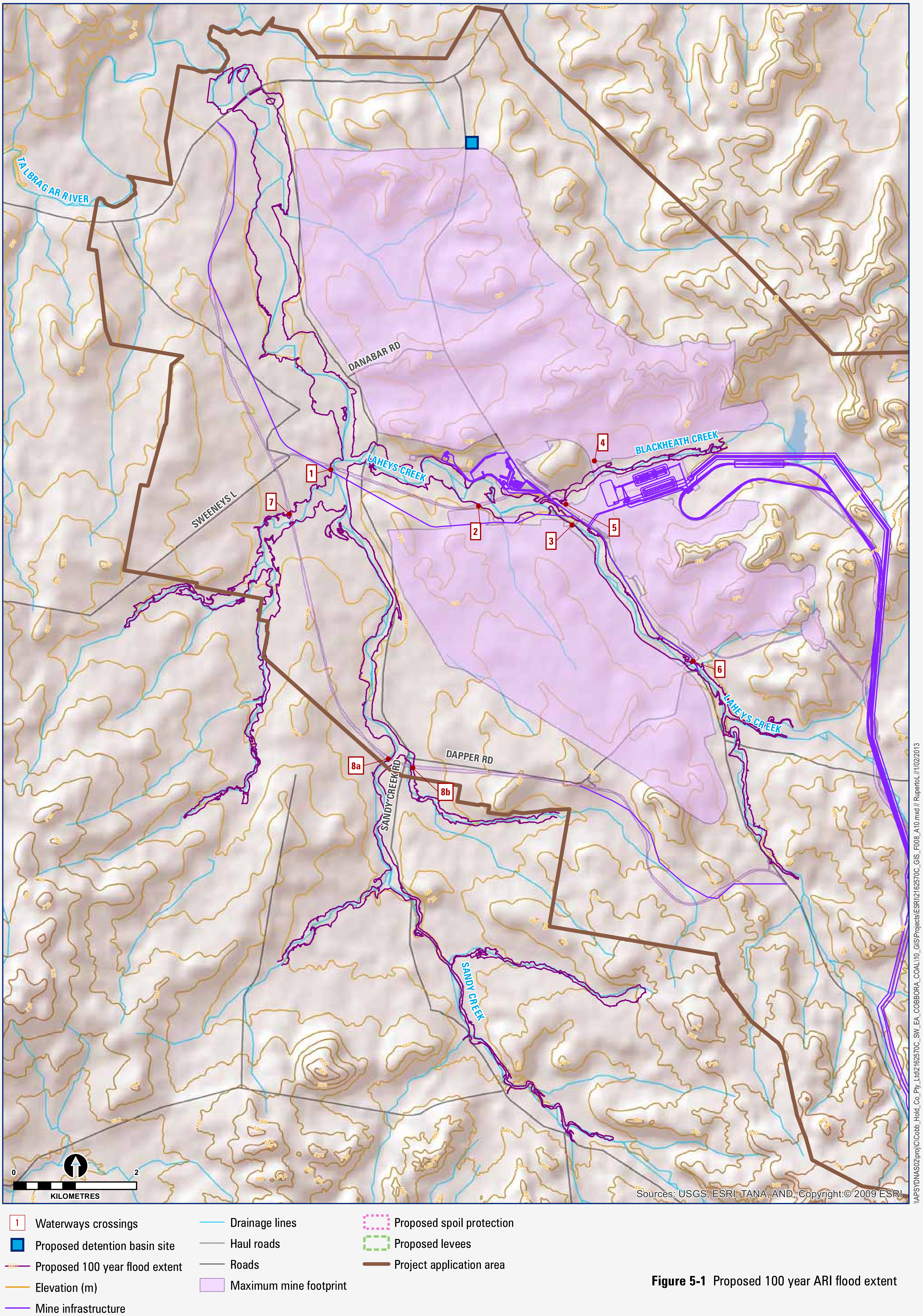


Figure 5-1 Proposed 100 year ARI flood extent

5.3 Post-mining phase

A detailed assessment of the potential surface water impacts following the completion of mining activities is provided in Appendix E. This is summarised below.

5.3.1 Final landform

The final rehabilitated landform (Year 21) is shown in Figure 5-2. The landform comprises a single final void corresponding to former mining area B. The design of the final landform backfills final voids at former mining areas A and C through considerable investment in spoil rehandling and rehabilitation. Backfilling the entire mining area B is not economically feasible; however, the final landform design requires filling of almost half of the area of the active mine void.

Rainfall falling on the final void and groundwater seepage will partially fill the void to form a lake. The water level in the void will be influenced by the balance between inflows from rainfall and groundwater, and outflow due to evaporation.

5.3.2 Final void water balance modelling

Water balance modelling has been undertaken to predict the long-term behaviour of final void B following the completion of mining.

The final void water balance model was developed using GoldSim software. The model was used to calculate the volume of water in the final void at the end of each day taking into account rainfall-runoff inflow, groundwater inflows/outflows and evaporation. The model was also used to calculate the salinity concentration in the final void at the end of each day. Instantaneous mixing of the various inflow types was assumed in the model, and no allowance was made for the stratification of the final void.

The final void water balance model was simulated at a daily time step for a period of 1,000 years. The model was simulated 100 times using 100 replicates (or sequences) of stochastic rainfall data.

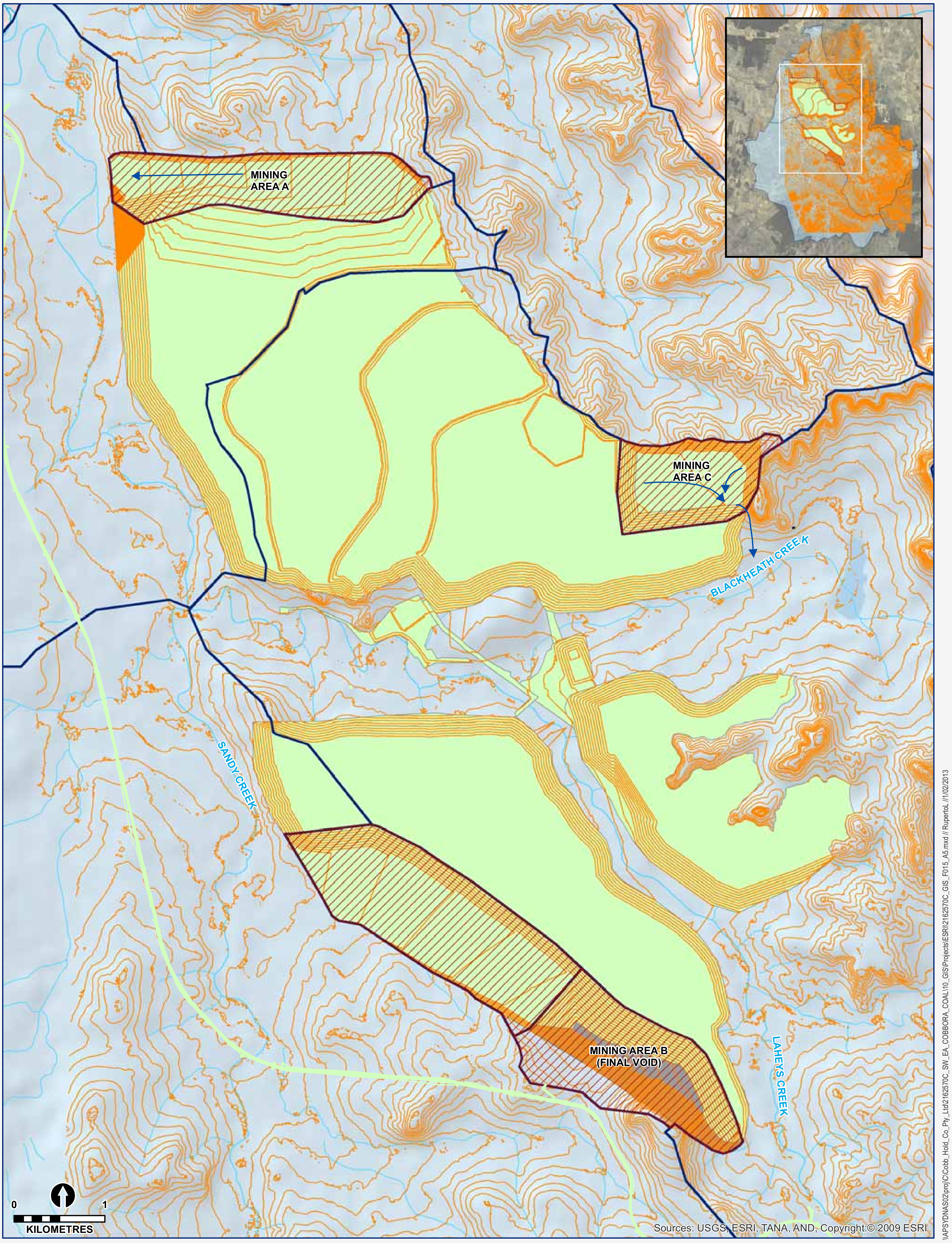
Refer to Appendix E for a detailed description of model methodology, assumptions and output results.

5.3.3 Potential impacts

The final void water balance indicates that the water level will initially rise steeply, but reach an average equilibrium over time. The void lake will not overtop and will act as a groundwater sink that will not impact nearby surface water bodies.

The salinity in the lake will increase over time. No groundwater will flow from this lake towards the creek, which offers benefit in terms of not increasing salinity in Sandy Creek. However, the void may potentially develop into a stratified lake which may lead to anoxic conditions. Water quality issues related to a confined stratified hypersaline lake have not been assessed at this stage because this would be undertaken as part of a detailed mine closure plan.

The final landform has been designed to eliminate two voids and minimise the scale of the third mining void. An unavoidable impact will be the formation of an isolated saline lake that cannot be eliminated at an economically viable cost. As no saline groundwater will migrate from that lake, the final void impacts are considered acceptable for the local surface water environment.



Year 21 mine elevation model 2m contours

Year 21 surface water drainage

Final landform catchments

Final void subcatchment boundary

Catchment boundary

Year 21 landuse

Final pit void

Rehabilitation area

Figure 5-2 Final landform

6. Mitigation measures

This section describes mitigation measures and response plans that are recommended for different stages of the Project. It is noted that many of the measures are an integral part of the operation of the mine so only a brief description is provided below, with more specific details provided in the respective appendices to this report.

6.1 Construction phase

6.1.1 Erosion and Sediment Control Plan

An Erosion and Sediment Control Plan (ESCP) should be prepared and implemented during the construction of all mine infrastructure. Erosion and sediment controls should be established to a standard consistent with the following guidelines:

- *Managing Urban Stormwater – Soils and Construction – Volume 1* (Landcom 2004).
- *Managing Urban Stormwater – Soils and Construction – Volume 2E Mines and Quarries* (DECCW 2008).

Erosion and sediment controls should include:

- minimising forward clearing, particularly areas around flow lines, drainage lines and watercourses
- minimising site disturbance by containing machinery access to areas required for approved construction works, access tracks or material stockpiles
- staging construction activities where practical, so that land disturbance is confined to the minimum possible area
- completing work and rehabilitating disturbed areas quickly and progressively
- minimising erosion from drainage lines that can be vulnerable to the erosive effects of concentrated flow
- intercepting and diverting clean water runoff from undisturbed areas so that it does not flow onto disturbed areas
- passing clean water through the site without mixing it with runoff from disturbed areas
- treating highly dispersive soils with gypsum to reduce the potential for tunnel erosion and surface rilling of disturbed areas
- limiting erosion potential within earthworks areas by managing runoff fetches and velocities, with measures such as diversion banks
- locating sediment traps, such as silt fences and check dams, downstream of disturbed areas
- treating runoff from large construction areas (greater than 2,500 m^2) in sedimentation basins or dams, before water is displaced to watercourses
- providing shaker ramps and rock pads at construction exits to remove excess mud from truck tyres and under bodies.

6.1.2 Creek crossings

A number of reasonably large creek crossings are required as part of the proposed mine infrastructure. As discussed in Section 5.1, these crossings have been initially sized to ensure minimal impact on upstream flood levels.

Crossings should be constructed during dry periods, where possible, and generic best practice stormwater/erosion control measures should be implemented. During wet weather, work zones should be isolated to avoid flooding working areas.

Watercourse crossings are a controlled activity under the Water Management Act 2000. The detailed design of the crossings will need to take into account NOW guidelines on design and construction of watercourse crossings which require consideration of the following:

- Minimisation of disturbance of the riparian corridor and its function.
- Preservation of native vegetation.
- Preservation of natural hydrological and geomorphological regimes.
- Rehabilitate and stabilise disturbed areas and protect against ongoing scour and erosion.

Erosion protection will be required at all structures and bridges, particularly for access roads where extreme events may overtop the bridge and local roads leading up to the structure. The appropriate erosion protection would be determined during the design phase. Typically, it would include rock revetment and scour protection to culvert inlets and outlets, bridge piers and abutments. It is essential that erosion protection measures for both the construction and operational phases of the Project be incorporated into the detailed design of these crossings.

All access and haul road crossings that have active fish movement will need to be fish-friendly and designed in accordance with *Policy and Guidelines for Fish Friendly Waterway Crossing* (NSW Fisheries 2003) and *Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (*Fairfull & Witheridge 2003).

6.1.3 Hazardous materials and effluent management

The risk of accidental spillages of hazardous materials during construction should be reduced by having designated storage facilities with appropriate handling practices and safeguards, in accordance with relevant Australian Standards and guidelines. This should include the provision of localised bunding and spill kits. Stormwater from construction sites should be diverted to nearby sedimentation dams, where containment and treatment of any incidents will be possible.

For the lifetime of the construction camp, raw sewage will be pumped from storage tanks by a licensed contractor and delivered under contract to a local government authority for disposal in an existing town sewage treatment facility.

6.2 Operational phase

6.2.1 Water supply security

During worst-case climatic conditions, CHC has a number of alternate options available to ensure the mine continues to operate. These options are summarised as follows, in decreasing order of priority:

- Implementation of additional operational efficiencies and water conservation measures to reduce mine water demand. These include minimising make-up water demands by implementing further water conservation measures in the CHPP process water system and reducing water demands for dust suppression with environmentally safe additives that help to bind dust particles to reduce airborne dust potential.
- Employing unused aquifer access licence entitlement to withdraw groundwater to supplement water supply.
- Purchasing of 'General' WALs from the open water market, if they are available, to meet the additional demand, and selling them back to the market when no longer required.
- Reducing coal production rates to match available water supplies. This is a worst-case scenario and assumes that the above options are either not available or not effective at providing additional water or reducing water demand.

6.2.2 Mitigation of potential impacts on refuge pools

To mitigate possible impacts on refuge pools an Aquatic Monitoring Strategy (AMS) will be developed for the Project to assess flow change and groundwater drawdown impacts on the quality and quantity of water in the persistent pools of Laheys and Sandy Creeks. The strategy will include:

- details of the proposed water level gauges, location and frequency of monitoring water level data at the persistent pools and reference sites (for comparison);
- monitoring the condition and health of instream biota representative of the Darling River aquatic ecological community and the Freshwater Catfish;
- the identification of trigger values for freshwater dam releases and/or water from the raw water dam to be released;
- details on existing flow data to ensure freshwater releases mimic natural patterns in flow, capture seasonality in the frequency, magnitude and duration of flows, as well as the natural variability to which the native fauna are adapted, where possible;
- monitoring the quality of freshwater releases;
- an adaptive management framework with feedback mechanisms; and
- a reporting program.

6.2.3 Sedimentation dam performance

In accordance with the proposed water management strategy, surplus water from sedimentation dams will be returned to Sandy Creek and Laheys Creek if it is not needed in the mine. During these events, it will be necessary to ensure treated water from these dams complies with specific concentration limits designed to protect the water quality of receiving watercourses.

Performance criteria were set using customised water quality objectives developed as part of this assessment (see Appendix B). Proposed concentration limits applicable to all sedimentation dam releases are shown in Table 6-1.

Table 6-1 Proposed sedimentation dam performance criteria

Parameter	Concentration limit (100%-ile in mg/L)	
	50th %ile	100th %ile
Aluminium	N/A	0.5
Iron	N/A	1.5
Manganese	N/A	2.0
pH	N/A	6.5 -8.5
TDS	350+	600+
TN	N/A	0.9
TP	N/A	0.5
TSS	N/A	50

(* based on default local EV, Section 2.2.2; + equivalent to approximately 550 and 940 µS/cm, respectively)

Compliance with the concentration limits provided in Table 6-1 will ensure water quality in receiving watercourses is not adversely affected.

6.2.4 Flood protection levees

Flood protection levees are proposed at two key locations in the Laheys Creek and Blackheath Creek catchments. Although there are no proposed open-mining areas along the waterways where floodwaters can enter, there are areas that require flood protection to prevent flooding from disrupting operations.

The first location is the area along the southern edge of Blackheath Creek where a flood protection levee equal to the 2,000-year ARI flood level (or other suitable, extreme-event flood level, to be determined during detailed design) will protect the coal stockpile. Alternatively, the coal stockpile platform on the southern bank of Blackheath Creek could be built above the 2,000-year ARI event (or other suitable extreme event), with a suitable freeboard allowance.

The second location extends along the edge of the workshop area on the northern bank of the lower reaches of Laheys Creek. It is assumed that this area is required to have flood protection up to the 2,000-year ARI event (or other suitable extreme event), plus a freeboard allowance. Alternatively, the embankment for the workshop and access road could be designed to be above the 2,000-year ARI event, with scour protection added to the embankment as it will be located on a bend of Laheys Creek where scour erosion could occur.

It should be noted that the 2,000-year ARI flood event was chosen as a reasonable upper limit reference event to protect critical infrastructure and is not proposed as a strict design requirement. The appropriate standard of flood protection for critical infrastructure will be confirmed during detailed design.

The levees prevent land from being flooded and therefore constitute controlled work under Part 8 of the Water Act 1912. The design of the levees will need to conform to NOW guidelines for such works.

6.2.5 Spoil emplacement protection measures

The flood impact assessment identified that one of the out of pit emplacement areas will be located on or just within the boundary of a 100-year ARI flood extent and will thus require scour protection to protect it from erosion.

It is recommended that instead of providing a dedicated levee, the toe of the out of pit emplacement itself be engineered similarly to a levee. During construction, a suitable material should be used to construct the bottom section of the out of pit emplacement up to the level of the 100-year ARI flood level plus a freeboard of 600 mm.

In addition to engineering the toe of the out of pit emplacement, erosion and sediment control measures should be installed along the embankment to ensure sediment laden runoff does reach the creek.

The spoil protection areas will modify flood behaviour in high order events and will prevent land from being flooded. They will therefore constitute controlled work under Part 8 of the Water Act 1912 and the design will need to conform to NOW guidelines for such works.

6.2.6 Dry detention basin

The flood impact assessment found that flows could increase in Flyblowers Creek north of Sandy Creek which flows north underneath the Golden Highway. The assessment noted that during Years 12 to 20, flood mitigation measures will be required to maintain existing peak flows in this tributary at the Golden Highway.

It is recommended that a dry detention basin be constructed to reduce peak flows at the Golden Highway culvert to baseline conditions. It is estimated that a dry detention basin with a capacity of approximately 70 ML will be required to achieve this. Further details on the features and location of the detention basin are provided in Appendix D.

The conceptual basin design presented in Appendix D should be investigated further during detailed design, in consultation with NOW, to determine any potential licensing requirements. It is likely that the basin will require NOW approval as it constitutes controlled work that affects the flow of water to or from a river (under Part 8 of the Water Act 1912).

6.2.7 Temporary diversion channels

Diversion channels will be required to temporarily redirect existing minor tributaries and drainage lines around the mine working areas during certain stages of mining.

In the early mining stages, the upstream portion of these tributary/drainage lines will generally be unaffected by the mine while the downstream section will need to be temporarily diverted around a mining area. As the mine workings expand, the particular tributary/drainage line should be incorporated into the active mine workings and the temporary diversion will no longer be required.

The intention of these temporary diversion channels is to prevent clean water from unaffected upstream catchments from flowing into the mine. Two locations have been identified where temporary diversions are required. See Appendix D for more details.

Initial concept design has been undertaken to ensure these diversions will be practical to construct. Initial calculations indicate that the diversions are feasible and will likely maintain similar average channel slopes and velocities for the length of the diversion. This should minimise impacts to downstream receiving channels.

Appropriate tie-in works and erosion protection structures may also be required at the ends of the diversions to minimise downstream erosion.

6.2.8 Wastewater management

For the duration of mining operations, wastewater from on-site facilities such as workshops, process and administration buildings will be managed by an on-site sewage treatment system. The basic sewerage system infrastructure will generally comprise:

- transfer pumps and mains
- storage tanks
- proprietary secondary treatment plant
- tertiary treatment and disinfection
- effluent transfer system.

Sewage will be pumped to the secondary treatment plant from ablution facilities located at the CHPP, administration and workshop areas, and amenity blocks. Following transfer to the treatment plant, the effluent will undergo secondary treatment and subsequent tertiary treatment and disinfection to achieve effluent quality for reuse with the potential for human contact, in accordance with relevant guidelines. The treated effluent will then be transferred to the mine water system for beneficial reuse on-site.

6.2.9 Flood emergency management plan

The flood impact assessment found that parts of the mine's access and haul road network could be affected during very extreme floods. These vulnerable areas should be identified in a Flood Emergency Management Plan for the site, which should also consider flood risk to external public roads that may be used by staff travelling to and from the site. The Plan should include instructions for staff both on and off the site on actions to take during a flood, with clearly identified communication protocols. It is also recommended that site inductions include a review of the Flood Emergency Management Plan to maximise staff awareness of flood risk and appropriate actions.

6.3 Post mining phase

The water balance assessment of the final landforms concluded that catchment modifications caused by the mine will not have a regionally significant impact on the broader Talbragar River or Macquarie River catchments. Impacts should be mitigated through long-term remediation of the catchment in the Project area, including reinstatement of naturalistic landforms, gullies and drainage lines, to minimise the final disturbance of the catchment.

The final landform has been designed to minimise the formation of void lakes at the mining areas. Due to economic constraints on the Project a void lake is unavoidable in the south eastern end of mining area B. This void will not overtop and will act as a groundwater sink and therefore will not impact on the surface water environment. Given that the final landform has been designed to minimise void lake formation as far as economically practical, further mitigation measures are not considered necessary.

7. Monitoring and management

This section outlines the recommended actions to manage and monitor the surface water aspects of the Project.

7.1 Site Water Management Plan

It is recommended that a comprehensive Site Water Management Plan (SWMP) be developed for the Project prior to commencement. The objective of this Plan is to ensure the operational performance of the mine, with respect to water, meets all relevant regulatory requirements.

The provisions of the SWMP would cover management of both surface water and groundwater sources at the mine site.

The SWMP should:

- Identify all relevant legislative and regulatory approvals relating to water management at the site.
- Identify relevant site-specific performance benchmarks, guidelines and criteria in relation to water management.
- Identify potential impacts on local water users and water-dependent ecosystems, upstream and downstream of the mine.
- Identify and assess water sources and their context, including groundwater and surface water.
- Identify operational water demands, reuse and disposal needs using a comprehensive mine water balance for the entire mining operation.
- Identify accountabilities and responsibilities to manage water resources at the mine site.
- Identify opportunities to maximise water conservation and reuse in lieu of using imported water.
- Include procedures to treat and control the release of water to the natural environment in accordance with regulatory requirements.
- Include a comprehensive monitoring program that includes both surface water and groundwater monitoring.
- Establish contingency measures and emergency procedures should adverse conditions or impacts be encountered during the operation of the mine.
- Establish a framework of continual improvement, auditing and reporting that is consistent with regulatory requirements and industry best practice.

The SWMP should be developed in consultation with relevant stakeholders and regulatory authorities, such as local community groups and water users, State Water, the Office of Water, the Office of Environment and Heritage, and the Central West Catchment Management Authority.

The Plan should also include a set of operational procedures that clearly articulate how different aspects of the mine's water management system are to be operated and maintained.

These include:

- Water supply management
- Stormwater management
- Mine water management
- Wastewater management
- Mine dewatering
- Dust suppression control
- Rehabilitation performance monitoring.

7.2 Surface water monitoring program

7.2.1 General principles

As discussed in Section 4.4, releasing treated water from sedimentation dams to Sandy Creek or Laheys Creek is likely to be regulated by an Environment Protection Licence (EPL).

The EPL would be developed following Project Approval and prior to the commencement of mining and would specify operating conditions. One of these conditions will include specific concentration limits that will need to be complied with by the mine for all points nominated in the EPL. The EPL will also specify minimum monitoring and reporting requirements, amongst other requirements.

The following are general principles that should be considered in the development of any surface water monitoring program:

- The management of the site should engage a responsible person to coordinate and implement the surface water monitoring program, in accordance with the responsibility matrix specified in the SWMP.
- All licensed points should be monitored, recorded and reported in accordance with the relevant EPL conditions.
- Should an exceedance of the licensed criteria be recorded, the responsible person should notify the OEH of the exceedance as soon as possible. Investigations should then be undertaken to determine the cause of the exceedance and possible mitigation actions that could either prevent or minimise the chance of reoccurrence.
- The surface water monitoring program should also include monitoring points that are upstream and downstream from the licensed releases to monitor potentially adverse trends in water quality that could warrant further investigations and/or preventative actions.
- Observations of creek bank and bed condition at discharge points and watercourse crossings should also be recorded.

7.2.2 Monitoring recommendations

Three licenced points and five monitoring points have been selected on the basis of the existing surface water monitoring program, which has been in operation since 2009 and was used to establish the baseline water quality conditions for the environmental assessment. Refer to Figure 7-1 for details.

The following surface water monitoring network has been recommended for the Project.

- SD1, SD2 and SD3 - Sedimentation dams where water is released to a receiving watercourse. These points could potentially be specified as the licensed points in the EPL for the Project.
- SW01 (Sandy Creek), SW02 (Laheys Creek) and SW05 (Talbragar River) – This would be established as the control points (monitoring only), upstream from the Project site.
- SW03 (Sandy Creek) and SW04 (Talbragar River at Elong Elong) – This would be established as control points (monitoring only) downstream from the Project site.

The location of the above monitoring points, in particular SD1, SD2 and SD3, are preliminary and may be refined as the mine water management system and associated infrastructure is confirmed during detailed design.

Equipment to be included at each monitoring point

Each monitoring point should have the capacity to monitor water quality and quantity to enable testing for compliance against relevant water quality criteria. This should include a flow gauging weir to estimate flow volume and an outlet pit to sample representative water quality at the point of sampling.

Sample collection and analysis

Samples should be collected by qualified professionals in accordance with *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales* (DEC 2004). Any laboratory used must be National Association of Testing Authorities (NATA) registered for each analysis required.

Training and equipment use

Personnel who undertake environmental monitoring must be appropriately trained in the technical and administrative aspects of sample collection, equipment calibration and use, field reporting requirements and EH&S aspects of field work. All analytical equipment should be calibrated to manufacturer's recommendations. Records of all calibrations should be kept as part of the Project monitoring file.

Reporting

The recording, reporting and assessment of monitoring results against prescribed criteria should be undertaken in accordance with the relevant provisions of the Project Approval and EPL for the Project.

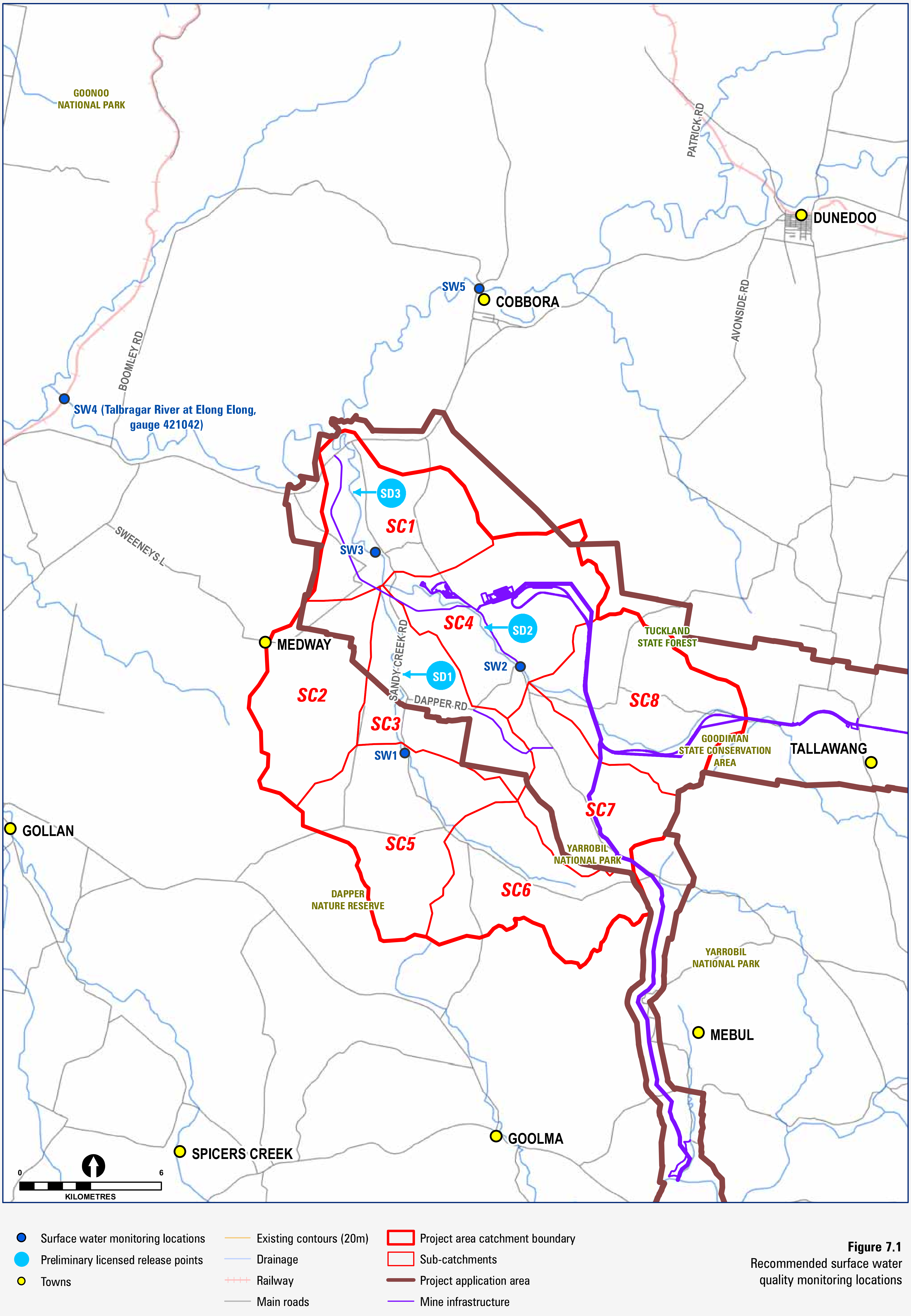


Figure 7.1
Recommended surface water quality monitoring locations

Topographic map source: NSW Department of Lands, 1989

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8. Conclusions

This report and its associated appendices have been prepared to assess the impacts of the proposed Cobbora Coal Mine on surface water. It considered:

- An overview of the Project, and the objectives and scope of the surface water assessment.
- The DGRs relating to surface water for the Project and the relevant legislation, policies and guidelines.
- The existing surface water environment of the Project area, including the local and regional hydrology, regional and local catchments, flooding, local water bodies, surface water quality and other surface water users.
- The proposed water management system and mine water balance, including a description of site water demands, water disposal methods, water supply infrastructure and water storage structures.
- The Project's potential impacts on surface water during construction and operation and post-closure, including flooding, interception of surface water, surface water extraction and disposal of excess water. This includes an assessment of potential cumulative impacts.
- The recommended mitigation measures and response plans for the Project.
- A recommended surface water monitoring program for the Project, including monitoring requirements, procedures and recommendations.

It has been found that the conceptually designed water management system will function effectively under a wide range of climatic conditions and stages of mine development. These ranged from some of the driest years in 111 years through to some of the wettest periods on record.

Detailed flood modelling demonstrated that the mine can be appropriately safeguarded against major floods, while the mine itself and associated infrastructure will not materially affect downstream properties.

The water management system is a robust one that can allow the mine to operate within contemporary environmental standards, so that CHC can comply with its anticipated licensing and statutory obligations.

Finally, based on current information, a post mining design has been developed that can provide a sustainable landform that will not impose unacceptable legacy issues on future generations.

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Appendix A

Cobbora Coal Project – Baseline Hydrological Environment

Cobbora Coal Project – Baseline Hydrological Environment

January 2013

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C	Final for Public Exhibition	6 September 2012	RL
D	Final post exhibition	31 January 2013	DE, RL

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Signed: .... Rob Leslie

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Fluvial Geomorphology Site Description Template

Glossary

AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
BoM	Bureau of Meteorology
CRD	Cumulative rainfall departure
DECCW	Department of Environment, Climate Change and Water
EC	Electrical conductivity
km	Kilometres
mg/L	Milligrams per litre
ML	Megalitres
NOW	New South Wales Office of Water
NTU	Nephelometric turbidity unit
OEH	Office of Environment and Heritage
RFO	River Flow Objective
SW	Surface water monitoring point
WQO	Water Quality Objective

1. Introduction

This document describes the baseline hydrological environment in the surface water catchments relevant to the assessment area.

This document provides information on the baseline surface water environment used by the technical reports that comprise the surface water assessment of the Project. These are listed as follows:

- *Cobbora Coal Project - Downstream Water Quality Impact Assessment.*
- *Cobbora Coal Project - Downstream Flow Impact Assessment.*
- *Cobbora Coal Project - Flood Impact Assessment.*
- *Cobbora Coal Project - Water Balance and Surface Water Management System.*

2. General catchment features

2.1 Topography and land use

The topography of the area covered by the Project is gently undulating to hilly, with elevations varying between approximately 320 and 620 metres Australian Height Datum (mAHD). The area is mostly cleared and used for agricultural purposes, including grazing sheep and cattle, cultivating cereal crops and forestry.

2.2 Soils

The Australian Soil Resource Information System (ACLEP 2010) provided information on soils within the assessment area. The predominant soil type is unit Qb17, which occurs in undulating country with gravelly or stony ridges comprising hard and friable neutral red soils. Along the Talbragar River, the soil unit is Gb11, occurring on river terraces and floodplains and comprising dark porous loamy soils with some cracking clays.

2.3 Dryland salinity

The *Salinity Risk Assessment of the Central West Catchment* (Humphries 2000) describes the salinity hazard rating of the Lower Talbragar catchment as 'very high'.

However, the Sandy Creek sub-catchment has relatively low salinity compared to more salinised catchments to the west. The Project targets only Triassic and Permian strata within the sub-catchment and not the Lachlan Orogen metasediments, which are generally associated with saline soils. The salinity risk is therefore much lower in this particular part of the catchment.

3. Climate

3.1 Local weather stations

There are no Bureau of Meteorology weather stations with complete long-term data sets within the assessment area. The nearest weather stations with long-term observation data are:

- Bureau of Meteorology Station 064009: Dunedoo Post Office (BoM 2011a), approximately 20 km north-east of the Project and in operation since 1912.
- Bureau of Meteorology Station 062013: Gulgong Post Office (BoM 2011b), approximately 20 km south-east of the Project and in operation since 1881.

Rainfall data from these sites has been analysed to understand local weather patterns. An operational Bureau of Meteorology Station 064026 is located at Cobbora (Ellismayne), however, the data set is incomplete. The closest station to the assessment area with long-term evaporation observations is located at Wellington Research Centre (BoM Station 065035) about 60 km to the south-west of the assessment area.

Two additional meteorological gauging stations were installed by CHC in the assessment area between 2009 and 2011. These have been used to supplement long-term records obtained from the BoM stations, and provide rainfall information specific to the assessment area. The locations of these weather stations are shown in Figure 3-1.

3.2 Rainfall and evaporation

Annual rainfall follows very similar patterns at each Bureau of Meteorology station. The historical average annual rainfall, however, was slightly higher at Gulgong station than at Dunedoo station.

The average annual rainfall at Gulgong station, measured between 1881 and 2011, was 651.6 mm/a. Average annual rainfall at the Dunedoo station, measured between 1912 and 2011, was 616.4 mm/a, a difference of approximately 35 mm/a. This may be mainly attributed to 14 years of above-average rainfall that occurred between 1881 and 1912, before the Dunedoo station operated. A comparison of annual rainfall at each station is shown in Figure 3-2

Average monthly rainfall and evaporation data is shown in Figure 3-2. Generally the average monthly rainfall recorded at Gulgong and Dunedoo stations is very similar. In the period of record from November 2010 to November 2011 (inclusive), rainfall recorded by the on-site meteorological stations was for half of the year well above the average monthly rainfall for the Dunedoo and Gulgong stations. This is the result of above-average rainfall, which was also experienced at Dunedoo and Gulgong.

The long-term (1889–2011) cumulative mean deviation (CMD) was calculated using rainfall data sourced from the Data Drill database to show the long-term trends in rainfall patterns (Figure 3-2). Data Drill accesses grids of data derived by interpolating the Bureau of Meteorology ‘s station records.

The CMD graph shows a negative gradient after the start of 2000 up to the end of 2009, indicating the area was in drought with below-average rainfall for the past 10 years. Since the beginning of 2010 the graph shows a positive trend, indicating above-average rainfall conditions.

The average annual evaporation from 1965 to 2005 (inclusive) recorded at the Wellington station was approximately 1,800 mm (BoM 2006) (which is reduced to 1,440 mm after applying the pan correction factor of 0.8 for surface water bodies in the central west region).

Overall, the records indicate that rainfall is generally greater in the summer months than in the winter months and there is a high level of evaporation in comparison to rainfall. The winter months of June and July are the exception, where rainfall and evaporation are relatively equal.

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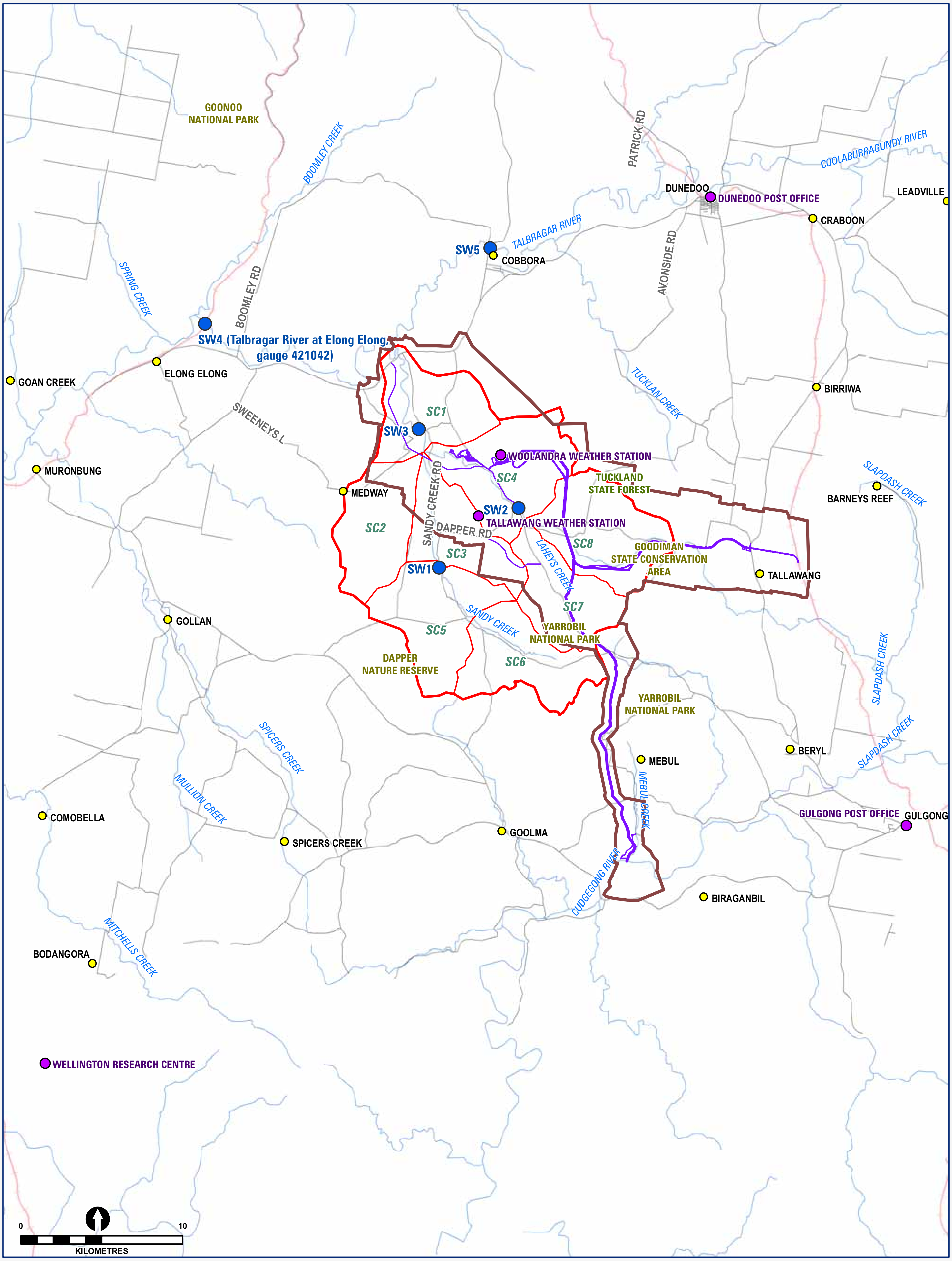

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- Surface water monitoring locations
- BOM weather station
- Towns
- Existing contours (20m)
- Drainage
- Railway
- Main roads
- Catchment boundary
- Sub-catchments
- Project application area
- Mine infrastructure

Figure 3.1 Weather stations and surface water monitoring locations

Topographic map source: NSW Department of Lands, 1989

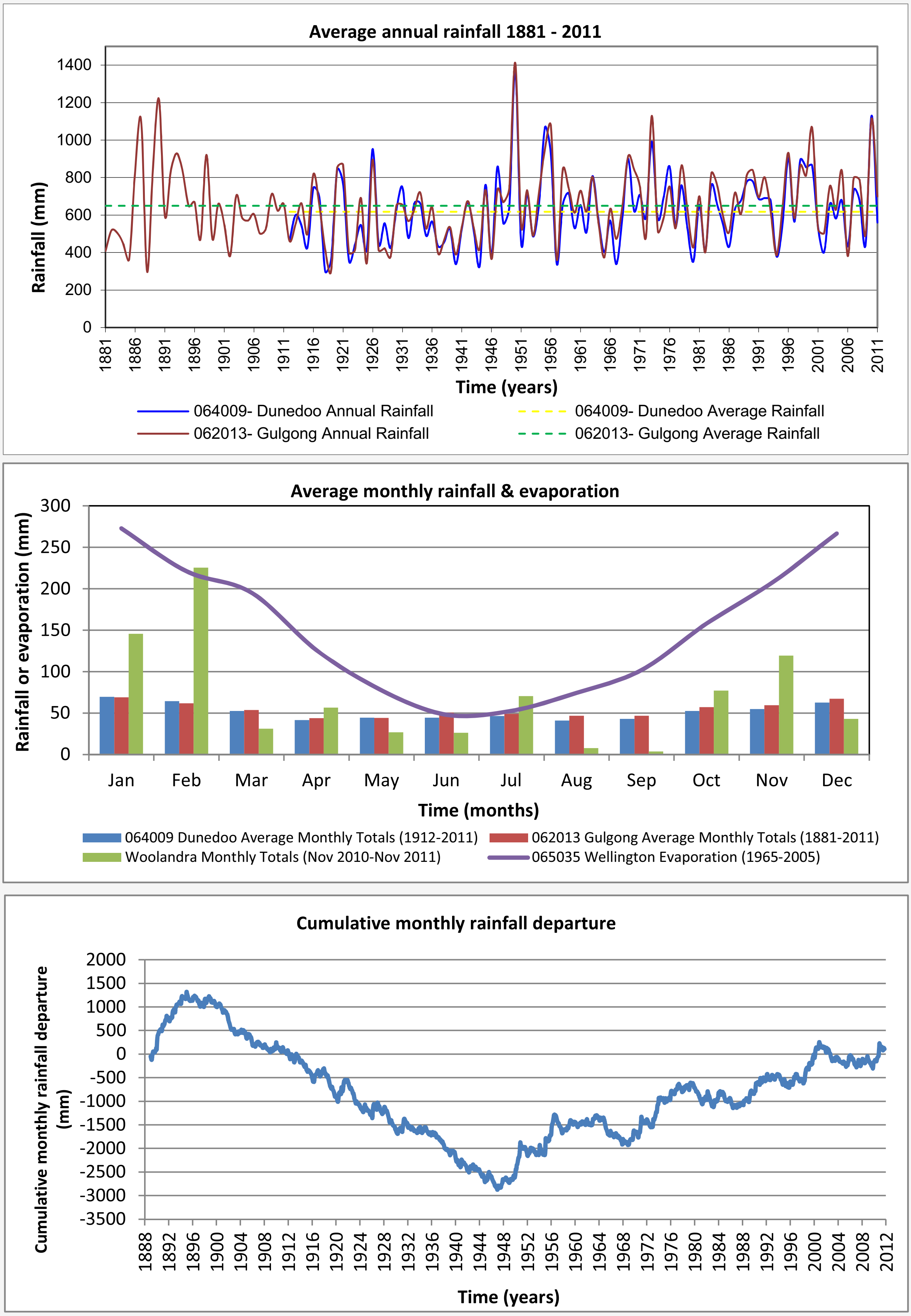


Figure 3.2 Rainfall and evaporation data for the Project Application Area

3.3 Climate change

Climate change is predicted to have a marked impact on many climate variables, including rainfall and evaporation. The effects of climate change are already being detected in Australia, and it is predicted that these changes will intensify as the century progresses (CSIRO and BoM 2007).

The following changes in climate are predicted for NSW by 2030 (CSIRO 2009, 2010), which covers the Project's 21-year lifetime:

- decrease in average annual rainfall by approximately 1%
- increase in average annual temperature by approximately 1°C
- increase in the number of very hot days (> 35°C) per year from an average of 26 days to 36 days
- increase in the number of extremely hot days (> 40°C) per year from an average of 2 days to 4 days
- increase in evapotranspiration by 2% to 4%.

Because predicted changes in climate variables over the Project lifetime are very low, the Project will not be required to implement adaptation strategies to account for climate change.

4. Surface water features

4.1 Regional surface water bodies

Rivers in the greater Cobbora area include the Talbragar River and Cudgegong River, which are tributaries of the Macquarie River. The Macquarie River is formed near Bathurst, at the junction of the Fish River and Campbells River, and extends north-west to the Barwon River upstream of Brewarrina. It flows through the Macquarie Marshes, which are one of the largest semi-permanent wetlands in south-eastern Australia, covering more than 150,000 ha. Refer to Figure 4-1 for further details.

Parts of the Cudgegong and Macquarie rivers upstream from the Macquarie Marshes are regulated under the *Water Sharing Plan for the Macquarie and Cudgegong Regulated Rivers Water Source*, which directs how the water available for extraction is to be shared and provided for environmental needs. Due to river regulation, and the construction and operation of Windamere Dam on the Cudgegong River and Burrendong Dam on the Macquarie River to supply downstream water users, the volume and pattern of flows in the watercourses have been significantly altered.

Traditionally, natural river flows were highest between June and October and lowest in late-summer and autumn. However, flows in much of the system are now at their highest during the irrigation season, which extends from October to March. In particular, the frequency, extent and duration of inundation in the Macquarie Marshes have been reduced since regulation of the Macquarie River.

The assessment area lies within the catchment of the unregulated Talbragar River (see Figure 4-1). The Talbragar River separates from the Coolaburragundy River at Dunedoo, and runs south-west, joining the Macquarie River just north of Dubbo.

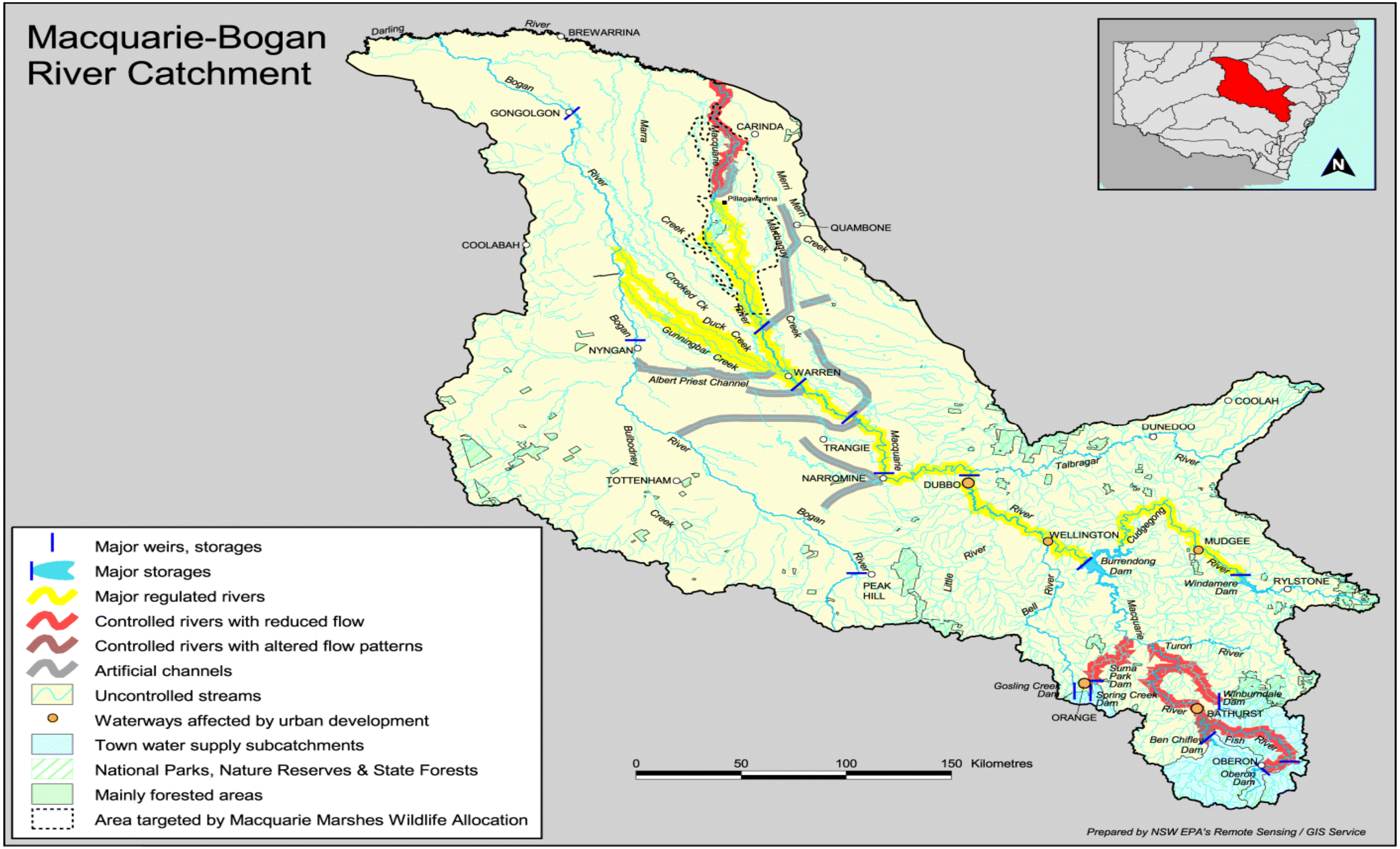


Figure 4-1 Watercourse classification in the Macquarie–Bogan catchment (DECCW 2006)

4.2 Local surface water bodies

The assessment area lies within the catchment of Sandy Creek, a tributary of the Talbragar River. Sandy Creek, Laheys Creek (a tributary of Sandy Creek) and a number of minor tributaries flow through the proposed mine area.

The Talbragar River, Sandy Creek and Laheys Creek are naturally ephemeral waterways and cease to flow during dry periods. There are no headwater storages to regulate flows, and therefore all flows directly reflect rain events, groundwater baseflows and evapotranspiration processes.

When observed during multiple site visits during 2009 and 2010, Sandy Creek and Laheys Creek were dry, apart from isolated stagnant pools. During the site visits in October, November and December 2011, running water was present in Sandy Creek, with stagnant pools at some locations; Laheys Creek was also flowing at most locations.

Laheys Creek is a small, densely vegetated channel over most of its length. Upstream of its confluence with Laheys Creek, Sandy Creek is a sandy, grassed channel showing evidence of bank erosion. Downstream of the confluence, Sandy Creek widens to become a broad, flat channel that is heavily vegetated with grasses and reeds.

Two farm dams have been constructed on Blackheath Creek, a tributary of Laheys Creek. These were constructed by the landowner approximately 30 years ago to service the property's irrigation needs. The larger Woolandra West dam is shown in Photo 4-1. A recent survey of the dam determined its capacity to be about 1,470 ML. The upstream smaller dam (referred to as the 'sausage dam') receives inflow from groundwater springs higher in the catchment and has a capacity of approximately 15 ML (see Photo 4-2).

Flyblowers Creek is a small creek catchment located north-west of the Sandy Creek catchment. This creek flows into the Talbragar River upstream of Sandy Creek and downstream of Tucklan Creek.

Fords Creek is a tributary of Laheys Creek and lies in the upper catchment. Fords Creek flows west and captures runoff from the forested areas near the Goodiman State Forest. Many small drainage channels and gullies drain into it.

The remainder of the Project Application Area covers catchments of minor tributaries and small creeks in the south and part of the tributary system draining to Tallawang Creek in the east. Tallawang Creek flows south into the Wyaldra Creek, which eventually flows into the Cudgegong River west of Gulgong.

Tucklan Creek flows in a northerly direction from the site into the Talbragar River, approximately 10 km upstream of the Sandy Creek – Talbragar River confluence. Tucklan Creek has a similar catchment area to Laheys Creek, but only approximately 1 km of its headwaters lie within the assessment area.

Photo 4-1 Woolandra West dam on Blackheath Creek

Photo 4-2 Sausage dam on Blackheath Creek

5. Baseline hydrologic conditions in local surface water bodies

5.1 Stream gauge information

No NSW Office of Water (NOW) gauging stations are currently operational within the assessment area or within the broader Sandy Creek catchment. However, Station 421042 is located on the Talbragar River at Elong Elong, approximately 10 km north-west and downstream of the assessment area (shown on Figure 3-1 as SW4).

Additional stream flow records are available from discontinued NOW stream gauges on the Talbragar River at Cobbora (close to SW5 on Figure 3-1) and on Sandy Creek at Medway (close to SW3 on Figure 3-1). Details of these gauges are provided in Table 5-1.

Table 5-1 NSW Office of Water stream flow gauges

Location	Gauge number	Period of record
Operational gauges		
Talbragar River at Elong Elong	421042	1964–present
Discontinued gauges		
Talbragar River at Cobbora	421028	1950–1954
Talbragar River at Naranmore	421037	1955–1976
Sandy Creek at Medway	421064	1966–1985

Source: PINEENA database

The Talbragar River is characterised by a seasonal discharge pattern, with lower flows during summer and autumn, and floods throughout winter and spring. Based on available recorded data from NOW, the median annual discharge at Elong Elong is 21,509 ML/a, with a maximum recorded annual discharge of 264,366 ML in 1998 and a minimum recorded annual discharge of 653 ML in 2005.

The flow duration curve developed from the Elong Elong gauge shows that although the highest recorded mean daily flow was 40,835 ML/d (in December 2010), for 50% of the time flows were less than 11.9ML/d and for 32% of the time there was no flow.

The flow record from Sandy Creek shows that for the period of record (1966–1985), the highest mean daily flow was 8,937 ML/d, which occurred in February 1971. The flow duration curve for Sandy Creek at Medway shows that for 50% of the time flows were less than 0.04 ML/d and for 46% of the time there was no flow.

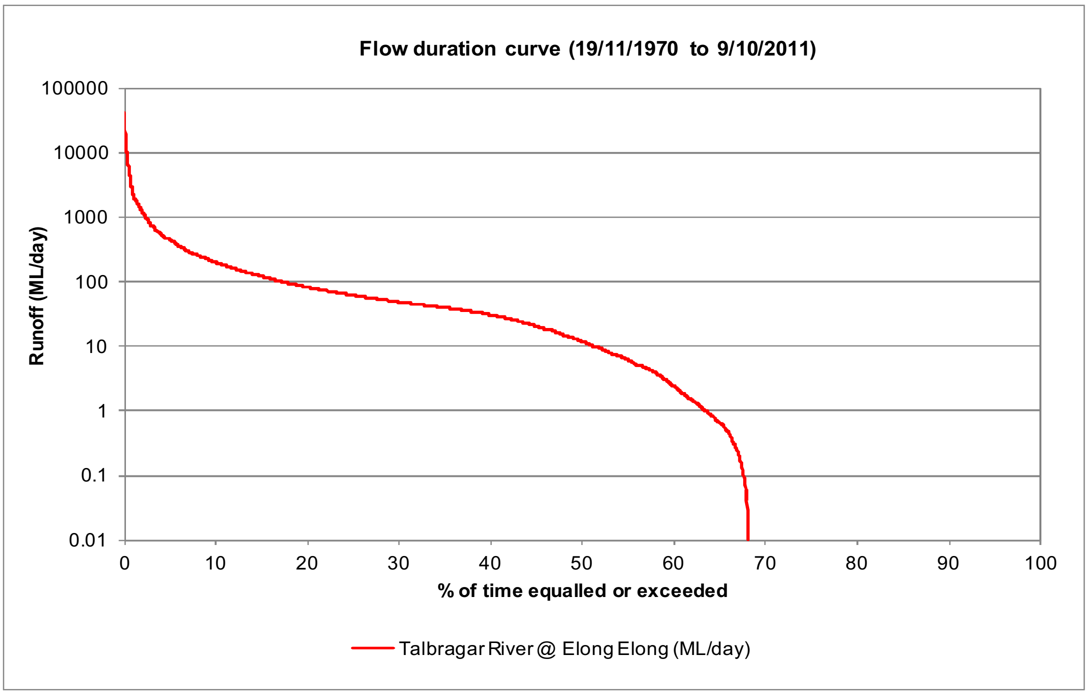


Figure 5-1 Flow duration curve for Talbragar River at Elong Elong

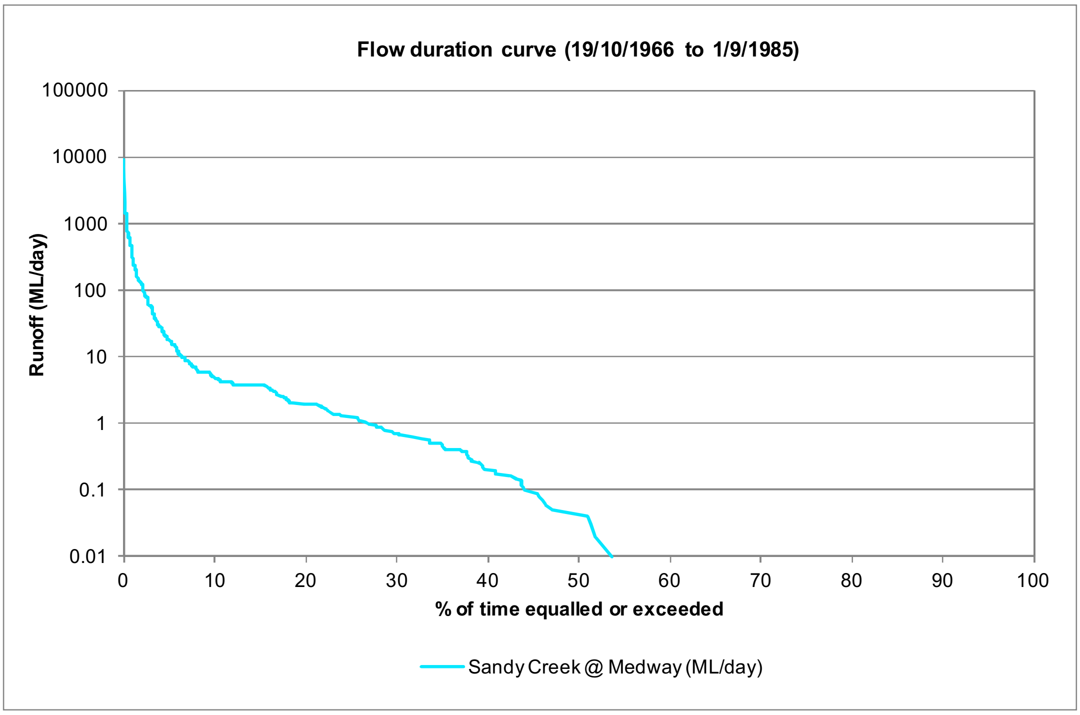


Figure 5-2 Flow duration curve for Sandy Creek at Medway

As part of Parsons Brinckerhoff's ongoing baseline surface water monitoring program, four water level gauging stations have operated on the Talbragar River, Sandy Creek and Laheys Creek since November 2009. The locations of the gauges are shown on Figure 3-1 and are described as follows:

- **SW1** - Located approximately 5 km upstream of the confluence with Laheys Creek at the intersection between Sandy Creek Road and Dapper Road.

- **SW2** – Located approximately 10 km upstream of the confluence with Sandy Creek, located on the upstream side of the intersection of Dapper and Spring Ridge roads.
- **SW3** – Located approximately 1.5 km downstream of the confluence with Laheys Creek.
- **SW5** – Located approximately 15 km upstream of the confluence of the Talbragar River and Sandy Creek, near Martin Street Cobbora.

Following a review of the baseline stream gauging data, including the water level data from the four installed gauges (SW1, SW2, SW3, and SW5) and NOW gauging records for nearby discontinued and active gauging stations (including SW4), the following observations were made:

- Water level data is available at stream gauges SW1, SW2, SW3 and SW5. These data were collated, reviewed and used to identify the water level and flow regimes that occurred during the water quality sampling occasions (see Section 7.2 for further discussion).
- Water level, daily discharge, a recent cross-section and a rating curve developed by NOW are available at the Elong Elong station 421042.
- Daily discharge data from three discontinued NOW gauges within the vicinity of the assessment area are also available and have been collated for the purposes of the *Downstream Flow Impact Assessment*. These data were converted to instantaneous flows at one of the sites (Sandy Creek at Medway) and used to supplement recently recorded data.

Table 5-2 summarises the stream gauging data that is currently available.

Table 5-2 Stream flow gauging data available

Gauge name	Gauge location/ description	Start date	End date	Duration (days)	Type of data	Time step	Data gaps	Comments/actions
SW1	Sandy Creek u/s of Laheys Creek (41010A)	19/11/2009	28/06/2011	586	Water level	4 times a day	Data gap from between 1/01/2010 and the 16/2/2010 due to Thiess installation	Gilbert & Associates site visit flagged that the gauge was not in the most suitable location (stilling well located in stagnant area, silted cross-section just downstream ponding water). Relocation to more appropriate cross-section was required.
SW2	Laheys Creek u/s of Sandy Creek (410103A)	19/11/2009	28/06/2011	586	Water level	Every 4 hours	A few small gaps between 20/1/2010 and 1/2/2010; 26/3/10 to 23/4/10; 25/5/2010 to 19/11/2010	Pipe underneath the road crossing is occasionally blocked by debris and creates an artificially high level in the recording pool – removal of debris is frequently required.
SW3	Sandy Creek d/s of Laheys Creek (410103A)	20/11/2009	28/06/2011	585	Water level	Every 4 hours	Gap between 25/05/2010 and 15/11/2010	
421064 (discontinued NOW gauge) at same location as SW3	Sandy Creek @ Medway 2 (421064)	02/10/1966	26/02/1998	11470	Water level	Daily	Some significant gaps	This record can supplement SW3 records.
421064 (discontinued NOW gauge) at same location as SW3	Sandy Creek @ Medway 2 (421064)	02/10/1966	26/02/1998	11470	Discharge	Daily	Some significant gaps	This record can supplement SW3 records.
SW4 (421042)	Talbragar River at Elong Elong (421042) – NOW gauge	20/11/1970	22/08/2011	14885	Average water level	Daily	Very minor gap between 28/12/2009 and 30/12/2009	Download data to current date came from NOW website: http://waterinfo.nsw.gov.au/water.shtml?ppbm=SURFACE_WATER&rs&3&rskm_url
SW4 (421042)	Talbragar River at Elong Elong (421042) – NOW gauge	01/12/1964	07/09/2011	17081	Discharge ML/d	Daily	Can easily covert this ML/d flow to m^3/s flow	Download data to current date came from BoM website. Data from 1/4/11 is from BoM station 64010.

Gauge name	Gauge location/ description	Start date	End date	Duration (days)	Type of data	Time step	Data gaps	Comments/actions
SW5	Talbragar River @ Cobbora	10/12/2009	28/06/2011	565	Water level	Daily	Few small gaps: 14/01/10 to 1/2/10; 25/05/10 to 1/6/10	
421028 (discontinued NOW gauge) at same location as SW5	Talbragar River @ Cobbora (421028) – discontinued	02/03/1949	01/10/1954	2039	Water level	Daily	Some significant gaps (e.g. some of 1950)	This record can supplement SW5 records.
421028 (discontinued NOW gauge) at same location as SW5	Talbragar River @ Cobbora (421028) – discontinued	02/03/1949	10/10/1954	2048	Discharge	Daily	Some significant gaps (e.g. some of 1950)	This record can supplement SW5 records.
421037 (discontinued NOW gauge)	Talbragar River @ Naranmore (421037) – discontinued	02/01/1956	01/06/1976	7456	Water level	Daily	Some gaps (e.g. 1956)	
421037 (discontinued NOW gauge)	Talbragar River @ Naranmore (421037) – discontinued	08/12/1955	01/06/1976	7481	Discharge	Daily	Some gaps (e.g. 1956)	

5.2 Water level gauging stations and associated data limitations

To develop reliable stage discharge rating curves for water level gauging station sites, accurate surveyed cross-sections of the creek cross-section at each gauge site are required. During the baseline review, no detailed cross-section survey information was found for water level gauges at SW1, SW2, SW3 and SW5.

For gauges located at SW1, SW2, SW3 and SW5, cross-sectional survey information and manual flow measurements were collected during November 2011 in order to develop stage discharge rating curves at these locations. Discharge volumes were measured using a SonTek FlowTracker Acoustic Doppler Velocimeter and the mid-section computation method. Table 5-3 summarises these discharge measurements.

Table 5-3 Discharge measurement summary

Site	Start date and time	Total width (m)	Total area (m^2)	Total discharge (m^3s^{-1})
SW1	23/11/2011 08:33 hours	6.000	0.430	0.0169
SW2	24/11/2011 08:50 hours	3.400	0.366	0.0227
SW3	24/11/2011 11:00 hours	2.100	0.601	0.0089
SW5	22/11/2011 11:42 hours	4.700	1.412	0.1000

Low flow manual measurements were required as a minimum to confirm the low flow portion of the rating curve and are more accurate than hydraulic calculations for lower flows.

Comparing the total discharge given in Table 5-3 at SW3 against the Sandy Creek flow duration curve in Figure 5-2 demonstrates that the flow gauging undertaken on 22/11/2011 and 23/11/2011 was conducted in conditions relating to the 90th percentile exceedance above the cease-to-flow condition. For the intermediate and higher flow portion of the rating curve, local hydraulic models of the gauge sites were constructed using hydraulic modeling software (HEC-RAS). These models were used to estimate the water level versus flow relationship. The stage-discharge plots generated from these analyses are shown in Figure 5-3.

The stage-discharge plots are presented in terms of water surface (WS) elevation rather than mAHD because the water levels were measured above temporary benchmarks established for each site. An investigation to convert the dataset to mAHD is continuing, including the possibility of undertaking further gauging during intermediate and high-flow conditions to refine the current rating curve regression equations.

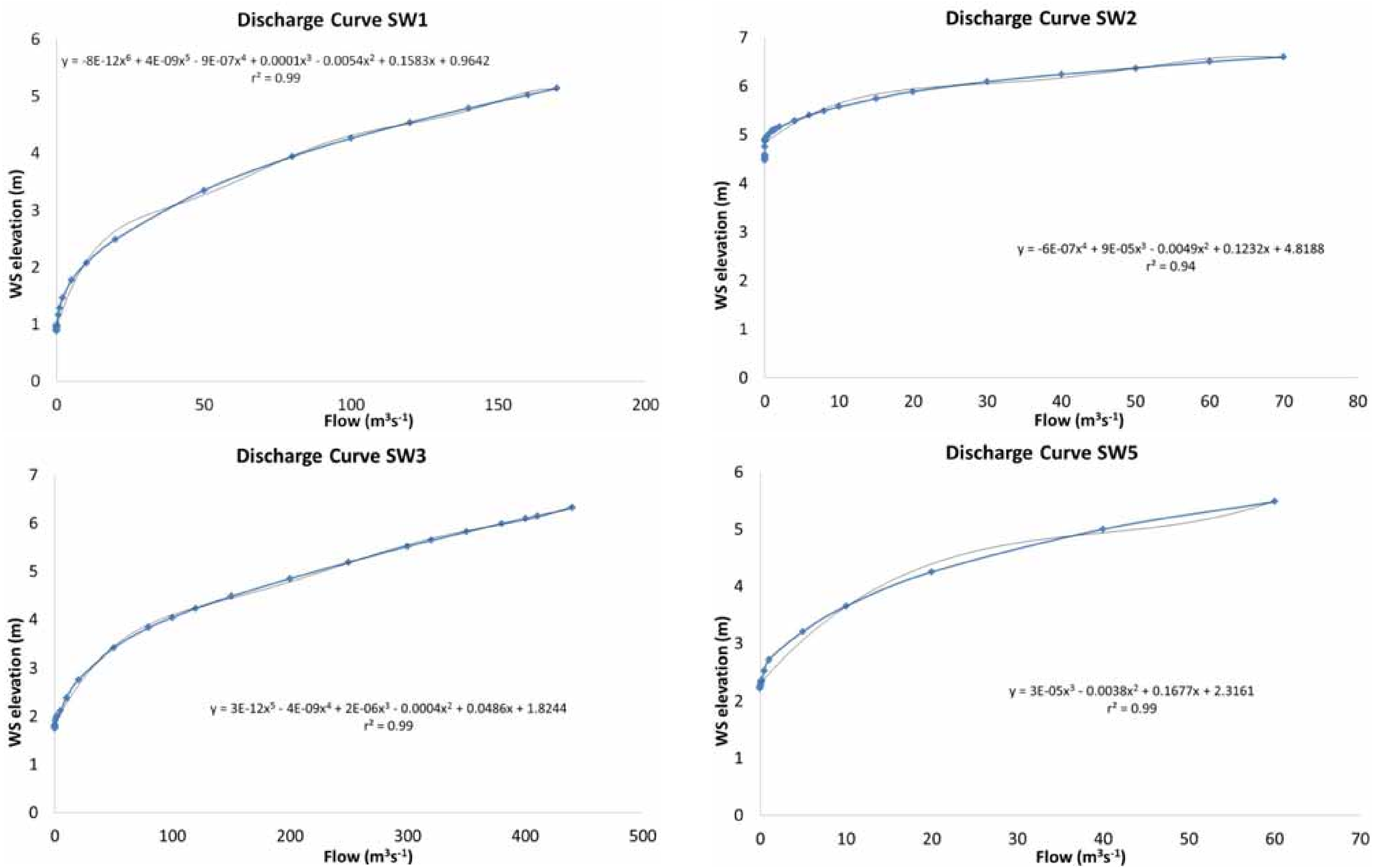


Figure 5-3 Stage-discharge regression plots for SW1, SW2, SW3 and SW5

5.3 Stage-discharge relationships used in the assessment

In the absence of stage-discharge relationships in mAHD at the water level gauging sites, rating curves were instead developed using the hydraulic model developed for the *Flood Impact Assessment*. The flood model includes cross-sections based on light detection and ranging (LiDAR) data, which is not as accurate as ground survey but can be accurate to a level of +/- 150 mm, depending on the data capture method and land cover.

The rating curves developed using the flood model were also used for the *Downstream Flow Impact Assessment*. It should be noted that these rating curves, while reasonably accurate for high flows, may be inaccurate for low-flow volume estimation and could underestimate low-flow volumes, due to the lack of detail on the bottom of the creek bed captured in the LiDAR data.

5.4 Baseline flood hydrology

Baseline hydrologic and hydraulic conditions in the local surface water bodies are described in detail in the *Flood Impact Assessment*, which provides estimates of peak flows, water levels and flood extents for a range of extreme flood events.

6. Water uses and local guidelines

Watercourses within the assessment area have been defined as ‘uncontrolled streams’ where the flow remains largely natural (DECCW, 2006). Regional Water Quality and River Flow Objectives have been developed for the Macquarie–Bogan uncontrolled rivers system by the Office of Environment and Heritage (OEH), formerly Department of Environment, Climate Change and Water (DECCW), in order to guide plans and actions to achieve healthy waterways.

Eleven Water Quality Objectives (WQOs) apply. Each is based on providing the right water quality for the environment and the different uses people have for water in the river system. They are based on measurable environmental values for:

- aquatic ecosystems
- visual amenity
- secondary recreational contact
- primary recreational contact
- livestock water supply
- irrigation water supply
- homestead water supply
- drinking water — disinfection only
- drinking water — clarification and disinfection
- drinking water — groundwater
- aquatic foods.

There are also six inland River Flow Objectives (RFOs), which deal with how water moves down rivers and streams. Each objective aims to improve river health by recognising the importance of natural river flow patterns. The RFOs are based on achieving improved environmental results by managing the river system. They are as follows:

- protect pools in dry times
- protect natural low flows
- protect important rises in water levels
- maintain wetland and floodplain inundation
- manage groundwater ecosystems
- minimise effects of weirs and other structures.

Local water quality and quantity vary naturally due to a number of factors, including the type of land the waters are draining (e.g. soils, slope), or rainfall and runoff patterns e.g. ephemeral or permanent streams). Therefore, regional objectives have been used in the downstream water quality and flow impact assessments in preference to generic guidelines.

7. Baseline water quality in local surface water bodies

The baseline surface water quality within the assessment area, including the Talbragar River, Sandy Creek and Laheys Creek catchments, was assessed by:

- defining objectives and guidelines
- reviewing and analysing baseline water sampling data
- comparing baseline water quality against relevant guidelines
- assessing surface water quality processes in the assessment area.

Baseline water sampling data were reviewed for each of the gauge locations SW1, SW2, SW3, SW4 and SW5 (see Figure 3-1). The samples were collected and analysed monthly by ALS Environmental from August 2009 to September 2011 (inclusive). Samples were analysed for physical parameters (electrical conductivity, pH, turbidity, temperature and dissolved oxygen), major ions, nutrients and a suite of metals.

7.1 Objectives and guidelines

ANZECC (2000) guidelines and DECCW (2006) water quality objectives (WQOs) were used to assess the baseline surface water quality. The ANZECC (2000) guidelines can be tailored to three different categories of ecosystems, depending on the level of disturbance of the ecosystem:

- Condition 1: high conservation/ecological value systems — effectively unmodified or other highly-valued ecosystems, typically occurring in national parks, conservation reserves or remote and/or inaccessible locations.
- Condition 2: slightly to moderately disturbed systems — ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. Typical examples include rural streams receiving runoff from land disturbed by agriculture.
- Condition 3: highly disturbed systems — measurably degraded ecosystems of lower ecological value.

For the purposes of determining baseline water quality conditions, water quality parameters have been assessed against Condition 2, as the Talbragar River, Sandy Creek and Laheys Creek catchments can be classified as *slightly to moderately disturbed systems* due to land uses in the catchments being dominated by agriculture and pastoralism.

7.2 Flow ranges relating to the surface water quality monitoring dataset

This section examines whether samples collected as part of the baseline monitoring program were representative of the range of flow conditions observed in the assessment area.

In the absence of site-specific flow gauging over an extended time, automatic water level measurements recorded at each site were used to examine whether variation in flow conditions was adequately captured.

The timing of water quality sampling events in relation to the water level record can be seen in the plots shown in Appendix A.1. The water quality samples were categorised into five water depth classes based on exceedances of the following nominal percentile water levels:

- < 25%ile = very low
- 25–50%ile = low
- 50–75%ile = medium
- 75–95%ile = high
- >95%ile = very high.

This provided a common basis for comparison across the monitoring sites, in terms of water depth classes. A summary of the results that compare between water level recordings and water quality sampling events is provided in Table 7-1.

Table 7-1 Comparison between water level data and water quality sampling occasions

Sampling location	Number of samples (number of no samples)	Sampling flow classification (based on water level measurements)				
		Very low	Low	Medium	High	Very high
SW1	14	5	3	4	2	0
SW2	18 (3)	5	4	4	0	2
SW3	18 (5)	4	3	4	2	0
SW4	18	6	2	6	3	1
SW5	15	6	7	0	2	0

Key: ■ = sufficient samples; ■ = more samples desirable; ■ = more samples required

The comparison shows that, in general, the dataset sufficiently covers the ‘very low’, ‘low’ and ‘medium’ water level conditions, but the ‘high’ and ‘very high’ water level conditions are under-represented. In summary, it was found that:

- No flows were observed in 3 out of 18 samples at SW2, and 5 out of 18 samples at SW3.
- No very high flow conditions were observed at SW1, SW3 or SW5.
- Only 2 out of 18 samples at SW2 and 1 out of 18 samples at SW4 were found to occur during high-flow conditions.
- No sampling was conducted during the period of very high flow in December 2010.
- The following observations are made for the 31 August 2009 to 28 June 2011 water quality sampling dataset:

- Samples taken were predominantly collected during ‘nil’ or ‘low’ flow conditions. ‘Medium’ and ‘high’ flow conditions were not represented equally in the sampling regime.

- Due to the ephemeral nature of Sandy Creek and Laheys Creek, ‘low flow’ is the ‘normal’ catchment condition for these creeks (see flow duration curve in Figure 4-2) and therefore the sampling undertaken to date can be considered representative of average conditions in the creeks.

Flow in the monitored reaches of the Talbragar River, Sandy Creek and Laheys Creek varied over the 25 -month monitoring period.

Throughout 2009, stagnant pools were observed at all sites and this situation only changed in January 2010 following heavy rainfall throughout December 2009. During most of 2010, SW1, SW2 and SW3 experienced low flows and SW4 and SW5 experienced medium to low flows. Flows then increased due to flood events that occurred during December 2010 to January 2011.

All monitoring sites recorded very high flows during the December 2010 monitoring event but no samples were collected during this period. Flows reduced slightly in February 2011 to low to medium at all sites.

The high-flow conditions monitored by the gauging stations were under-represented in the current water quality dataset. This is a common issue in routine water quality sampling and can result in the following estimation problems when using such data to understand the water quality within the system:

- Overestimation of total dissolved solids (TDS) and soluble metal/nutrient chemical concentrations by underestimating the dilution of water quality parameters that occurs during high-flow events.

- Underestimation of concentrations of total suspended solids and particulate-bound metals and nutrients by not taking high-magnitude or low-frequency storm events into account; such events deliver the majority of particulate matter to the channel via overland flow, increased bank erosion and increased capacity to entrain channel sediments.

These factors are important to consider when using routine sampling data as the basis for an assessment of the impacts of development on water quality.

7.3 Surface water quality monitoring findings

The results of the surface water quality monitoring were compared to the Condition 2 ANZECC water quality guidelines defined in Section 7.1. The detailed comparison is shown in Table 7-2.

Overall it was found that surface waters at SW1, SW2 and SW3 were dominated by chloride and sodium, with the highest value of chloride found at SW1 (2,640 mg/L during December 2009). Chloride and sodium concentrations recorded in the creeks (SW1, SW2 and SW3) were relatively high compared to ANZECC (2000) guidelines for irrigation water. SW1 and SW2 had similar magnesium concentrations, SW3 was slightly lower, and SW4 and SW5 had the lowest magnesium concentrations. SW4 and SW5 were typically dominated by magnesium and bicarbonate.

The pH measurements collected from Sandy Creek and Laheys Creek indicate neutral to slightly alkaline surface water, with an overall average of 7.77 for all sites. Upstream Sandy Creek (SW1) had an average pH of 7.86 and the lower reaches a pH of 7.54 (SW3). Laheys Creek had an average pH of 7.62. Sites along the Talbragar River had a similar average pH of 7.9 (SW4 and SW5).

Alkalinity concentrations were similar for sites SW2 and SW3, whereas SW1 had higher concentrations. Alkalinity concentrations at SW4 and SW5 had a greater range but were generally lower, except from January 2011 to May 2011 when SW4 and SW5 experienced higher levels of alkalinity.

Total nitrogen concentrations at all sites exceeded the ANZECC (2000) trigger level of 0.25 mg/L for the protection of aquatic ecosystems for all of the monitoring time, but the concentrations were below the long-term trigger value (5 mg/L) recommended for irrigation supply. Total phosphorus levels were also exceeded for the protection of aquatic ecosystems during 2011 at SW4 and SW5, these levels were also exceeded on numerous occasions at all sites during the monitoring period. The reactive phosphorus ANZECC guideline threshold for aquatic protection was also frequently exceeded, more often at SW4 and SW5 than the other three sites.

The majority of metals were generally below the guideline thresholds for livestock watering and irrigation, but exceeded the threshold for aquatic ecosystems during some of the sampling events.

Aluminum levels were above the threshold value for aquatic ecosystems 95% of the time, and elevated copper levels were recorded at all sites.

Dissolved iron levels were mostly below the threshold value; however, total iron was much higher. Manganese levels exceeded the guideline threshold for aquatic ecosystems most of the time at SW3, and, except at SW4 and SW5, exceeded the threshold for long-term irrigation on most occasions.

Zinc levels exceeded the ANZECC (2000) guideline threshold for the protection of aquatic ecosystems 40% of the time, but they were below the threshold for livestock watering and long-term irrigation.

Total suspended solids have no guideline levels under ANZECC (2000), but concentrations were generally either low (< 20 mg/L) or elevated (> 100 mg/L). The highest value of 992 mg/L at SW4 in December 2010 suggests that transport capacity in high-flow events, rather than source material, is the main control on sediment transport.

Turbidity levels mirrored suspended-solid concentrations with values generally below 10 nephelometric turbidity units (NTU) and the peak of 940 NTU also occurring at SW4 in December 2010. Levels frequently exceeded the 25 NTU guideline for aquatic ecosystems at all sites during high flow conditions.

A comprehensive table of results of each measured parameter is given in Table 7-2.

7.4 Discussion of baseline water quality monitoring results

7.4.1 Flow

Flows in the monitored reaches of the Talbragar River, Sandy Creek and Laheys Creek were variable over the 25-month monitoring period.

Flows during the 2009 monitoring events were nil too low for sites on Sandy Creek and Laheys Creek (SW1, SW2 and SW3), where large non-flowing pools were observed. The two sites on the Talbragar River (SW4 and SW5) were dry until significant rainfall in late December 2009, after which pools were present but not flowing.

Given the dry conditions in the region during the end of 2009, it is possible that the water present at SW1, SW2 and SW3 was a result of a combination of gradually evaporating surface water and limited groundwater baseflows. This is supported by the occasionally elevated metal concentrations detected at these locations.

Historical stream flow data from a site near SW3 are available for 1966–1999 (PINEENA NSW Department of Water & Energy 2008, gauge 421064). The historical flow data suggests a stream level of around 0.4–0.5 m occurs even at times of very low to no flow, which could indicate there is baseflow, at least in part, along Sandy Creek. This has also been noted following recent groundwater pump tests of shallow bores adjacent to the channel (refer to the *Groundwater Assessment* report).

Rainfall at the Dunedoo and Gulgong rain gauges was measured at 149 mm and 164.7 mm respectively for the month of December 2009. Over the Christmas period of 2009, 187.5 mm of rainfall was recorded at the on-site meteorological stations.

During 2010, nil to low flows were recorded at SW1, SW2 and SW3, and low to medium flows were recorded at SW4 and SW5. Flood events occurred during December 2010 to January 2011. However, there was a four-month gap between the monitoring event on 28 July 2010 and that on 20 December 2010.

The BoM states that 2010 began with El Niño conditions but was followed by a rapid transition into La Niña during autumn, resulting in the second half of the year (July to December) being the wettest on record for Australia (BoM 2011). It was noted in Section 7.2 that high flows have been under-represented during monitoring events.

La Niña conditions subsided in May 2011, and the remainder of the monitoring events in 2011 recorded low to medium flow in SW1, SW2 and SW3, and medium flows at SW4 and SW5.

7.4.2 Salinity

Salinity levels measured in the upstream locations of Sandy Creek (SW1) and Laheys Creek (SW2) were elevated. The high levels of salinity may be due to the soil and geological landscapes: Ballimore red earths at SW1, and Laheys Creek and Dapper Hill yellow soloths and solodic soils at SW2, which are characterised by saline soils, particularly in drainage depressions (Murphy et al 1998).

Salinity measurements in the creeks were also likely to be influenced by evaporation in the isolated stagnant pools, increasing the concentration of dissolved ions (Smith et al. 2004). In the upper reaches of Sandy Creek (SW1), the salinity has generally decreased from the beginning of the monitoring program in August 2009, when flows were very low to nil, to September 2011, when salinity levels were nearly half their original level.

Laheys Creek (SW2) and Talbragar River sites (SW4 and SW5) all follow a similar trend. However, salinity levels at SW3 in the lower reaches of Sandy Creek have generally increased. This could be due to gradual ponding of water at this site, caused by the collapse of a river bank in the December 2010 storm event with subsequent deposition of fine material and gradual cut-off of this creek channel.

7.4.3 Nutrients

Elevated concentrations of nutrients in the surface water are likely to be a result of the local land uses and river flows (Smith et al. 2004). The land surrounding Sandy Creek and Laheys Creek and the Talbragar River comprises agricultural enterprises, consisting for the most part of cattle and sheep grazing on improved pastures and dryland cropping.

Livestock waste and soil fertilisers may be transported through surface water runoff, dust movement from paddocks to the creek area, or stock movement within the riparian zone, potentially contributing to the concentrations of nitrogen and phosphorus in the surface water. In addition, periods of low flow, especially in 2009, might have led to increases in hyporheic upwelling (Dent et al 2001), supplying high nitrogen and phosphorus loads from the shallow groundwater system.

Sources of sediment that contribute to the nutrient load in these watercourses include overland erosion, especially along tracks that provide a conduit for surface water runoff, bank erosion during high-flow conditions and re-suspension of significant in-channel bed sediments. Watercourse crossings provide a mechanism for delivery and re-suspension of sediment to the creeks, with significant plumes of sediment resulting from vehicle traffic.

Ephemeral streams such as Laheys Creek and Sandy Creek will also retain large amounts of particulate organic matter in the dry channel that may be exported downstream during storm events (Cuffney et al 1989).

7.4.4 Metals

Some metals analysed were above the threshold for the protection of 95% of species in aquatic ecosystems, including aluminum, copper, cadmium, silver, manganese and zinc at all sites. Nickel was exceeded on a few occasions at SW4 and SW5. Chromium was exceeded regularly at SW4 and SW5. The protection of 95% of species, commonly associated with *slightly to moderately disturbed ecosystems* is considered relevant to the existing condition of the assessment area (see Section 7.1).

As no industrial discharges occur upstream of the assessment area, these levels are considered a natural reflection of the local soils/geology. In stagnant pools, such as those that occur in Laheys Creek and Sandy Creek, toxicants can also accumulate (Boulton et al 1990).

Table 7-2 Comparison of water quality monitoring data against ANZECC water quality guidelines

Sample Location	Description of site	Sample Date	Aluminium _ mg/L	Arsenic_ mg/L	Boron _ mg/L	Cadmium _ mg/L	Calcium - total mg/L	Chloride mg/L	Chromium - total_ mg/L	Copper_ mg/L	Dissolved Oxygen %sat	Electrical Conductivity µS/cm - field	Fluoride _ mg/L	Iron_ mg/L
Aquatic Ecosystems			0.06	0.024	0.37	0.0002			0.001	0.0014	90-110	30		
Livestock			5.00	0.5	5	0.01	1000		1	5			2	
Irrigation LTV			5.00	0.1	0.5	0.01			0.1	0.2		650	1	0.2
Irrigation STV			20.00	2	0.5	0.05		175	1	5			2	10
SW1	Sandy Creek, upstream of confluence with Laheys Creek	31-Aug-09	0.21	0.002	0.05	<0.00005	159	1790	<0.001	0.003	96	6940	0.4	0.7
		21-Sep-09	0.24	0.0015	0.05	<0.00005	146	1820	0.001	0.002	91	6800	0.5	0.5
		21-Oct-09	0.73	0.003	0.07	<0.00005	122	1860	0.002	0.004	126	7210	0.5	1.6
		20-Nov-09	0.57	0.0013	0.08	<0.00005	118	2240	<0.001	0.003	80	7810	0.6	1.4
		11-Dec-09	0.15	0.0028	0.11	<0.00005	113	2640	0.001	0.003	84	4800	0.7	0.5
		7-Jan-10	0.18	0.003	0.06	<0.00005	30	202	<0.001	0.005	50	1350	0.5	1.1
		18-Feb-10	0.09	0.0018	0.06	<0.00005	49	411	<0.001	0.001	89	2100	0.4	1.2
		26-Mar-10	0.07	0.0014	0.08	<0.00005	49	1030	<0.001	0.001	79	4270	0.5	0.3
		22-Apr-10	0.05	<0.001	0.05	<0.0001	72	691	<0.001	0.001	83	3190	0.4	0.2
		25-May-10	0.25	<0.001	0.06	<0.0001	83	727	<0.001	0.001	114	2730	0.3	0.4
		29-Jun-10	0.06	<0.001	<0.05	<0.0001	55	798	<0.001	0.001	67	3270	0.5	0.4
		28-Jul-10	0.07	<0.001	<0.05	<0.0001	44	539	<0.001	<0.001	79	2420	0.3	0.3
		20-Dec-10	0.40	0.002	<0.05	<0.0001	35	206	0.001	0.002	96	950	0.2	1.3
		24-Jan-11	0.08	0.001	0.05	0.0002	63	461	<0.001	0.002	112	2130	0.4	0.7
		25-Feb-11	0.03	0.001	0.05	<0.0001	61	567	<0.001	<0.001	85	2490	1.7	0.9
		24-Mar-11	0.08	0.001	0.06	<0.0001	80	762	<0.001	<0.001	72	3130	0.6	0.8
		20-Apr-11	0.04	0.001	<0.05	<0.0001	70	780	<0.001	<0.001	90	3220	0.5	0.8
		31-May-11	0.09	<0.001	<0.05	<0.0001	67	588	<0.001	<0.001	91	2640	0.4	0.8
		28-Jun-11	0.02	<0.001	<0.05	<0.0001	149	727	<0.001	0.002	101	2960	0.4	0.9
		30-Aug-11	0.08	<0.001	<0.05	<0.0001	61	631	<0.001	<0.001	92	2770	0.5	0.7
		26-Sep-11	0.32	0.010	<0.05	<0.0001	66	709	<0.001	<0.001	97	3210	0.5	0.9
		27-OCT-2011	0.32	0.002	0.05	0.00005	61	581	0.0005	0.001	79	2470	0.6	0.7
		28-NOV-2011	0.28	0.0005	0.025	0.00005	47	503	0.0005	0.0005	86	2320	0.5	0.8

Sample Location	Sample Date	Lead_ mg/L	Manganese_ mg/L	Mercury _ mg/L	Molybdenum _ mg/L	Nickel_ mg/L	Nitrates_ mg/L N	Nitrites_ mg/L N	pH - field	Phosphorus - total_ mg/L	Selenium _ mg/L	Silver_ mg/L	Sodium - total mg/L	Sulfates mg/L	Total Dissolved Solids @ 180°C_	Total Nitrogen _ mg/L N	Turbidity _ NTU	Zinc_ mg/L
Aquatic Ecosystems		0.0034	1.9	0.0006		0.011		0.7	6.5-8	0.02	0.011	5E-05				0.25	2.0	0.008
Livestock		0.1	-	0.002	0.15	1	400	30			0.02			1000	2000			20
Irrigation LTV		2	0.2	0.002	0.01	0.2				0.05	0.02					5		2
Irrigation STV		5	10	0.002	0.05	2				0.8	0.05		115			25		5
SW1	31-Aug-09	0.0006	1.300	<0.0001	<0.001	0.007	<0.01	<0.01	8.0	0.05	<0.001	<0.001	972	458	4200	0.9	14.0	<0.005
	21-Sep-09	0.0007	1.900	<0.0001	<0.001	0.006	<0.01	<0.01	8.2	0.12	<0.001	<0.001	964	466	4100	1.4	28.0	<0.005
	21-Oct-09	0.0026	1.300	<0.0001	0.001	0.011	<0.01	<0.01	8.4	0.28	<0.001	<0.001	1020	457	4500	2.4	96.0	0.01
	20-Nov-09	0.0022	1.600	0.0001	<0.001	0.009	<0.01	<0.01	8.4	0.23	<0.001	<0.001	1275	467	5000	2.6	52.0	0.11
	11-Dec-09	0.0009	1.400	<0.0001	0.002	0.011	<0.01	<0.01	8.1	0.15	<0.001	<0.001	1460	582	6000	2.2	2.6	<0.005
	7-Jan-10	0.0007	0.920	<0.0001	0.002	0.006	0.04	<0.01	7.7	0.11	<0.001	<0.001	148	91	690	1.9	6.6	0.008
	18-Feb-10	<0.0002	1.400	<0.0001	<0.001	0.004	<0.01	<0.01	7.6	0.08	<0.001	<0.001	268	63	1200	1.5	5.9	0.011
	26-Mar-10	<0.0002	0.66	<0.0001	<0.001	0.005	<0.01	<0.01	7.9	0.04	<0.001	<0.001	545	269	2700	1.0	6.0	0.006
	22-Apr-10	<0.001	0.686	<0.0001	<0.001	0.003	<0.01	<0.01	7.7	0.08	<0.01	<0.001	532	133	1800	0.9	6.3	<0.005
	25-May-10	<0.001	0.265	<0.0001	<0.001	0.001	0.08	<0.01	8.1	<0.01	<0.01	<0.001	274	58	1470	0.3	11.5	<0.005
	29-Jun-10	<0.001	0.23	<0.0001	0.001	0.002	<0.01	<0.01	7.4	0.02	<0.01	<0.001	504	74	1680	0.6	3.3	0.006
	28-Jul-10	<0.001	0.241	<0.0001	<0.001	0.002	0.04	<0.01	7.7	0.01	<0.01	<0.001	360	60	1170	1.6	3.5	<0.005
	20-Dec-10	<0.001	0.142	<0.0001	<0.001	0.004	0.3	0.03	7.7	<0.01	<0.01	<0.001	107	27	522	3.1	16.8	<0.006
	24-Jan-11	<0.001	0.33	<0.0001	0.001	0.002	0.01	<0.01	8.0	<0.01	<0.01	<0.001	276	76	1220	0.6	4.8	0.006
	25-Feb-11	<0.001	0.477	<0.0001	0.001	0.002	0.03	<0.01	7.8	0.08	<0.01	<0.001	326	62	1310	0.5	4.7	<0.005
	24-Mar-11	<0.001	0.754	<0.0001	0.001	0.002	0.02	<0.01	7.6	0.02	<0.01	<0.001	434	92	1680	0.6	4.4	<0.005
	20-Apr-11	<0.001	0.589	<0.0001	0.001	0.002	0.02	<0.01	7.8	0.04	<0.01	<0.001	407	119	1860	0.6	4.2	<0.005
	31-May-11	<0.001	0.505	<0.0001	<0.001	0.002	0.57	<0.01	7.9	0.11	<0.01	<0.001	288	66	1470	1.3	11.4	0.012
	28-Jun-11	<0.001	0.618	<0.0001	<0.001	0.002	0.72	<0.01	8.2	<0.01	<0.01	<0.001	78	87	1550	1.2	7.5	0.01
	30-Aug-11	<0.001	0.541	<0.0001	<0.001	0.002	0.01	<0.01	7.8	<0.01	<0.01	<0.001	317	74	1330	0.4	5.6	<0.005
	26-Sep-11	<0.001	0.741	<0.0001	<0.001	<0.001	0.02	<0.01	8.0	<0.01	<0.01	<0.001	397	83	1640	0.4	14.1	<0.005
	27-OCT-2011	0.0005	0.779	5E-05	0.0005	0.002	0.005	0.005	5.0	0.04	0.005	5E-04	300	45	1310	0.5	9.5	0.008
	28-NOV-2011	0.0005	0.199	5E-05	0.0005	0.002	0.02	0.005	8.0	0.005	0.005	5E-04	287	10	1180	0.8	9.4	0.003

Aquatic Ecosystems	ANZECC 2000 Guidelines for Aquatic Ecosystems
Livestock	ANZECC 2000 Guidelines for Livestock Drinking Water Quality
Irrigation LTV	ANZECC 2000 Guidelines for Irrigation Water Supply- LTV (Long Term Trigger Value)
Irrigation STV	ANZECC 2000 Guidelines for Irrigation Water Supply- STV (Short Term Trigger Value)
notes	
	exceed all EV trigger values
	exceed at least one EV trigger value
	exceed no EV trigger values
blue	applied 95% protections levels from table 3.4.1 of ANZECC guidelines chapter 3
green	2000 is the maximum TDS tolerance for sensitive livestock
orange	5 is low risk trigger for poultry and pigs lower for other livestock (sheep 0.4 and catle is 1)
red	maximum concentration for sensitive crops
purple	lower limit valie

Table 7-2 Comparison of water quality monitoring data against ANZECC water quality guidelines (continued)

Sample Location	Description of site	Sample Date	Aluminium _ mg/L	Arsenic_ mg/L	Boron _ mg/L	Cadmium _ mg/L	Calcium - total mg/L	Chloride mg/L	Chromium - total_ mg/L	Copper_ mg/L	Dissolved Oxygen %sat	Electrical Conductivity µS/cm - field	Fluoride _ mg/L	Iron_ mg/L	Lead_ mg/L	Manganese_ mg/L	Mercury _ mg/L	Molybdenum _ mg/L	Nickel_ mg/L	Nitrates_ mg/L N	Nitrites_ mg/L N	pH - field	Phosphorus - total_ mg/L	Selenium _ mg/L	Silver_ mg/L	Sodium - total mg/L	Sulfates mg/L	Total Dissolved Solids @ 180°C_	Total Nitrogen _ mg/L N	Turbidity _ NTU	Zinc_ mg/L
Aquatic Ecosystems			0.06	0.024	0.37	0.0002			0.001	0.0014	90-110	30			0.0034	1.9	0.0006		0.011		0.7	6.5-8	0.02	0.011	5E-05				0.25	2.0	0.008
Livestock			5.00	0.5	5	0.01	1000		1	5			2		0.1	-	0.002	0.15	1	400	30			0.02			1000	2000			20
Irrigation LTV			5.00	0.1	0.5	0.01			0.1	0.2		650	1	0.2	2	0.2	0.002	0.01	0.2				0.05	0.02					5		2
Irrigation STV			20.00	2	0.5	0.05		175	1	5			2	10	5	10	0.002	0.05	2				0.8	0.05		115			25		5
SW2	Laheys Creek	31-Aug-09	0.05	0.002	0.04	<0.00005	171	1880	<0.001	0.003	89	7480	0.2	2.7	<0.0002	1.500	<0.0001	<0.001	0.008	<0.01	<0.01	7.0	0.09	<0.001	<0.001	963	1120	4900	1.4	17.0	<0.005
		21-Sep-09	0.05	0.0012	0.04	<0.00005	134	1580	<0.001	0.002	55	6250	0.2	1.3	<0.0002	0.690	<0.0001	<0.001	0.006	<0.01	<0.01	7.3	0.03	<0.001	<0.001	838	874	4000	1.0	6.0	<0.005
		21-Oct-09	0.04	0.0015	0.04	<0.00005	140	1860	<0.001	0.003	92	7360	0.3	1.6	<0.0002	0.490	<0.0001	<0.001	0.007	<0.01	<0.01	7.3	0.11	<0.001	<0.001	943	920	4900	2.1	21.0	<0.005
		20-Nov-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		11-Dec-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		7-Jan-10	0.21	0.003	0.05	<0.00005	50	347	<0.001	0.003	56	2140	0.3	0.8	0.0003	1.300	<0.0001	<0.001	0.004	0.01	<0.01	7.3	0.09	<0.001	<0.001	197	216	1000	1.5	7.2	0.014
		18-Feb-10	0.33	0.0026	0.06	<0.00005	51	546	<0.001	0.002	88	2590	0.3	1.5	0.0003	1.200	<0.0001	<0.001	0.003	<0.01	<0.01	7.4	0.09	<0.001	<0.001	320	217	1700	1.2	10.0	0.006
		26-Mar-10	0.04	0.0025	0.06	<0.00005	29	624	0.002	0.001	53	2780	0.3	1.1	<0.0002	0.25	<0.0001	<0.001	0.004	<0.01	<0.01	7.6	0.09	<0.001	<0.001	339	210	1800	1.2	6.6	0.023
		22-Apr-10	0.11	0.002	<0.05	<0.0001	61	652	<0.001	0.001	52	2990	0.3	1.1	<0.001	0.562	<0.0001	<0.001	0.001	<0.01	<0.01	7.6	0.19	<0.01	<0.001	496	229	1760	1.8	8.1	<0.005
		25-May-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		29-Jun-10	0.48	<0.001	<0.05	<0.0001	61	922	<0.001	0.002	59	3750	0.2	0.8	<0.001	0.113	<0.0001	<0.001	0.001	0.03	<0.01	7.5	0.06	<0.01	<0.001	520	271	1930	0.8	11.9	0.007
		28-Jul-10	0.03	<0.001	<0.05	<0.0001	130	964	<0.001	0.003	72	5310	0.2	0.5	<0.001	0.210	<0.0001	<0.001	<0.001	0.04	<0.01	7.6	0.09	<0.01	<0.001	671	797	3230	1.0	6.4	<0.005
		20-Dec-10	1.64	0.002	<0.05	<0.0001	30	113	0.001	0.006	93	660	0.1	2.4	0.001	0.155	<0.0001	<0.001	0.004	0.16	0.02	7.2	0.17	<0.01	<0.001	62	103	354	1.1	51.4	0.01
		24-Jan-11	0.18	<0.001	0.06	0.0013	161	673	<0.001	0.004	90	3920	0.3	0.5	0.001	0.315	<0.0001	<0.001	0.002	<0.01	<0.01	8.0	<0.01	<0.01	<0.001	382	999	2780	1.0	2.9	0.01
		25-Feb-11	0.12	0.001	0.06	<0.0001	170	858	<0.001	0.003	76	4650	1.4	0.1	<0.001	0.580	<0.0001	0.001	0.002	0.07	<0.01	7.6	0.07	<0.01	<0.001	499	1190	3390	0.7	3.2	0.006
		24-Mar-11	0.17	0.002	0.06	<0.0001	171	975	<0.001	0.003	68	5040	0.4	0.1	<0.001	0.573	<0.0001	0.001	0.002	0.01	<0.01	7.7	0.04	<0.01	<0.001	565	1060	3450	0.8	4.6	<0.005
		20-Apr-11	0.64	0.001	0.05	<0.0001	161	1060	<0.001	<0.001	82	4990	0.4	0.8	<0.001	0.428	<0.0001	0.002	0.003	0.04	<0.01	8.1	<0.01	<0.01	<0.001	521	883	3530	1.1	13.0	<0.005
		31-May-11	0.38	<0.001	<0.05	<0.0001	194	1060	<0.001	0.006	84	5200	0.3	0.7	<0.001	0.322	<0.0001	<0.001	0.002	0.09	<0.01	7.8	0.06	<0.01	<0.001	532	1040	3710	1.1	11.8	0.009
		28-Jun-11	0.07	<0.001	<0.05	<0.0001	207	1260	<0.001	0.003	89	6290	0.3	0.3	<0.001	0.279	<0.0001	<0.001	0.002	0.02	<0.01	8.0	<0.01	<0.01	<0.001	763	1390	4240	0.5	4.9	0.006
		30-Aug-11	0.18	<0.001	<0.05	<0.0001	182	957	<0.001	0.003	93	5040	0.2	0.3	<0.001	0.341	<0.0001	<0.001	0.001	<0.01	<0.01	8.0	<0.01	<0.01	<0.001	536	1160	3080	0.7	3.6	<0.005
		26-Sep-11	0.31	0.011	0.05	0.0001	171	1100	0.001	0.004	87	5550	0.3	0.6	0.001	0.553	<0.0001	0.001	0.002	<0.01	<0.01	7.8	<0.01	<0.01	<0.001	613	1250	3640	0.7	11.8	<0.005
		27-OCT-2011	1.33	0.002	0.05	0.00005	106	780	0.0005	0.003	62	3390	0.3	1.3	0.001	0.574	5E-05	0.0005	0.002	0.005	0.005	7.9	0.06	0.005	5E-04	352	445	2210	0.6	14.6	0.003
		28-NOV-2011	0.50	0.0005	0.025	0.00005	80	468	0.0005	0.002	57	2690	0.3	0.6	0.0005	0.102	5E-05	0.0005	0.002	0.36	0.005	7.7	0.01	0.005	5E-04	252	407	1610	1.3	15.6	0.007

Aquatic Ecosystems	ANZECC 2000 Guidelines for Aquatic Ecosystems	
Livestock	ANZECC 2000 Guidelines for Livestock Drinking Water Quality	
Irrigation LTV	ANZECC 2000 Guidelines for Irrigation Water Supply- LTV (Long Term Trigger Value)	
Irrigation STV	ANZECC 2000 Guidelines for Irrigation Water Supply- STV (Short Term Trigger Value)	
	notes	
	(red)	exceed all EV trigger values
	(orange)	exceed at least one EV trigger value
	(green)	exceed no EV trigger values
	blue	applied 95% protections levels from table 3.4.1 of ANZECC guidelines chapter 3
	green	2000 is the maximum TDS tolerance for sensitive livestock
	orange	5 is low risk trigger for poultry and pigs lower for other livestock (sheep 0.4 and catle is 1)
	red	maximum concentration for sensitive crops
	purple	lower limit valie

Table 7-2 Comparison of water quality monitoring data against ANZECC water quality guidelines (continued)

Sample Location	Description of site	Sample Date	Aluminium _ mg/L	Arsenic_ mg/L	Boron _ mg/L	Cadmium _ mg/L	Calcium - total mg/L	Chloride mg/L	Chromium - total_ mg/L	Copper_ mg/L	Dissolved Oxygen %sat	Electrical Conductivity µS/cm - field	Fluoride _ mg/L	Iron_ mg/L	Lead_ mg/L
Aquatic Ecosystems			0.06	0.024	0.37	0.0002			0.001	0.0014	90-110	30			0.0034
Livestock			5.00	0.5	5	0.01	1000		1	5			2		0.1
Irrigation LTV			5.00	0.1	0.5	0.01			0.1	0.2		650	1	0.2	2
Irrigation STV			20.00	2	0.5	0.05		175	1	5			2	10	5
SW3	Sandy Creek, downstream of confluence with Laheys Creek	31-Aug-09	0.41	0.001	0.05	<0.00005	54	404	<0.001	0.001	91	1990	0.2	1.0	0.0006
		21-Sep-09	0.39	0.0012	0.05	<0.00005	59	408	0.001	0.001	91	1970	0.2	1.0	0.0009
		21-Oct-09	0.78	0.0017	0.07	<0.00005	62	461	0.001	0.002	92	2300	0.2	2.1	0.002
		20-Nov-09	0.87	<0.001	0.08	<0.00005	77	553	0.001	0.003	79	2620	0.3	1.5	0.0016
		11-Dec-09	0.64	0.0014	0.1	<0.00005	81	695	<0.001	0.005	86	3290	0.3	1.2	0.013
		7-Jan-10	0.18	0.003	0.06	<0.00005	34	241	<0.001	0.002	70	1400	0.2	2.1	0.0005
		18-Feb-10	0.31	0.001	0.07	<0.00005	39	206	<0.001	0.001	66	1210	0.2	1.4	0.0005
		26-Mar-10	0.3	0.002	0.07	<0.00005	19	174	<0.001	0.001	87	1130	0.2	0.9	0.0006
		22-Apr-10	0.26	<0.001	0.06	<0.0001	40	167	<0.001	0.001	83	1140	0.2	0.9	<0.001
		25-May-10	0.02	<0.001	<0.05	<0.0001	40	220	<0.001	<0.001	72	1220	0.2	3.3	<0.001
		29-Jun-10	0.31	<0.001	0.06	<0.0001	38	198	<0.001	<0.001	75	1200	0.2	1.7	<0.001
		28-Jul-10	0.28	<0.001	<0.05	<0.0001	40	213	0.001	<0.001	94	1290	0.1	0.9	<0.001
		20-Dec-10	0.90	0.001	<0.05	<0.0001	32	149	<0.001	0.004	88	690	<0.01	1.5	<0.001
		24-Jan-11	0.34	<0.001	0.08	0.0004	92	659	<0.001	0.002	99	2930	0.3	0.9	<0.001
		25-Feb-11	0.16	<0.001	0.07	<0.0001	93	822	<0.001	0.001	89	3420	0.3	0.5	<0.001
		24-Mar-11	0.08	0.001	0.07	<0.0001	94	922	<0.001	0.001	86	3500	0.4	0.4	<0.001
		20-Apr-11	0.22	<0.001	0.06	0.0002	89	886	<0.001	<0.001	91	3450	0.3	0.6	<0.001
		31-May-11	0.10	<0.001	0.05	<0.0001	89	975	<0.001	0.001	89	3690	0.3	0.6	<0.001
		28-Jun-11	0.04	<0.001	<0.05	<0.0001	94	939	<0.001	<0.001	91	3600	0.3	0.8	<0.001
		30-Aug-11	0.16	<0.001	0.05	<0.0001	94	780	<0.001	0.001	101	3670	0.4	0.4	<0.001
		26-Sep-11	0.23	0.008	0.06	0.0001	99	904	0.001	0.002	104	4030	0.3	0.7	<0.001
		27-OCT-2011	0.54	0.0005	0.06	0.00005	72	603	0.0005	0.002	69	2610	0.4	0.8	0.0005
		28-NOV-2011	0.52	0.0005	0.025	0.00005	71	532	0.0005	0.0005	74	2760	0.3	0.8	0.0005

Sample Location	Sample Date	Manganese_ mg/L	Mercury _ mg/L	Molybdenum _ mg/L	Nickel_ mg/L	Nitrates_ mg/L N	Nitrites_ mg/L N	pH - field	Phosphorus - total_ mg/L	Selenium _ mg/L	Silver_ mg/L	Sodium - total mg/L	Sulfates mg/L	Total Dissolved Solids @ 180°C_	Total Nitrogen _ mg/L N	Turbidity _ NTU	Zinc_ mg/L
Aquatic Ecosystems		1.9	0.0006		0.011		0.7	6.5-8	0.02	0.011	5E-05				0.25	2.0	0.008
Livestock		-	0.002	0.15	1	400	30			0.02			1000	2000			20
Irrigation LTV		0.2	0.002	0.01	0.2				0.05	0.02					5		2
Irrigation STV		10	0.002	0.05	2				0.8	0.05		115			25		5
SW3	31-Aug-09	2.500	<0.0001	<0.001	0.003	<0.01	<0.01	7.7	0.07	<0.001	<0.001	241	161	1100	0.9	15.0	<0.005
	21-Sep-09	3.100	<0.0001	<0.001	0.003	<0.01	<0.01	8.0	0.06	<0.001	<0.001	275	181	1100	0.9	31.0	<0.005
	21-Oct-09	3.400	<0.0001	<0.001	0.005	<0.01	<0.01	7.8	0.09	<0.001	<0.001	260	225	1300	1.2	75.0	<0.005
	20-Nov-09	2.500	<0.0001	<0.001	0.006	<0.01	<0.01	8.1	0.12	<0.001	<0.001	324	230	1600	1.8	54.0	0.063
	11-Dec-09	2.600	<0.0001	0.003	0.007	<0.01	<0.01	7.3	0.12	<0.001	<0.001	420	369	1900	1.8	1.8	0.005
	7-Jan-10	2.200	<0.0001	<0.001	0.006	<0.01	<0.01	7.3	0.07	<0.001	<0.001	139	147	720	1.3	9.2	0.013
	18-Feb-10	1.400	<0.0001	<0.001	0.004	<0.01	<0.01	7.1	0.04	<0.001	<0.001	121	96	720	0.9	19.0	<0.005
	26-Mar-10	1.5	<0.0001	<0.001	0.004	<0.01	<0.01	7.4	0.04	<0.001	<0.001	104	75	640	0.8	21	0.008
	22-Apr-10	1.060	<0.0001	<0.001	0.002	<0.01	<0.01	7.4	0.06	<0.01	<0.001	113	71	608	0.8	14.8	<0.005
	25-May-10	1.450	<0.0001	<0.001	0.003	0.02	<0.01	7.5	0.07	<0.01	<0.001	123	81	629	<0.1	16.2	0.021
	29-Jun-10	1.200	<0.0001	<0.001	0.003	0.02	<0.01	7.2	0.02	<0.01	<0.001	129	139	556	0.6	12.6	<0.005
	28-Jul-10	1.510	<0.0001	<0.001	0.002	0.04	<0.01	7.4	0.1	<0.01	<0.001	128	142	638	0.8	12.2	0.006
	20-Dec-10	0.123	<0.0001	<0.001	0.003	0.29	0.05	7.2	0.04	<0.01	<0.001	65	48	412	1.2	40.4	0.006
	24-Jan-11	0.551	<0.0001	0.001	0.003	0.01	<0.01	7.7	<0.01	<0.01	<0.001	354	222	1760	0.7	4.6	0.006
	25-Feb-11	0.676	<0.0001	0.001	0.002	0.03	<0.01	7.6	<0.01	<0.01	<0.001	454	213	1980	0.3	3.6	<0.005
	24-Mar-11	0.868	<0.0001	0.001	0.001	<0.01	<0.01	7.5	0.01	<0.01	<0.001	492	160	1930	0.4	3.7	<0.005
	20-Apr-11	1.090	<0.0001	<0.001	0.002	0.02	<0.01	7.6	0.25	<0.01	<0.001	415	152	1970	0.6	5.4	<0.005
	31-May-11	0.418	<0.0001	<0.001	0.001	0.02	<0.01	7.8	0.07	<0.01	<0.001	455	188	2220	0.5	4.3	<0.005
	28-Jun-11	0.526	<0.0001	0.001	0.002	0.02	<0.01	7.8	<0.01	<0.01	<0.001	538	211	2070	0.4	4.6	<0.005
	30-Aug-11	0.554	<0.0001	<0.001	0.002	<0.01	<0.01	8.0	<0.01	<0.01	<0.001	427	396	2000	0.3	2.5	<0.005
	26-Sep-11	0.654	<0.0001	0.001	0.001	<0.01	<0.01	7.9	<0.01	<0.01	<0.001	491	418	2290	0.4	9.8	<0.005
	27-OCT-2011	0.978	5E-05	0.0005	0.002	0.02	0.005	6.4	0.03	0.005	5E-04	295	256	1500	0.5	4.4	0.006
	28-NOV-2011	0.182	5E-05	0.0005	0.002	0.005	0.005	7.7	0.02	0.005	5E-04	295	321	1650	0.7	24.9	0.007

Aquatic Ecosystems	ANZECC 2000 Guidelines for Aquatic Ecosystems
Livestock	ANZECC 2000 Guidelines for Livestock Drinking Water Quality
Irrigation LTV	ANZECC 2000 Guidelines for Irrigation Water Supply- LTV (Long Term Trigger Value)
Irrigation STV	ANZECC 2000 Guidelines for Irrigation Water Supply- STV (Short Term Trigger Value)
notes	
	exceed all EV trigger values
	exceed at least one EV trigger value
	exceed no EV trigger values
blue	applied 95% protections levels from table 3.4.1 of ANZECC guidelines chapter 3
green	2000 is the maximum TDS tolerance for sensitive livestock
orange	5 is low risk trigger for poultry and pigs lower for other livestock (sheep 0.4 and catle is 1)
red	maximum concentration for sensitive crops
purple	lower limit valie

Table 7-2 Comparison of water quality monitoring data against ANZECC water quality guidelines (continued)

Sample Location	Description of site	Sample Date	Aluminium _ mg/L	Arsenic_ mg/L	Boron _ mg/L	Cadmium _ mg/L	Calcium - total mg/L	Chloride mg/L	Chromium - total_ mg/L	Copper_ mg/L	Dissolved Oxygen %sat	Electrical Conductivity µS/cm - field	Fluoride _ mg/L	Iron_ mg/L	Lead_ mg/L	Manganese_ mg/L	Mercury _ mg/L	Molybdenum _ mg/L	Nickel_ mg/L	Nitrates_ mg/L N	Nitrites_ mg/L N	pH - field	Phosphorus - total_ mg/L	Selenium _ mg/L	Silver_ mg/L	Sodium - total mg/L	Sulfates mg/L	Total Dissolved Solids @ 180°C_	Total Nitrogen _ mg/L N	Turbidity _ NTU	Zinc_ mg/L
Aquatic Ecosystems			0.06	0.024	0.37	0.0002			0.001	0.0014	90-110	30			0.0034	1.9	0.0006		0.011		0.7	6.5-8	0.02	0.011	5E-05				0.25	2.0	0.008
Livestock			5.00	0.5	5	0.01	1000		1	5			2		0.1	-	0.002	0.15	1	400	30			0.02			1000	2000			20
Irrigation LTV			5.00	0.1	0.5	0.01			0.1	0.2		650	1	0.2	2	0.2	0.002	0.01	0.2				0.05	0.02					5		2
Irrigation STV			20.00	2	0.5	0.05		175	1	5			2	10	5	10	0.002	0.05	2				0.8	0.05		115			25		5
SW4	Elong Elong gauging station on Talbragar River	31-Aug-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		21-Sep-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		21-Oct-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		20-Nov-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		11-Dec-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		7-Jan-10	32.00	0.002	0.07	<0.00005	16	39	0.063	0.032	64	300	0.2	39.0	0.006	0.790	<0.0001	<0.001	0.063	1.1	0.07	7.6	1.1	<0.001	<0.001	21	2	280	3.4	940.0	0.055
		18-Feb-10	6.50	0.001	0.04	<0.00005	27	32	0.013	0.01	101	380	0.2	8.5	0.0016	0.320	<0.0001	<0.001	0.019	1.2	0.04	7.6	0.59	<0.001	<0.001	22	<2	290	2.8	300.0	0.015
		26-Mar-10	1.20	0.001	0.04	<0.00005	25	110	0.002	0.003	74	810	0.2	1.5	0.0002	0.21	<0.0001	<0.001	0.01	<0.01	<0.01	7.8	0.14	<0.001	<0.001	52	5	480	1.2	29	0.008
		22-Apr-10	1.05	0.001	<0.05	<0.0001	48	110	0.002	0.002	69	830	0.2	1.6	<0.001	0.683	<0.0001	<0.001	0.008	<0.01	<0.01	7.7	0.18	<0.01	<0.001	68	<2	448	1.8	27.8	<0.005
		25-May-10	1.69	<0.001	<0.05	<0.0001	44	113	0.002	0.003	104	770	0.2	1.8	<0.001	0.981	<0.0001	<0.001	0.009	0.04	<0.01	8.3	0.13	<0.01	<0.001	58	<2	410	0.9	19.4	<0.005
		29-Jun-10	5.20	<0.001	<0.05	<0.0001	36	106	0.008	0.004	54	740	0.2	5.8	<0.001	0.442	<0.0001	<0.001	0.013	0.12	0.02	7.5	0.19	<0.01	<0.001	61	4	308	2.1	71.5	0.01
		28-Jul-10	10.20	0.001	<0.05	<0.0001	24	53	0.017	0.012	85	440	0.1	11.6	0.002	0.185	<0.0001	<0.001	0.022	0.76	0.03	7.7	0.68	<0.01	<0.001	29	2	252	3.1	179.0	0.018
		20-Dec-10	9.62	0.001	<0.05	<0.0001	44	106	0.016	0.011	86	830	0.1	11.3	0.002	0.501	<0.0001	<0.001	0.021	0.23	0.02	7.9	0.39	<0.01	<0.001	61	26	444	0.8	183.0	0.02
		24-Jan-11	2.81	<0.001	<0.05	<0.0001	76	149	0.004	0.004	92	1180	0.1	2.6	<0.001	0.151	<0.0001	<0.001	0.008	<0.01	<0.01	8.1	0.23	<0.01	<0.001	77	19	636	0.6	4.0	0.007
		25-Feb-11	1.18	0.001	<0.05	<0.0001	76	188	0.002	0.003	77	1410	0.7	1.4	<0.001	0.127	<0.0001	<0.001	0.005	0.03	<0.01	8.0	0.13	<0.01	<0.001	107	28	768	<0.1	4.8	<0.005
		24-Mar-11	1.07	<0.001	<0.05	<0.0001	79	198	0.002	0.002	89	1410	0.2	1.2	<0.001	0.145	<0.0001	<0.001	0.004	<0.01	<0.01	8.0	0.19	<0.01	<0.001	102	19	738	0.2	20.5	<0.005
		20-Apr-11	0.63	<0.001	<0.05	0.0017	76	230	<0.001	<0.001	93	1510	0.2	0.9	<0.001	0.171	<0.0001	<0.001	0.004	<0.01	<0.01	8.3	0.24	<0.01	<0.001	108	37	878	0.4	8.0	<0.005
		31-May-11	0.92	<0.001	<0.05	<0.0001	80	330	0.001	0.002	85	1800	0.2	1.0	<0.001	0.130	<0.0001	<0.001	0.003	<0.01	<0.01	7.8	0.23	<0.01	<0.001	149	50	1520	0.5	19.4	<0.005
		28-Jun-11	5.83	<0.001	<0.05	<0.0001	38	89	0.009	0.008	97	670	0.1	6.4	<0.001	0.195	0.0002	<0.001	0.014	0.47	<0.01	8.0	0.39	<0.01	<0.001	48	6	458	1.4	36.1	0.012
		30-Aug-11	1.49	<0.001	<0.05	<0.0001	70	177	0.003	0.003	99	1310	0.2	1.9	<0.001	0.130	<0.0001	<0.001	0.005	<0.01	<0.01	8.2	0.11	<0.01	<0.001	84	24	658	0.3	9.9	<0.005
		26-Sep-11	1.85	0.006	<0.05	<0.0001	65	170	0.004	0.003	96	1290	0.2	2.2	<0.001	0.182	<0.0001	<0.001	0.006	<0.01	<0.01	8.2	0.1	<0.01	<0.001	85	20	676	0.5	37.0	<0.005
		27-OCT-2011	2.13	0.001	0.025	0.00005	56	195	0.003	0.004	66	1130	0.2	2.3	0.0005	0.165	5E-05	0.0005	0.007	0.005	0.005	7.6	0.22	0.005	5E-04	93	31	632	0.8	33.0	0.014
		28-NOV-2011	36.40	0.002	0.025	0.00005	34	53	0.056	0.047	45	650	0.2	44.2	0.01	2.440	5E-05	0.0005	0.082	0.68	0.08	7.6	2.93	0.005	5E-04	36	13	340	3.8	1400.0	0.071

Aquatic Ecosystems	ANZECC 2000 Guidelines for Aquatic Ecosystems
Livestock	ANZECC 2000 Guidelines for Livestock Drinking Water Quality
Irrigation LTV	ANZECC 2000 Guidelines for Irrigation Water Supply- LTV (Long Term Trigger Value)
Irrigation STV	ANZECC 2000 Guidelines for Irrigation Water Supply- STV (Short Term Trigger Value)
	notes
	exceed all EV trigger values
	exceed at least one EV trigger value
	exceed no EV trigger values
blue	applied 95% protections levels from table 3.4.1 of ANZECC guidelines chapter 3
green	2000 is the maximum TDS tolerance for sensitive livestock
orange	5 is low risk trigger for poultry and pigs lower for other livestock (sheep 0.4 and catle is 1)
red	maximum concentration for sensitive crops
purple	lower limit valie

Table 7-2 Comparison of water quality monitoring data against ANZECC water quality guidelines (continued)

Sample Location	Description of site	Sample Date	Aluminium _ mg/L	Arsenic_ mg/L	Boron _ mg/L	Cadmium _ mg/L	Calcium - total mg/L	Chloride mg/L	Chromium - total_ mg/L	Copper_ mg/L	Dissolved Oxygen %sat	Electrical Conductivity µS/cm - field	Fluoride _ mg/L	Iron_ mg/L	Lead_ mg/L	Manganese_ mg/L	Mercury _ mg/L	Molybdenum _ mg/L	Nickel_ mg/L	Nitrates_ mg/L N	Nitrites_ mg/L N	pH - field	Phosphorus - total_ mg/L	Selenium _ mg/L	Silver_ mg/L	Sodium - total mg/L	Sulfates mg/L	Total Dissolved Solids @ 180°C_	Total Nitrogen _ mg/L N	Turbidity _ NTU	Zinc_ mg/L
Aquatic Ecosystems			0.06	0.024	0.37	0.0002			0.001	0.0014	90-110	30			0.0034	1.9	0.0006		0.011		0.7	6.5-8	0.02	0.011	5E-05				0.25	2.0	0.008
Livestock			5.00	0.5	5	0.01	1000		1	5			2		0.1	-	0.002	0.15	1	400	30			0.02			1000	2000			20
Irrigation LTV			5.00	0.1	0.5	0.01			0.1	0.2		650	1	0.2	2	0.2	0.002	0.01	0.2				0.05	0.02					5		2
Irrigation STV			20.00	2	0.5	0.05		175	1	5			2	10	5	10	0.002	0.05	2				0.8	0.05		115			25		5
SW5	Talbragar River at Cobbora	31-Aug-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		21-Sep-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		21-Oct-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		20-Nov-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		11-Dec-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		7-Jan-10	15.00	0.001	0.04	<0.00005	10	25	0.026	0.016	69	210	0.2	17.0	0.0046	0.290	<0.0001	<0.001	0.027	1.1	0.04	7.3	0.64	<0.001	<0.001	14	<2	240	3.1	460.0	0.041
		18-Feb-10	8.70	<0.001	0.04	<0.00005	28	18	0.017	0.015	100	340	0.2	11.0	0.0023	0.420	<0.0001	<0.001	0.027	1	0.08	7.6	0.98	<0.001	<0.001	16	<2	250	3.1	420.0	0.021
		26-Mar-10	1.50	0.001	0.04	<0.00005	13	25	0.004	0.004	63	340	0.2	2.2	0.0003	0.360	<0.0001	<0.001	0.012	<0.01	<0.01	7.6	0.38	<0.001	<0.001	18	<2	220	1.6	40	0.019
		22-Apr-10	2.81	0.001	<0.05	<0.0001	25	18	0.005	0.004	79	330	0.2	3.8	<0.001	0.490	<0.0001	<0.001	0.011	<0.01	<0.01	7.6	0.37	<0.01	<0.001	18	<2	192	1.7	76.2	0.007
		25-May-10	2.47	<0.001	<0.05	0.0006	26	28	0.004	0.004	92	340	0.1	3.3	<0.001	0.818	<0.0001	<0.001	0.011	<0.01	<0.01	7.6	0.35	<0.01	<0.001	18	<2	184	1.1	50.4	<0.005
		29-Jun-10	2.02	<0.001	<0.05	<0.0001	19	28	0.003	0.004	65	340	0.1	2.9	<0.001	0.523	<0.0001	<0.001	0.009	0.03	<0.01	7.5	0.17	<0.01	<0.001	19	<2	120	1.8	42.2	<0.005
		28-Jul-10	7.17	0.001	<0.05	<0.0001	26	39	0.012	0.009	82	440	<0.1	7.9	<0.001	0.132	<0.0001	<0.001	0.016	0.75	0.03	7.7	0.64	<0.01	<0.001	23	<2	250	4.2	131.0	0.016
		20-Dec-10	4.90	<0.001	<0.05	<0.0001	44	60	0.008	0.006	89	690	0.1	5.4	0.002	0.190	<0.0001	<0.001	0.013	0.22	0.02	8.1	0.37	<0.01	<0.001	40	<2	394	0.2	84.1	0.009
		24-Jan-11	3.81	<0.001	<0.05	<0.0001	74	92	0.005	0.004	91	1020	0.1	3.1	<0.001	0.132	<0.0001	<0.001	0.009	<0.01	<0.01	8.2	0.16	<0.01	<0.001	55	<2	536	0.5	4.0	0.01
		25-Feb-11	0.47	<0.001	<0.05	0.0002	70	124	<0.001	0.003	76	1140	0.7	0.5	<0.001	0.108	<0.0001	<0.001	0.005	0.05	<0.01	8.0	0.24	<0.01	<0.001	72	2	620	<0.1	7.0	<0.005
		24-Mar-11	3.28	<0.001	<0.05	<0.0001	67	120	0.005	0.004	84	1060	0.2	3.4	<0.001	0.123	<0.0001	<0.001	0.008	<0.01	<0.01	8.0	0.27	<0.01	<0.001	60	<2	590	0.3	20.6	0.006
		20-Apr-11	0.59	<0.001	<0.05	0.0001	72	142	<0.001	<0.001	94	1240	0.2	0.7	<0.001	0.123	<0.0001	<0.001	0.005	0.01	<0.01	8.3	0.25	<0.01	<0.001	68	5	710	0.5	12.8	<0.005
		31-May-11	1.07	<0.001	<0.05	<0.0001	73	149	0.002	0.002	91	1230	0.2	1.0	<0.001	0.127	<0.0001	<0.001	0.004	0.04	<0.01	8.2	0.3	<0.01	<0.001	69	6	702	0.7	20.3	<0.005
		28-Jun-11	1.48	<0.001	<0.05	<0.0001	45	74	0.002	0.005	94	710	0.1	1.5	<0.001	0.164	0.0002	<0.001	0.007	0.28	<0.01	8.2	0.37	<0.01	<0.001	38	<2	452	4.8	19.1	0.006
		30-Aug-11	1.83	<0.001	<0.05	<0.0001	64	106	0.003	0.004	95	1040	0.1	1.9	<0.001	0.146	<0.0001	<0.001	0.006	<0.01	<0.01	8.2	0.18	<0.01	<0.001	49	<2	456	0.3	26.7	<0.005
		26-Sep-11	3.16	0.006	<0.05	<0.0001	64	117	0.005	0.004	97	1160	0.2	3.2	<0.001	0.174	<0.0001	<0.001	0.008	<0.01	<0.01	8.2	0.2	<0.01	<0.001	60	6	602	0.3	49.6	0.025
		27-OCT-2011	2.67	0.0005	0.025	0.00005	63	149	0.004	0.004	68	1020	0.2	2.8	0.0005	0.178	5E-05	0.0005	0.008	0.06	0.005	8.9	0.24	0.005	5E-04	64	3	538	0.7	30.9	0.008
		28-NOV-2011	25.90	0.0005	0.025	0.00005	20	21	0.041	0.026	45	340	0.1	29.4	0.003	0.567	5E-05	0.0005	0.052	0.49	0.04	7.3	1.42	0.005	5E-04	15	2	370	1.8	159.0	0.033

Aquatic Ecosystems	ANZECC 2000 Guidelines for Aquatic Ecosystems
Livestock	ANZECC 2000 Guidelines for Livestock Drinking Water Quality
Irrigation LTV	ANZECC 2000 Guidelines for Irrigation Water Supply- LTV (Long Term Trigger Value)
Irrigation STV	ANZECC 2000 Guidelines for Irrigation Water Supply- STV (Short Term Trigger Value)
notes	
	exceed all EV trigger values
	exceed at least one EV trigger value
	exceed no EV trigger values
blue	applied 95% protections levels from table 3.4.1 of ANZECC guidelines chapter 3
green	2000 is the maximum TDS tolerance for sensitive livestock
orange	5 is low risk trigger for poultry and pigs lower for other livestock (sheep 0.4 and catle is 1)
red	maximum concentration for sensitive crops
purple	lower limit valie

8. Baseline geomorphology of local surface water bodies

A baseline geomorphology review was conducted to provide a snapshot of current geomorphic condition. Fluvial geomorphology classifications have been assigned according to the RiverStyles™ system (Thompson et al. 2001).

8.1 Geomorphic characterisation of watercourses

A rapid walkover survey has been used to characterise current geomorphological condition in Sandy Creek, Laheys Creek and the Talbragar River using the RiverStyles™ procedure (Thompson *et al.*, 2001). The completed templates from the rapid geomorphological walkover assessment at five representative sites are contained in Appendix A.2.

The watercourses of Talbragar River, Sandy Creek, Laheys Creek and other minor catchments in or near the assessment area are dominated by valley fills of Quaternary alluvium. The alluvium is characterised by gravels and sands interspersed with clays, and this varies in thickness from 0 to 28 m (refer to the *Groundwater Assessment* report for details).

In the Sandy Creek upper catchment, alluvial deposits are interspersed with short, bedrock-controlled sections where the longitudinal creek bed profile drops down, providing an overall stepped, longitudinal profile. The upstream Sandy Creek reach is confined with bedrock control as it steps down from the Tannabutta Group (shale, slate and thick-bedded volcaniclastic sandstone) that rims the catchment. A confined valley setting classification with occasional floodplain pockets has been assigned to this reach.

Downstream of those sections in Sandy Creek and Laheys Creek, the watercourses flood out into the broader valley floors of the higher order watercourse. Energy conditions are generally low in the broad valley floors where flows are dispersed. Many of these valley floors have been altered to allow cultivation and cropping. The valley floors have been channelised, often by excavation at one valley margin, to reduce saturation and increase agricultural productivity. The downstream reaches of Sandy Creek and Laheys Creek are alluvial discontinuous with either chain-of-ponds or valley fill features.

Water velocities during flood flows (i.e. the main channel-forming period) are estimated in Section 6.4.1.2. These data show higher peak velocities in Sandy Creek compared to Laheys Creek for the 2, 5 and 100 year ARI. Larger floods (i.e. 200 year ARI) have the opposite trend, with larger velocities estimated for Laheys Creek.

The Talbragar River is in a broad valley floor with a valley fill that has been altered by cultivation. The channel has moderate sinuosity and a gravel/sand bed. However, channel development is still minimal and flows are largely unconfined. The Talbragar River is classified as an alluvial continuous channel with channelised fill.

The walkover survey, therefore, found three main channel types. The locations and typical appearance of these are shown in Figure 8-1. More detailed analysis of the geomorphological structure of these creeks is provided in Section 8.2. The implications of these stream types and structure for hydrological functioning are summarised in Section 8.3.

8.2 Longitudinal profile analyses

The longitudinal profile for Sandy Creek and Laheys Creek were presented in the Flood Impact Assessment (Figure 6-4 and Figure 6-5, respectively). These figures indicate a similar overall gradient for the two creeks; a 94m drop in elevation over the course of the 24km Sandy Creek and a 59m drop in elevation over the course of the 13km Laheys Creek (Table 8.1). The upper reach in Sandy Creek (i.e upstream of the Laheys Creek confluence), however, has a gradient three times steeper than the lower reach (i.e. downstream from the Laheys Creek confluence). Contrasting this, Laheys Creeks has a much more uniform gradient throughout the channel length. Sinuosity is similar in all river reaches, with an index of between 1.3 and 1.5 calculated demonstrating 'intermediate' meandering channel form (Table 8.1).

Table 8-1 Geomorphological characteristics of Sandy Creek and Laheys Creek

Creek	Length (km)	Elevation drop (m)	Gradient (%)	Sinuosity (unitless ratio)
Sandy Creek Upper	13.2	74	0.6	1.5
Sandy Creek Lower	10.5		0.2	1.3
Sandy Creek (full length)	23.7	94	0.4	1.4
Laheys Creek	13.0	59	0.5	1.3

The sharp changes in gradient, 'knickpoints', observed on the upper reach of Sandy Creek are probably caused by the streampath crossing relatively resistant sandstone seams which are more stable than alluvium. This causes a bedrock dominated channel while allowing the lower part to steepen by slowing the rate of horizontal retreat.

Based on the presence of knickpoints and portions of the channel bed with markedly decreased gradient, erosion and deposition zones have been attributed to each of the creeks as indicated in Figure 8.2.

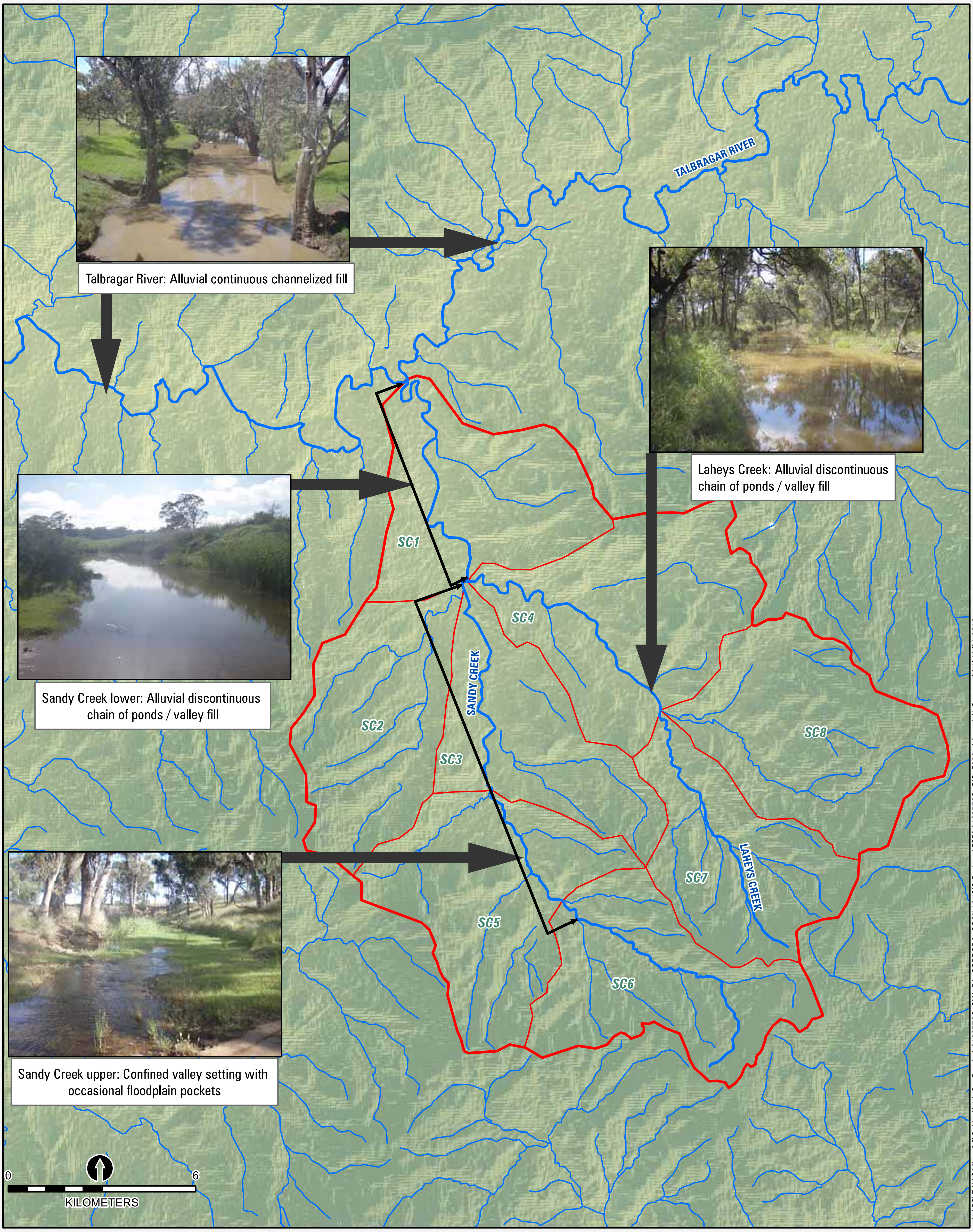
Five erosion zones are indicated on the map for Sandy Creek, four of which are in the upper Sandy reach. Six deposition zones are indicated, three of which are in the lower Sandy reach. Three of these six zones are associated with the junction with either Laheys Creek or the Talbragar River where flow velocities will naturally slow down due to the meeting of water from different directions. One deposition zone is in the middle of the lower reach, where the Golden Highway crosses over the creek. Four erosion zones are indicated on the map for Laheys Creek, interspersed throughout the creek length. Five deposition zones are indicated, one of which lies above the Spring Bridge Road ford and one below the confluence with Blackheath Creek.

8.3 Implications of stream types for hydrological functioning

Soil types present in the Sandy Creek and Laheys Creek sub-catchments retain runoff and release it slowly, particularly when vegetation is intact. They are also long-term sediment stores.

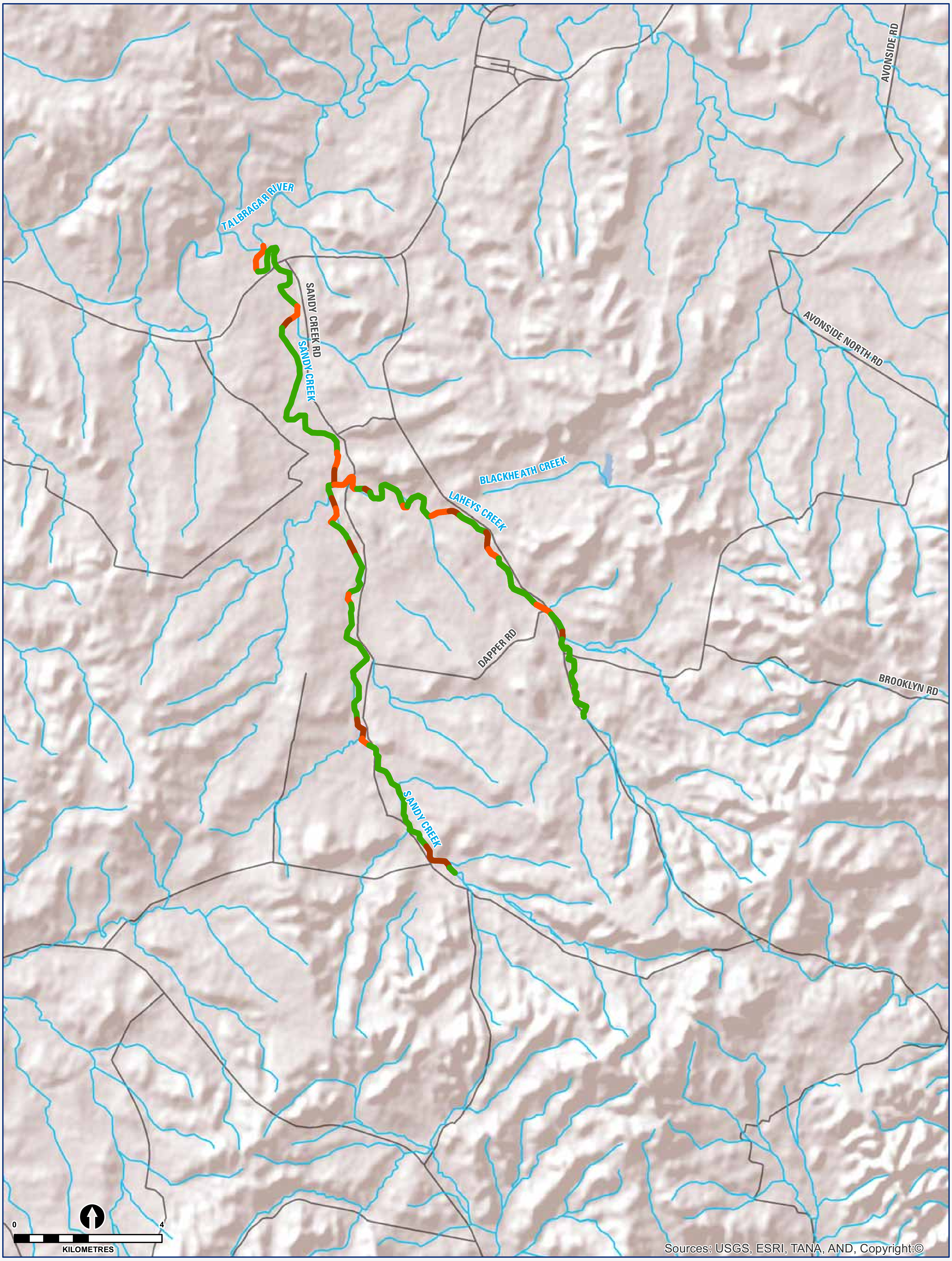
The confined upper reach of Sandy Creek will be dry for large periods of time, with limited connection to the floodplain. However, episodic flushing is predicted during high rainfall events. By contrast, the lower reaches of Sandy Creek and Laheys Creek will be inundated for a larger proportion of time, with slower flow velocities and associated larger residence times. Because of this, net accretion of fine sediment will occur.

Connectivity to the floodplain on the Sandy Creek lower reaches means that, during periods of high flow, water will overtop the banks and sediment deposition will occur. The Talbragar River channel will be inundated for longer periods than Sandy Creek and Laheys Creek, with intermediate flow velocities transporting fine sediment through the reach rather than depositing it. Its partial connectivity to the floodplain allows a removal mechanism for fine sediment onto the banks, but this connectivity is expected to be much less than the channel–floodplain interaction in the Sandy Creek lower catchment.



Drainage
Project area catchment boundary
Sub-catchment
Specific survey location (where access was limited)
Extent of walkover

Figure 8.1 Fluvial geomorphology river styles



Drainage lines
Roads

Stream Type
Deposition
Erosion
Stable

Figure 8-2 Stream type reaches according to longitudinal profile

9. Groundwater – surface water interaction

9.1 Overview

A brief summary of the groundwater system's relationship to the surface water environment is included here. The *Groundwater Assessment* report describes the system in detail.

Groundwater flow direction appears to mimic the topography, with a flow direction consistent with surface water flows. Available groundwater level data in the unconfined alluvium aquifer indicate an inferred groundwater flow direction north towards the Talbragar River.

Groundwater interaction with surface water across the assessment area takes the form of groundwater discharges, such as springs and seeps, including baseflows to Sandy Creek, Laheys Creek and the Talbragar River.

Discharge also occurs from the deeper fractured systems, probably along geological structures. The conceptual model developed for the groundwater assessment describes recharge to the groundwater system as occurring via direct rainfall infiltration in areas of unconsolidated alluvium, exposed sedimentary rock and fractured rock outcrop in the elevated areas. Recharge also occurs via vertical leakage to the underlying strata, during flood inundation of surrounding lands.

9.2 Refuge pools

During dry periods Sandy Creek and Laheys Creek retain persistent pools which, in some cases, can sustain in-channel aquatic habitats and provide refuge for fish and other biota. Full details of these habitats are provided in the *Aquatic Ecology Environmental Assessment* (Cardno, 2012). Pools that persist during sustained dry periods are likely to be groundwater fed rather than reliant on surface water runoff. Other pools that dry out shortly after rainfall events are likely to be surface water fed and do not receive significant groundwater inflow. It is also likely that some pools and habitats are reliant on a combination of surface and groundwater inflows; however, given that the creeks are ephemeral, groundwater inflows will govern levels in persistent pools rather than short duration surface water inflows.

The baseline groundwater modelling results were reviewed to identify the likely degree of groundwater dependency of pools within and adjacent to the main mining area identified in the aquatic ecology assessment (Cardno, 2012). Pool sites were deemed to be groundwater dependent where the modelled water table was found to be above the general ground level within the creek, allowing for the combined margin of error of the groundwater modelling and the aerial survey of ground levels. For this purpose a combined error of 1 metre was adopted; therefore, the groundwater dependency, or otherwise, of the pools was identified as follows:

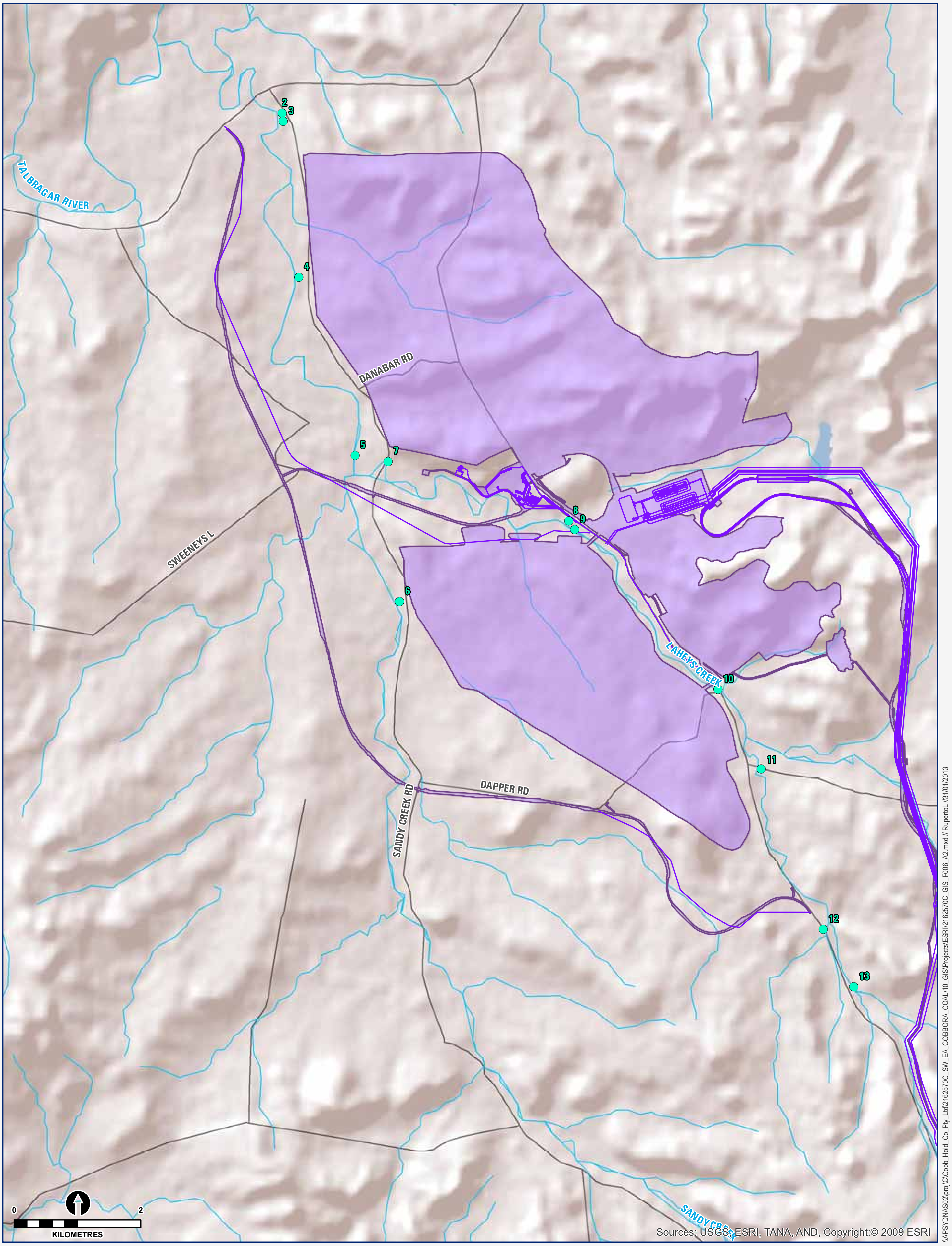
- If the water table elevation is higher than the creek bed level by more than 1 metre the pool site was deemed to be groundwater dependent.
- If the water table is within +/- 1 metre of the creek bed level the pool site was deemed to be potentially groundwater dependent.

- If the water table elevation is lower than the creek bed level by more than 1 metre the pool site was deemed to be independent of groundwater and instead reliant on surface water. It should be noted that such sites would not be persistent pool sites as the surface water flow would only sustain them for a short duration at the start of prolonged dry periods.

The results of this review are provided in Table 9-1 for 14 pool sites within and adjacent to the main mining area. The characteristics of these sites are given in the aquatic ecology assessment (Cardno, 2012). Figure 9-1 shows the locations of the sites.

Table 9-1 Groundwater dependency of refuge pools within the main mining area

Site	Location	Channel bed elevation (mAHD)	Groundwater surface elevation (mAHD)	Groundwater dependent?
1	Talbragar River upstream of Sandy Creek confluence	354.2	353.0	No
2	Sandy Creek downstream of Laheys Creek confluence	347.0	345.7	No
3	Sandy Creek downstream of Laheys Creek confluence	347.0	346.3	Potentially
4	Sandy Creek downstream of Laheys Creek confluence	353.5	351.7	No
5	Sandy Creek downstream of Laheys Creek confluence	361.0	362.4	Yes
6	Sandy Creek upstream of Laheys Creek confluence	373.0	372.2	Potentially
7	Laheys Creek downstream of Blackheath Creek confluence	365.0	362.4	No
8	Laheys Creek at Blackheath Creek confluence	378.0	373.8	No
9	Laheys Creek at Blackheath Creek confluence	378.0	374.3	No
10	Laheys Creek upstream of Blackheath Creek confluence	395.2	394.2	Potentially
11	Laheys Creek upstream of Blackheath Creek confluence	406.0	403.9	No
12	Laheys Creek upstream of Blackheath Creek confluence	428.8	426.0	No
13	Laheys Creek upstream of Blackheath Creek confluence	436.1	435.9	Potentially
14	Fords Creek	481.7	484.3	Yes



Refuge pools
Mine impact area
Mine infrastructure
Drainage lines
Roads

Figure 9-1 Refuge pools

10. Summary

This report has reviewed general catchment features and climate relevant to the assessment area. It has focused on local surface water features (i.e. Sandy Creek, Laheys Creek and the Talbragar River) and reviewed hydrologic conditions, water uses and associated local guidelines.

The assessment found that creeks were typically ephemeral and with limited flow volume monitoring data available. A range of environmental values, based on water uses in the Macquarie–Bogan unregulated river system, were identified. Key values include aquatic ecosystem, irrigation and livestock-watering use.

Water quality baseline data were also reviewed. Due to the ephemeral nature of the creeks in the assessment area, most samples were taken during low-flow conditions, which could overestimate salinity and dissolved metal/nutrient concentrations and underestimate concentrations of total suspended solids.

Finally, geomorphologic conditions were assessed, which identified three main geomorphological units (with two subsets) in watercourses located in the assessment area.

11. References

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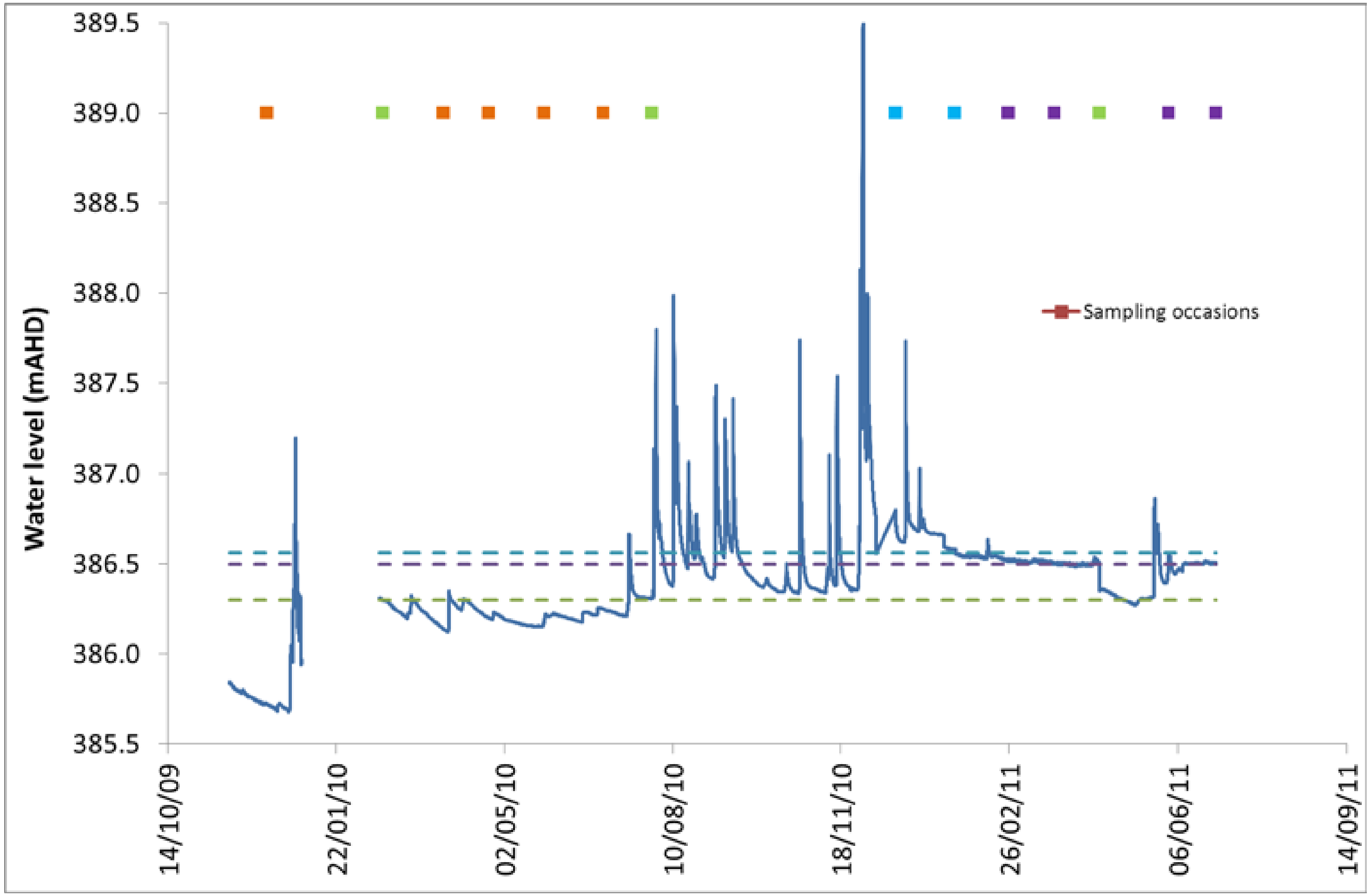
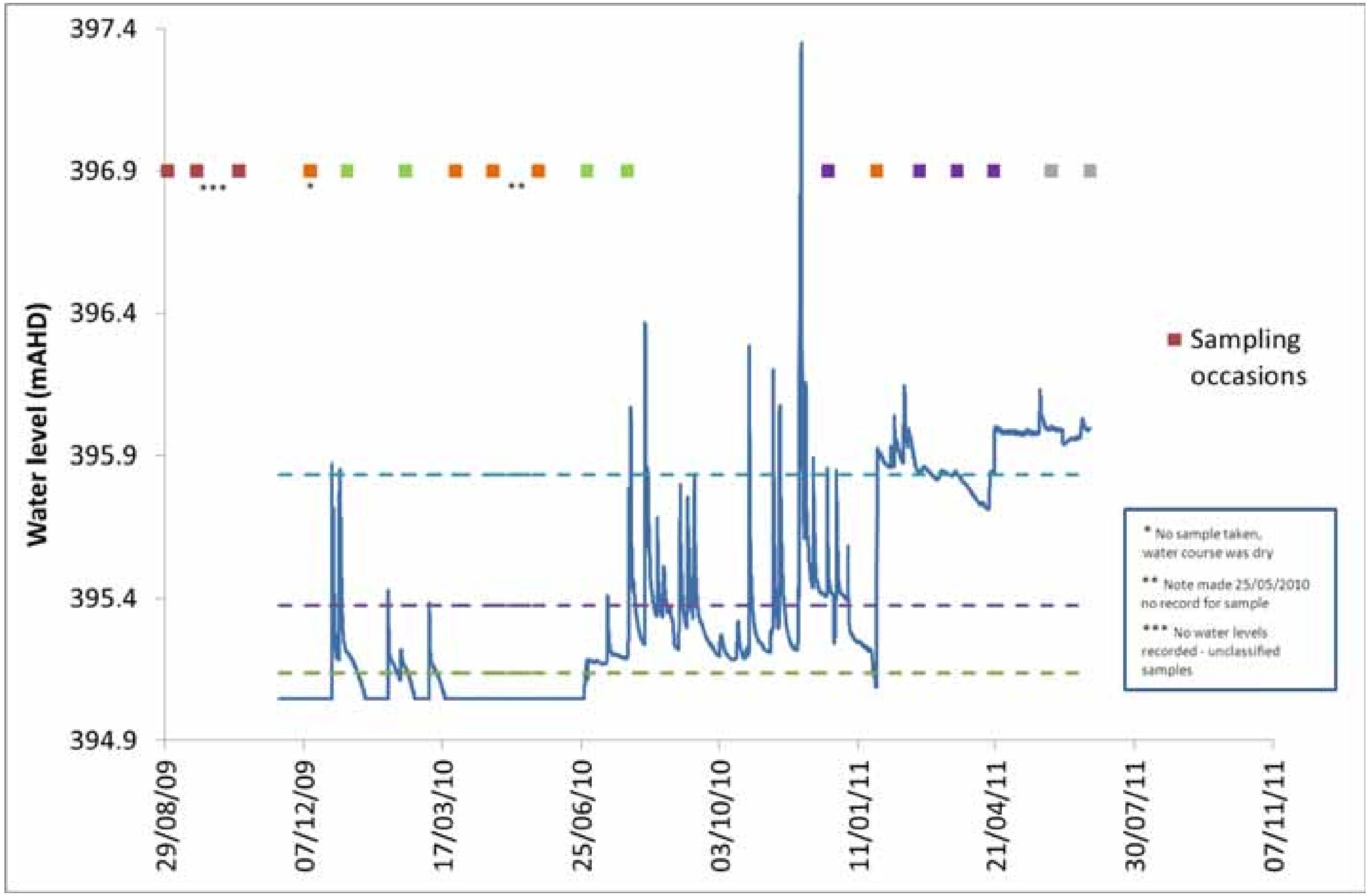
Appendix A.1

Temporal variations in water level during sampling events

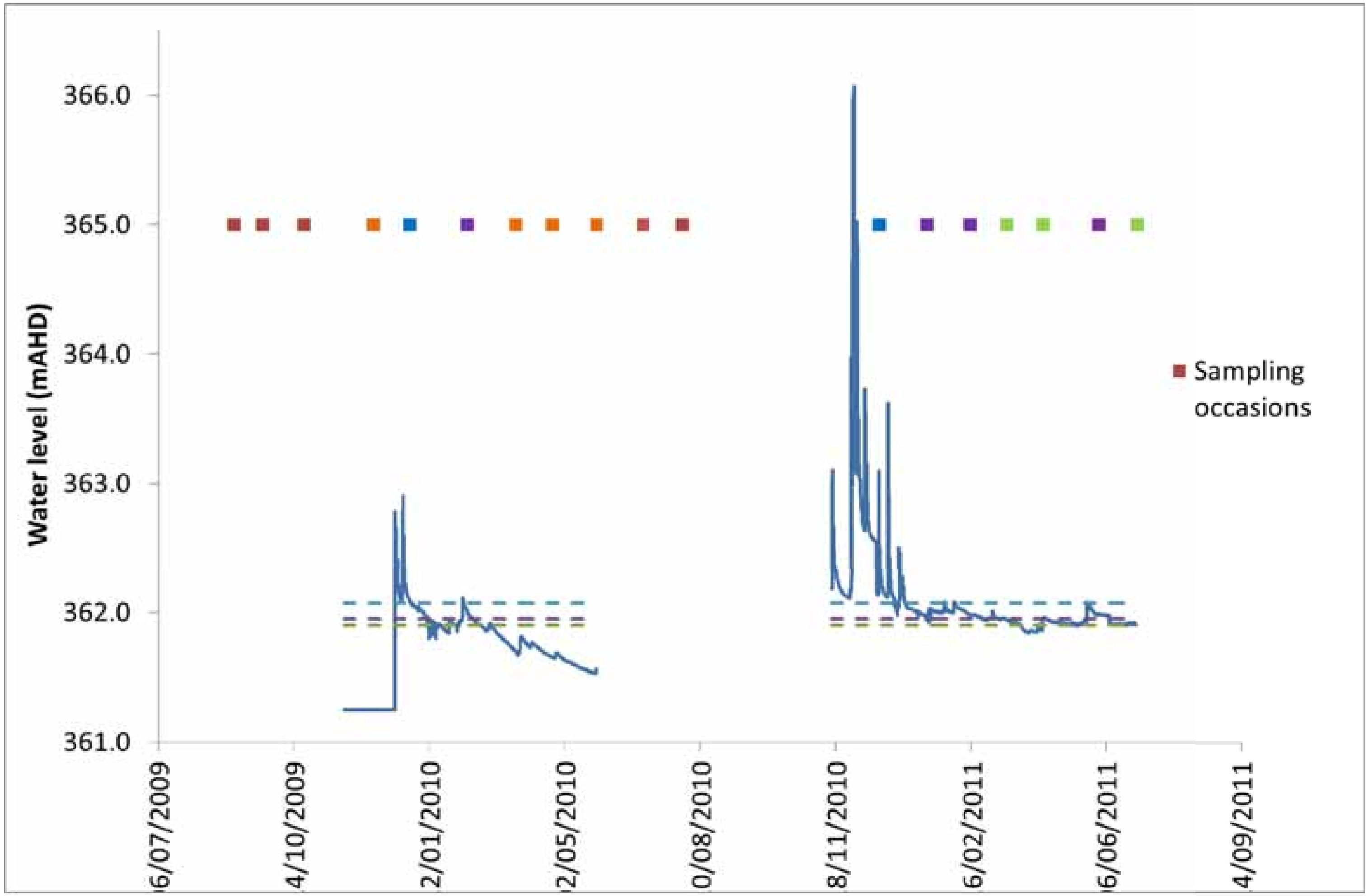
Sandy Creek upstream (SW1)



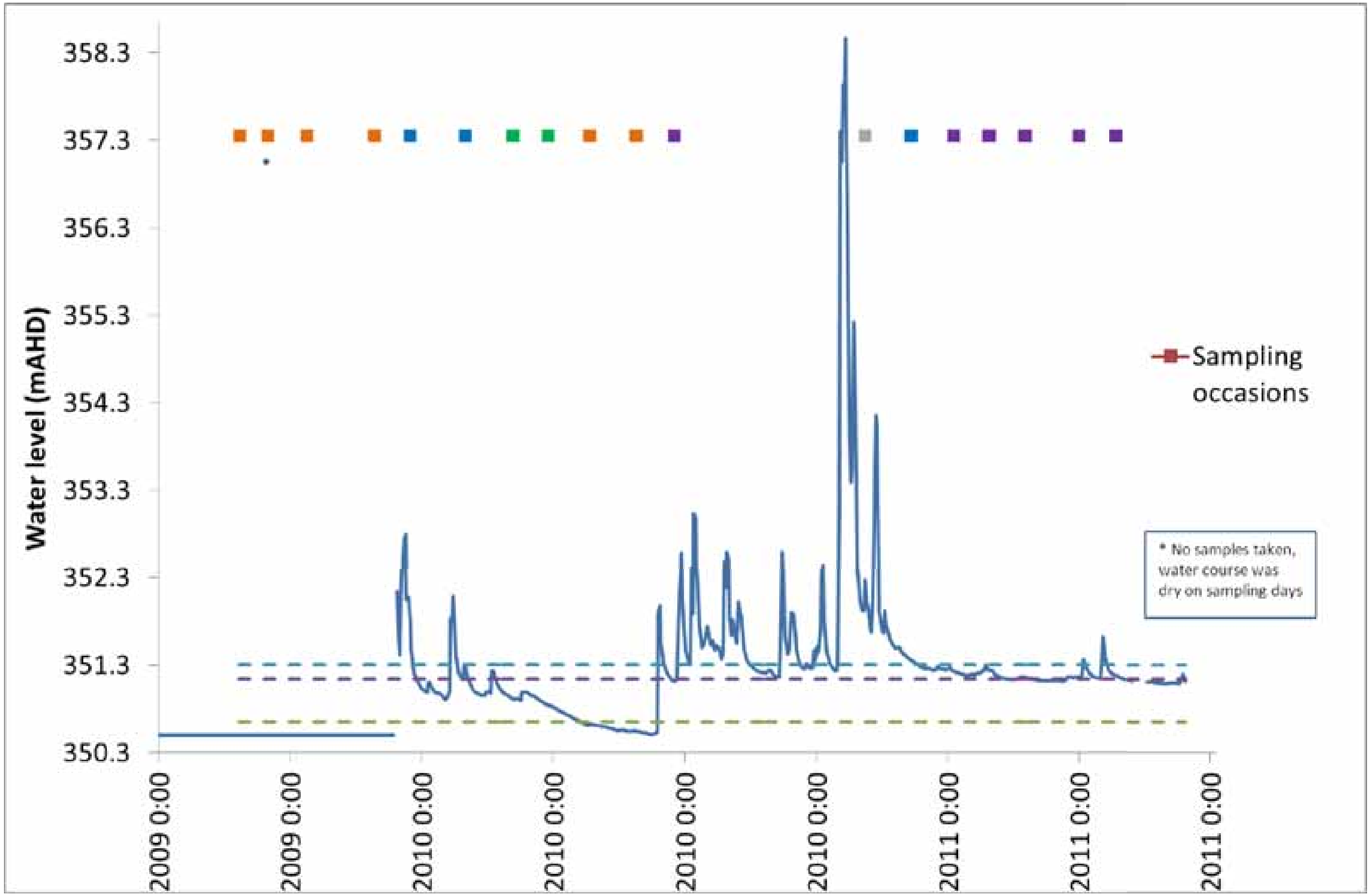
Laheys Creek (SW2)



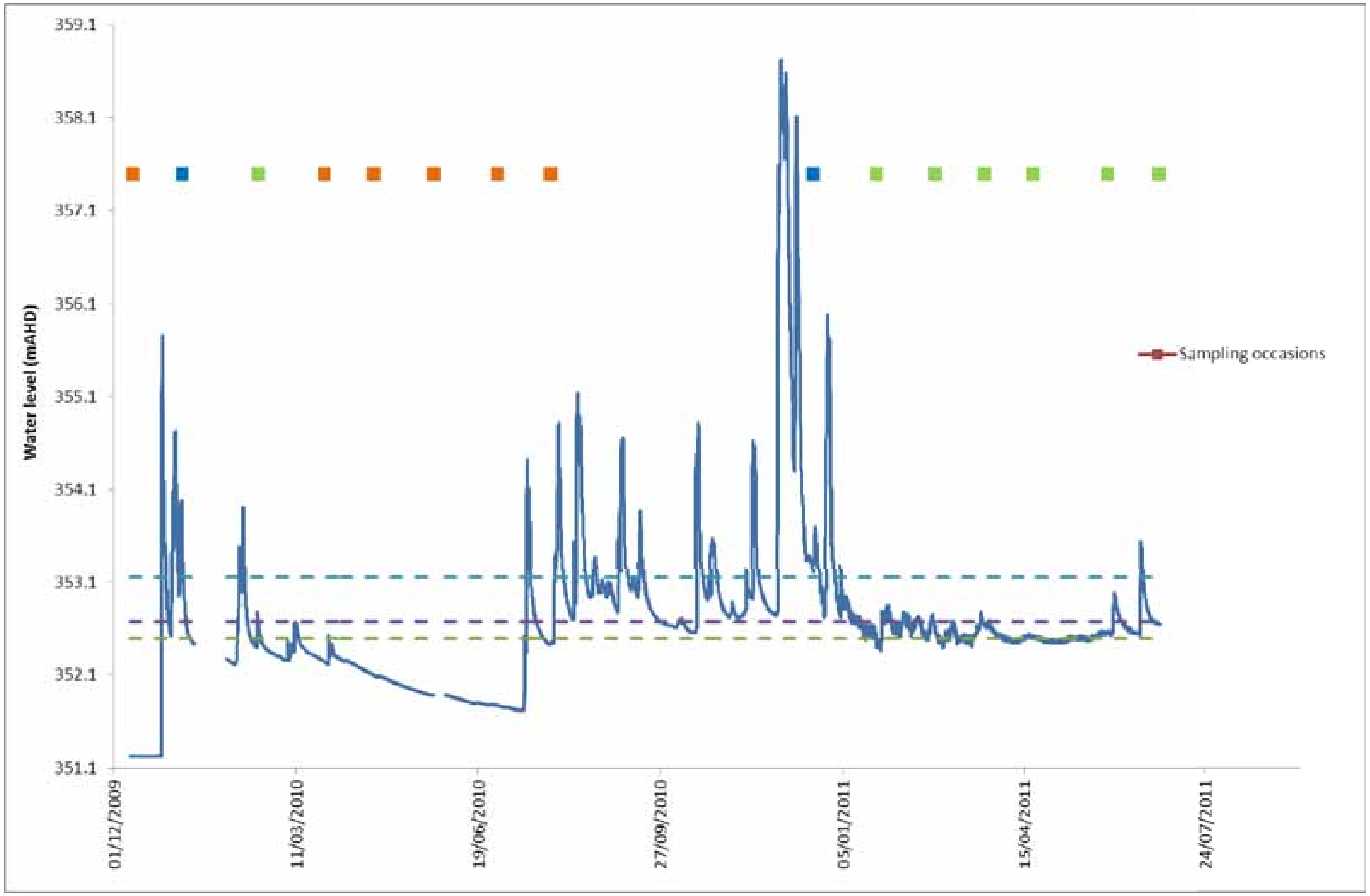
Sandy Creek Downstream (SW3)



Talbragar River at Elong Elong (SW4)



Talbragar River at Cobbora (SW5)



Appendix A.2

Fluvial Geomorphology Site Description Template

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	Cobbora Coal Project				**Date**	13/12/2011
Surveyor	DE	**Reach: Sandy Creek Upper (above confluence with Laheys Creek)**			**Time**	08:35 hrs
Drainage channel ☐	**Creek** X	**River** ☐	**Estuary** ☐	**Pond** ☐	**Wetland** ☐	**Lake** ☐
Weather conditions	Hazy sunshine, cool (approx. 15˚C), 23mm rain previous day		**U-S Grid ref**	-32.226743, 149.225686	**D-S grid ref**	-32.225291, 149.224516
Upstream elevation (m)	399m		**Downstream elevation (m)**	396m		**Slope** 3%

Watercourse attributes						
Dimensions	**Width (m)**	2.5m (DWF); 5m (BF)	**Max. depth (m)**	DWF = 0.06m BF = 0.65m	**Velocity (ms^{-1})**	0.1 – 0.3 m/s
Shape description		Trapezoidal at upstream Rectangular just above crossing at downstream point	**Roughness Height (m)**	0.02m (pebbles)	**Bank erosion**	Bare RHB along tree lined bank and on meander bend
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	20% benthic fungus cover	**Bank vegetation** U-S – 80% grass RHB, 100% grass & shrub LHB; D-S – 100% emergent macrophytes LHB & RHB		**Bench vegetation** 100% grass & shrub upstream and downstream on both LHB and RHB		**Organic matter** Logs Twigs / Leaves X Detritus X

Flow type								
Smooth surface flow	**Broken standing waves**	**Unbroken standing waves**	**Chute**	**Rippled**	**Scarcely perceptible flow**	**Upwelling**	**Free fall**	**Standing water**
☐[H1]	☐[H2]	☐[H3]	X[H4]	X [H5]	X[H6]	☐[H7]	☐[H8]	☐[H9]

Channel Planform							
Sinuosity (straight, low, intermediate, high)	Intermediate	***Form***	**Single** X	**Forked** ☐	**Braided** ☐		**Open** ☐
Sand bars X	**Gravel bars** X	**Rock outcrops** X		**Riparian strip** No		**Floodplain connectivity**	Yes, especially in downstream reach
Floodplain land use	Livestock grazing and hay growth					**Bank structure & angle**	LHB = Straight 35˚ RHD = Straight 45˚

Bed character							
% composition	**Boulder** U-S 0 D-S 0	**Cobble** U-S 5 D-S 0	**Gravel** U-S 30 D-S 0	**Sand** U-S 45 D-S10	**Fine sand** U-S 15 D-S 60		**Silt / clay** U-S 5 D-S 30
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Packing not armoured upstream Low compaction downstream			**Supply** X	**Deposition** X	**Erosion** X	**Conveying** X

*DWF = Dry weather flow, BF = Bankfull flow, RHB = Right hand bank, LHB = Left hand bank

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

Looking upstream from Sandy Creek Road crossing

Looking downstream from Sandy Creek Road crossing

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	Cobbora Coal Project				**Date**		13/12/2011
Surveyor	DE	**Reach: Sandy Creek Lower (below confluence with Laheys Creek)**			**Time**		09:20 hrs
Drainage channel ☐	**Creek** X	**River** ☐	**Estuary** ☐	**Pond** ☐	**Wetland** ☐		**Lake** ☐
Weather conditions	Bright sunshine, warm (approx. 20˚C), 23mm rain previous day			**U-S Grid ref**	-32.208535, 149.218175	**D-S grid ref**	-32.207536, 149.217982
Upstream elevation (m)	375m			**Downstream elevation (m)**	374m		**Slope** 1%

Watercourse attributes							
Dimensions	**Width (m)**	7.5m (DWF)	**Max. depth (m)**	0.45m	**Velocity (ms^{-1})**	<0.1 m/s	
Shape description		Trapezoidal at upstream & downstream points (west bank elevated)	**Roughness Height (m)**	0.0m	**Bank erosion**	Bare sandy banks on outside meander bends	
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	5% moss 2% emergent	**Bank vegetation** U-S – 80% grass RHB, 100% grass & shrub LHB; D-S – 100% emergent macrophytes LHB & RHB		**Bench vegetation** 100% grass & shrub upstream and downstream on both LHB and RHB		**Organic matter** Logs Twigs / Leaves X Detritus X	

Flow type								
Smooth surface flow X[H1]	**Broken standing waves** ☐[H2]	**Unbroken standing waves** ☐[H3]	**Chute** ☐[H4]	**Rippled** ☐[H5]	**Scarcely perceptible flow** X[H6]	**Upwelling** ☐[H7]	**Free fall** ☐[H8]	**Standing water** X[H9]

Channel Planform						
Sinuosity (straight, low, intermediate, high)	Low	*Form*	**Single** X	**Forked** ☐	**Braided** ☐	**Open** ☐
Sand bars X	**Gravel bars** No	**Rock outcrops** No		**Riparian strip** No	**Floodplain connectivity**	Partial, high banks will limit inundation to largest flood flows
Floodplain land use	Livestock grazing and hay growth				**Bank structure & angle**	LHB = Concave 55˚ RHD = Straight 15˚

Bed character								
% composition	**Boulder** U-S 0 D-S 0	**Cobble** U-S 0 D-S 0	**Gravel** U-S 5 D-S 0	**Sand** U-S 20 D-S10	**Fine sand** U-S 60 D-S 70		**Silt / clay** U-S 15 D-S 20	
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Low compaction upstream & downstream			**Supply** No	**Deposition** X	**Erosion** No	**Conveying** X	

***DWF = Dry weather flow, BF = Bankfull flow, RHB = Right hand bank, LHB = Left hand bank**

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Looking upstream from Dapper Road Crossing

50m upstream from Dapper Road Crossing

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	Cobbora Coal Project				**Date**	13/12/2011
Surveyor	DE	**Reach: Laheys Creek at Spring Ridge Road Crossing**			**Time**	09:50 hrs
Drainage channel ☐	**Creek** **X**	**River** ☐	**Estuary** ☐	**Pond** ☐	**Wetland** ☐	**Lake** ☐

Weather conditions	Bright sunshine, warm (approx. 26˚C), 23mm rain previous day	**U-S Grid ref**	-32.173633, 149.257336	**D-S grid ref**	-32.171962, 149.256327
Upstream elevation (m)	394m	**Downstream elevation (m)**	394m		**Slope** <1%

Watercourse attributes

Dimensions	**Width (m)**	7.5m	**Max. depth (m)**	Unknown (too deep, wide & coloured too measure)	**Velocity (ms^{-1})**	<0.1 m/s
Shape description		Trapezoidal at upstream & downstream points (south bank elevated)	**Roughness Height (m)**	0.0m	**Bank erosion**	Bare sandy banks on outside meander bends

Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	None	**Bank vegetation** U-S – 100% grass & shrub LHB & RHB; D-S – 60% grass LHB & RHB	**Bench vegetation** 100% grass, shrub & trees upstream and downstream on both LHB and RHB	**Organic matter** Logs X Twigs / Leaves X Detritus X

Flow type

Smooth surface flow	**Broken standing waves**	**Unbroken standing waves**	**Chute**	**Rippled**	**Scarcely perceptible flow**	**Upwelling**	**Free fall**	**Standing water**
X[H1]	☐[H2]	☐[H3]	☐ [H4]	☐ [H5]	X[H6]	☐[H7]	☐[H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	Straight	***Form***	**Single** X	**Forked** ☐	**Braided** ☐	**Open** ☐

Sand bars No	**Gravel bars** No	**Rock outcrops** No	**Riparian strip** No	**Floodplain connectivity**	Limited, high banks on both sides will limit inundation
Floodplain land use	Livestock grazing and hay growth			**Bank structure & angle**	LHB = Concave 25˚ RHD = Concave 20˚

Bed character

% composition	**Boulder** U-S 0 D-S 0	**Cobble** U-S 0 D-S 0	**Gravel** U-S 0 D-S 0	**Sand** U-S 40 D-S 50	**Fine sand** U-S 40 D-S 40	**Silt / clay** U-S 20 D-S 10

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Low compaction upstream & downstream	**Supply** No	**Deposition** X	**Erosion** No	**Conveying** X

***DWF = Dry weather flow, BF = Bankfull flow, RHB = Right hand bank, LHB = Left hand bank**

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Laheys Creek looking upstream from Spring Ridge Road Crossing

Laheys Creek looking downstream towards Spring Ridge Road Crossing

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	Cobbora Coal Project		**Date**	13/12/2011
Surveyor	DE	**Reach: Talbragar River at Cobbora Bridge**	**Time**	10:20 hrs

Drainage channel	**Creek**	**River**	**Estuary**	**Pond**	**Wetland**	**Lake**
☐	☐	X	☐	☐	☐	☐

Weather conditions	Bright sunshine, warm (approx. 26˚C), 23mm rain previous day	**U-S Grid ref**	-32.047988, 149.252594	**D-S grid ref**	-32.045824, 149.251767
Upstream elevation (m)	365m	**Downstream elevation (m)**	365m		**Slope** <1%

Watercourse attributes

Dimensions	**Width (m)**	12.5m	**Max. depth (m)**	Unknown (too deep, wide & coloured too measure)	**Velocity (ms^{-1})**	<0.1 m/s
Shape description		V-shaped incised channel	**Roughness Height (m)**	0.0m	**Bank erosion**	Some bare banks at livestock drinking access points

Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	None	**Bank vegetation** U-S & D-S – 75% grass LHB & RHB	**Bench vegetation** 100% grass U-S 100% grass & shrub D-S	**Organic matter** Logs X Twigs / Leaves X Detritus X

Flow type

Smooth surface flow	**Broken standing waves**	**Unbroken standing waves**	**Chute**	**Rippled**	**Scarcely perceptible flow**	**Upwelling**	**Free fall**	**Standing water**
X[H1]	☐[H2]	☐[H3]	☐ [H4]	☐ [H5]	☐[H6]	☐[H7]	☐[H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	Straight	***Form***	**Single** X	**Forked** ☐	**Braided** ☐	**Open** ☐

Sand bars	**Gravel bars**	**Rock outcrops**	**Riparian strip**	**Floodplain connectivity**	Partial, high banks will limit inundation to largest flood flows
No	No	No	No		

Floodplain land use	Livestock grazing and hay growth	**Bank structure & angle**	LHB = Concave 15˚ RHD = Convex 25˚

Bed character

% composition	**Boulder**	**Cobble**	**Gravel**	**Sand**	**Fine sand**	**Silt / clay**
	U-S 0 D-S 0	U-S 0 D-S 0	U-S 0 D-S 20	U-S 30 D-S 30	U-S 50 D-S 30	U-S 20 D-S 20

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Low compaction upstream & downstream	**Supply** No	**Deposition** X	**Erosion** No	**Conveying** X

*DWF = Dry weather flow, BF = Bankfull flow, RHB = Right hand bank, LHB = Left hand bank

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

Talbragar River looking upstream from Cobbora Bridge

Talbragar River looking downstream from Cobbora Bridge

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	Cobbora Coal Project				**Date**	13/12/2011
Surveyor	DE	**Reach: Talbragar River at Boomley Crossing**			**Time**	12:30 hrs
Drainage channel ☐	**Creek** ☐	**River** X	**Estuary** ☐	**Pond** ☐	**Wetland** ☐	**Lake** ☐

Weather conditions	Bright sunshine, warm (approx. 26˚C), 23mm rain previous day	**U-S Grid ref**	-32.107588, 149.089794	**D-S grid ref**	-32.106206, 149.085417
Upstream elevation (m)	332m	**Downstream elevation (m)**	332m		**Slope** <1%

Watercourse attributes

Dimensions	**Width (m)**	14m	**Max. depth (m)**	Unknown (too deep, wide & coloured too measure)	**Velocity (ms^{-1})**	<0.1 m/s
Shape description		Rectangular	**Roughness Height (m)**	0.0m	**Bank erosion**	Stable banks, no evidence of erosion

Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	None	**Bank vegetation** U-S & D-S – 95% grass LHB & RHB	**Bench vegetation** 100% grass & shrub U-S & D-S	**Organic matter** Logs X Twigs / Leaves X Detritus X

Flow type

Smooth surface flow	**Broken standing waves**	**Unbroken standing waves**	**Chute**	**Rippled**	**Scarcely perceptible flow**	**Upwelling**	**Free fall**	**Standing water**
X[H1]	☐[H2]	☐[H3]	X[H4]	X[H5]	☐[H6]	☐[H7]	☐[H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	Low	***Form***	**Single** X	**Forked** ☐	**Braided** ☐	**Open** ☐
Sand bars X	**Gravel bars** X	**Rock outcrops** No		**Riparian strip** No	**Floodplain connectivity**	Partial, high banks will limit inundation to largest flood flows
Floodplain land use	Livestock grazing and hay growth				**Bank structure & angle**	LHB = Straight 35˚ RHD = Straight 30˚

Bed character

% composition	**Boulder** U-S 0 D-S 0	**Cobble** U-S 0 D-S 0	**Gravel** U-S 0 D-S 20	**Sand** U-S 30 D-S 40	**Fine sand** U-S 50 D-S 30	**Silt / clay** U-S 20 D-S 10
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Low compaction upstream Packed not armoured downstream		**Supply** No	**Deposition** X	**Erosion** No	**Conveying** X

*DWF = Dry weather flow, BF = Bankfull flow, RHB = Right hand bank, LHB = Left hand bank

Talbragar River looking upstream at Boomley Crossing

Talbragar River looking downstream at Boomley Crossing

Appendix B

Cobbora Coal Project –
Downstream Water Quality Impact Assessment

Cobbora Coal Project - Downstream Water Quality Impact Assessment

January 2013

Cobbora Holding Company Pty Limited

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A+ GRI Rating: Sustainability Report 2010

Revision	Details	Date	Amended By
A	Draft for EMM/CHC review	5 March 2012	DE
B	Final draft for Adequacy Review	31 August 2012	RL
C	Final for Public Exhibition	6 September 2012	RL
D	Final post exhibition	31 January 2013	DE, RL

Author: ....Dan Evans

Signed: ....

Reviewer: ....Rob Leslie

Signed: ....

Approved by: ....Rob Leslie

Signed: ....

Date: ....31 January 2013

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Contents

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Appendices

Glossary

AWBM	Australian Water Balance Model
BL	Baseline load
EAP	Environmental Action Plan
EVs	Environmental Values
LTV	Long Term Value
NOW	NSW Office of Water
OL	Operational load
STV	Short Term Value
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WQO	Water Quality Objective

1. Introduction

This report presents the assessment of potential impacts associated with the operation of the Project on the water quality of natural receptors within the assessment area and further downstream.

1.1 Scope of assessment

For the purposes of the assessment, the assessment area includes all potential receptors defined as those watercourses that drain the assessment area i.e. Sandy Creek and Laheys Creek, and those that are likely to receive discharges from the proposed mined areas, which include Sandy Creek, Laheys Creek and the Talbragar River.

The Macquarie River, which receives tributary inflow from the Talbragar River, was not included in the assessment due to the relatively insignificant contributions of discharges from Sandy Creek and Laheys Creek to flows in the broader Macquarie River system. Refer to the *Downstream Flow Impact Assessment* report for further details.

The methodology used to assess the potential water quality impacts of the Project involved the following sequence of tasks:

- Reviewed potential surface water users within the receptor area and local water quality objectives (WQOs) relevant to the system.
- Developed project-specific or customised WQOs based on published guidelines.
- Quantitatively assessed the potential impacts of the Project on water users.
- Identified potential mitigation measures to minimise assessed impacts.
- Assessed the potential cumulative impacts of this Project, in relation to other projects in the vicinity of the assessment area on water quality in the Talbragar River.

2. Water quality objectives

2.1 Environment Values

Environmental values (EVs) are values that the community considers important for a healthy ecosystem for public benefit, welfare, safety or health.

Environmental values for an uncontrolled river segment within the Macquarie-Bogan catchment have been identified under the *Macquarie-Bogan River Water Quality and River Flow Objectives* by the Office of Environment and Heritage (formerly Department of Environment, Climate Change and Water).

The relevant environmental values and corresponding objectives adopted for the receiving waters downstream of the Project are listed in Table 2-1.

Table 2-1 Environmental Values for the uncontrolled river segment within the Macquarie-Bogan catchment

Environment Value	Objective
Aquatic ecosystems	Maintaining or improving the ecological condition of water bodies and their riparian zones over the long term.
Visual amenity	Maintaining aesthetic qualities of waters.
Secondary contact recreation	Maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed.
Primary contact recreation	Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed.
Livestock water supply	Protecting water quality to maximise the production of healthy livestock.
Irrigation water supply	Protecting the quality of waters applied to crops and pasture.
Homestead water supply	Protecting water quality for domestic use in homesteads, including drinking, cooking and bathing.
Drinking water	Maintaining or improving the quality of drinking water drawn from the raw surface and groundwater sources before any treatment.
Aquatic foods (cooked)	Protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities. (Note: The ANZECC 2000 Guidelines lists this environmental value as Aquaculture and human consumption of aquatic foods).

Source: *Macquarie-Bogan River Water Quality and River Flow Objectives* (Department of Environment, Climate Change and Water 2006).

2.2 Development of Project-specific Water Quality Objectives

2.2.1 Overview

Water quality data collected by the baseline surface water monitoring program were compared against ANZECC water quality triggers to characterise the baseline water quality conditions. Refer to Section 7 in the *Baseline Hydrological Environment* report for details.

The baseline water quality conditions indicate that customised or project-specific water quality objectives (WQOs) need to be developed and used as the basis for assessing the potential water quality impacts of the Project for the following reasons:

- ANZECC trigger values are based on steady-state conditions that by definition do not occur in ephemeral streams such as Sandy Creek, Laheys Creek and the Talbragar River.
- The nature of the Project area (distinct geology and ephemeral headwater creeks) means it was not possible to define a reference site with 2 years contiguous data.
- The baseline chemical concentrations were found to exceed the ANZECC guidelines in many cases.

The customised WQOs were developed using a procedure generally accepted in NSW which is based on a variation from the standard ANZECC assessment procedure (DEC 2006). The Project's impacts were then modelled and assessed against customised water quality objectives to determine the potential significance of these impacts.

Sections 2.2.2 and 2.2.3 describe the process for establishing the customised WQOs for the Project. Section 3 presents the modelling and impact assessment results.

2.2.2 Default Water Quality Objectives

As a first step towards the development of customised WQOs for the Project, default WQOs were identified, consisting of a collation of indicators that are common to all EVs and the stringent triggers among the sets of values recommended by the *Macquarie-Bogan Water Quality and River Flow Objectives* (DECCW 2006). These default WQOs are presented in Table 2-2.

Default values for toxicants that were not included in the DECCW (2006) document were developed based on ANZECC 2000 toxicant guidelines. The ANZECC 2000 default values for freshwater species providing a 95% level of protection was adopted for toxicants. These values are considered appropriate to assess '*slightly to moderately disturbed systems*' such as those encountered in an area used for stock grazing. The ANZECC guidelines (2000a) indicate that it is appropriate to compare dissolved concentrations of metals to the water quality objectives. Default WQOs for specific toxicants are outlined in Table 2-3. Similar to physical and chemical stressors, aquatic ecosystem triggers are the most stringent of the EV(s) and therefore form the basis for values in Table 2-3.

Table 2-2 Macquarie-Bogan Uncontrolled Rivers Water Quality Objectives

Parameter	Minimum constraint	EV source
Total phosphorus	50 µg/L (rivers in the Murray-Darling Basin)	Aquatic ecosystems
Total nitrogen	500 µg/L (rivers in the Murray-Darling Basin)	Aquatic ecosystems
Chlorophyll-a	5 µg/L*	Aquatic ecosystems
Turbidity	5 NTU	Homestead water use
Salinity (electrical conductivity)	30-350 µS/cm (upland rivers**)	Aquatic ecosystems
Dissolved oxygen	> 6.5 mg/L (> 80% saturation)	Drinking water
PH	6.5-8.5	Drinking water
Temperature	15°-35°C for prolonged exposure.	Primary contact
Chemical toxicants	Refer to ANZECC 2000 guidelines	
Faecal coliforms	95% of samples should be 0 coliforms/ 100 mL throughout the year. Up to 10 coliform organisms may be accepted occasionally in 100 mL. Coliform organisms should not be detected in 100 mL in any two consecutive samples.	Drinking water
Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour.	Visual amenity
Total dissolved solids	500-1000 mg/L is acceptable based on taste.	Homestead water supply
Suspended solids	<40 µg/L (freshwater)	Aquatic foods

Note:
* In absence of an upland rivers guideline the lowland rivers guideline was applied
**>250m AHD

Table 2-3 Selected toxicant water quality objectives

Group	Parameters	Unit	ANZECC freshwater water quality objectives	Level of protection
Dissolved Metals and Metalloids	Aluminium	(mg/L)	0.055 (pH>6.5) NE* (pH<6.5)	95%
	Arsenic	(mg/L)	0.024	95%
	Boron	(mg/L)	0.37	95%
	Cadmium	(mg/L)	0.0002	95%
	Chromium	(mg/L)	0.001	95%
	Copper	(mg/L)	0.0014	95%
	Lead	(mg/L)	0.0034	95%
	Manganese	(mg/L)	1.9	95%
	Nickel	(mg/L)	0.011	95%
	Zinc	(mg/L)	0.008	95%

* Not established

WQOs outlined in the ANZECC guidelines (2000a) for 95% level of protection for freshwater species are soft water quality objectives (hardness <60 mg/L as $CaCO_3$). Table 2-4 summarises the conversion factors that should be applied at each sampling event to determine an appropriate specific WQO for selected metals depending on the hardness of the water (adopted from Table 3.4.4 ANZECC Guidelines, 2000a).

Table 2-4 Approximate factors to apply to soft water quality objectives for selected metals in freshwaters of varying hardness

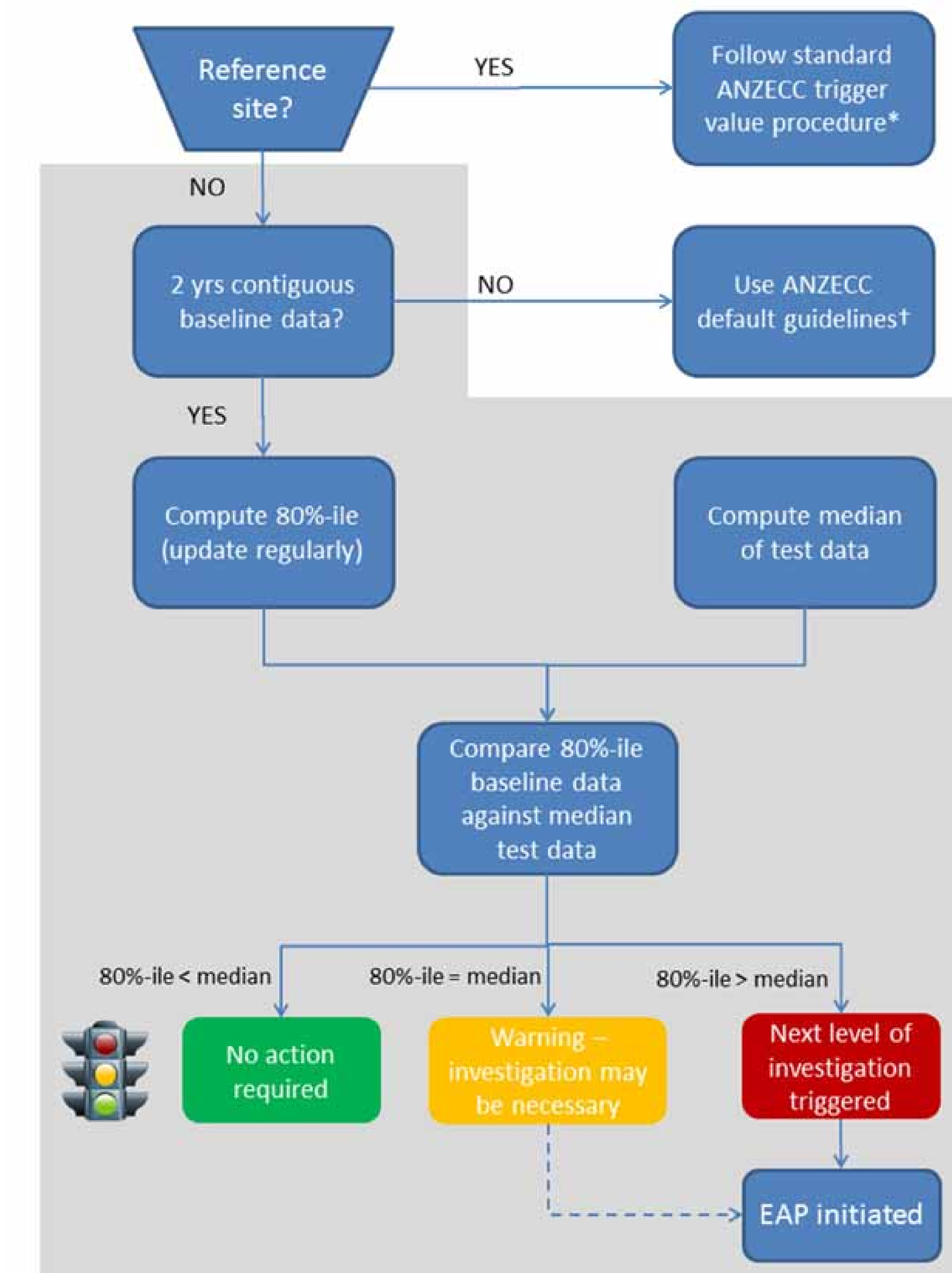
Category	Mean hardness (mg/L of $CaCO_3$)	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Soft (0 – 59)	30	No adjustment – use water quality objectives above					
Moderate (60 – 119)	90	X 2.7	X 2.5	X 2.5	X 4.0	X 2.5	X 2.5
Hard (120 – 179)	150	X 4.2	X 3.7	X 3.9	X 7.6	X 3.9	X 3.9
Very hard (180 – 240)	210	X 5.7	X 4.9	X 5.2	X 11.8	X 5.2	X 5.2
Extremely hard (400)	400	X 10.0	X 8.4	X 9.0	X 26.7	X 9.0	X 9.0

2.2.3 Customised water quality objectives

Development of site-specific trigger values, based on background data, was adopted for this Project according to a procedure outlined in ANZECC (2000a) and summarised in Figure 2-1. This approach is recognised in both NSW and QLD state procedures as a legitimate variation from the standard ANZECC assessment procedure (DEC 2006).

The minimum data requirements specified in ANZECC (2000a) have been satisfied – 25 data points from August 2009 to September 2011. The ANZECC (2000a) guideline also recommends 24 monthly data points over a 2 year period. It has been demonstrated that these samples have been collected from a representative range of flow conditions, based on comparison to 25, 50, 75 and 95 percentile automatic water level recordings for the 2 year period (refer to the *Baseline Hydrological Environment* report for details).

The customised WQOs were set using a mass-balance model to compute the 80^{th} percentile concentrations of the relevant water quality parameters for the baseline condition, and then by comparing these 80^{th} percentile concentrations to the default WQOs. For parameter concentrations that exceeded the default WQOs, the baseline 80^{th} percentile concentrations were adopted as the customised WQOs for the Project. The results of this process and the customised WQO trigger values are presented in Section 3.



(*ANZECC, 2000a; †ANZECC, 2000b; EAP = Environmental Action Plan)

Figure 2-1 Approach to development of site specific water quality trigger values (grey shading indicates proposed approach)

3. Assessment of potential impacts

This section presents the findings of an assessment of the potential downstream water quality impacts associated with the operation of the Project using a customised mass-balance model method.

3.1.1 Modelling objectives

The purpose of the water quality modelling was to provide a quantitative assessment of the impacts on water quality in the main streams near the proposed mine site over the life of the Project. This was achieved by firstly analysing the existing water quality in the main streams to identify the baseline loads and concentrations of key water quality parameters. As part of this assessment, customised WQOs were developed for the watercourses, in accordance with the procedure described in Section 2.2.

Five mine stages were selected to be consistent with other elements of the surface water assessment, namely mine stages associated with year 1, 4, 12, 16 and 20. The mass balance model was run for all five mine stages. Model predictions of loads and concentrations for the key water quality parameters were compared against baseline conditions and customised WQOs to assess the potential significance of any impacts.

The model results were then used to determine whether the water quality of the natural watercourses within the assessment area remain within the customised WQOs throughout the mine life and inform the development of project-specific water quality criteria that would need to be applied to any discharges from the mine site (e.g. sedimentation dam discharges) to ensure no long-term adverse environmental impacts.

3.1.2 Model setup

A mass balance model was set up in Microsoft Excel. A series of linked worksheets were designed to calculate baseline load (BL), baseline concentration, operational load (OL) and operational concentration, for comparison against customised WQOs.

The model was set up for the period 20/11/1970 to 01/01/2011 with a daily time-step to coincide with flow data availability. Chemical concentrations from 31/08/2009 – 28/06/2011 were matched to the flow data record using 50th percentile concentrations.

The following parameters were included in the pre-mining or BL water quality model:

- Metals (Aluminium, Arsenic, Cadmium, Chromium, Copper, Iron, Manganese, Nickel, Selenium, Zinc [all dissolved form])
- Total dissolved solids
- Total nitrogen
- Total phosphorus
- Total suspended solids.

These parameters were selected on the basis of previously collected baseline monitoring data, guideline WQOs and professional judgements about the potential water quality impacts of mining, based on previous studies.

For the OL calculations, releases from the sedimentation dams were assumed to occur when there was need for a controlled discharge or overflow due to excess water at the mine site.

The mass balance model mixes the water released from the proposed water management system with the unregulated water in the stream and calculates water quality concentrations of the water quality indicators. This calculation does not include any form of physical or geochemical processes within the watercourse and thus predicts conservative concentration values.

Sections 3.1.2.1 and 3.1.2.2 describe the detailed approach towards generating BL and OL concentrations, respectively. A model schematic is shown in Figure 3-1. The data sources and assumptions for this water quality mass-balance model are summarised in Appendix B.1.

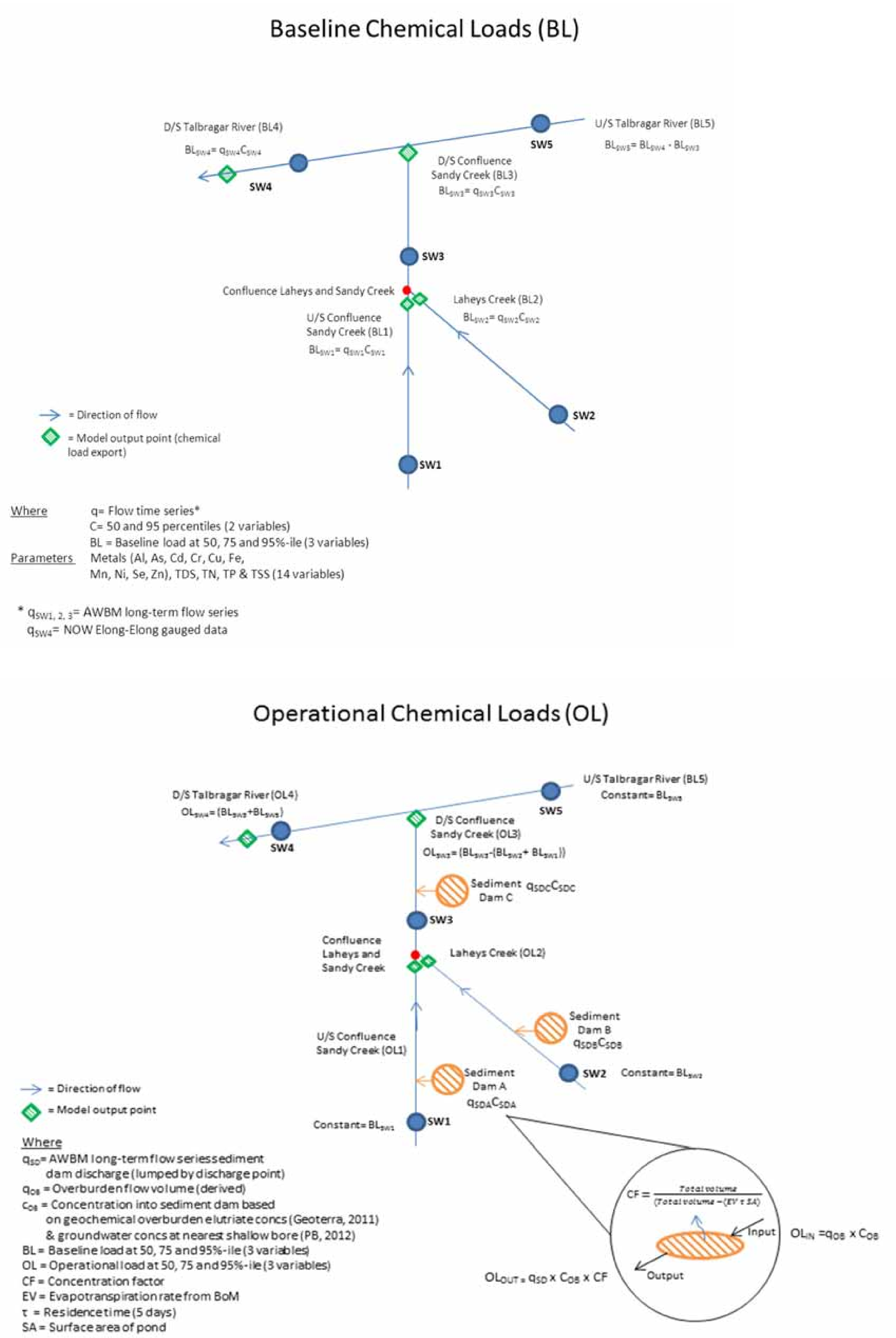


Figure 3-1 **Model schematic for Baseline and Operational Scenarios**

3.1.2.1 Baseline scenario

For the baseline scenario (pre-mining case), chemical loads were estimated for sites SW1, SW2, SW3, SW4 and SW5 as illustrated on the schematic in Figure 3-1. The chemical load at each stream was compiled on a daily time step over the period of 20/11/1970-01/01/2011 as this was the period of common data from the Australian Water Balance Model (AWBM) developed for the *Water Balance and Surface Water Management System Report* and NSW Office of Water (NOW) flow gauge at modelling point SW4.

The temporal representativeness of chemical sampling data was assessed in the *Baseline Hydrological Environment* report. This indicated that high flow events were under-represented in the sampling programme. Nevertheless, captured data from the high flow events suggested lower concentrations for parameters of concern than during low and intermediate flow conditions. To investigate whether flow could be used as a surrogate for water quality variability, regression plots for all sites were constructed. The indicative regression relationships between measured flow at SW4 and concentrations of Zn, TP, TDS and TSS are shown in Figure 3-2.

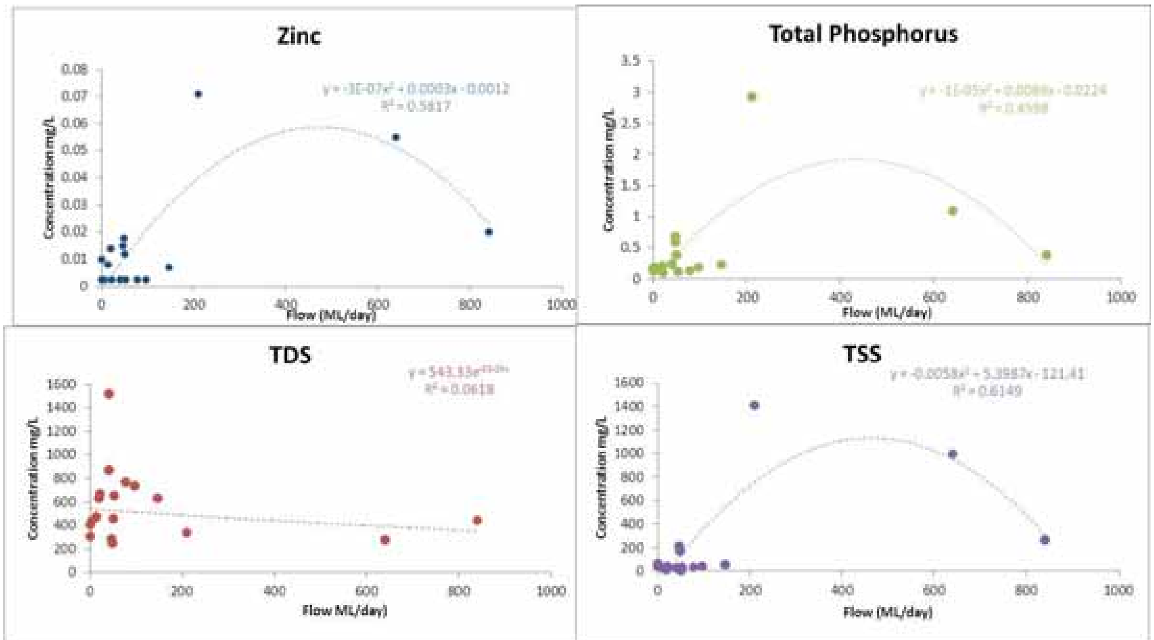


Figure 3-2 Flow versus water quality regression plots at SW4

Polynomial trend lines were fitted to zinc, phosphorus and TSS and an exponential trend line was fitted to TDS. None of these regression relationships showed strong correlation, as measured by the r^2 value. The pattern of scatter was similar for zinc, phosphorus and TSS, suggesting TSS is correlated with phosphorus and zinc. These plots show low concentrations at low flows (due to lack of source inputs) and high flows (due to volumetric dilution) and high concentrations in intermediate flows (due to first flush inputs from rapid surface water pathways).

Conversely, large variability in TDS during low flow conditions (due to a balance between low inputs but more ion-rich baseflow inputs from sub-surface flow pathways and evaporation of water in semi-permanent pools) and similar values of approximately 400 mg/L at flows >200 ML/day indicate a less variable source of water with similar composition, probably from surface water runoff.

For mass balance modelling, concurrent time series of concentrations of assessed water quality parameters were required. The measured data points were only available for 24 months from August 2009 to June 2012. Had the regression relationships been strongly correlated with the flows, these could have been used to develop a flow varying concentration time series. In the absence of this correlation, constant concentrations corresponding to the 50th percentile based on monthly sampling data were used instead.

The AWBM model simulated flows for SW1, SW2 and SW3 and NOW gauge data for SW4 were used in the mass balance modelling. Flows at SW5 on the upstream Talbragar River reach were estimated by subtracting the AWBM model estimates for SW3 from NOW gauged flows at SW4.

The BL was estimated by multiplying the daily discharge at each location by the 50th percentile concentration at each location for each parameter (Figure 3-1). This load was determined for upstream of the confluence Sandy Creek (BL1); Laheys Creek (BL2); downstream of the confluence of Sandy Creek (BL3); and downstream of the Talbragar River (BL4). BL5 (upstream Talbragar River) was calculated as BL4-BL3. Once the daily load was calculated it was converted to the 50th percentile for each of the parameters.

3.1.2.2 Operational scenario

The operational scenario includes the effect of sedimentation dam discharges on the watercourses in the assessment area. These sedimentation dam inputs were treated as 'lumped discharges' based on the location of release into the receiving watercourse (refer to the *Water Balance and Surface Water Management System Report*), and therefore the inputs vary on both a temporal (due to land changes in the different phases of the Project) and spatial scale (due to different volume and concentration input values).

The concentrations of chemicals entering the sedimentation dams were based on a previous geochemical investigation (Geoterra, 2010), hydrogeological monitoring (PB, 2012) and baseline TSS values in cease to flow conditions.

Elutriate testing data (1:5 deionised water extract) from overburden wastes was deemed to provide the highest representation of chemical composition of runoff into the sedimentation dams and was considered a worst-case representation of potential chemical inflows to the sedimentation dams (Geoterra, 2010). No nutrient leachate testing was conducted as part of the Geoterra report so the 50th percentile total nitrogen and total phosphorus concentrations from shallow bores closest to the sedimentation dams were used as inputs to the model.

The sedimentation dams were sized according to Blue Book recommendations (refer to the *Water Balance and Surface Water Management System*), which assumes a settling efficiency of 95%. It is clear that this will not remove the finest fraction of particulate matter or low density material. To estimate potential TSS concentrations from the sedimentation dams, cease to flow values in the adjacent Sandy Creek and Laheys Creek watercourses were used (19mg/L, n = 21).

The concentration of chemicals discharged from the sedimentation dams are likely to increase slightly when compared to the inputs described above due to evaporation. Water loss estimates for each sedimentation dam were calculated using the water balance model (refer to the *Water Balance and Surface Water Management System Report*) and converted to volumes based on the surface area of each sedimentation dam and the residence time.

The total load at the confluence was based on the sum of the BL plus the total sedimentation dam load. This gave the OLs for each of the mine years. BL4 was derived using the sum of the BL5 (assumed to be a constant throughout the Project life) and OL3 for each of the operational years.

3.1.3 Modelling results

Resulting chemical concentrations from the model simulations are described below for both baseline and operation scenarios. Appendix B.2 contains all tabulated outputs from the modelling runs together with comparisons to WQOs, using the 'RAG' (Red, Amber, Green) colour coding system.

3.1.3.1 Baseline scenario results and development of customised WQOs

The following observations are made from comparison of the BL3 (Sandy Creek) chemical concentration data to default WQOs:

- For primary contact, arsenic, cadmium, chromium, copper, nickel, selenium and zinc are all below the default WQO but aluminium, iron and TDS exceed the default WQO.
- For livestock water supply all parameters are below the default WQO reflecting that the pre-mining water quality is suitable for this EV.
- For irrigation all parameters are below the default WQO for Short Term Value (STV) but iron and manganese are approximately 5 times higher than the default WQO for Long Term Value (LTV).
- For aquatic ecosystems TP and TN are above the default WQO value. There is no default WQO set for TSS but the baseline value is 16 mg/L.
- This suggests that untreated water in Sandy Creek is only suitable for livestock water supply and irrigation (short term).

The following observations can be drawn from comparison of the BL4 (Talbragar River) chemical concentration data to default WQOs:

- For primary contact, arsenic, cadmium, chromium, copper, nickel, selenium, TDS and zinc are all below the default WQO but as for Sandy Creek, aluminium and iron exceed the default WQO.
- TDS in the Talbragar River is approximately a third of the concentration of that in Sandy Creek. This discrepancy is significant and shows that the Talbragar River is supported by larger flows which dilute the ion-rich baseflow and lead to less evaporative loss and subsequent concentration of salts.
- For livestock water supply all parameters are below the default WQO. For irrigation all parameters are below the default WQO for STV and LTV except iron which is approximately 10 times higher than the default WQO for LTV and TP, which is approximately 5 times higher than the default WQO for LTV.
- For aquatic ecosystems TP and TN are both above the default WQO value.
  These observations suggest that the Talbragar River has potential to become eutrophic and develop algal blooms during low flow periods.

TP concentrations in Sandy Creek are lower and as phosphorus is the limiting nutrient in this water type, there is a lower risk of algae generation. There is no default WQO set for TSS but the baseline concentration is 40 mg/l, 2.5 times higher than the concentration in Sandy Creek.

These observations suggest that untreated water in the Talbragar River is only suitable for irrigation (short term). However, with basic treatment it could be suitable for livestock water supply and irrigation long term.

The procedure for using this baseline concentration data generated from the model to set customised WQOs is detailed in Section 2. The summary above shows that arsenic, cadmium, chromium, copper, nickel, selenium and zinc do not require customised WQOs, as baseline concentrations are below the default WQOs for all EVs. However, aluminium, iron, total nitrogen and TSS require customised WQOs for both the SW3 (Sandy Creek) and SW4 (Talbragar River) sites because default WQOs are exceeded for these parameters. In addition, customised WQOs are required for manganese and TDS at SW3 and total phosphorus at SW4. The customised WQOs are given in Table 3-1.

Table 3-1 Customised WQOs for SW3 and SW4

Parameter	Customised Water Quality Objectives (mg/L)	
	SW3	SW4
Total suspended solids (TSS)	34	202
Total dissolved solids (TDS)	1,978	-*
Total nitrogen	0.9	2.7
Total phosphorus	-*	0.5
Aluminium	0.5	8.4
Iron	1.5	10.2
Manganese	2.1	-*

* Default WQO values were used

3.1.3.2 Operational scenario results and impact assessment

Estimated chemical concentrations at SW3 (Sandy Creek) and SW4 (Talbragar River) during the five mine stages are shown in Figure 3-3. Six parameters were selected for in-depth analysis because they exceeded the default WQOs during baseline modelling and experience suggests that these have the potential to increase during mine operation.

The main observations made from the modelling results of chemical concentration change due to mining operations are:

- A maximum increase in concentrations of 5% above baseline conditions for TDS is predicted for SW4, as shown in Figure 3-3.. The increased TDS at SW4 remains well below the customised WQO at this site.
- There is no change in compliance with customised WQOs at SW4 for all mining years.
- A maximum increase in concentrations of 52% above baseline conditions for TDS is predicted for SW3. The TDS concentrations during operational years exceed the most stringent customised WQO by 6 to 8%.
- Maximum increases in concentrations of 34% and 19% above baseline conditions are predicted for TN and TP respectively at SW3. The TN concentrations during operational years exceed the most stringent customised WQO by 1% only. The TP concentrations remain below the customised WQOs for the site.

- Concentrations of Mn, TDS and TN are consistently lower in the Talbragar than in Sandy Creek. Conversely Aluminium, TP and TSS are higher in the Talbragar.

Comparing these estimated concentrations with the customised WQOs (see Appendix B.2):

- SW3 is below the customised WQOs for irrigation (both STV and LTV) uses.
- SW3 is below the customised WQOs for contact recreation and livestock apart from the elevated TDS.
- SW3 is below the customised WQO's for aquatic ecosystems apart from TN which is iust exceeded by 1% for years 12 and 20.
- SW4 is below the customised WQOs for all EVs.

Model predictions suggest that SW3 (Sandy Creek) will be impacted to a larger degree than SW4 (Talbragar River), particularly in relation to elevated concentrations of TDS, TN and TP. Note that TN and TP values used for the analyses were based on groundwater bore concentrations in the absence of measured data from surface runoff. Since the Project will change the land use from livestock pasture to mining, nutrient loads in the form of TN and TP concentrations are likely to significantly reduce over the life of the mine.

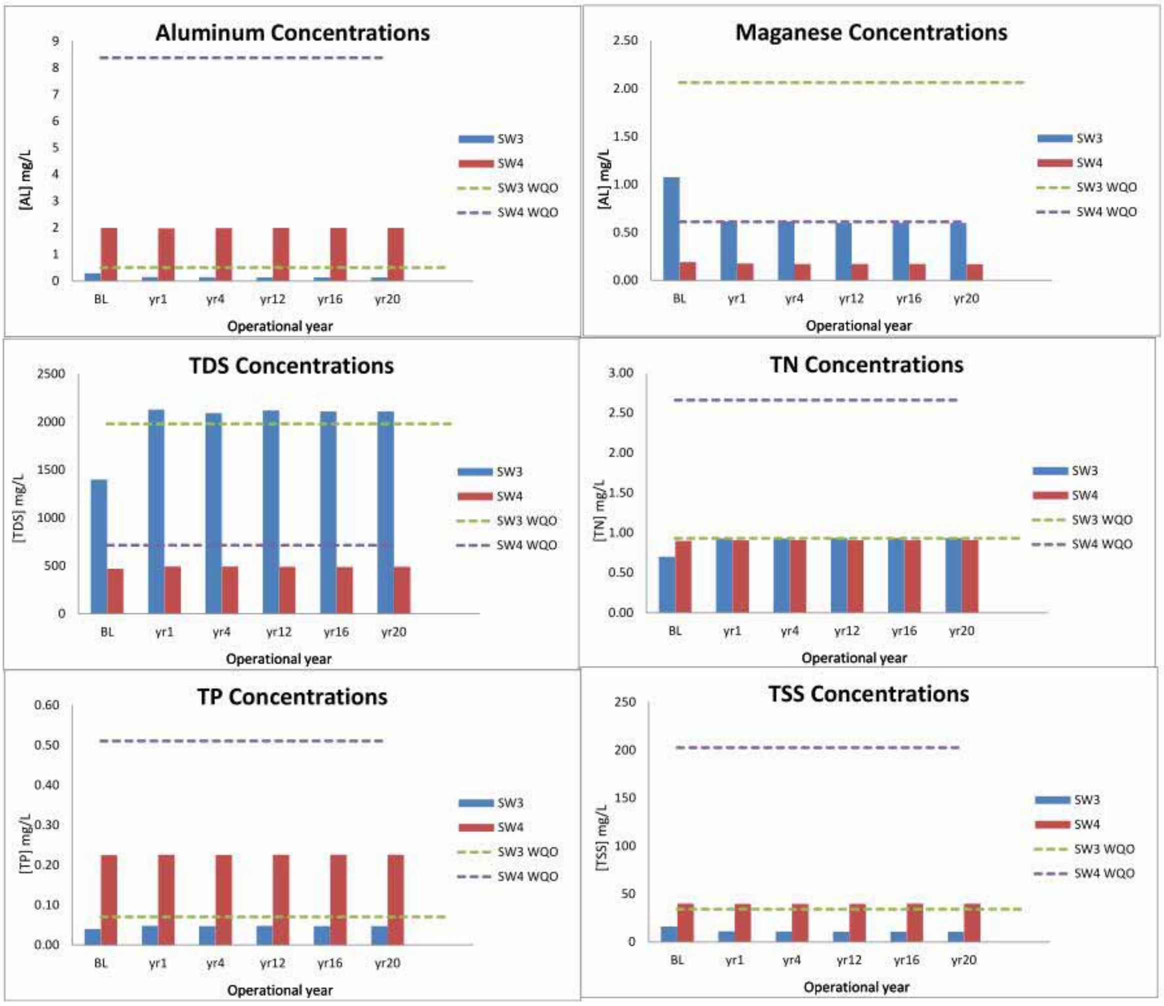


Figure 3-3 Model-predicted changes in chemical concentration at SW3 (Sandy Creek) and SW4 (Talbragar River) during the Project

3.1.3.3 Post mining impacts

The *Downstream Flow Impact Assessment* identified that there will be an increase in flows in the receiving creek systems in the post mining case of up to 12% in dry years (with lesser increases in average and wet years) due to changes in catchment characteristics and topography of the final landform. The *Groundwater Assessment* (PB, 2103) identified that there is a reduced likelihood of dryland salinity during and post mining due to induced drawdown in groundwater levels and increased recharge through backfilled areas. The increased creek flows will ensure higher dilution of salt in the watercourses and this in combination with the reduced likelihood of dryland salinity should ensure that there are no long term adverse impacts on salinity levels in the downstream catchments. The *Water Balance and Surface Water Management System* report shows that the final void lake in mining area B will act as a groundwater sink and will not overflow to the surface water system under a broad range of climatic scenarios, taking into account uncertainty in the key factors that govern the water balance of the final void lake.

The combination of these factors ensures that there will be no long term adverse water quality impacts in the creeks from the final rehabilitated landform.

4. Mitigation measures

4.1 General mitigation measures

A number of general or industry best practice mitigation measures have been recommended to minimise or avoid potential impacts of the Project on the surrounding surface water environment. These measures are discussed in detail in the *Water Balance and Surface Water Management System Repo*rt and *Surface Water Assessment* reports.

A more specific mitigation measure relates to the application of project-specific discharge criteria to any water discharged from the Project to the surrounding environment. A discussion of the water quality discharge criteria recommended for the Project, as applied to sedimentation dam discharges, is provided below.

4.2 Sedimentation dam performance criteria

In accordance with the *Water Balance and Surface Water Management System Report*, sedimentation dams will return treated surplus water to the adjacent creeks. During discharge events, it will be necessary to set performance criteria to protect water quality conditions in the receiving watercourses.

A goal seek function in Microsoft Excel was used to assess the response of Sandy and Laheys Creeks to increases/decreases in sedimentation dam contributions. By increasing the sedimentation dam chemical loads to a level whereby the customised WQOs for that watercourse were reached, a 'tolerable' load was determined.

This sensitivity analysis process found that there was a 1:1 relationship between input and response, possibly because the composition of water from the sedimentation dams was similar to that of the receiving watercourses. On this basis, the most stringent customised WQOs have been recommended as the Project discharge limits, rounded to the nearest significant figure (Table 4-2).

Exceptions to this approach were made for TSS and TDS. For TSS the most stringent customised WQO would require a discharge limit of 30 mg/L, which is not considered feasible. Instead a limit of 50 mg/L is proposed, which would improve baseline conditions in the Talbragar River and is a generic limit for managed discharges from sediment basins in Environment Protection Licences for mining projects.

Due to the sensitivity of salt loads in the catchment, more detailed consideration was given to TDS. Baseline TDS concentrations determined from the water quality mass-balance model were reviewed and are presented in Table 4-1.

Table 4-1 Modelled baseline TDS concentrations

Site	TDS concentrations (mg/L)		
	Minimum	Median	Maximum
SW1	522	1510	6000
SW2	354	3230	4900
SW3	412	1400	2290
SW4	252	469	1520
SW5	184	423	710

The minimum modelled baseline concentrations were used to set proposed performance criteria for TDS for sedimentation dams as follows:

- The results of the leachate sampling predicted that the overburden would contain low to moderate salinity (low $EC_{1:2}$ median of 238 µS/cm). Inflow to the sedimentation dams during high rainfall events will dilute salt levels below this value.
- The minimum modelled baseline concentrations in the receiving watercourses will result from dilution during flow events. This is also when sedimentation dams are likely to discharge into the creeks.
- To safeguard the receiving environment, a 50%-ile TDS limit is therefore proposed based on minimum concentrations modelled for Laheys Creek (which are lower than those modelled for Sandy Creek), with a 100%-ile limit set based on other similar sites.

Overall, discharge from sedimentation dams will be infrequent. Until trigger levels are established based on actual measured discharge concentrations, interim limits based on stringent WQO's and standard best practice for other mine sites as shown in Table 4-3 should ensure water quality conditions in the receiving watercourses are not adversely affected.

Table 4-2 Proposed sedimentation dam performance criteria

Parameter	Concentration limits (mg/L)	
	50^{th} %ile	100^{th} %ile
Aluminium	N/A	0.5
Iron	N/A	1.5
Manganese	N/A	2.0
pH*	N/A	6.5 -8.5
TDS	350^{+}	600^{+}
TN	N/A	0.9
TP	N/A	0.5
TSS	N/A	50

(* based on default local EV, Section 2.2.2; $^{+}$ equivalent to approximately 550 and 940 µS/cm, respectively)

Tests for pH, TDS and TSS can be performed rapidly on-site with portable equipment. The testing for these parameters should therefore be undertaken to confirm performance adequacy during storms when dams reach full capacity. For more involved laboratory analysis of metals and nutrients, a quarterly sample should be sufficient, but this should be reviewed based on the first sample sets. This testing is only required when water is displaced to Sandy Creek, Laheys Creek or the Talbragar River. If these limits are found to be exceeded in samples, a series of management responses should be triggered which will be detailed in the operational Water Management Plan for the Project.

To achieve the 50 mg/l limit for TSS, a flocculant may be required. This could include salt, ferric chloride or sulphate, gypsum, alum or PACs/PAMs. Selection of suitable flocculant would be on the basis of effectiveness, dosing rate required and potential toxicity to a waterflea, fish and freshwater alga species relevant for the area. If alum is selected, pH would need to be monitored and controlled to avoid aluminium toxicity outside of the 5.5 – 7.5 pH solubility range. By reducing the sediment load, an associated reduction in total nutrient and metal load should also be achieved, due to the affinity for these contaminants to the particulate phase.

Additional management responses to elevated metals and also acidity in sedimentation basins may include, but not be limited to, diversion of overburden runoff to the dirty water dam, dilution / blending with alternative higher quality water prior to discharge or increased pumping of contaminated water from the sedimentation dams to the dirty water dams.

5. Cumulative impacts

Cumulative impacts arise due to the influence of other construction and development activities in the local area. Any such activities have the potential to compound or exacerbate the specific impacts of the Project, thereby forming a cumulative impact.

Other projects in the region include Ulan, Moolarben and Wilpinjong Mines. Moolarben and Wilpinjong Mines are located within catchments that drain east into the Goulburn River, hence are not relevant to this assessment.

The Ulan Mine, however, is located on top of the Great Dividing Range and runoff from this mine flows in both directions, eastwards to the Goulburn River but also northwards into both Mona and Cockabutta Creeks. These two creeks subsequently flow into the Talbragar, approximately 35 and 25 km upstream, respectively, of the Sandy Creek confluence with the Talbragar River.

The Ulan Coal Mine was therefore considered as a potential contributor to cumulative impacts in combination with this Project.

5.1 Ulan project overview

The Ulan Mine Complex is one of the most established coal mining operations in the western coalfields of NSW (Xstrata, 2012). The Ulan Mine Complex lies within the Mid-Western Regional Council (MWRC) Local Government Area, located near the village of Ulan in the central west of NSW, approximately 45 kilometres north-north-east of Mudgee and 25 kilometres north-east of Gulgong. The Ulan Mine Complex covers an approximate area of 17,959 hectares and is located at the headwaters of the Goulburn and Talbragar River catchments.

In November 2010, Ulan Coal Mining Limited was granted Project Approval (08_0184) from the NSW Department of Planning, for the continuation of existing and new underground longwall mining and open cut activities to produce up to 20 Mtpa of product coal from its mining operations for the next 21 years (Xstrata, 2012).

5.2 Potential impacts

The water quality impact assessment for the Ulan Mine focussed on changes to TDS in the Talbragar River. The statement concluded that the project would have a negligible effect on the river due to the implementation of a wastewater treatment process to meet prescribed discharge standards. The baseline surface water monitoring program implemented as part of this assessment (refer to the *Baseline Hydrological Environment* report) included almost one year's worth of data that would have taken into account any effects associated with the operation of the Ulan Mine, since project approval was awarded. The water quality model for the OL case predicted a maximum 5% increase in TDS values in the Talbragar River above the baseline case, which is still below the default WQO set for the Macquarie-Bogan catchment.
The cumulative impact of the Project on the Talbragar River is therefore deemed insignificant.

6. Conclusions

This report has assessed the impact of mine operation on water quality within the Sandy Creek catchment and further downstream in the Talbragar River. The relevant environmental values and default water quality objectives for the Macquarie-Bogan Catchment were reviewed. This resulted in the development of customised water quality objectives for the Project for those parameters where baseline concentrations exceeded the default water quality objectives.

The potential impacts of the Project were assessed using a mass-balance model to predict potential changes in the water quality of local watercourses over several operational stages of the mine. The main impacts were localised to Sandy Creek, with elevated levels of nutrients and TDS predicted in all operational years. The impacts on these parameters in the Talbragar River were assessed to be minor due to the larger catchment size and flows.

The final rehabilitated landform will not result in adverse impacts on water quality in the downstream catchments due to increased flows providing enhanced dilution, the reduced likelihood of dryland salinity and the isolation of the final void lake at mining area B from the adjacent surface water environment.

The potential cumulative impacts of the Project on the water quality in the Talbragar River, considering the operation of the existing Ulan Mine upstream of the confluence of Sandy Creek with the Talbragar River, were deemed to be negligible.

7. References

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Appendix B.1

Water quality model data sources and assumptions

B1 Data Sources

- Daily Flow data along Sandy Creek and Laheys Creek was supplied by AWBM model described in the Water Balance and Surface Water Management system Technical Report.
- Daily flow from sedimentation dams into streams was supplied by AWBM model.
- Flow data along the Talbragar River at SW4 was supplied by Office of Water gauge 421042 (Talbragar at Elong Elong).
- Baseline metals and nutrient concentrations in the streams were supplied by ALS monthly routine monitoring over the period of September 2009-November 2011 at SW1, SW2, SW3, SW4 and SW5.
- Metal concentrations entering sedimentation dams were supplied by a previous geochemical report (Geoterra, 2010).
- Nutrient concentrations entering the sedimentation dams were supplied by groundwater monitoring (PB, 2012).

B2 Assumptions

The following assumptions have been made in constructing this water quality model:

- The chemical concentration over the sampling period of September 2009-November 2011 was taken to be representative of the total range in baseline concentrations for low flow to high flow events.
- Chemical concentration percentiles of 50 and 80 were determined from the 2nd year of monthly sampling data and represent the expected ranges in concentration.
- Concentrations that were below the limit of detection were taken to be half of what the value was that they were less than (i.e. <0.01 became 0.005).
- Minor tributaries were assumed to have no significant impact to the water quality of Laheys creek, Sandy Creek and the Talbragar River.
- The west Woolandra farm dams with a combined capacity of approximately 1,460 ML in the Laheys Creek catchment were included in the baseline flow and calculation of baseline load for BL2.
- Flow data for SW5 did not exist therefore it was found using SW4 (office of water gauge data) subtracted by SW3 (AWBM downstream confluence sandy creek data).
- The chemical load at upstream Talbragar River BL5 was calculated by subtracting the downstream chemical load at the Talbragar River (BL4) by the downstream of the confluence of Sandy Creek (SW3). Where the case occurred that BL3>BL4 and a negative load was found the load for BL5 was assumed to be the same as BL4.
- From BL4 load assumption a new flow was found at SW4. This was found using the daily peak flow from the modelled parameters excluding manganese and TDS.
- The new SW4 flow resulted in a new loading at BL4 and BL5.

- Sedimentation dams entering the same stream were combined for volume, surface area and discharge.

- There is no mixing in the sedimentation dams between the settling zone and the sediment zone.

- Chemical concentrations entering the sedimentation dams was considered to be the same as chemical loads found in overburden runoff from elutriate testing in Geoterra (2010). Land use was not taken into consideration.

- Inflow into the sedimentation dams is unknown. Therefore, the volume of the settling zone in the sedimentation dam was used to determine the outflow concentration of the chemicals.

- TSS from the sedimentation dams was found using the average concentration from baseline creek data during ‘no flow’ periods.

- For the operational case OL4=baseline BL5 + operational OL3.

- Sedimentation dams can discharge 1/5 of the settlement zone volume.

Appendix B.2

Model results of chemical concentration

Table B2.1 Fitness for use for primary/secondary contact recreation at SW3 (Sandy Creek)

SW3	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	TDS (mg/L)
secondary/Primary contact recreation	0.20	0.0500	0.0050	0.050	1.000	0.30	0.1000	0.010	5.000	1000
BL3 median	0.29	0.0005	0.00005	0.001	0.001	0.89	0.0025	0.005	0.003	1400
diff from ANZECC	out	0.0500	0.0050	0.050	1.000	out	0.1000	0.010	5.000	out
WQO	**0.50**	**0.0500**	**0.0050**	**0.050**	**1.000**	**1.46**	**0.1000**	**0.010**	**5.000**	**1978**
OL3 median yr1	0.15	0.0016	0.00005	0.001	0.002	0.78	0.0021	0.005	0.078	2128
OL3 median yr4	0.14	0.0015	0.00005	0.001	0.002	0.78	0.0020	0.005	0.003	2093
OL3 median yr12	0.14	0.0014	0.00005	0.001	0.002	0.77	0.0020	0.005	0.003	2120
OL3 median yr16	0.13	0.0014	0.00005	0.001	0.002	0.77	0.0020	0.005	0.003	2110
OL3 median yr20	0.13	0.0014	0.00005	0.001	0.002	0.77	0.0020	0.005	0.003	2110

Table B2.2 Fitness for use for livestock water supply at SW3 (Sandy Creek)

SW3	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	TDS (mg/L)
Livestock water supply	5.00	0.5000	0.0100	1.000	5.000	1.000	0.020	20.000	2000
BL3 median	0.29	0.0005	0.00005	0.001	0.001	0.0025	0.005	0.003	1400
diff from ANZECC	5.00	0.5000	0.0100	1.000	5.000	1.000	0.020	20.000	2000
WQO	**5.00**	**0.5000**	**0.0100**	**1**	**5.000**	**1.000**	**0.020**	**20.000**	**2000**
OL3 median yr1	0.15	0.0016	0.0001	0.001	0.002	0.002	0.005	0.078	2128
OL3 median yr4	0.14	0.0015	0.0001	0.001	0.002	0.002	0.005	0.003	2093
OL3 median yr12	0.14	0.0014	0.0001	0.001	0.002	0.002	0.005	0.003	2120
OL3 median yr16	0.13	0.0014	0.0001	0.001	0.002	0.002	0.005	0.003	2110
OL3 median yr20	0.13	0.0014	0.0001	0.001	0.002	0.002	0.005	0.003	2110

Legend

Concentration within custom water quality objective guidelines
Concentration equal to custom water quality objective guidelines
Concentration outside custom water quality objective guidelines
Unable to compare concentration to NOW water quality objective guidelines

Table B2.3 Fitness for use for irrigation STV at SW3 (Sandy Creek)

SW3	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Irrigation STV	20	2	0.05	1	5	10	10	2	0.05	5	25	0.8
BL3 median	0.29	0.0005	0.00005	0.0005	0.001	0.89	1.075	0.0025	0.005	0.0025	0.7	0.04
diff from ANZECC	20	2	0.05	1	5	10	10	2	0.05	5	25	0.8
WQO	**20**	**2**	**0.05**	**1**	**5**	**10**	**10**	**2**	**0.05**	**5**	**25**	**0.8**
OL3 median yr1	0.146	0.002	0.000	0.001	0.002	0.780	0.617	0.002	0.005	0.078	0.928	0.048
OL3 median yr4	0.141	0.001	0.000	0.001	0.002	0.777	0.615	0.002	0.005	0.003	0.927	0.047
OL3 median yr12	0.136	0.001	0.000	0.001	0.002	0.773	0.598	0.002	0.005	0.003	0.936	0.047
OL3 median yr16	0.135	0.001	0.000	0.001	0.002	0.772	0.598	0.002	0.005	0.003	0.935	0.047
OL3 median yr20	0.135	0.001	0.000	0.001	0.002	0.772	0.598	0.002	0.005	0.003	0.935	0.047

Table B2.4 Fitness for use for irrigation LTV at SW3 (Sandy Creek)

SW3	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Irrigation LTV	5.00	0.1000	0.01000	0.100	0.200	0.20	0.20	0.200	0.020	2.000	5.00	0.05
BL3 median	0.29	0.0005	0.00005	0.001	0.001	0.89	1.08	0.003	0.005	0.003	0.70	0.04
diff from ANZECC	5.00	0.1000	0.01000	0.100	0.200	out	out	0.200	0.020	2.000	5.00	0.05
WQO	**5.00**	**0.1000**	**0.01000**	**0.100**	**0.200**	**1.46**	**2.06**	**0.200**	**0.020**	**2.000**	**5.00**	**0.05**
OL3 median yr1	0.15	0.0016	0.00005	0.001	0.002	0.78	0.62	0.002	0.005	0.078	0.93	0.05
OL3 median yr4	0.14	0.0015	0.00005	0.001	0.002	0.78	0.61	0.002	0.005	0.003	0.93	0.05
OL3 median yr12	0.14	0.0014	0.00005	0.001	0.002	0.77	0.60	0.002	0.005	0.003	0.94	0.05
OL3 median yr16	0.13	0.0014	0.00005	0.001	0.002	0.77	0.60	0.002	0.005	0.003	0.93	0.05
OL3 median yr20	0.13	0.0014	0.00005	0.001	0.002	0.77	0.60	0.002	0.005	0.003	0.94	0.05

Legend

- Concentration within custom water quality objective guidelines
- Concentration equal to custom water quality objective guidelines
- Concentration outside custom water quality objective guidelines
- Unable to compare concentration to NOW water quality objective guidelines

Table B2.5 Fitness for use for aquatic ecosystems at SW3 (Sandy Creek)

SW3	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
Aquatic Ecosystems	0.20	0.02	
BL3 median	0.70	0.04	16
diff from ANZECC	out	out	out
WQO	**0.93**	**0.07**	**34**
OL3 median yr1	0.93	0.05	11
OL3 median yr4	0.93	0.05	11
OL3 median yr12	0.94	0.05	11
OL3 median yr16	0.93	0.05	11
OL3 median yr20	0.94	0.05	11

Legend

- Concentration within custom water quality objective guidelines
- Concentration equal to custom water quality objective guidelines
- Concentration outside custom water quality objective guidelines
- Unable to compare concentration to NOW water quality objective guidelines

Table B2.6 Fitness for use for primary / secondary contact recreation at SW4 (Talbragar River)

SW4	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	TDS (mg/L)
secondary/Primary contact recreation	0.20	0.050	0.0050	0.050	1.000	0.30	0.100	0.010	5.000	1000
BL4 median	1.99	0.001	0.0001	0.004	0.004	2.23	0.009	0.005	0.008	469
diff from ANZECC	out	0.050	0.0050	0.050	1.000	out	0.100	0.010	5.000	1000
WQO	**8.37**	**0.050**	**0.0050**	**0.050**	**1.000**	**10.18**	**0.100**	**0.010**	**5.000**	**1000**
OL4 median yr1	1.98	0.001	0.0001	0.004	0.004	2.22	0.008	0.005	0.016	492
OL4 median yr4	1.98	0.001	0.0001	0.004	0.004	2.23	0.008	0.005	0.008	493
OL4 median yr12	1.99	0.001	0.0001	0.004	0.004	2.23	0.009	0.005	0.008	490
OL4 median yr16	1.99	0.001	0.0001	0.004	0.004	2.23	0.009	0.005	0.008	489
OL4 median yr20	1.99	0.001	0.0001	0.004	0.004	2.23	0.009	0.005	0.008	490

Table B2.7 Fitness for use for livestock water supply at SW4 (Talbragar River)

SW4	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	TDS (mg/L)
Livestock water supply	5.00	0.500	0.0100	1.000	5.000	1.000	0.020	20.000	2000
BL4 median	1.99	0.001	0.0001	0.004	0.004	0.009	0.005	0.008	469
diff from ANZECC	5.00	0.500	0.0100	1.000	5.000	1.000	0.020	20.000	2000
WQO	**5.00**	**0.500**	**0.0100**		**5.000**	**1.000**	**0.020**	**20.000**	**2000**
OL4 median yr1	1.98	0.001	0.0001	0.004	0.004	0.008	0.005	0.016	492
OL4 median yr4	1.98	0.001	0.0001	0.004	0.004	0.008	0.005	0.008	493
OL4 median yr12	1.99	0.001	0.0001	0.004	0.004	0.009	0.005	0.008	490
OL4 median yr16	1.99	0.001	0.0001	0.004	0.004	0.009	0.005	0.008	489
OL4 median yr20	1.99	0.001	0.0001	0.004	0.004	0.009	0.005	0.008	490

Legend

- Concentration within custom water quality objective guidelines
- Concentration equal to custom water quality objective guidelines
- Concentration outside custom water quality objective guidelines
- Unable to compare concentration to NOW water quality objective guidelines

Table B2.8 Fitness for use for irrigation STV at SW4 (Talbragar River)

SW4	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Irrigation STV	20.00	2.000	0.0500	1.000	5.000	10.00	10.00	2.000	0.050	5.000	25.00	0.80
BL4 median	1.99	0.001	0.0001	0.004	0.004	2.23	0.19	0.009	0.005	0.008	0.90	0.23
diff from ANZECC	20.00	2.000	0.0500	1.000	5.000	10.00	10.00	2.000	0.050	5.000	25.00	0.80
WQO	**20.00**	**2.000**	**0.0500**	**1.000**	**5.000**	**10.00**	**10.00**	**2.000**	**0.050**	**5.000**	**25.00**	**0.80**
OL4 median yr1	1.98	0.001	0.0001	0.004	0.004	2.22	0.18	0.008	0.005	0.016	0.91	0.23
OL4 median yr4	1.98	0.001	0.0001	0.004	0.004	2.23	0.17	0.008	0.005	0.008	0.91	0.23
OL4 median yr12	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.009	0.005	0.008	0.91	0.23
OL4 median yr16	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.009	0.005	0.008	0.91	0.23
OL4 median yr20	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.009	0.005	0.008	0.91	0.23

Table B2.9 Fitness for use for irrigation LTV at SW4 (Talbragar River)

SW4	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Irrigation LTV	5.00	0.100	0.0100	0.100	0.200	0.20	0.20	0.200	0.020	2.00	5.00	0.05
BL4 median	1.99	0.001	0.0001	0.004	0.004	2.23	0.19	0.009	0.005	0.01	0.90	0.23
diff from ANZECC	5.00	0.100	0.0100	0.100	0.200	out	0.20	0.200	0.020	2.00	5.00	out
WQO	**5.00**	**0.100**	**0.0100**	**0.100**	**0.200**	**10.18**	**0.20**	**0.200**	**0.020**	**2.00**	**5.00**	**0.51**
OL4 median yr1	1.98	0.001	0.0001	0.004	0.004	2.22	0.18	0.008	0.005	0.02	0.91	0.23
OL4 median yr4	1.98	0.001	0.0001	0.004	0.004	2.23	0.17	0.008	0.005	0.01	0.91	0.23
OL4 median yr12	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.009	0.005	0.01	0.91	0.23
OL4 median yr16	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.009	0.005	0.01	0.91	0.23
OL4 median yr20	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.009	0.005	0.01	0.91	0.23

Legend

- Concentration within custom water quality objective guidelines
- Concentration equal to custom water quality objective guidelines
- Concentration outside custom water quality objective guidelines
- Unable to compare concentration to NOW water quality objective guidelines

Table B2.10 Fitness for use for aquatic ecosystems at SW4 (Talbragar River)

SW4	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
secondary/Primary contact recreation	0.20	0.02	
BL4 median	0.90	0.23	40
diff from ANZECC	out	out	out
WQO	**2.66**	**0.51**	**202**
OL4 median yr1	0.91	0.23	40
OL4 median yr4	0.91	0.23	40
OL4 median yr12	0.91	0.23	40
OL4 median yr16	0.91	0.23	40
OL4 median yr20	0.91	0.23	40

Legend
Concentration within custom water quality objective guidelines
Concentration equal to custom water quality objective guidelines
Concentration outside custom water quality objective guidelines
Unable to compare concentration to NOW water quality objective guidelines

Appendix C

Cobbora Coal Project –
Downstream Flow Impact
Assessment

Cobbora Coal Project - Downstream Flow Impact Assessment

January 2013

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Signed: .... Rob Leslie

Approved by: ....Rob Leslie

Signed: .... Rob Leslie ......

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Glossary

AWBM	Australian Water Balance Model
FDC	Flow Duration Curve
NOW	NSW Office of Water
WSP	Water Sharing Plan

1. Introduction

This report assesses the impact of the Project on creek flows in the Sandy Creek catchment where the mining areas are located and downstream in the Talbragar River system, which receives flow from the Sandy Creek catchment.

1.1 Scope of assessment

For the purposes of the assessment, the assessment area includes all potential receptors defined as those watercourses that drain the proposed mining areas and are likely to receive discharges from these areas, i.e. Sandy Creek and Laheys Creek, and the downstream system of the Talbragar River through to the Macquarie River and Macquarie Marshes.

The assessment also reviews the significance of the watercourses in the mining areas in terms of their relative flow contributions to the downstream river system.

It is important to note that the raw water supply for the Project will include licensed river extraction from the Macquarie and Cudgegong Regulated Rivers system. Cobbora Holding Company Pty Limited (CHC) has purchased (high security) Water Access Licences (WALs) from this water source in accordance with the relevant Water Sharing Plan.

To secure these WALs, a detailed impact assessment was prepared by the NSW Office of Water (NOW) before approval for the WALs was granted by the Minister in June 2011. This assessment considered potential flow impacts in the Macquarie and Cudgegong Regulated Rivers and concluded that the proposed extraction would not adversely affect downstream water users. No further discussion or analysis of this matter has therefore been included in this assessment. Please refer to Section 4.3 of the *Surface Water Assessment* report for further details.

2. Catchment overview

This section provides an overview of the broader catchment within which the Project is located. More detailed descriptions of the regional catchments and water bodies are provided in *Baseline Hydrological Environment*.

The Project is located within the upper catchment of the Macquarie River, which flows into the Macquarie Marshes, a region of national environmental significance, approximately 600 km downstream of the Project area.

The Macquarie Marshes are one of the largest semi-permanent wetlands in south-eastern Australia. Parts of the marshes are listed:

- under the Ramsar Convention, as a National Trust Landscape Conservation Area
- on the Australian Heritage Commission's Register of the National Estate
- in the Directory of Important Wetlands in Australia.

The marshes are fed by the Macquarie River. The Macquarie River and its largest tributary, the Cudgegong River, are regulated rivers. The volume and pattern of flows are largely controlled by a series of man-made structures including Windamere Reservoir on the upper Cudgegong River and Burrendong Reservoir on the Macquarie River. These structures have altered the frequency, extent and duration of inundation in the Macquarie Marshes.

The regulation of these rivers is governed by the *Water Sharing Plan (WSP) for the Macquarie and Cudgegong Regulated River Water Source 2003*. The WSP provides water for environmental needs and directs how much water is available for extraction and how it is to be shared. While the Macquarie Marshes are not part of the WSP area, the WSP includes rules about the release of flows to improve environmental outcomes for the marshes.

The WSP limits the long term annual average extraction from the Macquarie-Cudgegong system to 391 GL/year. All flows above this are reserved for the environment. In the long-term, approximately 73% of the average annual flow is protected for environmental health. Water extraction is managed to ensure that these long-term environmental flows are protected.

The mining area will be adjacent to Sandy Creek and its tributary, Laheys Creek. In the absence of appropriate controls, the Project has the potential to impact these two ephemeral creeks and smaller tributaries flowing into them. Sandy Creek flows into the Talbragar River on the western side of the assessment area. After approximately 60 km, the Talbragar River flows into the Macquarie River approximately 8 km downstream of Dubbo. The Macquarie River flows into the Macquarie Marshes 540 km downstream of this confluence.

3. Catchment flow contributions

3.1 Water budget for the Cudgegong-Macquarie River System

In order to assess the significance of surface water runoff in Sandy and Laheys Creeks to the regional waterbodies, a water budget was prepared for the regulated segment of the Cudgegong-Macquarie River system. This is shown diagrammatically in Figure 3-1. This figure presents mean (or average) and 50th percentile (or median) daily flow rates along the Macquarie River from Burrendong Reservoir to the Macquarie Marshes. The daily flows for the ungauged catchments were obtained from average yield per unit area measured at the reference gauging stations as summarised in Table 3-1.

Table 3-1 Gauging station catchment details and flows

Station	Watercourse	Location	Catchment area (km^2)	Start of record	End of record	50%ile exceedance flow (ML/day)	Mean flow (ML/day)
421064	Sandy Creek	Medway	260	21/09/1966	01/09/85	1	17
421042	Talbragar River	Elong Elong	3050	10/11/1964	none	41	160
421001	Macquarie River	Dubbo	19600	01/06/1885	none	1520	3050
421031	Macquarie River	Gin Gin	26940	10/11/1964	none	900	2370
421004	Macquarie River	Warren Weir	26570	01/01/1898	none	610	1870
421090	Macquarie River	Marebone Weir	not reported	17/09/1976	none	210	750
421022	Macquarie River	Oxley Station	reported as 3565 – likely to be erroneous	01/01/1941	none	330	800
421147	Macquarie River	Pillicawarrina	not reported	23/06/1987	none	150	550

The approach taken to estimate the runoff yield from ungauged catchments is described in the Section 3.2. Key findings of the water budget are discussed in Section 3.3.

3.2 Estimation of flows from ungauged catchments

To estimate flows for the ungauged catchments, the following steps were completed:

- Catchment areas were calculated using geospatial software analysis of available topographic contour and stream network data. The following should be noted with respect to the catchment area calculations:
    - Contour data was used to delineate Laheys and Sandy Creeks only. Talbragar and Macquarie Rivers were delineated using stream network and basin polygon data.
    - The Macquarie River catchment downstream of Dubbo is difficult to define because of the large number of diversions and relatively flat topography. The catchment calculation for this area was based on professional judgement.
- Long term historical flow data for a number of streamflow gauge locations were obtained from:

    a) NSW Office of Water (NOW) website for current active gauges.

    b) PINNEENA DVD database for discontinued gauges.

- Recorded mean flow values were used to calculate the flow duration curve at each gauged location.
- The flow duration curve at each site was divided by its catchment area to obtain unit flow rates.
- The unit flow duration curves were multiplied by the ungauged catchment areas to estimate the flow duration curve at the ungauged locations. It should be noted that only single flow gauges were used and no regression analysis was carried out on multiple gauges.

3.3 Water budget findings

The Sandy Creek sub-catchment is approximately 8% of the Talbragar River catchment to the Sandy Creek and Talbragar River confluence; and approximately 1% of the Macquarie River catchment to the Talbragar River and Macquarie River confluence. Therefore, the Sandy Creek sub-catchment is a very small portion of the broader Macquarie River catchment system.

Daily mean and 50th percentile (or median) flow rates are shown on the watercourse schematic in Figure 3-1, depicting flows and extraction below the two storages – Burrendong and Windamere Dams. Other data were sourced from the WSP (NSW Government, 2006) and Dam Storage Records (NSW Government WaterInfo website, 2011). Different units for flow and extracted water volumes are presented based on standard unit conventions. The flow data show the estimated flow for the entire sub-catchment, derived from the recorded flow data at the most appropriate gauging station on the watercourse.

The mean daily flow of Sandy Creek (at Medway below its confluence with Laheys Creek) is 17 ML/day. In comparison:

- The mean daily flow of the Talbragar River above its confluence with the Macquarie River at Elong Elong is estimated to be 160 ML/day based on long-term gauging station records.
- The mean daily flow of the Macquarie River at the Dubbo Gauging Station (upstream of its confluence with the Talbragar River) is estimated to be 3,050 ML/day.
- The mean daily flow of the Macquarie River at Warren Weir is estimated to be 1,870 ML/day, 61% of mean daily flow at Dubbo gauging station and lower than at Dubbo due to water extraction between these two points.
- The mean daily flow of the Macquarie River at Oxley Station is estimated to be 800 ML/day, 26% of mean annual flow at Dubbo gauging station, lower than at Warren Weir due to further water extraction between these two points.

The flow values show that the mean daily flow in Sandy Creek is approximately 11% of the mean daily flow in the Talbragar River at Elong Elong, 0.9% of the mean daily flow in the Macquarie River at Warren Weir and 2% of the mean daily flow in the Macquarie River at Oxley Station.

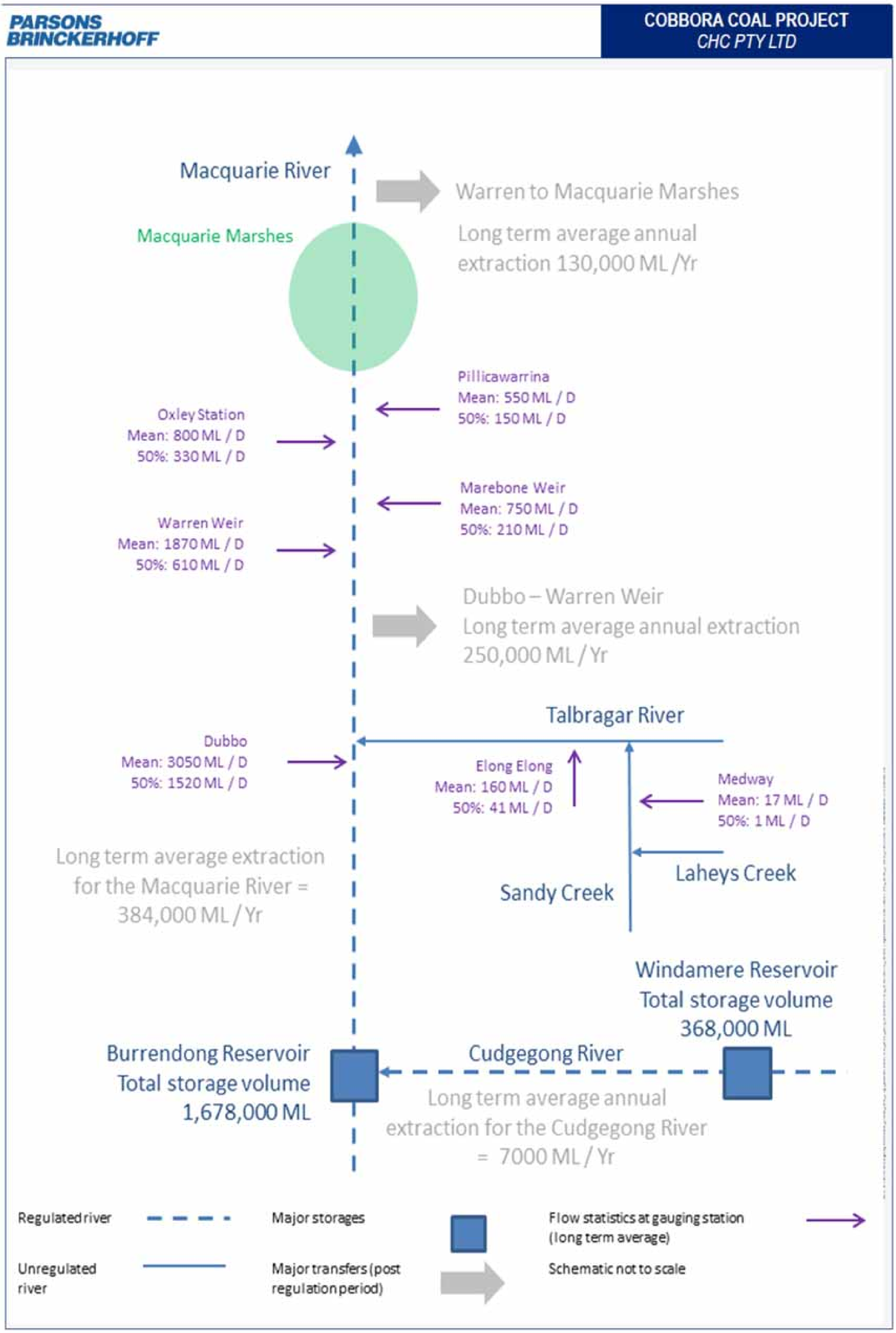

Figure 3-1 Macquarie System Water Regulation Schematic

4. Water flow objectives

The Talbragar River, Laheys Creek and Sandy Creek are within the Macquarie-Bogan River catchment. The NSW Government has developed a list of flow objectives to be used for this catchment. This Project will not extract any water from Sandy Creek, Laheys Creek or the Talbragar River but will restrict or capture a proportion of the runoff contributions from the assessment area into these watercourses. By meeting the flow objectives described for each stream, potentially adverse impacts on flows in the downstream catchments can be minimised.

Sandy Creek, Laheys Creek and the Talbragar River are all defined as 'uncontrolled streams' in that their flow pattern remains largely natural (NSW Government, 2006). NSW Government guidelines stress the importance of protecting pools in dry times, natural low flows and important rises in water levels.

Objectives for 'uncontrolled rivers' in the Macquarie-Bogan catchment can be summarised as follows:

- During periods of 'no flow' (flows exceeded 100% of the time) it is important to protect water levels in pools as these may act as refuges for aquatic plants and animals. Reduction in water levels under these conditions may make it difficult for a species to recover after a drought. The objectives state that during a period of no flow, extraction from the streams is not permitted in order to protect these pools.

- Extraction during 'very low flow' (flows exceeded 95% of the time) or 'low flows' (flows exceeded 80% of the time) imposes long artificial droughts that increase stress on aquatic plants and animals. The objectives state that extraction during very low and low flow conditions cannot be more than 30-50% of the available flow on a daily basis.

- It is important to protect 'high flows' (flows exceeded 20% of the time). Height, duration, frequency and season are all important in protecting shape of channel, water quality and reproduction of plans and animals. The objectives state that extraction during these flow conditions cannot be more than 30-50% of the available flow on a daily basis.

To identify how these quantifiable objectives translate to flows for Sandy Creek and the Talbragar River, flow duration curves (FDCs) of these two watercourses were examined. The derivation and details of these curves are described in the *Baseline Hydrological Environment* report.

Table 4-1 sets out the baseline condition flow objective values, based on the NSW Government guidelines and the Sandy Creek and Talbragar River FDCs.

Table 4-1 Baseline condition flow objective values

Flow objective	Sandy Creek		Talbragar River	
	Flow percentile/ percentile range (from FDC)	**Flow/flow range (ML/day)**	**Flow percentile/ percentile range (from FDC)**	**Flow/flow range (ML/day)**
No flow	>54%	0.006	>68%	0.030
Very low flow (Below 95% of all days with flow)	51%	0.010	65%	0.650
Low flow (Below 80% of all days with flow)	43%	0.046	54%	7.090
Extraction during low flow	30-50% of available flow	0.014-0.023	30-50% of available flow	2.127-3.545
High flow (Above 20% of all days with flow)	11%	6.795	14%	132.660
Allowable extraction during high flow	30-50% of available flow	2.039-3.398	30-50% of available flow	39.798-66.330

The following key points summarise the flow objectives:

- The no flow, very low flow, low flow and high flows for Sandy Creek are 0.006, 0.010, 0.046 and 6.795 ML/day, respectively.
- The no flow, very low flow, low flow and high flows for Talbragar River are 0.030, 0.650, 7.090 and 132.660 ML/day, respectively.
- During no flow and very low flow in both Sandy Creek and Talbragar River no extraction is permitted.
- During low flow and high flow in Sandy Creek the maximum permissible extraction would be 0.014 to 0.023 and 2.039 to 3.398 ML/day, respectively.
- During low flow and high flow in the Talbragar River the maximum permissible extraction would be between 2.127 to 3.545 and 39.798 to 66.330 ML/day, respectively.

5. Assessment of potential impacts

5.1 Mine water balance model results

The water balance assessment for the Project (refer to the *Water Balance and Surface Water Management System* report) found that, for the key rainfall reference years, the yield from Sandy Creek will increase for wet and average conditions (rainfall reference years 1990 and 1906 respectively), but decrease for dry conditions (rainfall reference year 1967) during mining operations after year 4. The order of decreases in yield for dry conditions is from 3% to 6% during mining years 4 to 20. The yield under dry conditions is increased in year 1 of operations by 7% and is also increased in the post mining case (after year 21) by 12%.

The water balance model results in terms of changed to baseline annual flow volumes at the outlet of the Sandy Creek catchment for the key rainfall reference years are given in Table 5-1.

Table 5-1 Summary of expected changes to Sandy Creek outlet creek flowsfor key rainfall reference years

Year	Annual flow (ML/yr)			Change in annual flow (ML/yr)			Change in annual flow (%)		
	10th %ile dry year (1967)	50th %ile median year (1906)	90th %ile wet year (1990)	10th %ile dry year (1967)	50th %ile median year (1906)	90th %ile wet year (1990)	10th %ile dry year (1967)	50th %ile median year (1906)	90th %ile wet year (1990)
0 (baseline)	575	1,852	26,088	-	-	-	-	-	-
1	618	1,960	27,241	43	108	1,154	+7	+6	+4
4	559	2,014	27,355	-16	161	1,267	-3	+9	+5
12	538	2,046	27,301	-37	193	1,214	-6	+10	+5
16	540	2,043	27,462	-35	191	1,374	-6	+10	+5
20	548	1,930	27,439	-27	78	1,351	-5	+4	+5
Post mining	642	1,933	28,830	67	81	2,742	+12	+4	+11

5.2 Flow impact assessment

The water balance assessment for the Project (refer to the *Water Balance and Surface Water Management System* report) indicates that, during operational years 4 to 20, the

Project will result in annual average flow volumes similar, but slightly higher, than the baseline conditions for median and wet years, and similar but slightly lower for dry years. Post mining there is a slight increase in the annual flows from Sandy Creek for all conditions due to changes to catchment topography and runoff characteristics.

This report assesses the detailed impact on the daily flow regime at the downstream Sandy Creek point (confluence of Sandy Creek and Talbragar River) and downstream at the Talbragar River point near the Elong Elong flow gauge.

Flows in Sandy Creek are based on the flows produced by the AWBM that was developed for the mine water balance analysis. For the baseline scenario, baseline flows were calibrated to actual data recorded at the Medway gauging station on Sandy Creek (refer to the *Water Balance and Surface Water Management System* report).

For the mining scenario, flows were taken from the water balance model outputs and assigned to specific reporting points on Sandy Creek and Talbragar River, following the procedure described in the *Downstream Water Quality Impact Assessment* report.
The mining scenario flows included controlled releases to the creek from sedimentation dams.

Predicted variations in flows from baseline conditions for a number of mining stages are given in Table 5-2 and 5-3 at the outlet of Sandy Creek to the Talbragar River and at the Talbragar River downstream of the Sandy Creek confluence. Figures 5-1 to 5-4 provide flow duration curves for the model nodes SW1 to SW4 comparing the baseline flow conditions to years 1 and 20 of mining.

The model results show that:

- Flows are increased across the percentile ranges in the reaches of Laheys Creek and Sandy Creek adjacent to and downstream of the mining areas, and in the Talbragar River, reflecting the overall impact of increased flow (and reduced frequency of ‘no flow’ days) due to releases from the mining areas.
- There are more significant changes to the low flow conditions than the high flow conditions.
- Flow increases are highest at year 1 and mostly significant for low flow rather than high flow conditions.
- In general, flow impacts downstream of the assessment area are minor for high flows, i.e. in the order of a 1% increase in the Talbragar River.
- Zero, low and very low flows will be slightly less frequent, particularly in the reaches of Laheys and Sandy Creeks adjacent to and downstream of the mining areas..
- Post mining the impacts on the flow regime in the creeks will be similar to the impacts experienced during mining, but with slightly higher magnitudes of increased flow across the flow range for dry and wet conditions.

Table 5-2 Flow impacts for Sandy Creek at outlet to Talbragar River

Objective	Flow percentile (from FDC)	Baseline (ML/day)	Year 1 (ML/day)	Year 1 change	Year 4 (ML/day)	Year 4 change	Year 12 (ML/day)	Year 12 change	Year 16 (ML/day)	Year 16 change	Year 20 (ML/day)	Year 20 change
No Flow	54%	0.0057	0.0141	+148%	0.0094	+64%	0.0088	+55%	0.0096	+69%	0.0067	+18%
Very Low Flow	51%	0.0103	0.0248	+141%	0.0170	+66%	0.0164	+59%	0.0182	+77%	0.0123	+19%
Low Flow	43%	0.0459	0.0998	+118%	0.0752	+64%	0.0735	+60%	0.0834	+82%	0.0566	+24%
High Flow	11%	6.7947	7.6176	+12%	8.3936	+24%	8.2947	+22%	9.2873	+37%	7.3928	+9%

Table 5-3 Flow impacts for Talbragar River at Elong Elong

Objective	Flow percentile (from FDC)*	Baseline* (ML/day)	Year 1 (ML/day)	Year 1 change	Year 4 (ML/day)	Year 4 change	Year 12 (ML/day)	Year 12 change	Year 16 (ML/day)	Year 16 change	Year 20 (ML/day)	Year 20 change
No Flow	>80%	0.0008	0.0023	+168%	0.0100	+20%	0.0010	+19%	0.0011	+27%	0.0009	+5%
Very Low Flow	76%	0.0084	0.0225	+169%	0.0107	+28%	0.0110	+32%	0.0120	+43%	0.0090	+8%
Low Flow	64%	1.0820	1.2960	+20%	1.1879	+10%	1.2017	+11%	1.2669	+17%	1.1396	+5%
High Flow	16%	115.0632	115.8615	+1%	116.4275	+1%	116.0601	+1%	116.3156	+1%	115.7048	+1%

**Note that the mass balance water quality model used to determine flow impacts modified the FDC for the Talbragar River at Elong Elong to address data inconsistencies in chemical load. This modified FDC was used in the flow impact assessment rather than the original FDC which is discussed in Section 4 and Table 4.1. Therefore, the baseline FDC flow values used in the flow impact assessment differed from the FDC derived from the Elong Elong gauge record. However, the modified values adopted are suitable for assessment of flow impacts across a range of flow categories.*

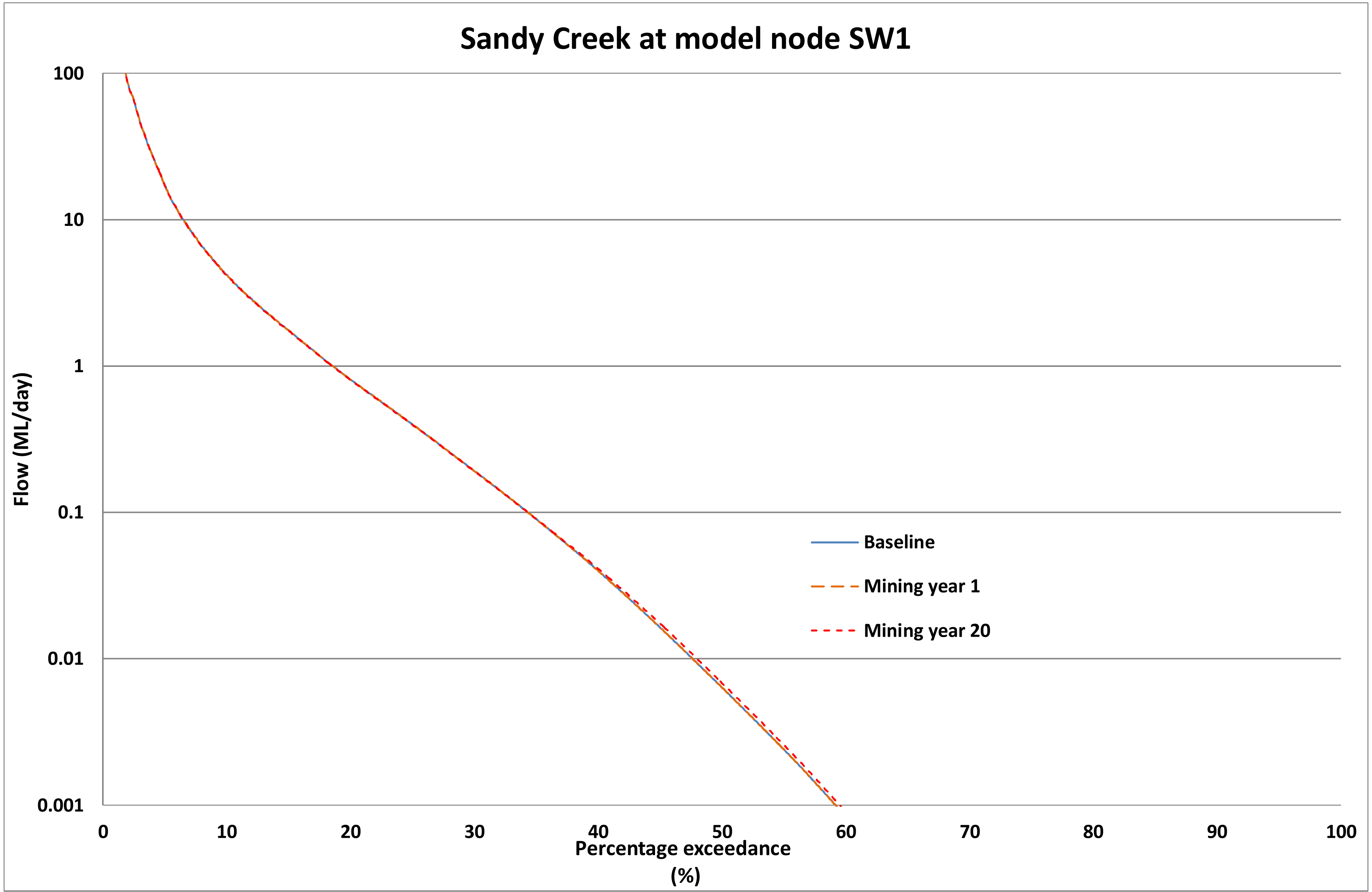

Figure 5-1 Flow duration curve for model node SW1 – Sandy Creek upstream of confluence with Laheys Creek

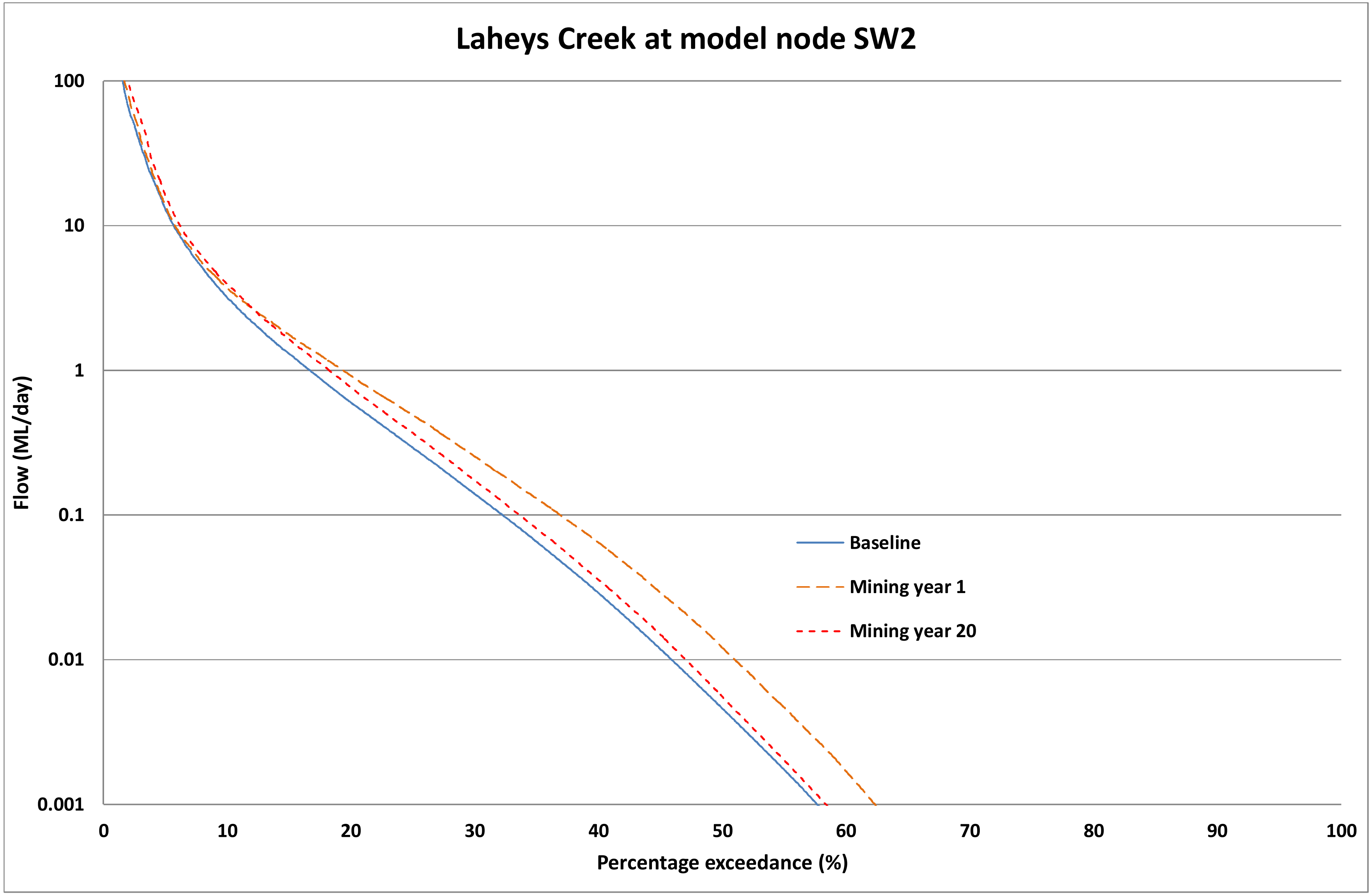

Figure 5-2 Flow duration curve for model node SW2 – Laheys Creek upstream of confluence with Sandy Creek

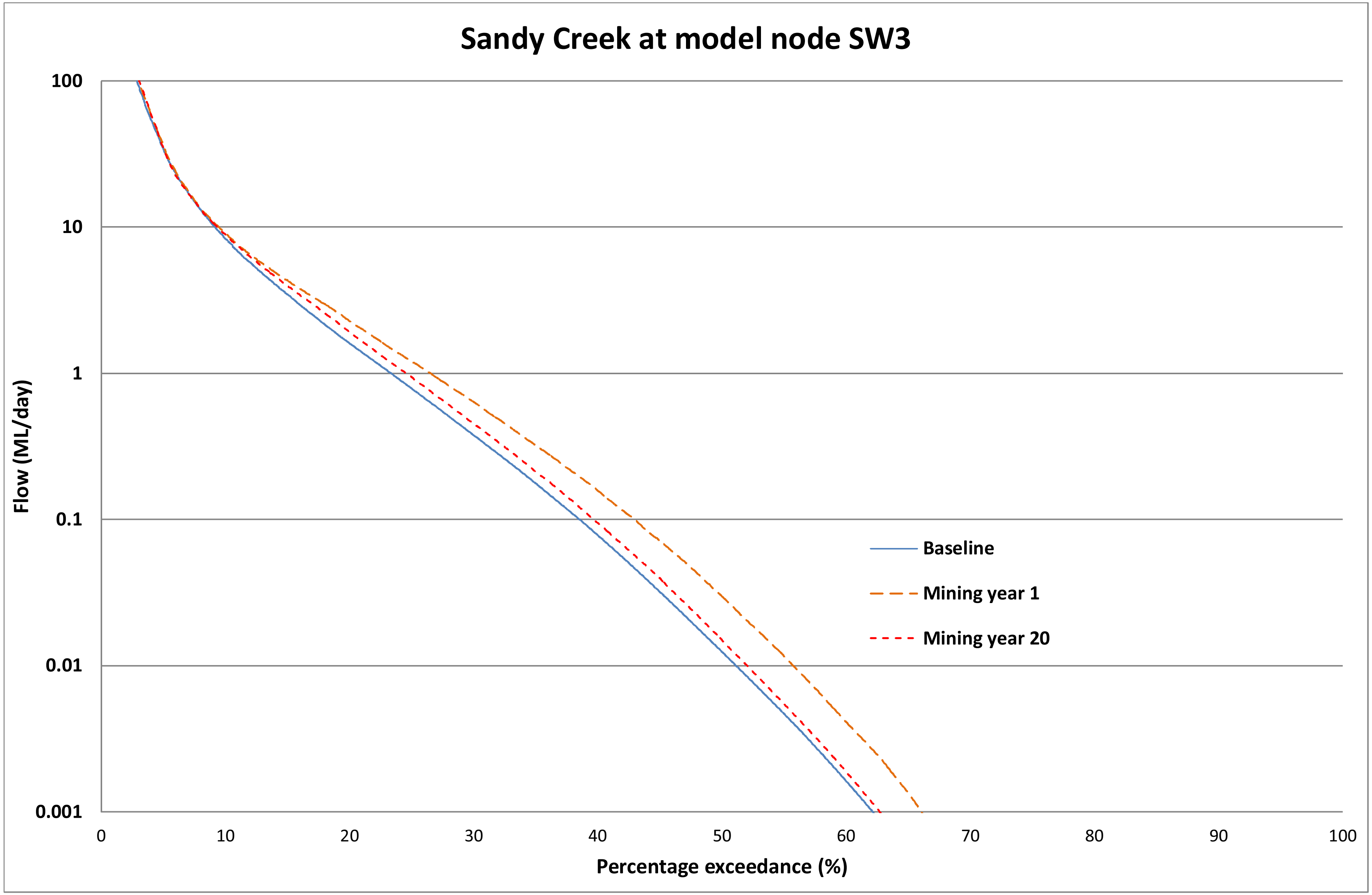

Figure 5-3 Flow duration curve for model node SW3 – Sandy Creek upstream of confluence with Talbragar River

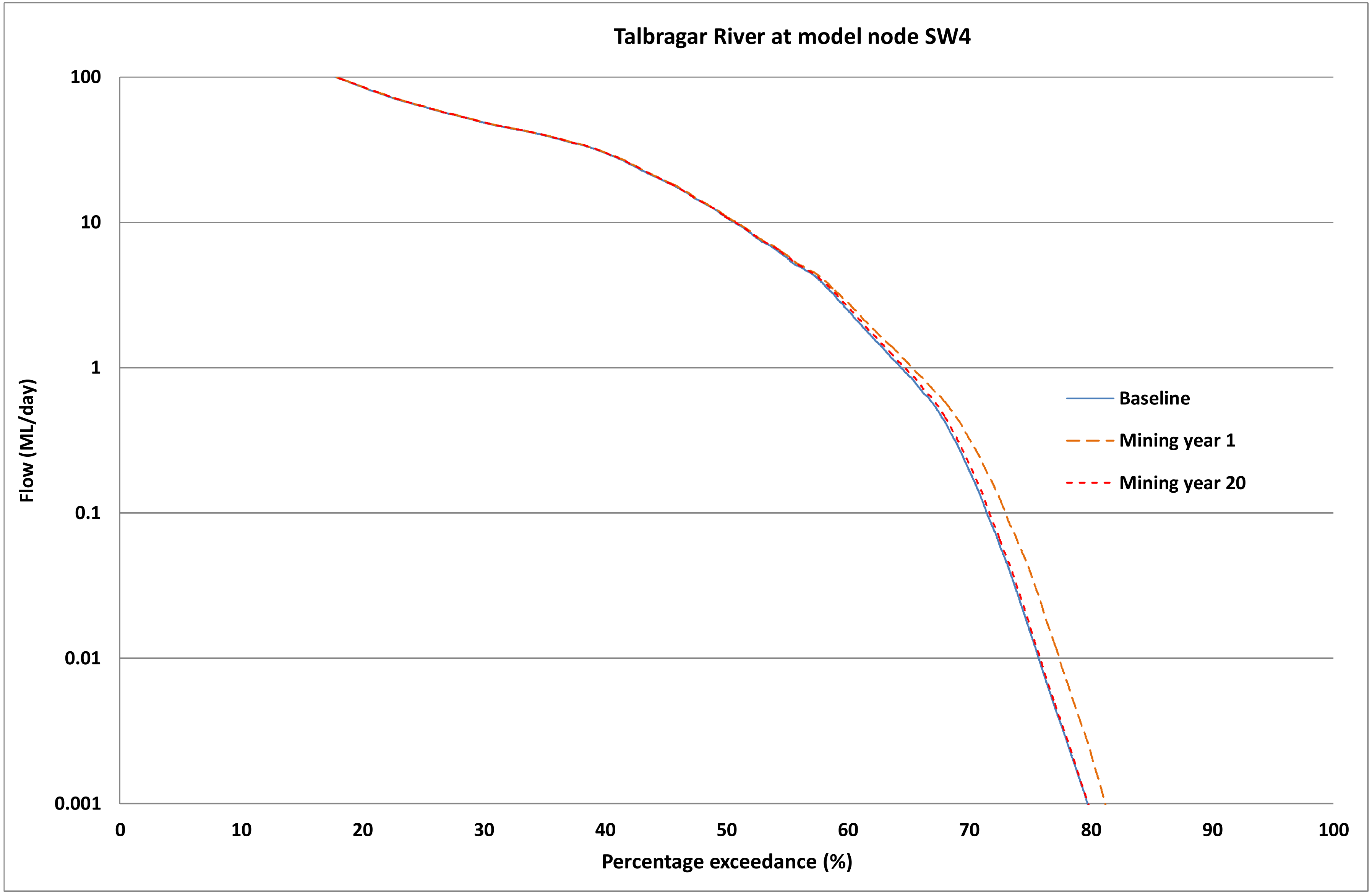

Figure 5-4 Flow duration curve for model node SW4 – Talbragar River downstream of confluence with Sandy Creek

5.3 Summary of impacts and potential mitigation measures

The potential impacts of the Project on flows in Sandy Creek and the Talbragar River can be summarised as follows:

- In terms of annual average flow volume, there is a reduction in the yield of the Sandy Creek system during dry rainfall years of up to 6% but an increase in yield during median and wet years. A 6% yield reduction in Sandy Creek equates to approximately a 0.6% reduction in yield in the Talbragar River at Elong Elong based on the mean flow relationship between the Medway and Elong Elong gauges (see Figure 3.1).
  This impact in the Talbragar catchment reduces further downstream as the influence of the Sandy Creek sub-catchment is reduced.

- While there is a potential decrease in the annual yield from the Sandy Creek system in low rainfall years, the modelling shows that the periodic releases of water from the mine will modify the flow duration statistics in the receiving creeks such that there is a minor increase in flows within the ranges defined by the NOW flow objectives.

- The general increase in mean daily flow will reduce the ephemeral characteristics of Laheys and Sandy Creeks, and to a lesser extent the Talbragar River. The mean daily flow increases are most significant for Laheys and Sandy Creeks in the reaches adjacent to and downstream of the mining areas, and are most significant for low flows.

The impacts on downstream flow in the Talbragar River are considered minor, given that the impacts on the annual average flow volume at the Elong Elong gauge would be less than 1%. Releases from the mine could affect the ephemeral nature of the Talbragar River to some extent by reducing the number of no-flow days and increasing the magnitude of flows within the low flow range, however, impacts on the high flow range are in the order of 1%, which are negligible. The minor impact on the river's ephemeral characteristics and on the low flow regime would reduce further downstream as the characteristics of the broader Talbragar River catchment govern the flow regime. For this reason, no mitigation measures are deemed necessary to address potential impacts of the Project on the Talbragar River.

The impacts on Sandy Creek are more significant, with up to a 6% reduction in annual flow volume for the reference low rainfall year, but increased annual flow volumes for the reference median and high rainfall years. However, the model shows that there are significant increases in mean daily flows, , particularly in the low to very low flow regime. These changes could positively affect the semi-permanent pools that occur within the Sandy Creek and Laheys Creek catchments downstream of the mining areas.

While the overall flow volume may be decreased during dry years, the changes to the flow duration statistics and increases in the frequency and magnitude of low and very low flows will mean that these pools will be fed more regularly and will dry out less frequently.

5.4 Impacts of flow changes on refuge pools and mitigation measures

Section 9.2 of the *Baseline Hydrological Environment* presented an assessment of the groundwater dependence of ecological refuge pools within and adjacent to the main mining area. Given the ephemeral nature of the creeks, pools that persist during prolonged dry periods are reliant on groundwater inflows rather than surface water flows, The downstream flow impact assessment concluded that the changes to the surface water flow regime will not have adverse impacts on the pools, and will instead increase the frequency of low flows to the pools. However, it is important to also consider the impact of groundwater drawdown on the pools that depend on groundwater inflows to sustain them during prolonged dry periods,

Table 5-4 presents the predicted reductions in groundwater elevation due to drawdown for the later stages of mining and identifies which pools will no longer receive groundwater inflows as a result. The locations of the pools are shown in Figure 9.1 of the *Baseline Hydrological Environment*.

As for the baseline assessment, the groundwater dependency of the pools during mining operations was determined as follows:

- If the water table elevation is higher than the creek bed level by more than 1 metre the pool site was deemed to be groundwater dependent.
- If the water table is within +/- 1 metre of the creek bed level the pool site was deemed to be potentially groundwater dependent.
- If the water table elevation is lower than the creek bed level by more than 1 metre the pool site was deemed to be independent of groundwater.

The impacts of the drawdown on the refuge pools during mining operations are as follows:

- No adverse impacts related to groundwater drawdown at Year 1.
- At Year 4 the drawdown at site 6 has the potential to result in loss of groundwater inflow and potential loss of a persistent groundwater fed pool at this site.
- At Year 12 the drawdown at sites 6 and 10 is significant and likely to result in loss of groundwater inflow at these sites. Site 5 is also potentially affected at Year 12.
- From Year 16 drawdown may also cause loss of a persistent groundwater fed pool at site 3.
- It should be noted that the predicted drawdown at sites 3 and 5 is close to the combined margin of error in ground level and groundwater modelling data. Therefore, the adverse impacts of groundwater drawdown on refuge pools can only be conclusively demonstrated at sites 6 and 10.

The groundwater modelling results indicate that groundwater levels will fully recover within 50 years post mining. Therefore, there will be a recovery of groundwater inflow to the affected pools in the long term.

To mitigate possible impacts on refuge pools an Aquatic Monitoring Strategy (AMS) will be developed for the Project to assess flow change and groundwater drawdown impacts on the quality and quantity of water in the persistent pools of Laheys and Sandy Creeks. The strategy will include:

- details of the proposed water level gauges, location and frequency of monitoring water level data at the persistent pools and reference sites (for comparison);
- monitoring the condition and health of instream biota representative of the Darling River aquatic ecological community and the Freshwater Catfish;

- the identification of trigger values for freshwater dam releases and/or water from the raw water dam to be released;
- details on existing flow data to ensure freshwater releases mimic natural patterns in flow, capture seasonality in the frequency, magnitude and duration of flows, as well as the natural variability to which the native fauna are adapted, where possible;
- monitoring the quality of freshwater releases;
- an adaptive management framework with feedback mechanisms; and
- a reporting program.

Table 5-4 Groundwater drawdown impacts on refuge pools

(adverse impacts highlighted in bold text)

Site	Location	Channel bed elevation (mAHD)	Baseline groundwater surface elevation (mAHD)	Groundwater fed under baseline conditions?	Year 4 groundwater surface elevation (mAHD)	Groundwater fed at Year 4?	Year 12 groundwater surface elevation (mAHD)	Groundwater fed at Year 12?	Year 16 groundwater surface elevation (mAHD)	Groundwater fed at Year 16?	Year 20 groundwater surface elevation (mAHD)	Groundwater fed at Year 20?
1	Talbragar River upstream of Sandy Creek confluence	354.2	353.0	No	353.0	No	353.0	No	353.0	No	353.0	No
2	Sandy Creek downstream of Laheys Creek confluence	347.0	345.7	No	345.7	No	345.6	No	345.4	No	345.1	No
3	Sandy Creek downstream of Laheys Creek confluence	347.0	346.3	Potentially	346.3	Potentially	346.2	Potentially	**346.0**	**No**	**345.6**	**No**
4	Sandy Creek downstream of Laheys Creek confluence	353.5	351.7	No	351.7	No	341.0	No	340.4	No	343.3	No
5	Sandy Creek downstream of Laheys Creek confluence	361.0	362.4	Yes	362.3	Yes	**361.7**	**Potentially**	**361.7**	**Potentially**	**361.8**	**Potentially**
6	Sandy Creek upstream of Laheys Creek confluence	373.0	372.2	Potentially	**371.9**	**No**	**370.0**	**No**	**363.0**	**No**	**363.0**	**No**
7	Laheys Creek downstream of Blackheath Creek confluence	365.0	362.4	No	362.1	No	357.2	No	356.4	No	356.2	No
8	Laheys Creek at Blackheath Creek confluence	378.0	373.8	No	372.6	No	372.0	No	371.9	No	371.7	No
9	Laheys Creek at Blackheath Creek confluence	378.0	374.3	No	372.6	No	372.0	No	371.8	No	371.6	No
10	Laheys Creek upstream of Blackheath Creek confluence	395.2	394.2	Potentially	394.2	Potentially	**388.0**	**No**	**380.8**	**No**	**376.0**	**No**
11	Laheys Creek upstream of Blackheath Creek confluence	406.0	403.9	No	403.9	No	403.4	No	402.7	No	397.2	No
12	Laheys Creek upstream of Blackheath Creek confluence	428.8	426.0	No	426.0	No	426.0	No	425.9	No	425.6	No
13	Laheys Creek upstream of Blackheath Creek confluence	436.1	435.9	Potentially	435.9	Potentially	435.8	Potentially	435.8	Potentially	435.8	Potentially
14	Fords Creek	481.7	484.3	Yes	484.3	Yes	484.3	Yes	484.3	Yes	484.3	Yes

5.5 Impacts of flow changes on geomorphology and mitigation measures

The influence of flow changes on fluvial geomorphology is summarised in this section. Predicted decreases in flow yield for Sandy Creek during dry years could lead to a slight increase in deposition of the fine sediment load at the wetted perimeter boundary and in deeper pools. However, water quality modelling (refer to the *Downstream Water Quality Impact Assessment*) suggests an overall reduction in fine sediment load, due to increased settling efficiency in the sedimentation dams, so the overall impact will be negligible. The very slight decrease in flow yield in the Talbragar River would have a negligible effect on sediment deposition, even at baseline sediment load levels.

Predicted increased flow yield in average and wet years could lead to minor increases in bank erosion (due to higher erosive and entrainment capacity) and consequently higher sediment loads sourced from the eroded material. However, these gradual changes are likely to be of small magnitude over the lifetime of the Project and no stretches of Sandy and Laheys Creek were identified as having severe erosion issues. The impact of increased flows in wetter years in the Talbragar, which conveys high flows already, would be minimal. Management should be put in place to monitor areas prone to erosion after discharge events and if necessary provide mitigation measures to abate or repair any bank damage.

An increase in frequency of flow events might lead to slightly increased erosion and sediment transport within Sandy Creek and Laheys Creek due to the limited time for vegetation to establish and stabilise material deposited in flood events and lower bed material compaction. Contrasting this, less fluctuation in water levels would decrease wet-dry bank failure cracking at channel / bank interface resulting in less erosion. Overall, the effect of increased frequencies is therefore considered to be negligible.

It is not envisaged that any of these changes in the flow regime will lead to large scale modification of channel morphology in Laheys Creek, Sandy Creek or the Talbragar River.

Two factors might lead to changes in flows at the local reach scale: discharge points from the sedimentation dams to the creeks and watercourse crossings. Potential impacts of the overflows from the sedimentation dams, such as erosion and scouring of the river bed, should be mitigated by angling the outfall flow 45º to the stream flow and by using small pipes appropriate to the peak flow volumes calculated using Blue Book guidelines (Landcom, 2004). Exit velocities should be reduced using baffles, blocks placed in the outfall apron or an energy-dissipater. Large stones or geotextile matting should also be placed at the outfall to avoid scouring of bed and banks. Inspection of the outfalls after storm events to check for damage to the creek banks is essential so that necessary repairs can be made.

Table 5-5 lists the sediment transport regime (as detailed in the *Baseline Hydrological Environment* report) for each of the locations where watercourse crossings have been proposed.

Table 5-5 Sediment transport regime at watercourse crossings

Crossing number	Creek	Sediment regime
1	Sandy	Stable
2	Laheys	Stable
3	Laheys	Erosion / deposition
4	Blackheath	Not classified
5	Blackheath	Not classified
6	Laheys	Deposition
7	Sandy Creek Tributary	Not classified
8a	Sandy	Stable
8b	Sandy	Stable

Mitigation measures to minimise the impact of watercourse crossings on geomorphology are given in Section 7 of the *Flood Impact Assessment*. Apart from these measures, care should be taken to minimise disturbance as much as possible, reduce sediment incursion into watercourses using silt curtains, divert flows temporarily while conducting works using stable ancillary channels and stabilise / rehabilitate disturbed land and creek banks using ground cover solutions in accordance with Blue Book guidelines (Landcom, 2004). This should be adhered to at all sites, but particular attention to any changes in geomorphological structure during works should be exercised at crossings 3 and 6 where dynamic sediment transport regimes have been noted.

6. Cumulative impacts

Cumulative impacts arise due to the influence or impacts of other construction and development activities in the local area. Any such activities have the potential to compound or exacerbate the specific impacts of the Project, thereby forming a cumulative impact.

Other projects in the region include Ulan, Moolarben and Wilpinjong Mines. Moolarben and Wilpinjong Mines are located within catchments that drain east into the Goulburn River, hence are not relevant to this assessment.

The Ulan Mine, however, is located on top of the Great Dividing Range and runoff from this mine flows in both directions, eastwards to the Goulburn River but also northwards into both Mona and Cockabutta Creeks. These two creeks subsequently flow into the Talbragar, approximately 35 km and 25 km upstream, respectively, of the Sandy Creek confluence with the Talbragar.

The Ulan Coal Mine was therefore considered as a potential contributor to cumulative impacts in combination with this Project.

6.1 Ulan Coal Mine project overview

The Ulan Mine Complex is one of the most established coal mining operations in the western coalfields of NSW (Xstrata, 2012). The Ulan Mine Complex lies within the Mid-Western Regional Council (MWRC) Local Government Area, located near the village of Ulan in the central west of NSW, approximately 45 kilometres north-north-east of Mudgee and 25 kilometres north-east of Gulgong. The Ulan Mine Complex covers an approximate area of 17,959 hectares and is located at the headwaters of the Goulburn and Talbragar River catchments.

In November 2010, Ulan Coal Mine Limited was granted Project Approval (08_0184) from the NSW Department of Planning, for the continuation of existing and new underground longwall mining and open cut activities to produce up to 20 Mtpa of product coal from its mining operations for the next 21 years (Xstrata, 2012).

6.2 Potential cumulative impacts

Increases in baseflow losses of 0.18-0.21 ML/day may result in the Talbragar River system due to the Ulan Coal Mine (Umwelt, 2009). Baseflow losses are predicted to increase to 0.38 ML/day after cessation of mining. Ulan Coal Mine Limited proposes to offset these losses by discharge of treated surplus mine water.

The Cobbora Project will result in a net gain of surface water in the Talbragar River during average and wet years, but minor losses of at most 0.6% in dry years at the Elong Elong gauge (based on the mean flow relationship between the two systems). Given the minor impacts of the Project and the management actions proposed at Ulan to offset baseflow impacts, it is concluded that there is negligible cumulative impact of both mining operations on the Talbragar River.

It should also be noted that for all flow objective categories, there will be an increase in flow magnitude in Laheys Creek, Sandy Creek and the Talbragar River because the Project will reduce the ephemeral characteristics of Laheys and Sandy Creeks by introducing more regular flow into the system.

7. Conclusion

This report has demonstrated that Sandy Creek and Laheys Creek do not influence flows in the Talbragar or Macquarie Rivers to a significant degree, based on their small catchment area and annual flow contributions to the downstream systems. NSW Government flow objectives for the Macquarie-Bogan catchment were reviewed on the basis of flow volumes in Sandy Creek and the Talbragar River. This showed that cease to flow, very low flow, low flow and high flow conditions require protection. The impact of the Project on these flow conditions was assessed and found to be minor in the Talbragar River system and significant in the Sandy Creek system, where isolated semi-permanent pools would experience more regular low flows and less frequent drying. However, groundwater drawdown may result in the loss of persistent groundwater fed pools at up to 4 sites during operations. Recovery of groundwater levels at these sites will occur within 50 years post mining, and an Aquatic Monitoring Strategy will be developed to monitor and address potential impacts. The assessment concluded that no significant geomorphological changes or impacts are likely, provided good practice construction and rehabilitation measures are employed to minimise disturbance and stabilise and rehabilitate disturbed areas within flow channels and floodplains. This applies to construction of watercourse crossings, flood levees and scour protection measures around sedimentation basins and spoil emplacement areas. Finally, cumulative impacts from this Project and the Ulan Coal Mine Project on the Talbragar River were assessed and found to be negligible.

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Appendix D

Cobbora Coal Project – Flood Impact Assessment

Cobbora Coal Project – Flood Impact Assessment

January 2013

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Glossary

Annual exceedence probability (AEP)	Chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, there is a 5% chance (that is, a one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see 'average recurrence interval').
Australian Height Datum (AHD)	Reference point (very close to mean sea level) for all elevation measurements, and used for correlating depths of channels and water levels.
Average recurrence interval (ARI)	Long-term average number of years between the occurrences of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20-year ARI flood event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	Land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Digital elevation model (DEM)	Digital representation of ground surface topography or terrain. It is also widely known as a digital terrain model (DTM).
Discharge	Rate of flow of water measured in terms of volume per unit time — for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving — for example, metres per second (m/s).
Flood	Relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam; and/or local overland flooding associated with major drainage before it enters a watercourse; and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences, excluding tsunami.
Floodplain	Area of land that is subject to inundation by floods up to and including the probable maximum flood event — that is, flood-prone land.
Freeboard	Factor of safety used for setting floor levels, levee crest levels, etc. to provide reasonable certainty that the correct risk exposure has been selected when a particular flood has been chosen as the basis for design.
Hydrologic Engineering Centre River Analysis System (HEC-RAS) model	Software package that allows modellers to perform one-dimensional steady and unsteady flow river hydraulics calculations, sediment transport – mobile bed modelling and water temperature analysis.
Hydrologic Engineering Centre's Statistical Software Package (HEC-SSP)	Software package that allows modellers to perform statistical analysis of hydrological data. HEC-SSP can perform flood flow frequency analysis, volume frequency analysis, duration analysis and a curve combination analysis.
Hydraulics	Study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrograph	Graph that shows how the discharge or flood level at a particular location varies with time during a flood.

Hydrology	Study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Light detection and ranging (LiDAR)	Optical remote-sensing technology that can measure the distance to, or other properties of, a target by illuminating the target with light (often pulses from a laser).
Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
m/s	Metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second. A unit of measurement for flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
Model	Mathematical representation of the physical processes involved in runoff generation and stream flow. Models are often run on computers, due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Peak discharge	Maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	Largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood-producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land — that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event, should be addressed in a floodplain risk management study.
Probable maximum precipitation (PMP)	Greatest depth of precipitation for a given duration that is meteorologically possible over a given size of storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends. It is the primary input to PMF estimation.
Root mean square (RMS) error	Frequently used measure of the differences between values predicted by a model or an estimator and the values actually observed from the thing being modelled or estimated. RMS is a good measure of accuracy.
Runoff	Amount of rainfall that actually ends up as stream flow; also known as rainfall excess.
Velocity	Speed of floodwaters, usually in m/s (metres per second).
Water surface profile	Graph showing the flood level at any given location along a watercourse at a particular time.
Watershed Bounded Network Model (WBNM)	Integrated software package for flood hydrograph studies on natural and urban catchments. WBNM is an event-based hydrologic model and calculates flood hydrographs from storm rainfall hyetographs. It can be used to model sub-catchments, reservoirs, on-site detention and other local drainage structures.
XP-RAFTS	Software package used for runoff routing for hydrologic and hydraulic analysis of drainage and conveyance systems.

1. Introduction

Parsons Brinckerhoff has been commissioned by Cobbora Holding Company Pty Limited (CHC) to prepare a flood impact assessment for the Cobbora Coal Project (the Project).

This report contributes to the surface water assessment that Parsons Brinckerhoff undertook for the Project's environmental assessment (EA) report.

The assessment of potential impacts of the Project on the dominant flow regime in the catchments (i.e. normal to low flows) is addressed in the *Downstream Flow Impact Assessment* report, which forms Appendix C to the *Surface Water Assessment* report.

1.1 Background

The Project will be developed near Dunedoo in the central west of New South Wales (NSW).The Project Application Area is approximately 274 square kilometres (km^2). The primary purpose of the Project is to provide coal for five major NSW power stations.

The mine will extract around 20 million tonnes per annum (Mt/a) of run-of-mine (ROM) coal. From this, approximately 9.5 Mt/a of product coal will be sold to Macquarie Generation, Origin Energy and Delta Electricity under long-term contract. In addition, approximately 2.5 Mt/a will be produced for export or the spot domestic market.

The Project's key elements are:

- an open-cut mine
- a coal-handling and preparation plant (CHPP)
- a train-loading facility and rail spur
- a mine infrastructure area
- supporting infrastructure, including access roads, water supply and storage, and electricity supply.

Construction is expected to commence in mid-2013, with coal being supplied to customers from the first half of 2015. The mine life will be 21 years.

1.2 Study area

The study area generally covers the entire Project Application Area, with special focus on three zones where flood impacts could be significant. The three zones are listed below and shown in Figure 1-1.

- **Zone 1**: Sandy Creek Main Mining Area. This zone comprises the channel and floodplains of Sandy Creek from its headwaters to the confluence with the Talbragar River, and includes Laheys Creek and its alluvial floodplain. A hydraulic model was set up to assess the impacts in this zone since most of the mining areas and mine infrastructure lie in this catchment. This hydraulic model includes Blackheath Creek, one of the main tributaries of Laheys Creek. Flooding in this zone is associated with flows in Sandy Creek and Laheys Creek (the main tributary of Sandy Creek), and in the tributaries and gullies draining to these watercourses.

- **Zone 2**: Flyblowers Creek. This zone contains a small creek and its catchment (which is adjacent to the Sandy Creek catchment). This creek flows into the Talbragar River upstream of Sandy Creek and downstream of Tucklan Creek. The natural drainage line of part of this catchment will need to be diverted to accommodate the mining area.

- **Zone 3**: Proposed rail spur corridor. This zone contains the proposed rail spur and rail corridor that generally run along the top of small tributary catchments but cross a number of watercourses and gullies, including Fords Creek, Lambing Yard Creek and Tallawang Creek.

1.3 Catchment description

The majority of the study area is located in the lower Talbragar River sub-catchment of the mid-Macquarie River catchment. For most of its length, the Talbragar River valley is broad and flat, and bordered by undulating hills that become less apparent as the Talbragar River progresses towards Dubbo. Due to excessive clearing in its upper catchment, the Talbragar River is highly salinised. Native vegetation only remains on the rocky sandstone hills formed by the inliers of the coarse Pilliga Sandstone.

Sandy Creek is a tributary of the Talbragar River, and Laheys Creek is a tributary of Sandy Creek. The upper reaches of each creek flow parallel to one other in a northerly direction through the study area. Laheys Creek merges with Sandy Creek approximately 7 km upstream of the confluence with the Talbragar River (refer to Figure 1-1). Sandy Creek and Laheys Creek are both ephemeral watercourses — that is, they are usually dry for part of the year. Land within the Sandy Creek catchment is mainly rural, with some areas of native vegetation in the upper reaches of the catchment.

Photo 1-1 and 1-2 were taken during a site visit in September 2011. Photo 1-1 shows a section of the lower reaches of Sandy Creek. The creek channel reveals a low-flow area through which the lower flows can meander. The lower parts of the banks are steep and less vegetated. The creek channel also contains a high-flow area where the banks are gentler and more vegetated.

Photo 1-2 shows the lower reaches of Laheys Creek just upstream of its confluence with Sandy Creek. This channel also shows a low-flow channel with a less vegetated and steeper bank. The higher flow part of the creek bed has wider, gently sloping banks and sections of sandstone and conglomerate outcropping.

Flyblowers Creek is a small creek catchment located north-west of the Sandy Creek catchment. This creek flows into the Talbragar River upstream of Sandy Creek and downstream of Tucklan Creek (Zone 2).

Fords Creek is a tributary of Laheys Creek and lies in the upper catchment. Fords Creek flows west and captures runoff from the forested areas near the Goodiman State Forest. Many small drainage channels and gullies drain into it. The proposed rail corridor runs along Fords Creek and crosses a number of these channels and gullies (Zone 3).

The remainder of the study area covers the catchments of minor tributaries and small creeks in the south and part of the tributary system draining to Tallawang Creek in the east (Zone 3). Tallawang Creek flows south into the Wyaldra Creek, which eventually flows into the Cudgegong River west of Gulgong.

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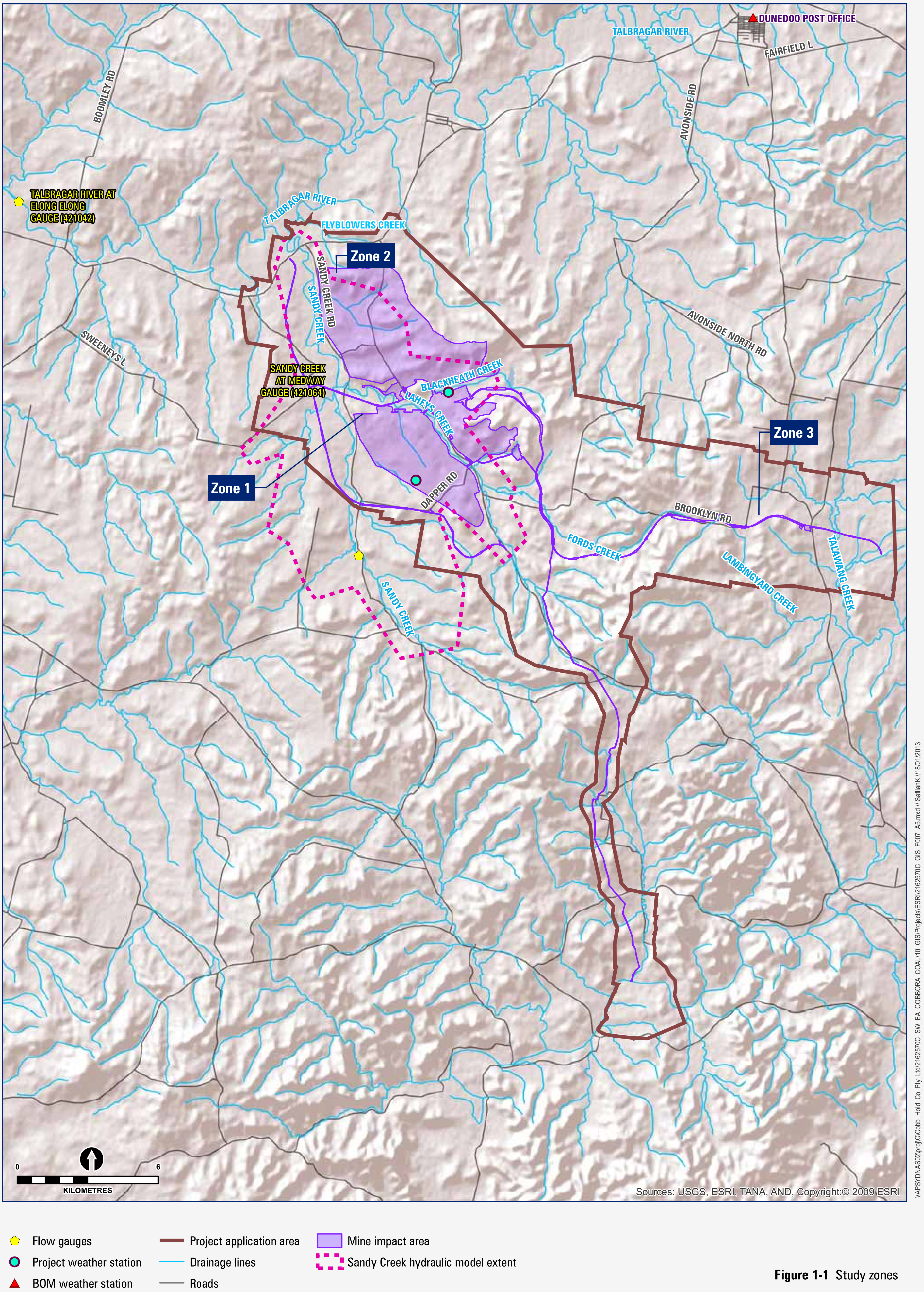

Figure 1-1 Study zones

Photo 1-1 Lower reaches of Sandy Creek

Photo 1-2 Lower reaches of Laheys Creek

2. Scope, approach and limitations

2.1 Scope of the assessment

As part of the Project's environmental assessment, a flood impact assessment is required to meet the Director General's Environmental Assessment Requirements (DGRs) and support the application for Project Approval.

The brief received from CHC described the scope of works required to complete a surface water impact assessment, including flooding. The CHC brief requested that Parsons Brinckerhoff:

- Conduct a hydraulic analysis to determine flood extent and flood velocities in the study area and downstream as far as the Project could affect flooding.
- Consider the impacts of flooding in Sandy Creek and Laheys Creek on the safety of the mine under a range of annual exceedence probabilities (AEP) up to the 0.05% AEP, or 2,000-year Average Recurrence Interval (ARI), event.
- Determine the need for levees to protect the mine under a range of events.

Parsons Brinckerhoff has interpreted the DGRs and the CHC brief to define the scope of works for this flood impact assessment as follows:

- Describe the existing flood conditions, including the history of flooding, and the extent, level and frequency of flooding in the affected catchments for a range of annual exceedence probabilities (where data permit).
- Assess the flood impacts of the Project, particularly for scouring, erosion, and changes to flooding levels and frequencies upstream and downstream of the study area.
- Identify appropriate mitigation measures for minimising impacts of flooding behaviour upstream and downstream of the study area.
- Identify appropriate mitigation measures for minimising impacts of flooding in and adjacent to the proposed railway corridor.
- Identify appropriate flood mitigation infrastructure required for safety of the mine.

2.2 Assessment approach

2.2.1 Existing flood conditions

The following methodology was used to determine the existing flood conditions in the study area:

- The magnitude and frequency of historical flood flows in the Talbragar River were estimated based on a Log-Pearson Type III flood frequency curve fitted to the peak annual flow series from the Talbragar River flow gauge at Elong Elong, which is located downstream of the study area.

- The magnitude and frequency of historical flood flows in Sandy Creek were estimated by developing relationships between Sandy Creek maximum daily flow and Talbragar River maximum daily flows, and using the Talbragar River flood frequency curve at Elong Elong.
- The magnitude of peak flood flow rates of Sandy Creek and Laheys Creek and in minor tributaries within the study area for a range of extreme flood events were estimated using a Watershed Bounded Network Model (WBNM) hydrologic model developed for this assessment.
- Flood levels, extents and velocities within the Sandy Creek and Laheys Creek catchments for a range of extreme flood events were estimated using a one-dimensional (1D) hydraulic model (HEC-RAS) developed for this assessment.
- An inundation plan for the 100-year average recurrence interval (ARI) event was developed using the results of the HEC-RAS model to identify existing areas affected by extreme event flooding in the Sandy Creek and Laheys Creek catchments.

2.2.2 Impacts and mitigation measures

The following methodology was used to determine the potential impacts on existing flood conditions and suitable mitigation measures:

- The mine plans at different stages of development were analysed to determine the worst-case, future, modified catchment condition that would have most significant adverse impacts on flooding within the catchments upstream and downstream of the Project.
- Hydrologic (WBNM) and hydraulic (HEC-RAS) models were developed to represent a worst-case future condition by modifying the existing conditions models.
- The existing and future case HEC-RAS model results were compared to identify areas where flood behaviour changed as a result of the proposed mine and infrastructure.
- The HEC-RAS model results were used to assess vulnerable infrastructure that would require protection from the 100-year and 2,000-year ARI flood events. Vulnerable infrastructure included the active-mining areas, out-of-pit emplacement areas, coal stockpiles, mine infrastructure area and workshop area.
- Protection was assumed to be flood protection levees around open mine pit areas, coal stockpile areas and the workshop area for the 2,000-year ARI event, as well as erosion protection for the base of the spoil emplacement for the 100-year flood level (with freeboard allowance applied for both design events).
- The 2,000-year ARI flood event was chosen as a reasonable upper limit reference event for protection of critical infrastructure; however, this will be confirmed at the design stage based on a detailed risk assessment for the Project.
- The HEC-RAS model results were used to assess the impacts of proposed watercourse crossings for mine access and haul roads on flood levels and flow rates. Preliminary design of the crossings was undertaken in consultation with CHC to meet specific design criteria, including flood immunity for the roads and afflux limits.

- Hydrologic modelling (using WBNM and XP-RAFTS) was used to size a temporary flood detention basin for the diverted portion of the Flyblowers Creek catchment, where mitigation is required to avoid downstream impacts for nine years of operation.

- The proposed rail spur corridor was assessed and watercourse crossing locations identified. Local hydrologic and hydraulic models were developed for significant creek crossings to assess flooding impacts and flow capacity requirements. For crossings of minor streams and drainage lines, indicative types and sizes of openings were determined based on the catchment area and channel shape determined from topographic data.

- Drainage requirements for the proposed rail spur corridor were assessed based on the proposed horizontal and vertical rail alignment and areas of cut and fill. Appropriate longitudinal drainage measures were identified for the corridor.

2.3 Limitations of the assessment

Detailed hydraulic analyses were undertaken for Sandy Creek and Laheys Creek; these analyses were represented by the hydraulic model shown in Figure 1-1 (Zone 1).
The hydraulic model simulates flooding in the Sandy Creek catchment from its headwaters to its confluence with the Talbragar River (over a channel length of approximately 24 km).

The majority of the mining areas, mine infrastructure and CHPP lie within this zone. Also modelled was the main portion of Laheys Creek (i.e. where a clearly defined channel is evident) from its confluence with Sandy Creek to approximately 13 km upstream, and the lower 3 km of Blackheath Creek.

Woolandra West Dam is upstream of the modelled extent and is not included in the existing or proposed case model, i.e. it is assumed that the flood flow from the catchment passes through the dam site without attenuation. This is a conservative approach to modelling the catchment flood response.

The lower portions of minor tributaries and gullies where the topographic data define a clear, incised channel were also included in the hydraulic model.

Zones 2 and 3 include several areas outside the Sandy Creek main mining area/hydraulic model extent but still within the study area where potential flood impacts could occur.
Flood impacts within these zones were assessed separately from the hydraulic model using other suitable assessment methods. These are:

- The potential for changed flooding behaviour and peak flows of Flyblowers Creek, north of the Sandy Creek catchment, during mine stages Year 12 to Year 20 (Zone 2).

- Proposed rail crossings of minor streams and drainage lines along the rail spur that lie in the eastern portion of the study area, including Crossings 9 to 29, but excluding crossings 11 and 28 (Zone 3). The minor stream and drainage line crossings were assessed using estimation methods based on catchment area and channel shape rather than detailed hydraulic modelling.

Flooding impacts of the power easement and water pipeline have not been considered significant because impacts on flooding will only occur during construction, and these will be addressed as part of the design for this infrastructure.

3. Available data

Section 3 details relevant data sourced and relied on for the assessment. In each case, the data were appraised for accuracy and suitability.

3.1 Topography and aerial photography

The following topographic and aerial photography data were used:

- For the Watershed Bounded Network Model (WBNM) hydrologic model catchment definition, 1:100,000 topographic maps (Cobbora 8733) and other topographic information supplied from the online Cobbora GIS portal were used.
- For hydraulic models, a digital terrain model was prepared using the 12D software, as follows:
  - CHC provided light detection and ranging (LiDAR) data prepared by AAM Hatch. The data were obtained from aerial laser survey of the study area between June and August 2009.The data were supplied as thinned ground points in ASCII format, and a triangulated irregular network was created with the LiDAR thinned points to form the digital terrain model. LiDAR data acquisition was controlled to achieve a vertical accuracy within 0.15 m root mean square (RMS). Horizontal coordinates were referenced to MGA zone 55, and elevations were reduced to Australian Height Datum (AHD).
  - CHC also provided 1 m contour data that were used to define topography in areas outside the extent of the LiDAR digital terrain model.
  - Cross-section surveys were undertaken in November 2011 at three locations within the Sandy Creek catchment for low-flow measurement purposes and these cross-section surveys were included in the hydraulic model for the December 2010 verification flood event.
- Aerial photography supplied from the online Cobbora GIS portal was used to estimate channel and floodplain roughness in the hydraulic model.

In addition, CHC provided the following design data sourced from the Cobbora GIS online portal:

- details of all proposed infrastructure for the mine
- details of mine layout during the various stages of the 21 years of active mining.

3.2 Design rainfall intensity data

Design rainfall intensity estimates were derived using *Australian Rainfall and Runoff* (Engineers Australia 2001). While these estimates are based on the statistical assessment of rainfall depths by the Bureau of Meteorology (BoM) in the mid-1980s, in the absence of more recent data, they remain the best available.

Intensity frequency duration (IFD) input parameters determined for the Sandy Creek catchment area are provided in Section 5 of this report.

3.3 Pluviograph records

Although there are no BoM rainfall stations operating within the Sandy Creek catchment, two on-site meteorological stations were installed by CHC in the study area between 2009 and 2011 (shown on Figure 1-1). An analysis of the daily rainfall data recorded by these stations between November 2010 and November 2011 matched well with nearby BoM rainfall gauges (Cobbora and Tallawang) and were therefore considered reliable.

The rainfall data received during the December 2010 flood event was captured by the on-site gauging stations and was used to verify the hydrologic and hydraulic models. This is discussed in Section 5.3 of this report.

3.4 Stream gauge records

A number of NSW Office of Water (NOW) stream gauges have previously operated near the Sandy Creek catchment. The Sandy Creek gauging station (421064) ceased to operate in 1985 and there is currently no active gauge station operating within the Sandy Creek catchment. Two other gauging stations along the Talbragar River have also ceased to operate. However, station 421042 ‘Talbragar River at Elong Elong’ is an active station. It is located on the Talbragar River approximately 20 km downstream of the confluence of Sandy Creek and the Talbragar River, which is the downstream limit of the hydraulic model. Gauges 421042 and 421064 were both used in this flooding assessment and their locations are shown on Figure 1-1.

The flow record from Sandy Creek shows that for the period of record (1966–1985) the highest recorded mean daily flow was 8,937 ML/d, which occurred in February 1971.The highest maximum daily flow recorded at the Talbragar River flow gauge was 65,246 ML/d, which occurred in February 1971, and the highest mean daily flow recorded was 40,835 ML/d, which occurred in December 2010. Flow duration curves developed from these gauge records are presented and discussed in the *Baseline Hydrological Environment* report (which forms Appendix A to the surface water assessment report).

Flows recorded at the gauge on the Talbragar River at Elong Elong and at the gauge on Sandy Creek at Medway have been analysed for the period when these data records overlap (1970–1985). This analysis showed very little correlation between concurrent daily flows recorded at the Sandy Creek Medway gauge and the flows recorded at the Talbragar River Elong Elong gauge. However, detailed analysis of the recorded flows at these two gauges during annual peak events resulted in the following observations:

- Double-peak flow events were recorded at Elong Elong for most of the major events.
- In general, the first peak tends to be smaller and is recorded at the gauge one to two days earlier than the second higher peak.
- Events on Sandy Creek are generally single-peak; the peak tends to occur around the same time and be of similar magnitude to the first peak recorded at Elong Elong.
- For events where double peaks are not observed at the Elong Elong gauge, the recorded flow at Elong Elong is still comparable to the Sandy Creek peak flow within one day of the peak flow occurring in Sandy Creek.

The February 1971 flood event flows plotted in Figure 3-1 provide a typical example of this observation. The magnitude of the first peak at Elong Elong (shown in red on 01/02/1971) is comparable to the peak at Sandy Creek (shown in blue on 01/02/1971).

From this typical observation it can be concluded that:

- The first significant flow response at Elong Elong (which occurred on 01/02/1971) is mainly due to flow from the Sandy Creek catchment passing through Elong Elong on the Talbragar River.
- The peak flow at Elong Elong (which occurred on 03/02/1971) represents peak flows from the Talbragar River catchment upstream of the confluence with Sandy Creek.
- The trends described above generally occur following prolonged dry conditions when the Talbragar River and Sandy Creek are at baseflow or low-flow conditions. Following initial rainfall and onset of wet conditions, a double-peak pattern at Elong Elong is less evident due to high flows occurring in both systems and the higher flow in the Talbragar River dominating the flow record at Elong Elong.

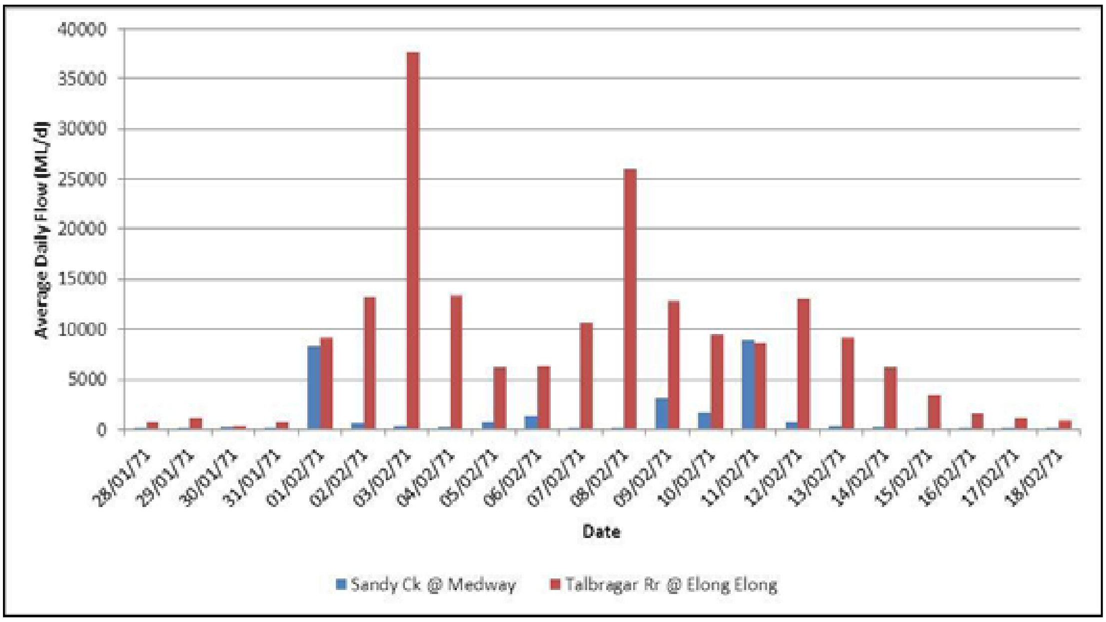

Figure 3-1 Comparison of Sandy Creek and Talbragar River average daily flow during the February 1971 event

The above observations suggest that the initial peak flows registered at Elong Elong during an event record the discharge from the smaller Sandy Creek catchment before the response from the larger Talbragar catchment, particularly for events occurring after prolonged dry conditions. Therefore, the instantaneous flows recorded at the Elong Elong gauge can be transposed to estimate instantaneous flows in Sandy Creek, where only mean daily flows are recorded.

Figure 3-2 presents the relationship between average daily flow at Sandy Creek and instantaneous peak flow in the Talbragar River on the same day that Sandy Creek peaks for reliable periods of overlapping records at both gauges. This comparison was made to identify patterns in the average daily flow record at Sandy Creek and the daily peak flows at Talbragar River.

Of the overlapping 15-year record, only 11 years of data were used in the comparison due to the potential unreliability of the remaining data. Figure 3-2 confirms that a reasonable correlation can be established between the daily flow at Sandy Creek and the instantaneous peak flow in the Talbragar River at Elong Elong for those years where the data are considered reliable.

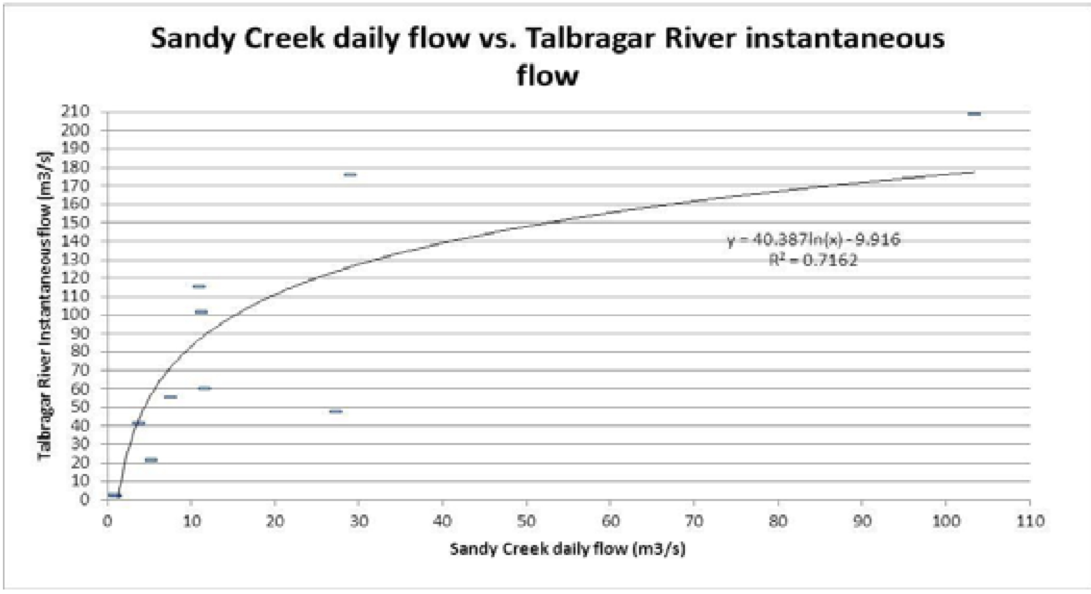

Figure 3-2 Relationship between Sandy Creek daily flow and Talbragar River instantaneous flow during annual peak events

3.5 Water level data

Water level gauges were established within the study area. Data were collected to obtain an understanding of the existing baseflow conditions when it was identified that no flow records existed for the study area.

Three gauges (SW1, SW2 and SW3) were installed in the Sandy Creek catchment and have been operational since November 2009. Only water level data, not flow data, were collected at the gauging stations and one low flow measurement was taken at the three sites in November 2011.

While this information would be useful for a low-flow analysis, the data are of limited use for flooding assessment due to the short duration of record (November 2009 to February 2012) and data gaps. The data therefore do not provide an understanding of high-flow or flooding behaviour at these sites. However, the water levels recorded at the three gauges during the December 2010 flood event were used to verify the hydrologic and hydraulic models, as discussed in Section 5.3.

3.6 Other data

In addition to the above, the following data were used in the flood impact assessment:

- aerial photography, vegetation, terrain and watercourses topographic information reviewed from the online GIS portal
- photographs and site understanding developed during a number of site inspections during 2010 and 2011.

4. Flood frequency analysis and flood history

4.1 Flood frequency analysis

Where sufficient flood records are available, the relationship between flood magnitude and flood frequency can be obtained through flood frequency analysis. Flood frequency analysis provides a statistical analysis of recorded stream flows, allowing us to estimate the magnitude of floods of a selected probability of exceedence. For long-duration records, Book IV of *Australian Rainfall and Runoff* (Engineers Australia 2001) recommends that the 1-in-100 annual exceedence probability (AEP) flood is the largest event that should be estimated by direct frequency analysis for important work, and that the maximum flood that should be estimated by this means under any circumstances is the 1-in-500 AEP event.

Flow has been recorded at the Talbragar River gauge at Elong Elong (421042) for 41 years (from 1970 to 2011). This is a relatively long period of record and is acceptable for flood frequency analysis. A log-Pearson type III (LPIII) distribution was fitted to the data using the flood frequency analysis software HEC-SSP. The analysis was based on the method described in Book VI, Section 2.7.2 of *Australian Rainfall and Runoff* (Engineers Australia 2001).

The results are summarised in Table 4-1 and Figure 4-1. The design peak 100-year average recurrence interval (ARI) discharge at Elong Elong was estimated to be 1,234 m^3/s.
This estimated flow relates to the second flow response of the Talbragar River observed during historical flood events that is governed by flows from the wider Talbragar catchment, rather than the first, and lower, flow response that is related to outflow from the Sandy Creek catchment to the Talbragar River. Refer to Section 3.5 for further discussion.

Table 4-1 Flood frequency analysis — Talbragar River at Elong Elong

Storm event	Estimated flow (m^3/s)	Estimated 95%-ile lower bound flow (m^3/s)	Estimated 95%-ile upper bound flow (m^3/s)
2-year ARI	43	27	68
5-year ARI	169	104	306
50-year ARI	893	469	2,113
100-year ARI	1,234	624	3,103

A flood frequency analysis for the Sandy Creek gauge at Medway (421064) was also considered; however, given the shorter period of record available (i.e. 15 years) and lack of maximum daily flow data, statistical analysis of this data was considered to be less reliable and was not carried out. An alternative method was developed to overcome this issue by translating flows estimated for the Talbragar River from flood frequency analysis of the Elong Elong record to Sandy Creek. This analysis is discussed in Section 5.3.1.

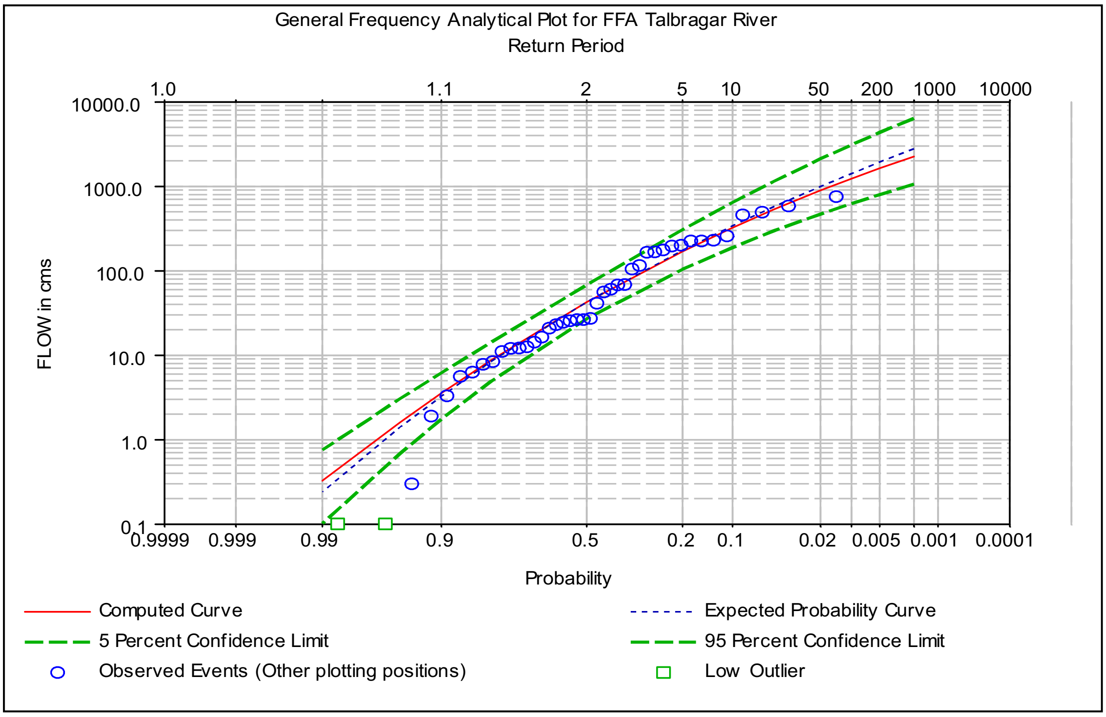

Figure 4-1 Annual series flood frequency analysis — Talbragar River at Elong Elong

4.2 Flood history

Flood information is limited in the study area and no flood studies are available for the Talbragar River, Sandy Creek or Laheys Creek. Dubbo City Council commissioned a *Talbragar River Flood Study* (Rust PPK 1995); however, this study only considered the reach of the Talbragar River immediately upstream from Dubbo.

Warrumbungle Shire Council indicates there is no flood information available for the Talbragar River in the vicinity of Cobbora (P Southwell 2009, pers. comm.). Further communication with Warrumbungle Shire Council and the Dubbo State Emergency Service office (A Luzuriaga 2009, pers. comm.) indicates that flood information for the Talbragar River at Cobbora is very limited.

It was suggested the major periods of flood concern for the Talbragar River are when the Macquarie River is also flooding. However, coinciding high flows in the Macquarie and Talbragar rivers rarely cause a flood risk for Dubbo, which is located near the confluence. The February 1955 flood reflected such conditions — the Talbragar River 'backed up' the Macquarie River, causing extensive inundation of parts of central and northern Dubbo (A Luzuriaga 2009, pers. comm.).

In December 2010, the Talbragar River experienced its biggest flood since 1955, and again water backed up in the Macquarie River because the Talbragar River was flowing at a higher level. As a result, the Macquarie River flooded parts of the Dubbo central business district (*Daily Liberal* 2011).

The Dubbo Local Flood Plan suggests that the Talbragar River floods 'every few years', with only the floods of 1870, 1920, 1926, 1950 and 1955 known to have flows that have risen above bank level and entered the surrounding floodplain.

The 1955 flood is stated to be the most severe, estimated to be a 200-year ARI event (Department of Natural Resources 2006). High rainfall in the upper catchment also produced high-velocity flows across the catchment, removing large areas of topsoil and damaging houses. The township of Ballimore was inundated with depths over 1 m. However, Ballimore is approximately 30 km downstream of Cobbora and the depths there cannot be correlated to the study area.

Since the Dubbo Local Flood Plan was prepared, the December 2010 flood event caused extensive damage and losses to agriculture, infrastructure and households in the lower Macquarie River. The December 2010 floods were the largest recorded since 1955 in the Talbragar River and the largest recorded since 1990 for the Macquarie River at Dubbo (*Daily Liberal* 2011). In contrast, the floods of 1920 and 1950 (the next highest) were known to result only in backwater flooding in low spots along the Talbragar River.