



Centennial Myuna Pty Ltd

Water Management Plan

June 2023

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Glossary

Alkalinity		A measure of the ability of an aqueous solution to neutralise acids. Alkalinity of natural waters is due primarily to the presence of hydroxides, bicarbonates, and carbonates. It is expressed in units of calcium carbonate (CaCO ₃).
Alluvial		Deposition from running waters.
Ambient		Pertaining to the surrounding environment or prevailing conditions.
Aquifer		An underground layer of permeable material from which groundwater can be usefully extracted.
Australian Datum	Height	A common national surface level datum approximately corresponding to sea level
Average interval	recurrence	A statistical estimate of the average period in years between the occurrence of a flood of a given size or larger, e.g. floods with a discharge equivalent to the 1 in 100-year average recurrence interval flood event will occur on average once every 100 years.
Baseflow		The component of flow in a watercourse that is driven from the discharge of underground water.
Baseline monitoring		Monitoring conducted over time to collect a body of information to define specific characteristics of an area (e.g. species occurrence or water quality) prior to the commencement of a specific activity.
Bore		Constructed connection between the surface and a groundwater source that enables groundwater to be transferred to the surface either naturally or through artificial means.
Catchment		The land area draining through the mainstream, as well as tributary streams, to a particular location.
Clean water		Water that has not come into physical contact with coal or mined carbonaceous material.
Dewatering		The removal or pumping of water from an above or below ground storage, including the mine water within the water collection system of mine workings. Water removed from mine workings is regarded as dewatering unless the workings are flooded and at equilibrium with the surrounding strata (in which case the removal is considered groundwater extraction).
Dirty water		Water that has an elevated sediment load.
Discharge		The quantity of water per unit of time flowing in a stream, for example cubic metres per second or megalitres per day.
Electrical conductivity		A measure of the concentration of dissolved salts in water.
Flood		Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Floodplain		Area of land that is periodically inundated by floods up to the probable maximum flood event.
Geomorphology		Scientific study of landforms, their evolution and the processes that shape them. In this report relates to the form and structure of waterways.

Goaf		The part of a mine from which the mineral has been partially or wholly removed, including the waste left in workings.
Groundwater		Water occurring naturally below ground level.
Groundwater extraction		For the purposes of this plan, groundwater extraction has been defined as the removal of groundwater from a groundwater source or aquifer, either via direct removal for use via a production bore or via incidental flow of groundwater from the aquifer into the mine workings during and after mining. Groundwater extraction includes the pumping of underground water from flooded mine workings in equilibrium with the surrounding strata as well as the removal of water from perched aquifers recharged directly from rainfall infiltration.
Guideline		A numerical concentration or narrative statement that provides appropriate guidance for a designated water use or impact.
Hardness		The concentration of multivalent cations in water. Generally, hardness is a measure of the concentration of calcium and magnesium ions in water and is expressed in units of calcium carbonate (CaCO ₃) equivalent. Hardness may influence the toxicity and bioavailability of substances in water.
Ion		Electrically charged atom.
Licensed point	discharge	A location where the premises discharge water in accordance with conditions stipulated within the site Environmental Protection License.
Median		The middle value, such that there is an equal number of higher and lower values. Also referred to as the 50th percentile.
Percentile		The value of a variable below which a certain percent of observations falls. For example, the 80th percentile is the value below which 80 percent of values are found.
pH		The value taken to represent the acidity or alkalinity of an aqueous solution. It is defined as the negative logarithm of the hydrogen ion concentration of the solution.
Potable water		Water of a quality suitable for drinking.
Riparian		Pertaining to, or situated on, the bank of a river or other water body.
Runoff		The amount of rainfall which ends up as streamflow, also known as rainfall excess.
Run of mine		Raw coal production (unprocessed).
Sediment		Soil or other particles that settle to the bottom of lakes, rivers, oceans, and other waters.
Stream order		Stream classification system, where order 1 is for headwater (new) streams at the top of a catchment. Order number increases downstream using a defined methodology related to the branching of streams.
Subsidence		The vertical difference between the pre-mining surface level and the post-mining surface level at a point.
Surface water		Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks, and drainage lines.
Topography		Representation of the features and configuration of land surfaces.

Toxicity	The inherent potential or capacity of a substance to cause adverse effects in a living organism.
Tributary	A stream or river that flows into a main river or lake.
Trigger value	The concentration or load of physicochemical characteristics of an aquatic ecosystem, below which there exists a low risk that adverse ecological effects will occur. They indicate a risk of impact if exceeded and should 'trigger' action to conduct further investigations or to implement management or remedial processes.
Turbidity	A measure of clarity (turbidity) of water. Turbidity more than 5 NTU is just noticeable to the average person.

Abbreviations

AHD	Australian Height Datum
ARI	Average recurrence interval
BOM	Bureau of Meteorology
Centennial	Centennial Coal Company Limited
Centennial Myuna	Centennial Myuna Pty Limited
CHP	Coal handling plant
DPE -Water	Department of Planning and Environment – Water
RR	Department of Regional NSW – Resource Regulator
EPA	Environment Protection Authority
EPL	Environment protection licence
ESCP	Erosion and sediment control plan
ha	Hectare
HWC	Hunter Water Corporation
kL/day	Kilolitre per day
km	Kilometre
L/s	Litre per second
LDP	Licensed discharge point
LMCC	Lake Macquarie City Council
LOR	Limit of reporting
m	Metre
mg/L	Milligram per litre
ML	Megalitre
ML/day	Megalitre per day
ML/year	Megalitre per year
mm	Millimetre
Mtpa	Million tonnes per annum
NTU	Nephelometric turbidity unit
OEH	Office of Environment and Heritage
PIRMP	Pollution Incident Response Management Plan
ROM	Run of mine
RWMP	Regional water management plan
SILO	Scientific Information for Landowners
SSTV	Site-specific trigger value
TARP	Trigger action response plan
TDS	Total dissolved solids
TOC	Top of casing

TSS	Total suspended solids
WMP	Water management plan
WSP	Water sharing plan
μS/cm	Micro siemens per centimetre

1. Introduction

Myuna Colliery is an underground coal mine owned and operated by Centennial Myuna Pty Limited (Centennial Myuna), a wholly owned subsidiary of Centennial Coal Company Limited (Centennial). Myuna Colliery's Surface Facilities Area is in Wangi Wangi on the western side of Lake Macquarie, 25 km south-west of Newcastle, as shown in Figure 1-1.

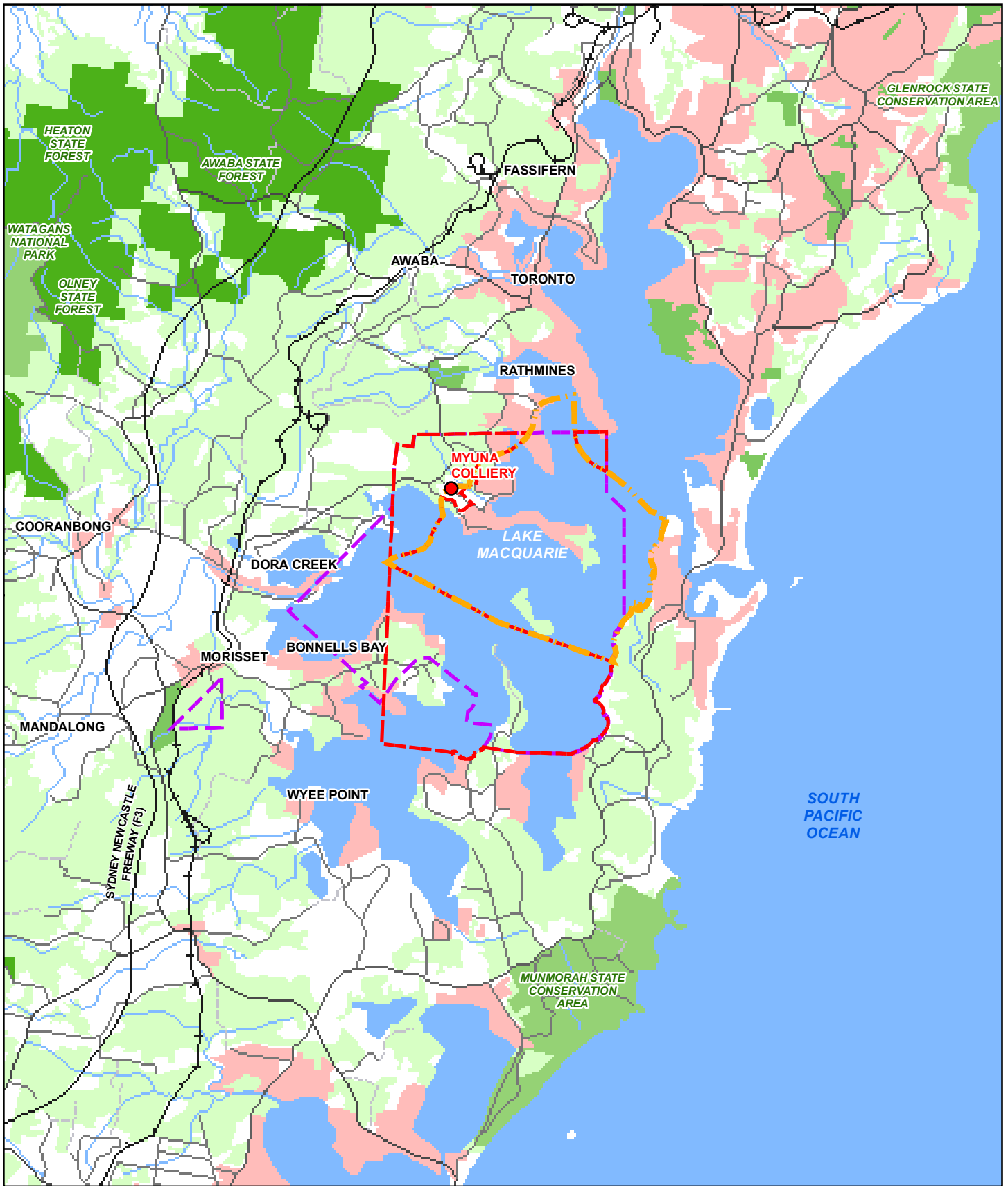
On 27 February 2012 Centennial Myuna received approval for the Myuna Coal Project under Part 3A of the *Environmental Planning and Assessment Act 1979*. The new approval (PA 10_0080) allowed for the continuation of mining at the Myuna Colliery at a maximum extraction rate of 2 Mtpa of ROM coal for a period of 21 years up to 31 December 2032. On 27 February 2015, Centennial Myuna was granted a modification to this approval (MOD 1) which allowed for an increased rate of production up to a maximum of 3 Mtpa and an increase in personnel from 210 to up to 300 full time employees. Mining of three seams, the Wallarah, Great Northern and Fassifern coal seams.

This site-specific Water Management Plan (WMP) was prepared for Myuna Colliery as a sub-plan of the Northern Operations Regional Water Management Plan (RWMP) that encompasses the northern coal operations owned by Centennial. Both the site-specific and regional management plans apply to all operations at Myuna Colliery and include the existing and approved operations and associated infrastructure within the site boundary. The WMP will be progressively updated as water management requirements change over time.

In accordance with the conditions of development consent PA 10_0080 MOD 1 for Myuna Colliery, this WMP was prepared by Lachlan Hammersley and reviewed by Dr Stuart Gray of GHD Pty Ltd in consultation with Centennial Myuna.

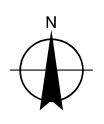
The WMP was provided to the following regulatory authorities for consultation in July 2017:

- NSW Department of Primary Industries – Water (DPE-Water, formerly NSW Office of Water).
- NSW Environment Protection Authority (EPA).
- NSW Department of Industry – Resources and Energy (DRE, formerly Division of Resources and Energy in the Department of Trade and Investment, Regional Infrastructure and Services).
- Lake Macquarie City Council (LMCC).
- NSW Office of Environment and Heritage (OEH).
- Consultation received is provided in Appendix A. A register of comments addressed is provided in Appendix B.



<p>LEGEND</p> <ul style="list-style-type: none"> Existing Rail Principal Road Secondary Road Minor Road Track Watercourse 	<ul style="list-style-type: none"> Lake Built up areas Recreation area State Forest Forest Or Shrub 	<ul style="list-style-type: none"> Myuna Colliery 1977 Development Consent SH110-148 Project Application Area - Myuna Coal Mine MP10_0080 MOD1 Mining Lease 1638
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 Metres
 Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56



Centennial Myuna Pty Ltd
 Water Management Plan
 Locality Plan

Job Number		
Revision		1
Date		1 Dec 2021

Figure 1-1

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 Data source: © Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3 2006; Centennial: Boundaries. Created by:

1.1 Overview of site operations

1.1.1 Site features

Approved Project Area

The approved Project Area for Myuna Colliery includes areas covered by Project Approval 10_0080 and development consent SH110/148. The encompasses the mining leases of:

Mining Lease 1632.

Mining Lease 1370.

Mining Purpose Lease 334.

Mine access and surface facilities

Infrastructure at the Surface Facilities Area is shown in figure 1-2. Personnel and materials are transported underground from the Surface Facilities Area to the underground workings by a combination of rail mounted drift winders via the men and materials drift and mobile vehicles.

Access to Surface Facilities Area is via Summerhill Drive, near the township of Wangi Wangi. The primary items of existing approved infrastructure include mine infrastructure (i.e. portals, drive houses, ventilation shafts and fan houses, bore holes, switch rooms, diesel, oil and water storage tanks and an emergency coal stockpile area), coal handling plant (CHP) (i.e. breakers, crushers, feeders, storage bins and conveyors), workshop and administration infrastructure.

Coal handling, processing, and transport

ROM coal produced at Myuna Colliery is transferred from the underground workings to the surface CHP via underground conveyors. Coal is delivered to the ROM bin and then fed through a primary screen before being transported to a rotary breaker. From the rotary breaker, the coal travels through feeders, screens and into crushers before being loaded into a final product bin. From the final product bin, the coal is loaded onto the Origin Energy-owned enclosed overland conveyor and delivered to the Eraring Power Station.

In the event of break downs or servicing of the enclosed overland conveyor, Centennial Myuna temporarily stores coal in a dedicated stockpile area in the north of the Surface Facilities Area, as shown in figure 1-2.






Paper Size A4
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Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56



LEGEND

-  Licensed Discharge Point
-  Watercourse
-  10m Contours



Centennial Myuna

Centennial Myuna Pty Ltd
 Water Management Plan

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 Revision | A
 Date | 16 Jun 2023

**Surface Facilities Area and
 Licensed Discharge Points**

Figure 1-2

Coal is recovered from the stockpile by front end loader, loaded onto trucks and dumped into a CHP reclaim hopper for transportation to Earing Power Station via the enclosed overland conveyor, as required.

As Myuna Colliery does not wash ROM coal, there is no coal reject material produced on site. A negligible amount of waste rock from the CHP is transported from the waste bin to the Awaba Waste Management Facility for disposal.

1.1.2 Coal production

The approved Project Area encompasses the coal measures and three seams previously mined at Myuna Colliery and as such, includes some previous workings and areas requiring new workings to be developed. Mining operations continue to be carried out using continuous miner methods in the Wallarah, Great Northern and Fassifern coal seams. Product coal is produced at a maximum rate of up to 3 Mtpa of ROM coal.

1.1.3 History

A summary of the history of the Myuna Colliery is provided in Table 1-1.

Table 1-1 History of Myuna Colliery

Date	Event
1977	Construction of Earing Power Station commenced.
1977	Myuna Colliery granted development consent (SH 110/148) to supply coal to Earing Power Station.
1979	Development of Myuna Colliery commenced.
1982	Coal production at Myuna Colliery commenced at a maximum rate of 1.3 Mtpa of ROM coal.
2002	Centennial purchased Myuna Colliery as part of the Powercoal acquisition.
2012	Centennial Myuna received PA 10_0080 for the continuation of mining up to 2032 at a maximum rate of 2 Mtpa of ROM coal and a maximum of 210 full time employees.
2015	Centennial Myuna received a modification to PA 10_0080 (MOD 1) allowing an increase in production to a maximum rate of 3 Mtpa of ROM coal and a maximum of 300 full time employees.

1.2 Approvals and licensing requirements

1.2.1 Project approval

The WMP addresses specific water components of the conditions of development consent PA 10_0080 (MOD 1), which was granted in February 2015. The relevant requirements of the WMP are outlined in Table 1-2, along with the sections of the WMP where each of these have been addressed.

Table 1-2 Project approval 10_0080 (MOD 3) conditions

Condition		Where addressed
Schedule 3 22.	The Proponent shall prepare and implement a Water Management Plan for the surface facilities sites to the satisfaction of the Secretary and in consultation with NOW, DRE and LMCC. This plan must:	Section 1
(a)	Be prepared by suitably qualified and experienced persons whose appointment has been approved by the Secretary.	Section 1
(b)	Be submitted for approval to the Secretary within seven months of the date of this approval.	Section 1
(c)	Include: A Site Water Balance. An Erosion and Sediment Control Plan. A Surface Water Management Plan. A Groundwater Monitoring Program. A Surface and Ground Water Response Plan.	See below
Site Water Balance		
Schedule 3 23. (a)	The Site Water Balance must include details of: Sources and security of water supply. Water use on site. Water management on site. Any off-site water transfers. Groundwater transfers from the underground operations to the surface.	Section 3
(b)	Investigate and implement all reasonable and feasible measures to minimise potable water use from the town water supply and to reuse and recycle water.	
Erosion and Sediment Control Plan		
Schedule 3 24. (a)	The Erosion and Sediment Control Plan must: Be consistent with the requirements of the <i>Managing Urban Stormwater – Soils and Construction, Volume 2E: Mines and Quarries</i> (DECC 2008, or its latest version).	Section 3 Section 5 Appendix E Centennial Myuna
(b)	Identify activities that could cause soil erosion and generate sediment particularly in relation to activities near waterways.	Sediment and Erosion Control Plan

Condition		Where addressed
(c)	Describe the location, function, and capacity of erosion and sediment control structures.	
(d)	Describe what measures would be implemented to maintain the structures over time.	
(e)	Describe the sediment and erosion control measures to be implemented for all activities undertaken at the site.	
Surface Water Management Plan*		
Schedule 3 25. (a)	The Surface Water Management Plan must: Include detailed baseline data on surface water flows and quality of Wangi Creek.	Section 2 Section 4 Section 5
(b)	Provide a geomorphic description of Wangi Creek up and downstream of the mine water discharge point.	Section 5.4
(c)	Detail surface water quality and stream health assessment criteria, including trigger levels for investigating any potentially adverse surface water impacts.	Section 6
(d)	Provide a program to monitor: Surface water discharges from the surface facilities sites. Stream health, channel stability, water flows and water quality within Wangi Creek. Water quality of Lake Macquarie.	Section 4
(e)	Investigate mitigation and management measures to prevent/limit any incision and degradation of the channel of Wangi Creek from mine discharge water.	Section 3
(f)	Include a detailed review of water management at the Myuna Colliery surface facilities site, with particular reference to the water storages within the dirty water management system and in consultation with EPA, to: Determine whether the capacity, integrity, retention time and management of the dirty water storages (particularly the CHP Dam) are sufficient to ensure that water discharged from the site. Meets all relevant ANZECC water quality criteria, including for metals and suspended solids. Assess all reasonable and feasible options for reducing salt load and/or salt concentration for discharges into Wangi Creek.	Section 5

Condition		Where addressed
	<p>Assess appropriate options to improve storage and retention times in accordance with <i>The Blue Book – Managing Urban Stormwater (MUS): Soils and Construction</i> (Landcom).</p> <p>Propose upgrades of the dirty water storages sufficient that discharges meet all relevant ANZECC criteria.</p> <p>Propose any other appropriate changes to the water management system.</p>	
(g)	Identify and assess practical measures to minimise potable water consumption, maximise recycled water use and improve the management of sewage and surface rainfall runoff for the project, including quantifying the abatement potential of identified measures and their related costs and benefits.	Section 3
Groundwater Monitoring Program		
Schedule 3 26. (a)	<p>The Groundwater Monitoring Program must include:</p> <p>Baseline data of groundwater levels (including alluvial and weathered rock aquifers), yield and quality in the region, and any privately owned groundwater bores that may be affected by mining operations on site.</p>	Section 2.4 Section 5.3 Section 4.3
(b)	Groundwater assessment criteria based upon analysis of baseline data for groundwater, surface water, including trigger levels for investigating any potentially adverse groundwater impacts.	Section 6
(c)	A program to monitor and/or validate the impacts of the project on alluvial and coal seam aquifers, and any groundwater bores.	Section 4.3 Section 7
Surface and Ground Water Response Plan		
Schedule 3 27. (a)	<p>The Surface and Ground Water Response Plan must describe what measures and/or procedures would be implemented to:</p> <p>Respond to any exceedances of the surface water, stream health, and groundwater assessment criteria.</p>	Section 6 Appendix A
(b)	Mitigate and/or offset any adverse impacts on riparian vegetation located within and adjacent to the site.	Section 6 Appendix A

Condition		Where addressed
Environmental Management, Reporting and Auditing		
Schedule 5 2. (a)	The Proponent shall ensure that the management plans required under this approval are prepared in accordance with any relevant guidelines, and include: detailed baseline data;	Section 5
(b)	A description of: the relevant statutory requirements (including any relevant approval, licence, or lease conditions). any relevant limits or performance measures/criteria. the specific performance indicators that are proposed to be used to judge the performance of, or guide the implementation of, the project or any management measures;	Section 1.2 Section 6
(c)	A description of the measures that would be implemented to comply with the relevant statutory requirements, limits, or performance measures/criteria;	Section 3 Section 4 Section 6
(d)	A program to monitor and report on the: impacts and environmental performance of the project. effectiveness of any management measures (see c above);	Section 4
(e)	A contingency plan to manage any unpredicted impacts and their consequences and to ensure that ongoing impacts reduce to levels below relevant impact assessment criteria as quickly as possible;	Section 6.1
(f)	A program to investigate and implement ways to improve the environmental performance of the project over time;	Myuna Environmental Strategy
(g)	A protocol for managing and reporting any: incidents. complaints. non-compliances with statutory requirements; and exceedances of the impact assessment criteria and/or performance criteria; and	Myuna Environmental Strategy

Condition		Where addressed
(h)	A protocol for periodic review of the plan.	Section 9

** The Secretary may require the Proponent to implement upgrades and other changes identified under paragraph (f), in accordance with condition 4 of schedule 2. EPA may also require measures to be implemented under the terms of the site's environment protection licence.*

1.2.2 Statement of commitments

The environmental assessment for the 2012 project approval (AECOM, 2011) included a Statement of Commitments detailing additional environmental management measures proposed by Centennial Myuna for the project. Commitments made that are relevant to operational water management at the Myuna Colliery are summarised in Table 1-3.

Table 1-3 Water management actions from Statement of Commitments

Commitment	Action	Where addressed
Operations carried out in a manner that minimises potential impacts to groundwater	<p>Within six months of project approval, a variation to EPL 366 will be lodged with the OEH to:</p> <p>Combine licensed discharge points LDP001 and LDP002 into a single licensed discharge point, LDP B (now LDP 9), with a combined discharge volume of 13 ML/day.</p> <p>Establish a licensed discharge point at the Emergency Coal Stockpile Sediment Dam, LDP A (Now LDP 10), for event-based discharges where rainfall exceeds 80 mm in 24 hours.</p> <p>Enable volumetric exceedances during rainfall events greater than:</p> <p>15 mm in the preceding 24 hours at LDP B (LDP 9).</p> <p>140 mm in the preceding 24 hours at LDP A (LDP 10).</p>	Section 1.2.3
	The Proponent (i.e. Myuna Colliery) will undertake an investigation of water reuse options at Myuna Colliery within six months of Project Approval	Section 3

1.2.3 Environment protection licence

Myuna Colliery currently holds environment protection licence (EPL) 366, which includes requirements to monitor water quality and quantity of discharges from the site. Water is currently licensed to be discharged from the mine through the following licensed discharge points (LDPs), as shown in

Figure 1-2:

- LDP 10 (A) – Emergency discharge to Wangi Creek via the Emergency Coal Stockpile Dam for event-based discharges where rainfall exceeds 140 mm in the preceding 24 hours.
- LDP 9 (B) – Discharge of up to 13 ML/day to Wangi Creek via the Mine Water Settling Pond 3.

Water quality concentration limits specified by EPL 366 for LDP 10 and LDP 9 are presented in Table 1-4.

Table 1-4 LDP 10 and LDP 9 water quality concentration limits

Parameter	100th percentile concentration limit
Oil and grease	10 mg/L
pH	6.5–8.5
Total suspended solids (TSS)	50 mg/L

1.2.4 Groundwater bore licences

Centennial Myuna currently holds a Water Access Licence (WAL) 41560 under the Water Management Act 2000, This licence entitles a volume for extraction from the North Coast Fractured and Porous Rock Groundwater Source, of up to 4,380 ML/year from underground workings via the miscellaneous works approval 20MW065029. Groundwater extraction activities from the mine were previously permitted through bore licence 20BL172565 under the Water Act 1912.

1.2.5 Water Management Plan objectives

The WMP has been developed to address the approvals and licensing requirements presented in Section 1.2 through the completion of the following:

- Collation and review of existing information and studies relating to the operation of the water management system at Myuna Colliery.
- Establish an understanding of the water management system at the site.
- Categorise the existing conditions that are specific to water management requirements.
- Develop catchment plans for the site.
- Identify the clean and dirty water management systems.
- Undertake a review of the capacity of the dirty water surface storages in accordance with *Managing Urban Stormwater: Soils and Construction Volume 1* (Landcom, 2004) and *Volume 2* (DECC, 2008).
- Determine the suitability of waterway conditions.
- Undertake a water quality assessment and review of existing water quality assessment criteria.
- Manage water discharge from site, in terms of volume and quality, to a level that is acceptable for environmental management and community expectations.
- Minimise water discharges from the premises by maximising, where practicable, opportunities for the reuse and recycling of water on site.

- Manage discharge to natural waterways in accordance with EPL 366 conditions or as agreed with the EPA
- Determine the future water management requirements.
- Review and develop water monitoring requirements.

2. Environment

2.1 Climate

2.1.1 Rainfall

Myuna Colliery has site-based rainfall and weather stations located on site. Site-specific rainfall data has been collected daily since 2005. For assessments requiring a large historical set of rainfall data (i.e. greater than 50 years), daily rainfall data is obtained from the Scientific Information for Landowners (SILO) database operated by the Queensland Department of Science, Information Technology, and Innovation. SILO patched point data is based on historical data from a particular Bureau of Meteorology (BOM) station with missing data 'patched in' by interpolation with nearby stations.

Rainfall data was obtained from the SILO database for the Toronto WWTP Station (BOM station number 61322), located approximately 8 km north-east of Myuna Colliery. The rainfall data was selected based on the length and quality of the data record and proximity to the site.

Figure 2-1 presents the historical SILO patched point daily rainfall data from the Toronto WWTP Station between 1901 and 2016.

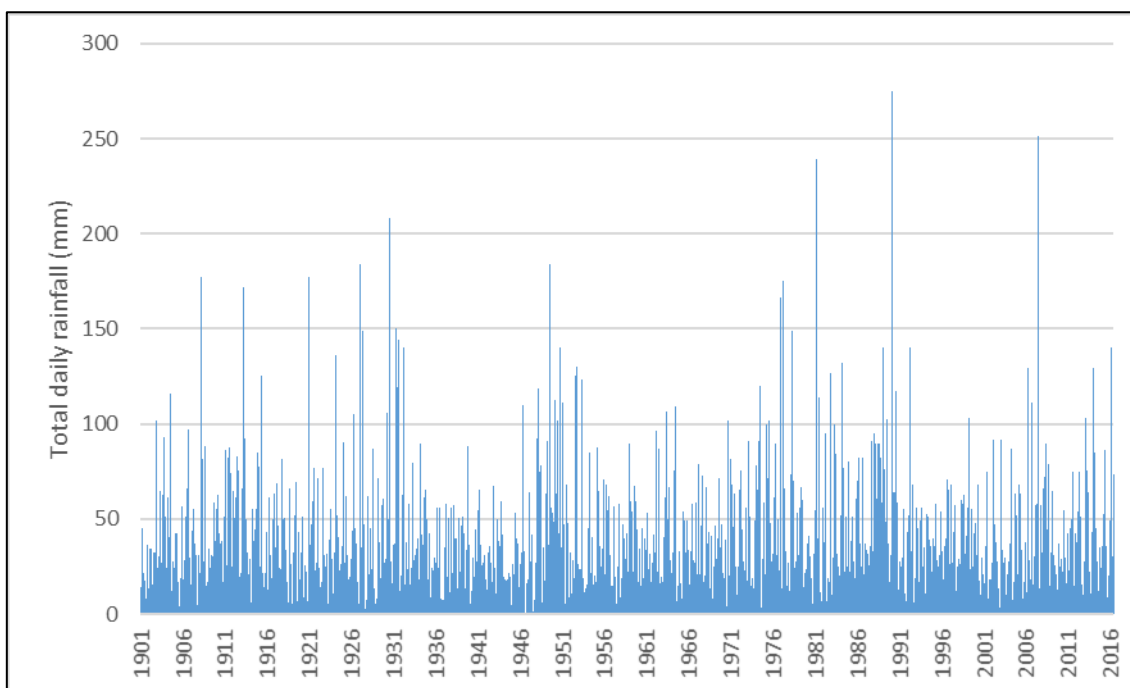


Figure 2-1 Historical daily rainfall at Toronto WWTP Station

The annual statistics associated with Figure 2-1 are:

- Minimum rainfall total – 595 mm in 1944.
- Average rainfall total – 1,116 mm.
- Median rainfall total – 1,062 mm.
- Maximum rainfall total – 2,059 mm in 1990.

2.1.2 Evaporation

Evaporation estimates are not collected by the meteorological station at Myuna Colliery. Evapotranspiration has been collected historically however no basis for this data has been detailed. Historical SILO patched point daily evaporation data was also obtained for the Toronto WWTP Station, which has been interpolated from long term averages from 1901 to 1969 and interpolated daily averages from 1970 to 2016. This data was reviewed, and average monthly evaporation rates were determined. The average daily evaporation rates are presented in Figure 2-2.

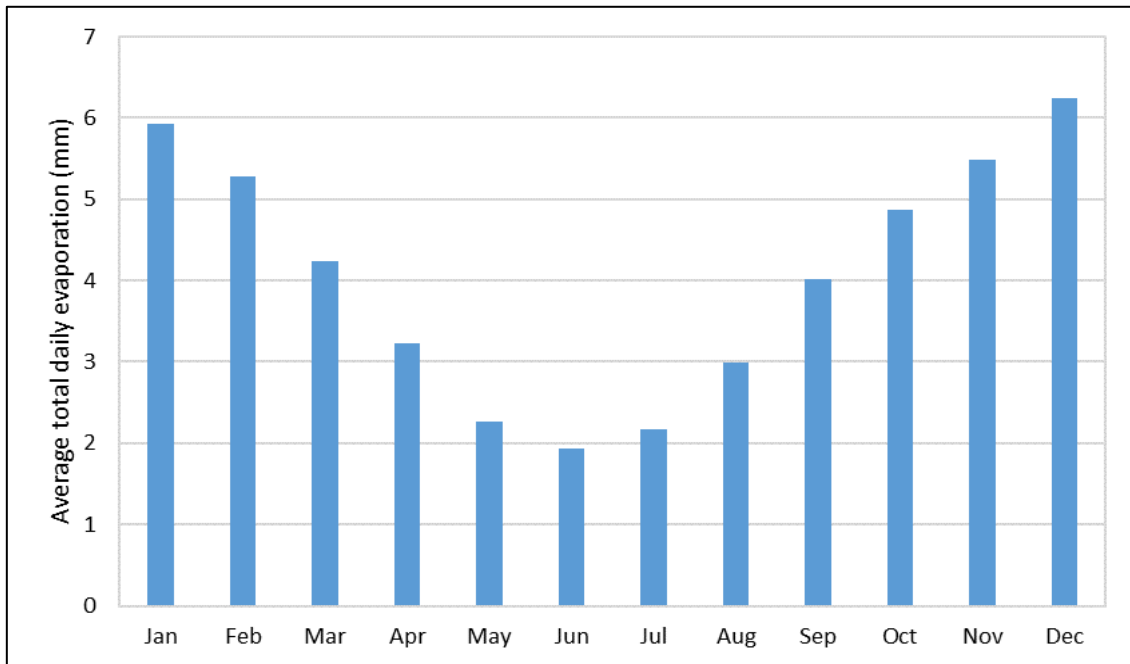


Figure 2-2 Average daily evaporation each month at Toronto WWTP Station

Total average annual evaporation is approximately 1,471 mm, compared to the annual average rainfall total of approximately 1,116 mm. This gives an annual deficit (difference between annual rainfall and annual evaporation) of approximately 355 mm.

2.2 Topography and hydrology

The Surface Facilities Area is located within the catchment of Wangi Creek, which flows into Lake Macquarie. Most existing workings in the Wallarah, Great Northern and Fassifern coal seams are located beneath Lake Macquarie. Ground elevations range from 0 m AHD to approximately 70 m AHD within the Myuna Colliery holding boundary.

The Surface Facilities Area at Myuna Colliery is in the lower reaches of Wangi Creek. Water discharged from Myuna Colliery enters the estuarine reach of Wangi Creek before discharging into Lake Macquarie. Upstream of the Surface Facilities Area, the creek is a freshwater environment. Adjacent to the Surface Facilities Area, Wangi Creek is reasonably well-defined, with a width in the order of 5 m and vegetated along the invert of the creek.

Downstream of LDP 10 and LDP 9, discharges flow through a piped network prior to outflowing into an earthen channel. This channel runs parallel to Wangi Creek for approximately 200 m. The channel is constrained by fill material along the left bank, which is steep and up to 4 m to 5 m high. Along the left bank, a levee type structure exists which separates flows from the LDP discharge channel and flows in Wangi Creek.

Wangi Creek is the only watercourse directly influenced by mine water discharge from Myuna Colliery. However, mine workings are located beneath several other watercourses as well as Lake Macquarie.

The watercourses and catchments within the approved Project Area is shown on Figure 2-3.

2.3 Geology

The geology within the approved Project Area affects both the mining operations and management of water. Water management is affected by the stratigraphy, which influences the potential for infiltration into the workings. The location of regional aquifers in relation to the workings also affects the management of water on-site.

The Newcastle Coalfields Regional Geology 1:100,000 map (NSW Department of Mineral Resources, 1995) indicates that land within the approved Project Area is characterised by outcropping of Triassic Age Munmorah Conglomerate across the onshore areas and Quaternary sand and mud deposits across Lake Macquarie. These deposits are underlain by the late Permian Newcastle Coal Measures.

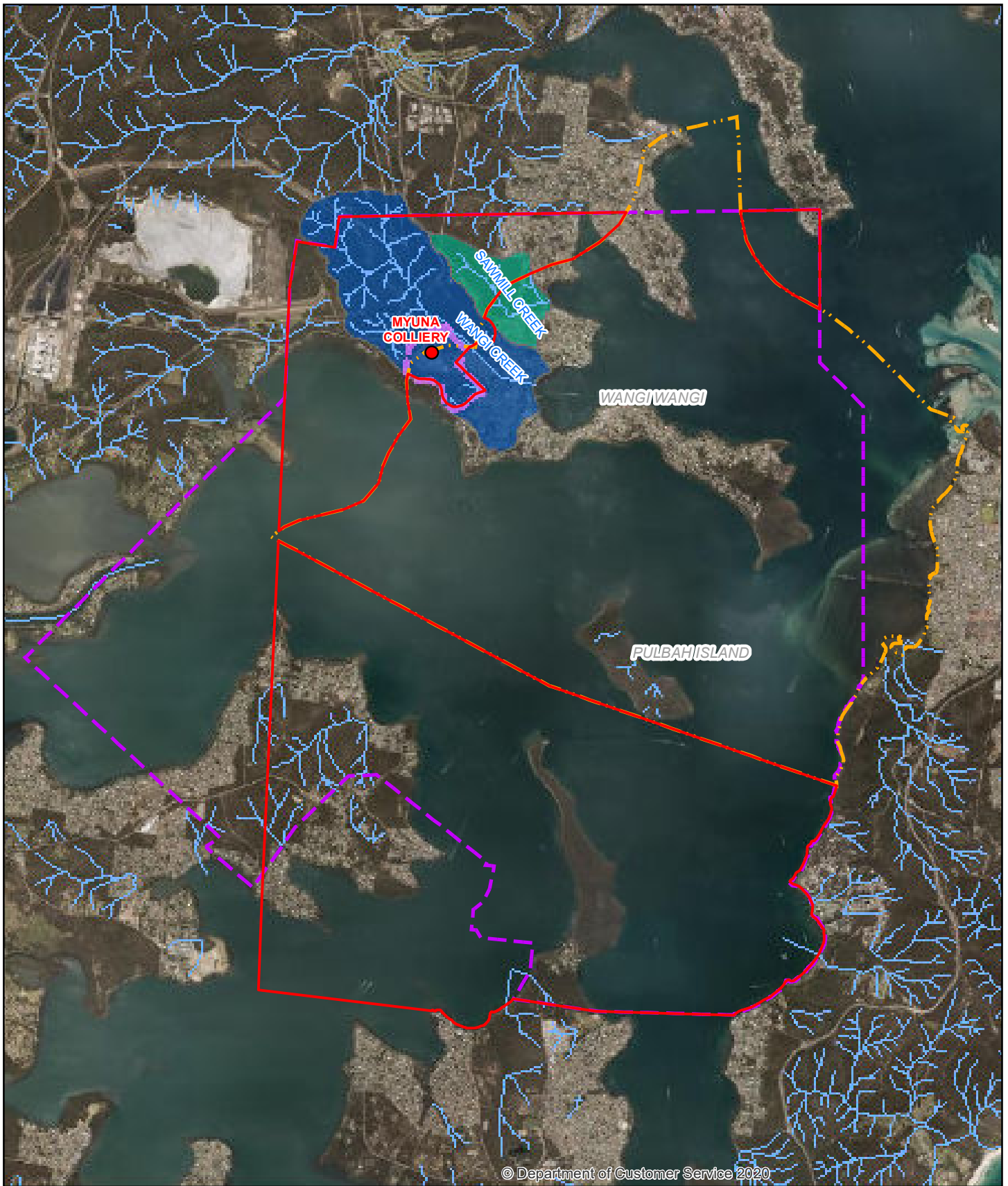
The stratigraphic sequence at Myuna Colliery is outlined in Table 2-1.

Table 2-1 Stratigraphic sequence

Period	Stratigraphy		Unit/lithology
	Group	Subgroup	
Quaternary			Alluvium
Triassic	Narrabeen	Clifton	Munmorah Conglomerate Dooralong Shale
Permian	Newcastle Coal Measures	Moon Island Beach	Vales Point Seam Karignan Conglomerate Wallarrah Seam Mannering Park Tuff Teralba Conglomerate Great Northern Seam Karingal Conglomerate
		Awaba Tuff	Awaba Tuff
		Boolaroo	Fassifern Seam

The coal seams mined at Myuna Colliery are part of the late Permian Age Newcastle Coal Measures, which dip to the southeast at a grade of generally less than 1 in 20. The Moon Island Beach, Awaba Tuff and Boolaroo Formations of the Newcastle Coal Measures outcrop and/or subcrop to the north-west, north, north-east, east, and south-east of the Myuna Colliery approved Project Area.

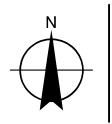
The Wallarrah Seam ranges in thickness from between 2 m and 3 m across the approved Project Area and is predominantly overlain by Karignan Conglomerate, described as a medium to coarse grained pebble conglomerate. The Dooralong Shale makes up the roof of the Wallarrah Seam in the east and the Wallarrah Seam is underlain by Mannering Park Tuff claystone/mudstone.



LEGEND

- Project Approval Area - Myuna Coal Mine MP10_0080 MOD1
- Myuna Colliery 1977 Development Consent SH110-148
- Mining Lease 1638
- Surface Facilities Area
- Watercourse
- Sawmill Creek Catchment
- Wangi Creek Catchment

Paper Size A4
 0 215 430 860 1,290 1,720
 Metres
 Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56



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Revision	1
Date	1 Dec 2021

Watercourses within Approved
 Project Area

Figure 2-3

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The Great Northern Seam generally varies in thickness between 2.5 m and 3 m across the approved Project Area. Teralba Conglomerate tends to form the roof of the Great Northern Seam in most areas, although this is replaced by shale, mudstone, or tuffaceous siltstones in some areas. The Awaba Tuff siltstone/claystone underlies the Great Northern Seam in most areas.

Both the Wallarah and Great Northern seams tend to split, deteriorate, and thin along the north/south zone to the west and south-west of the approved Project Area.

The Fassifern Seam is the most extensive coal reserve throughout the lease area, with a thickness more than 6 m in areas where the seam is not split. The seam is at its greatest thickness at Wangi Point. Between the Wangi Peninsula and Pulbah Island the seam splits in two. The lower split is the preferred mining section in this area. The splits coalesce to the south of Pulbah Island and beyond the approved Project Area. Awaba Tuff generally overlies the Fassifern Seam, while the floor is composed of claystones. A schematic of the coal seam stratigraphy and the mining process has been presented in Figure 2-4 (Centennial Myuna, 2014).

2.4 Hydrogeology

The groundwater sources in the vicinity of Myuna Colliery are generally low yielding and predominantly within the Quaternary alluvium, weathered and/or fractured rock and coal seams.

The Quaternary material includes alluvium, which occurs along the watercourses draining into Lake Macquarie and lake sediment underlying Lake Macquarie. The alluvium forms and unconfined shallow aquifer with a thickness of up to 10 m.

Groundwater flow within the Triassic and Permian rocks underlying the Myuna Colliery approved Project Area is predominantly within the coal seams. The overburden and interseam strata tend to have very low hydraulic conductivities (unless fracturing creates a secondary permeability).

2.4.1 Groundwater users

A search of the NSW groundwater borehole database was undertaken within 3 km of the Project Application Area. The search found 82 bores, of which 67 draw groundwater from alluvial. The remainder extract water from weathered sandstone. The alluvial bores are predominantly used for domestic purposes and range from depths of 1 m to 10.1 m below ground level. Note: that no bores were found within the Approved Project Area.

The water bearing zones consist predominantly of sandy strata and the standing water level within the bores range from 0.1 m- to 6.5 m below ground level. The salinity ranges used to describe the salt concentrations within bores were 0-3000 parts per million (ppm) with most lying between 0-500 ppm. There were no beneficial users of coal seam groundwater identified because of this search. Approximate groundwater bore locations identified from searches of the NSW groundwater bore database are shown on Figure 2 5. Note: that a historic groundwater bore is located within the Myuna Colliery lease, however the licence for this has been cancelled.

2.4.2 Groundwater dependant ecosystems

Potential groundwater dependent ecosystems (GDEs) within the vicinity of Myuna Colliery have been mapped in the *Groundwater Dependent Ecosystem Atlas* (BOM, 2015). Potential GDEs within 3 km of Myuna Colliery include various vegetation communities that surround Lake Macquarie. Whiteheads Lagoon, Lake Petite and Lake Macquarie are listed by BOM (2015) as potential GDEs.

High priority GDEs are listed in WSPs. The closest high priority GDE listed in the Hunter Unregulated and Alluvial Water Sources WSP are coastal wetlands located approximately 20 km to the north of Myuna Colliery (GHD, 2015b). These are outside the zone of potential influence by the operations.

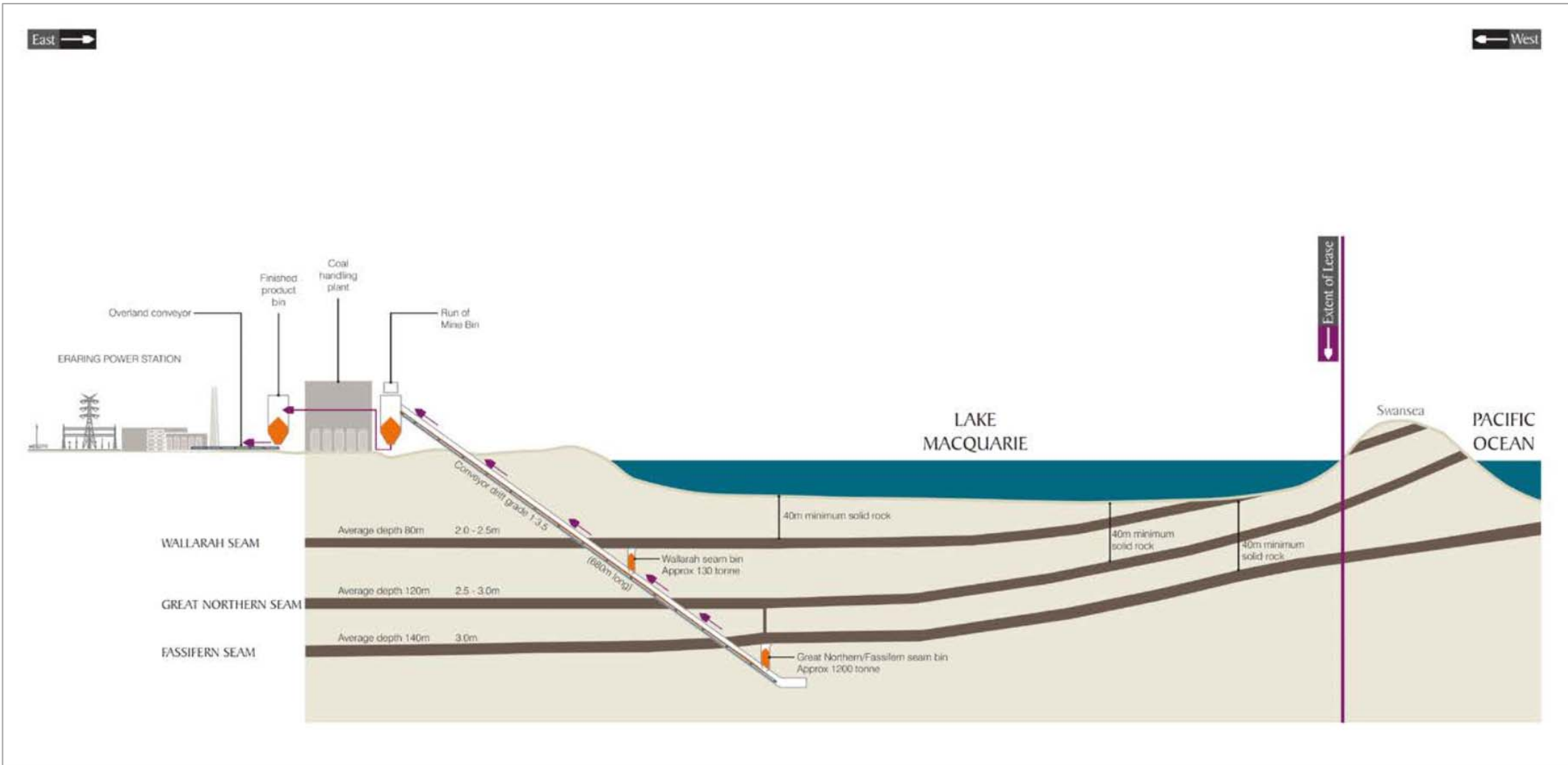
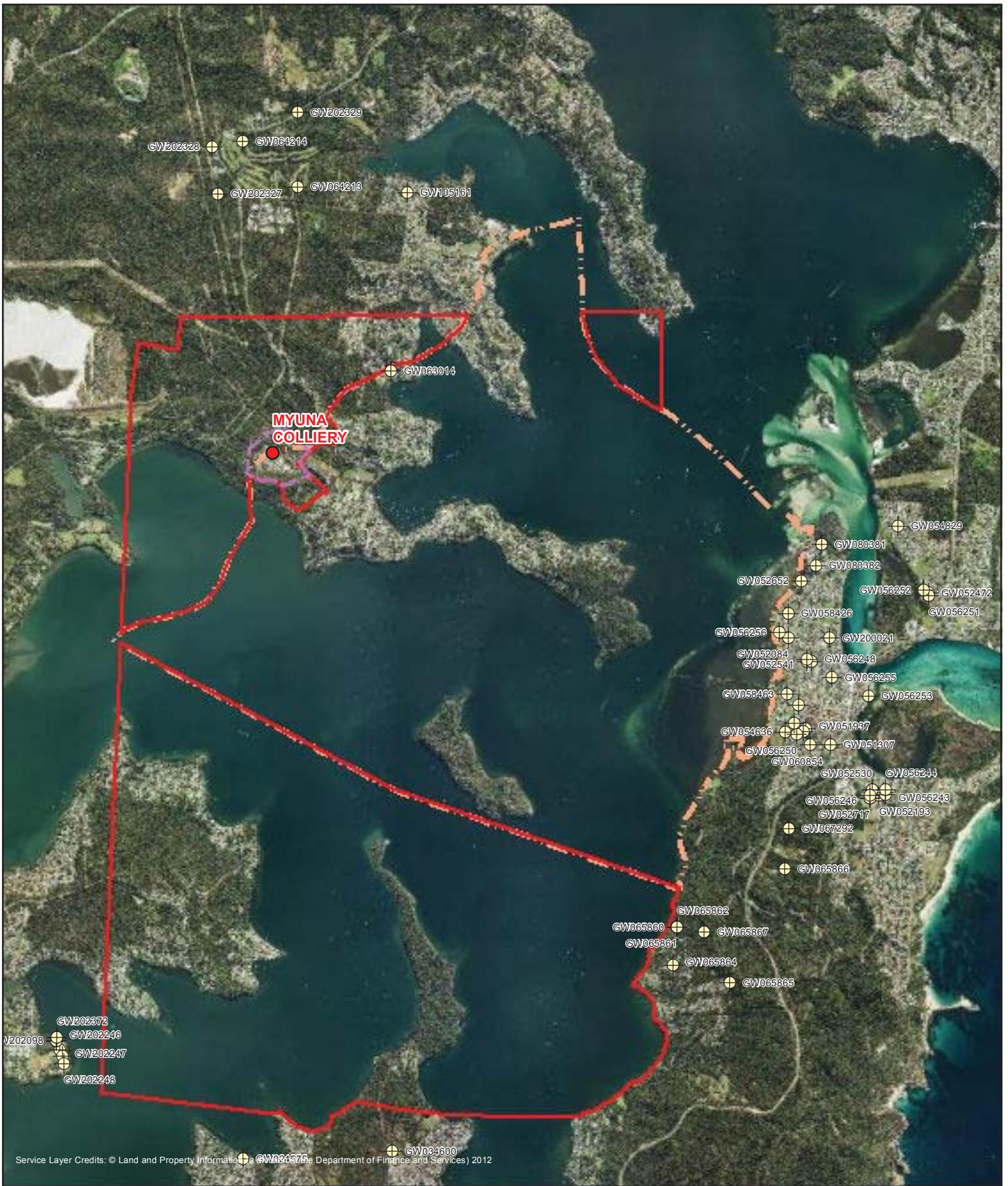


Figure 2-4 Coal seam stratigraphy and mining process (Centennial Myuna, 2014)



LEGEND

- Myuna Colliery Surface Facilities
- Project approval boundary
- ⊕ Registered bores
- Development consent boundary
- Surface Facilities Area

Paper Size A4
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 Map Projection: Transverse Mercator
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Revision	A
Date	17 Aug 2016

NSW groundwater bore database search results

Figure 2-5

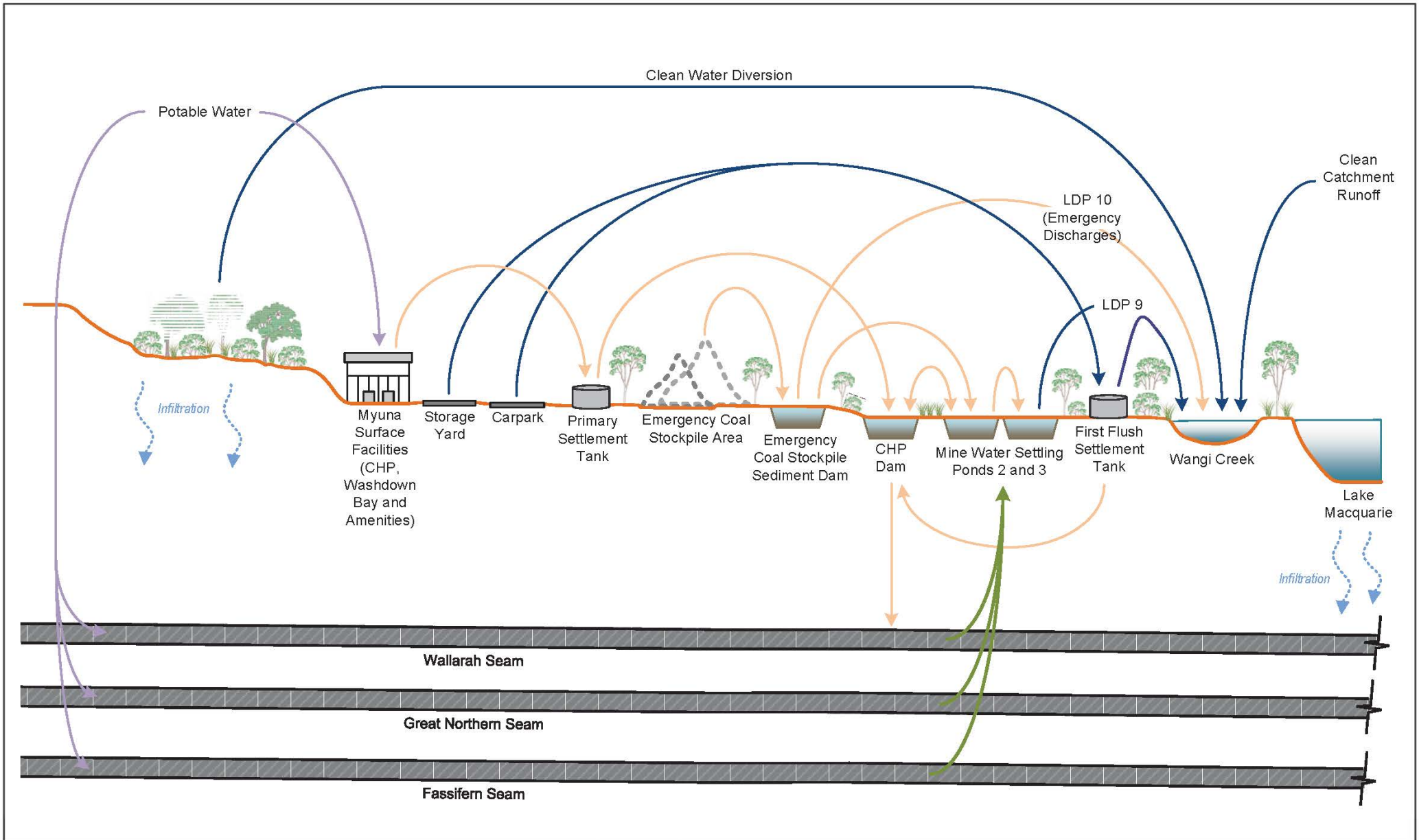
3. Water management

3.1 Water management overview and objectives

The water management system at Myuna Colliery is comprised of clean and dirty surface, potable, waste, and underground elements. Sources of water include potable water supply, rainfall, runoff, and groundwater inflow into the underground mine workings. The primary potable water demands are for underground operations, machinery washdown, fire-fighting storage and staff amenities.

Surface water runoff from areas where there is no coal storage, transportation, handling or processing or any disturbance, is clean water, as it generally contains negligible concentrations of coal fines or sediments. Runoff is diverted around dirty water and coal-contact catchments to avoid mixing with clean water runoff. Clean water runoff is typically from natural and impervious catchments such as areas of vegetation, sealed roads, and sealed car parks.

Dirty water is runoff from disturbed areas and areas likely to contain suspended sediment, and hydrocarbons. This typically includes workshop and fuel storage areas. Coal-contact water is runoff from catchments where coal storage, transportation, handling, or processing occurs and is managed within the dirty water management system.



	Clean water	Groundwater	<small>© 2016. Whilst every care has been taken to prepare this figure, GHD make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the figure being inaccurate, incomplete or unsuitable in any way and for any reason.</small>	LOCATION	Myuna	Centennial Myuna Pty Ltd Water Management Plan Water Management Schematic		DATE June 2023	Figure 3-1
	Potable water			SEAM	NA				
	Wastewater			DRAWN	SM				
	Dirty water			CHECKED	TD				
				APPROVED	LH				
				SCALE	NTS				

3.2 Surface water management

An assessment of the water management structures associated with the Surface Facilities Area has previously been undertaken by GHD (2012a) and has been summarised in Table 3-1.

Table 3-1 Water management structures

Location	Purpose	Outflow	Water type	Approximate Catchment area (ha)	Capacity (ML)
Workshop Washdown Sump	Capture water from workshop washdown bay and remove hydrocarbons	Primary Settlement Tank	Dirty	0.2	0.25
Primary Settlement Tank	Provides a primary capture and settlement function for the CHP Dam	CHP Dam	Dirty	2.84	0.04
First Flush Tank (GPT)	Emergency fail safe for pollution events in carpark or hardstand	CHP Dam or LDP 9	Clean or Dirty	2.43	0.30
CHP Dam	Receives water from the captured flow in the Primary Settlement Tank.	Underground or overflow to Mine settling pond 2	Dirty	0.93	1.05
Mine Water Settling Pond 2	Receives mine water from the underground, overflows from the CHP Dam and some surrounding runoff.	Mine water settling pond 3	Clean (Mine Water)	0.1	1.80
Mine Water Settling Pond 3	Receives overflows from Mine Water Settling Pond 2.	LDP 9	Clean (Mine Water)	0.1	1.65
Emergency Coal Stockpile Sediment Dam (including additional spill volume)	Receives dirty water from the Stockpile Area and provides a settlement function.	CHP Dam or underground or Overflow via LDP 10	Dirty	2.58	4.55

Of the storages listed in Table 3-1, the First Flush Tank is defined as catering for a clean water inflow. The other storages cater for either a mine or dirty water inflow.

3.2.1 Inputs

The inputs into the surface water system consist of:

- Rainfall in catchment areas (both clean and dirty).
- Transfer of water from underground working and storages.
- Potable water from plant and equipment washdown activities.

3.2.2 Outputs

The locations where the surface water system can discharge from the Myuna Colliery are:

- LDP 10 – Emergency discharge to Wangi Creek via the Emergency Coal Stockpile Dam (only after a rainfall event of over 140 mm in a 24-hour period).
- LDP 9 – Discharge of up to 13 ML/day to Wangi Creek via the CHP Dam and Mine Water Settling Pond 3.

3.2.3 Clean water management

Clean water diversions and pipe network

Clean water diversions are constructed to convey the 20-year average recurrence interval (ARI) storm event and are lined such that erosion within the channel is mitigated. The 20-year ARI design storm event is in accordance with the guidance documented in *Managing Urban Stormwater – Soils and Construction Volume 2E: Mines and Quarries* (DECC; 2008) for non-erosive hydraulic capacity of drainage controls.

Figure 3-2 and Figure 3-3 present the clean water catchments and diversions at Myuna Colliery respectively. Table 3-2 summarises the features of the clean water diversions in place at Myuna Colliery.

Table 3-2 Clean water catchment diversion flows

Diversion location	Purpose	Approximate catchment area (ha)	Estimated channel flow (L/s)
Clean Water Diversion 1	Diverting the south eastern external catchment around the pit top to the clean water drainage network and onto Wangi Creek.	3.10	440
Clean Water Diversion 2	Diverting the southern external catchment to the clean water drainage network and into LDP 9.	4.80	630
Clean Water Diversion 3	Diverting the western external catchment to the clean water drainage network and into the LDP 9.	1.10	180
Clean Water Diversion 4	Diverting the northern external catchment to clean water drainage network and into the LDP 9.	1.00	170
Clean Water Diversion 5	Diverting the northern external catchment to clean water drainage network and into the LDP 9.	3.40	470
Clean Water Diversion 6	Diverting the western catchment of the Coal Stockpile to Wangi Creek.	2.30	340
Clean Water Diversion 7	Diverting the western catchment of the Coal Stockpile to Wangi Creek.	0.50	90
Clean Water Diversion 8	Diverting the clean water from the internal Haul Road to Wangi Creek.	1.60	250
Clean Water Diversion 9	Diverting the north western external catchment to the clean water drainage network and into the LDP 9.	1.00	200

Surface Facilities Area

The topography surrounding the Surface Facilities Area makes the diversion of external clean catchment runoff critical to an effective water management system. The Surface Facilities Area has a series of five diversions that feed into a stormwater pit and pipe network.

Diversion 1 diverts clean water from the southern area of the surface facilities into a stormwater network which discharges to a drainage line and onto Wangi Creek. This portion of the clean water system includes the workshop and store roof and helipad catchments.

Diversions 2, 3, 4, 5 and 9 include the diversions of catchments around the western and northern aspects of the Surface Facilities Area. These catchment areas are conveyed to LDP 9 via a stormwater network through the middle of the facilities area. Located within this same network are the catchments that contribute to the First Flush Tank. This includes catchments from the carpark, bathhouse and office roof area and runoff from around the washdown bay.

Emergency stockpile area

To reduce the runoff loads on the Emergency Stockpile Dam, clean water diversions have been constructed around the stockpile pad. These diversions, identified as channels 6, 7 and 8, effectively reduce the dirty water catchment to the Emergency Stockpile Area by approximately 55%. These diversions all convey water to Wangi Creek via open channels.

3.2.4 Dirty Water Management

Dirty water management network overview

Dirty water management structures are to be consistent with the requirements of Managing Urban Stormwater – Soils and Construction Volume 1 (Landcom, 2004) and Volume 2E: Mines and Quarries (DECC 2008).

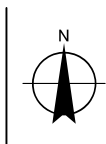
Within the Surface Facilities Area there are two key areas where dirty water management is required to mitigate the risk of coal-laden water being discharged from the colliery into Wangi Creek. These two areas can be identified as the CHP processing area and storage yard and the Emergency Stockpile Area.

Dirty water runoff from the CHP processing area and storage yard is directed through a series of open drains, and a drainage network to the Primary Settlement Tank. The Primary Settlement Tank has a limited volume and acts to capture large sediment material conveyed in runoff before discharging into the CHP Dam. The CHP Dam is where the settlement of coal material occurs.



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56



LEGEND

- Licensed Discharge Point
- Dirty Water Catchments
- First Flush Tank
- Watercourse
- LDP9
- 10m Contours
- Wangi Creek



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Clean Water Catchment Areas Figure 3-2

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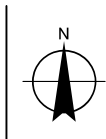
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Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56



LEGEND

-  Licensed Discharge Point
-  Clean Water Diversions
-  Clean Water Pit and Pipe Network
-  Watercourse
-  10m Contours



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Clean Water Diversion
 and Stormwater Network

Figure 3-3

Dirty water runoff from the Emergency Stockpile Area is directed to the Emergency Stockpile Dam. This water is transferred to the CHP Dam or directly to the underground workings

The dirty water catchments are shown on Figure 3-4 while the dirty water flow paths and drainage network are shown on Figure 3 5

Workshop Washdown Sump

The Workshop washdown sump receives surface water run-off from the workshop washdown bay, fuels storage area and materials storage. To improve the quality of the water the sump is fitted with an oil water separator system. This is dewatered to the Primary Settlement tank via a float triggered submersible pump.

Primary Settlement Tank

The Primary Settlement Tank has a small capacity and is used to capture sediment material prior to sediment entering the CHP Dam. It receives inflows from a drainage network of surface inlet pits and sheet flow from the surrounding catchment area. The tank has a small pipe which discharges to the CHP Dam and if the capacity is exceeded, the tank will overflow to the CHP Dam.

CHP Dam

The CHP Dam is dewatered to the underground workings water storage by a submersible pump and drainage line. The CHP Dam is managed to prevent overflow into the settlement dams. If overflow occurs the water will mix with settling pond water before being discharged offsite through LDP 9 into Wangi Creek.

- The CHP dirty water catchment and pipe network is presented in Figure 3-6

Emergency Stockpile Dam

Within the western corner of the Emergency Stockpile Area is the Emergency Stockpile Dam Sump which is bound by a bund approximately 1 m high and a storage depth of approximately 0.5 m. The Emergency Coal Stockpile area is used as a dam during extreme rainfall event.

Dirty water runoff from the Emergency Stockpile Area is captured in the Emergency Stockpile Dam. This water is dewatered to either the CHP dam or directly into the underground workings. If the capacity of the dam is exceeded, then the dam will overflow into Wangi Creek via LDP 10.

The Emergency Stockpile Dam catchment and clean water diversions are presented on Figure 3-7.

Mine Water Settling Ponds 2 and 3

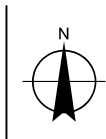
Inflow to the Settling Pond 2 includes pumped water from the underground workings and surface runoff from the surrounding area. Mine Water Settling Pond is constantly overflowing via its concrete weir to Mine Water Settling Pond 3.

Mine Water Settling Pond 3 discharges through an overflow weir outlet. This discharge flows through LDP 9 before reaching Wangi Creek. The volumetric limit for LDP 9 is 13 ML/day. The discharge volumes through LDP 9 can be controlled with the operation of valves and the various underground pumps to the surface. The standard transfer rates per day from underground to the surface are dependent upon operational conditions. Three main transfer pumps can operate simultaneously with a maximum rate of 10.5 ML/day to the surface.



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Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56



LEGEND

- Licensed Discharge Point
- CHP Processing Area and Storage Yard
- Emergency Coal Stockpile Area
- Pit Top General
- 10m Contours
- Watercourse



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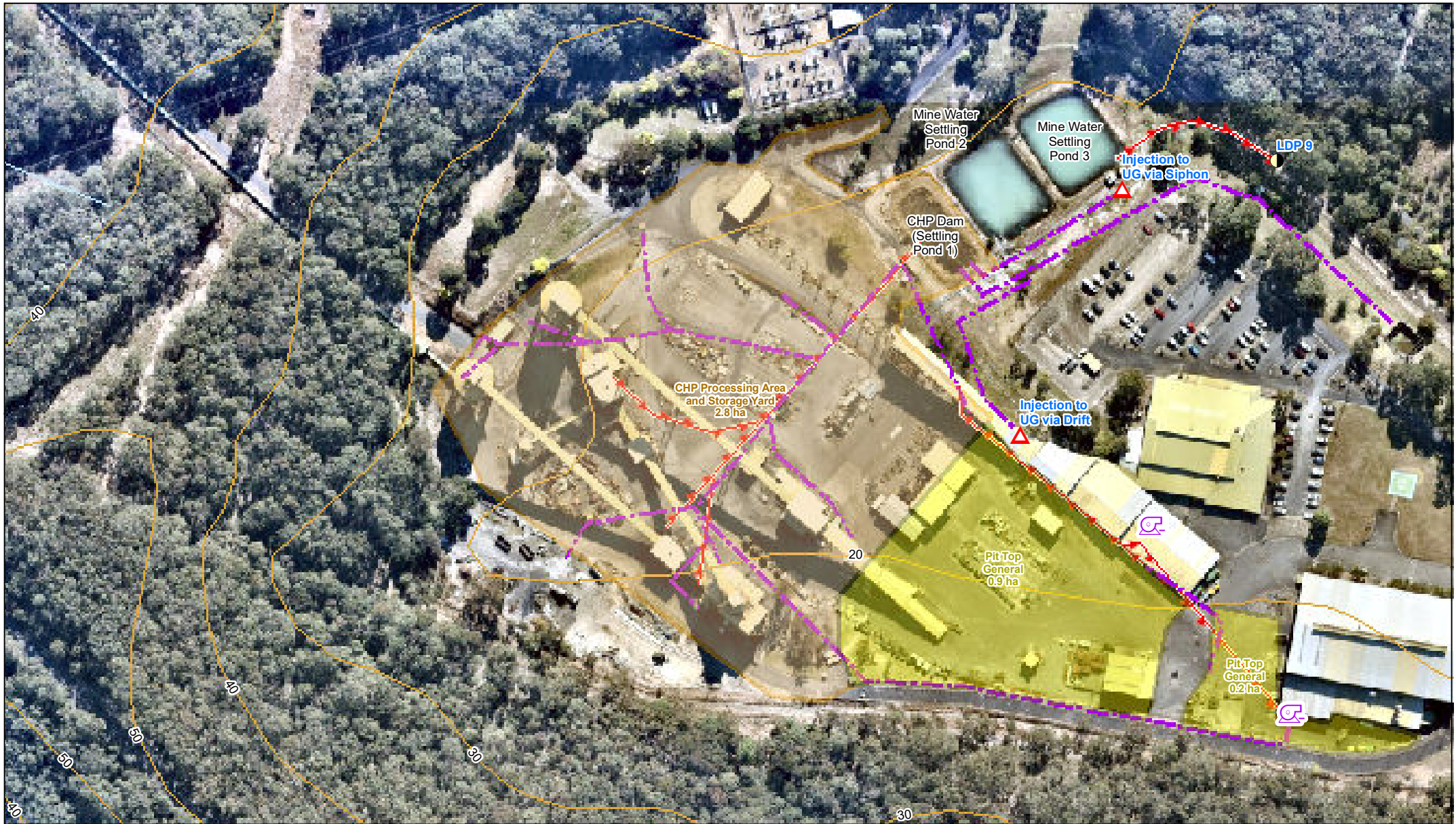
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Revision	1
Date	1 Dec 2021

Dirty Water Catchment Areas **Figure 3-4**

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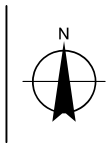
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Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56



LEGEND

- Dirty Water Pump Locations
- Injection Point
- Licensed Discharge Point

- Pit Top General
- CHP Processing Area and Storage Yard
- Dirty Water Pit and Pipe Network

- Dirty Water Flow Paths
- 10m Contours
- Watercourse



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 Revision | 1
 Date | 1 Dec 2021

CHP Dirty Water Catchment
 and Pipe Network

Figure 3-6

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Data source: © LPMA: DCTB & DTDB, 2007; AECOM: LDP data, 2009; Centennial: Drainage network, 2012; Nearmap: Aerial dated 20160504, extracted 20160720. Created by:

3.2.5 Management of potential contamination

Contamination risks across the general surface areas are mitigated through the establishment of 'dirty' areas for activities with the potential to cause contamination (e.g. re-fuelling), through establishing spill containment areas and by locating emergency spill kits in high-risk areas.

The clean water diversion network redirects water around site and into Wangi Creek. Rooftop and carpark catchments are directed to the First Flush Tank which can either be pumped to the CHP Dam or overflow to LDP 9. To mitigate the risk of a contaminated stormwater system, the First Flush tank is fitted with an oil mop system and can be pumped in the dirty water system, if required.

Run-off from the workshop and Washdown Bay is captured in the Workshop Sump. Oil is removed using by an oil mop. To mitigate this risk of overflow or failure into the clean water system, water levels in the Workshop Sump is monitored through level sensors, inspections are undertaken weekly, and routine maintenance is completed quarterly. Spills of hazardous materials are managed in accordance with Myuna Colliery's Pollution Incident Response Plan (PIRP). Clean up equipment and absorbent materials are available from spill stations. They are also available in bulk from the Myuna Colliery store.

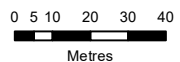
3.2.6 Sediment, erosion, and drainage controls

Myuna Colliery will undertake progressive rehabilitation of disturbed areas within the Surface Facilities Area as required. Areas of rehabilitation will be inspected regularly and assessed for evidence of erosion or sedimentation. In monitoring of rehabilitated areas, the focus will be on both the level of vegetation establishment and the adequacy of erosion, sediment, and drainage controls.

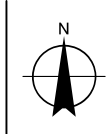
The condition of erosion and sediment controls will be recorded during site inspections and maintenance will be undertaken as required in response to observed defects. Refer to the Erosion and Sediment Control Plan (GHD, 2013b) in Appendix E for details on sediment loads and location, function, and capacity of sediment control structures. The Erosion and Sediment Control Plan (GHD, 2013b) is consistent with the requirements of the guideline document *Managing Urban Stormwater – Soils and Construction, Volume 2E: Mines and Quarries* (DECC, 2008).



Paper Size A4



Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56



LEGEND

- Licensed Discharge Point
- Clean Water Diversions
- Dirty Water Flow Paths
- Emergency Coal Stockpile Area
- Clean Water Pit and Pipe Network
- Watercourse
- 10m Contours



Centennial Myuna Pty Ltd
Water Management Plan

**Emergency Stockpile Dam
Catchment and Clean Water
Diversions**

Job Number	1
Revision	1
Date	1 Dec 2021

Figure 3-7

3.3 Groundwater and underground water management

The underground mine water management system is modified from time to time to adapt to the current mining conditions. Within the current area of operations and within each seam, water in the underground workings is collected and then transferred to underground storages to allow the settling of fines prior to being pumped to the surface.

The underground storages include:

- Great Northern Seam Dam (421 Dam)
- 642 Dam.
- Old Fassifern Dam (720 Dam).
- Wallarah Dam.

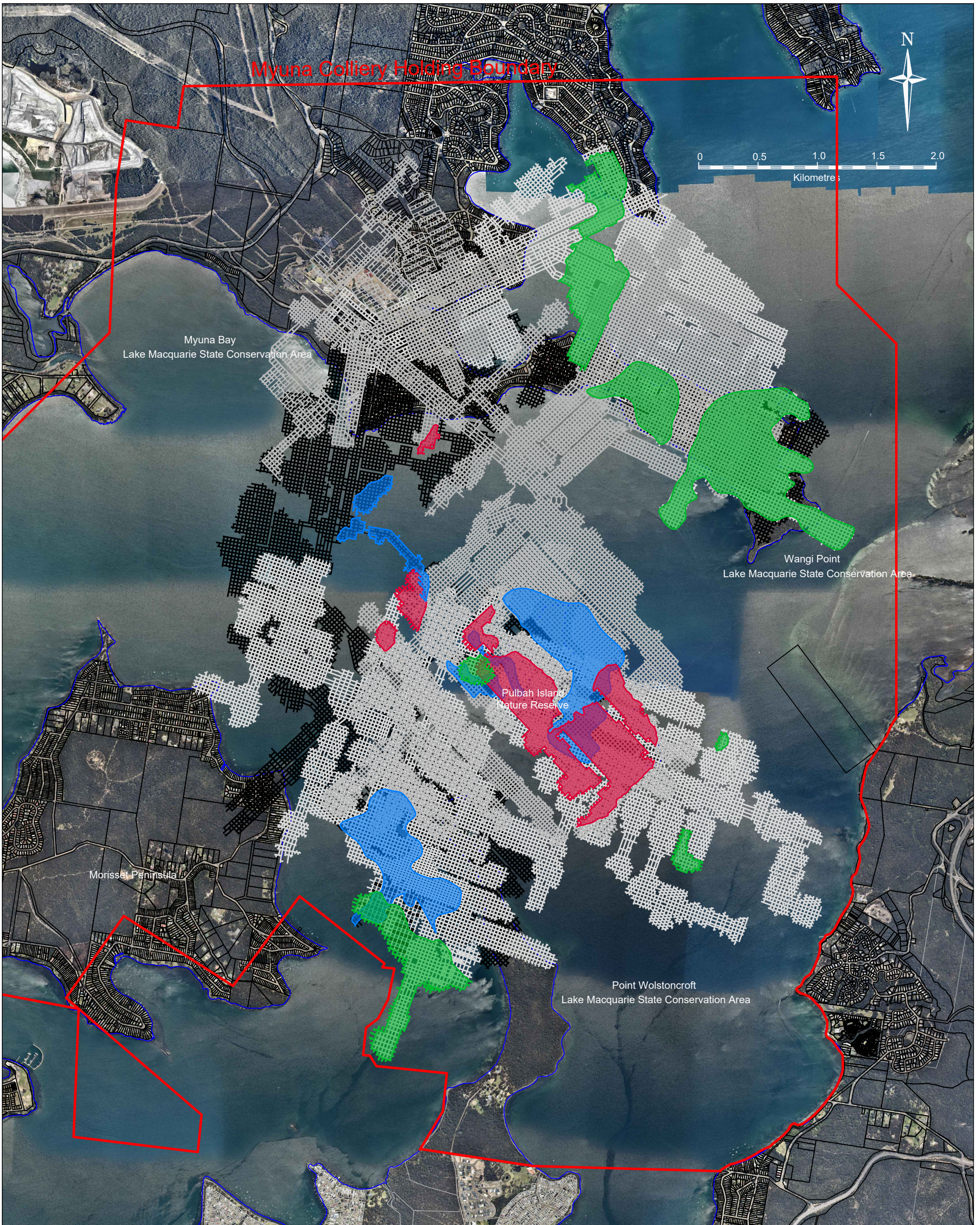
Figure 3-8 shows areas of underground stored water within each seam, as at February 2022.

3.3.1 Inputs

The inputs into the underground water system consist of groundwater recharge through natural hydrogeological processes, transfers from the CHP Dam at the surface and potable supply for mining operations.

3.3.2 Outputs

Water from underground is transferred to the surface and is discharged through LDP 9. Myuna Colliery manages water quality in a preliminary way within the underground storages prior to discharge at the surface.



LEGEND		DRAWN : DH		MYUNA COLLIERY	
Myuna Coal Operation Boundary Lake Macquarie and Wyong Cadastre Fassifern seam workings Great Northern seam workings Wallarah seam workings	February 2022 - Wallarah seam Stored water Volume = 1,381 megalitres February 2022 - Great Northern seam Stored water Volume = 1,045 megalitres February 2022 - Fassifern seam Stored water Volume = 2,184 megalitres	DATE : 13.06.2012	TITLE		
<i>Note: Seam water bodies - Volume calculated using an average seam height of 3m and a recovery ratio of 33.3%.</i>		CHECKED :	MYUNA COLLIERY COLLIERY HOLDING SHOWING SURFACE DETAIL AND UNDERGROUND WORKINGS AND AREAS OF STORED WATER February 2022		
		DATE :			
		APPROVED :			
		DATE :			
		SCALE	CAD FILE	PLAN NO.	REV.
		Scale Bar	MY11145_rev6	MY11145	6 A3

3.3.1 Hydrogeological model

A hydrogeological model to estimate groundwater inflow into the underground workings at Myuna Colliery up to the year 2200 was developed in 2010 by GHD. GHD (2014a) has revised the hydrogeological model for Myuna Colliery as part of the preparation of the Northern Operations Water and Salt Balance (GHD, 2014b).

Figure 3-9 presents the groundwater inflows predicted by hydrogeological modelling for Myuna Colliery. Current groundwater inflows into the active mining areas are estimated to be approximately 6.8 ML/day. Predicted inflows into the mine are expected to peak in 2032 at approximately 7.5 ML/day.

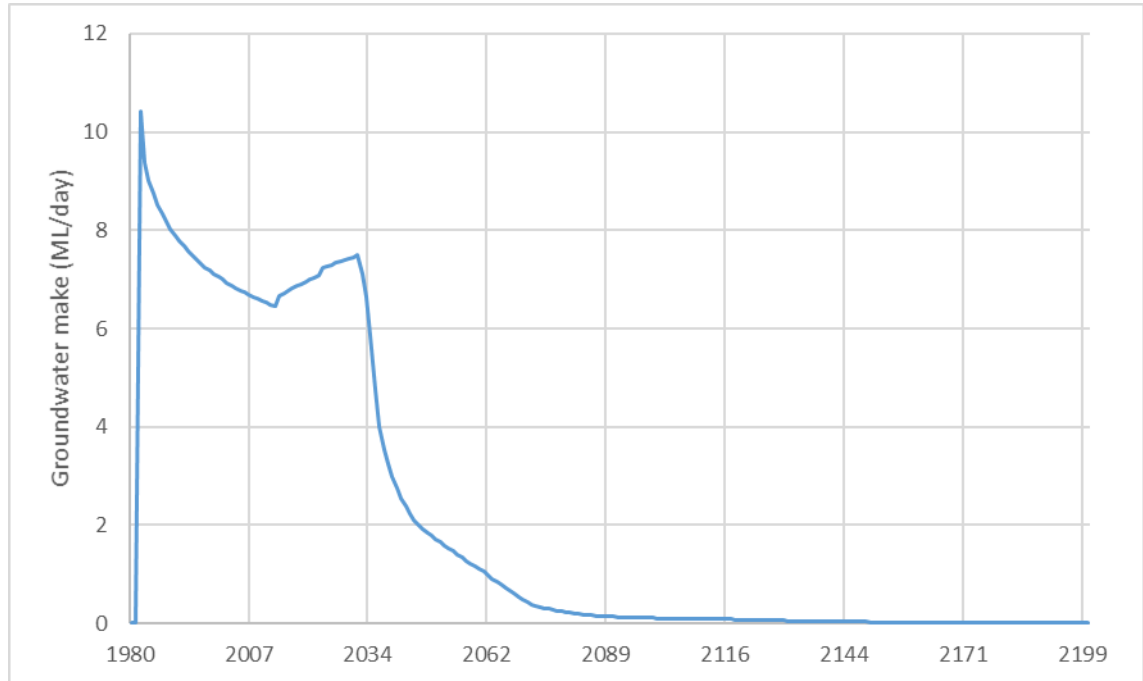


Figure 3-9 Predicted groundwater inflows into underground workings

The hydrogeological model was last review as part of the Annual Groundwater Management Report, prepared in 2020, this also reviewed the potential impact to alluvial aquifers. It was predicted that there will be no drawdown of alluvial aquifers greater than 0.1 m due to mining at Myuna Colliery. The Annual Groundwater Management Report was completed in accordance with 20BL172565 which has been superseded by WAL41560 and is no longer required.

3.4 Potable and wastewater systems

Potable water is provided to Myuna Colliery by HWC, through the Toronto and Wangi Wangi systems. The Wangi Wangi system provides water on demand to the underground workings and Surface Facilities Area while the Toronto system provides a secondary supply and can be switched over to supply the Surface Facilities Area and underground in an emergency.

Myuna Colliery will periodically investigate reasonable and feasible measures to minimise potable water on site.

Wastewater at Myuna Colliery includes grey water and sewage and is also serviced by HWC.

3.4.1 Inputs

The inputs into the site potable and wastewater systems consist of potable water provided to the underground workings, washdown bay, amenities, CHP, and on-site storage tanks.

3.4.2 Outputs

The outputs from the site potable and wastewater system are grey water and sewage from buildings directed to the HWC sewage system.

3.4.3 Water Security

There is a provision of water storage held for firefighting contingency on the Centennial Myuna site. However, a constant flow of water is necessary for underground mining operations. Myuna site has connections to two separate Hunter Water zones to enable supply contingency.

3.4.4 Maximisation of water reuse and recirculation

Potable water is provided to Myuna Colliery by HWC. Water reuse options within Myuna Colliery are limited to dust suppression within the Emergency Stockpile Area and firefighting.

At Myuna Colliery there is no permanent stockpile and most trafficked areas are paved. Therefore, opportunities for dust suppression within the Surface Facilities Area are limited.

To reuse water at Myuna Colliery water treatment would be required due to the salt content of the groundwater into the underground workings.

The reuse of captured underground water in mining activities is not possible due to the high electrical conductivity (EC) of the water. This is due to the nature of the groundwater environment and the influence of salt content present within Lake Macquarie.

3.5 Site water balance

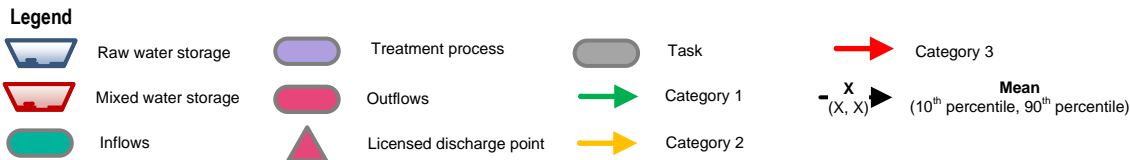
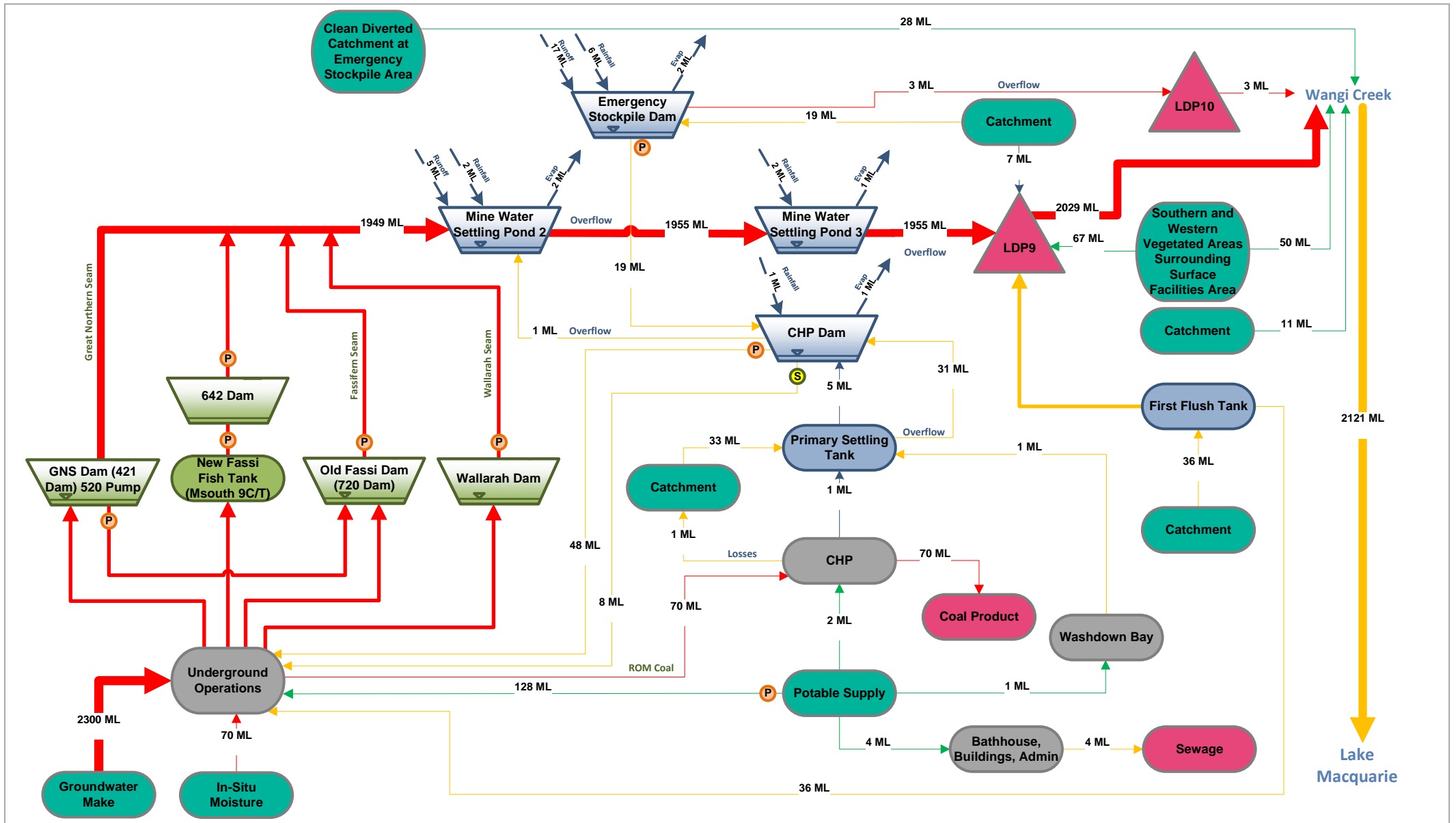
A site water balance was developed for Myuna Colliery in 2010 and has been progressively updated over time (GHD, 2016). The water balance was developed to quantify transfers within the site under existing and future operational conditions using various rainfall patterns.

3.5.1 Annual water balance

A summary of the predicted average annual inputs and outputs for the Myuna Colliery water management system under existing conditions in 2016 is provided in Table 3-3. A water cycle schematic for existing conditions (2021) is shown in Figure 3-10.

Table 3-3 Water Balance 2021

Water management element	Existing Conditions 2021 Volume (ML/year)
INPUTS	
Direct rainfall onto storages and runoff	13.3
Catchment runoff	168.0
Groundwater make	2,313.0
Potable water supply	105
In Situ moisture	92
TOTAL INPUTS (rounded)	2691
OUTPUTS	
Evaporation	12
Discharges through LDP 10	0
Discharges through LDP 9	1884.0
Wastewater system	11
CHP losses	1
Product Coal Moisture	92
TOTAL OUTPUTS (rounded)	2056
CHANGE IN STORAGE	
Surface water storages	0
Underground water storage	635
TOTAL CHANGE IN STORAGE (rounded)	0
BALANCE	
Inputs – outputs – change in storage	635



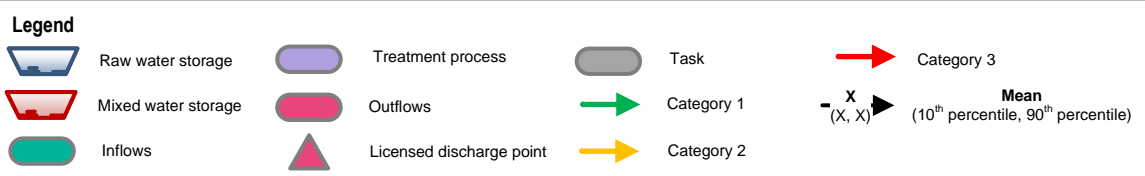
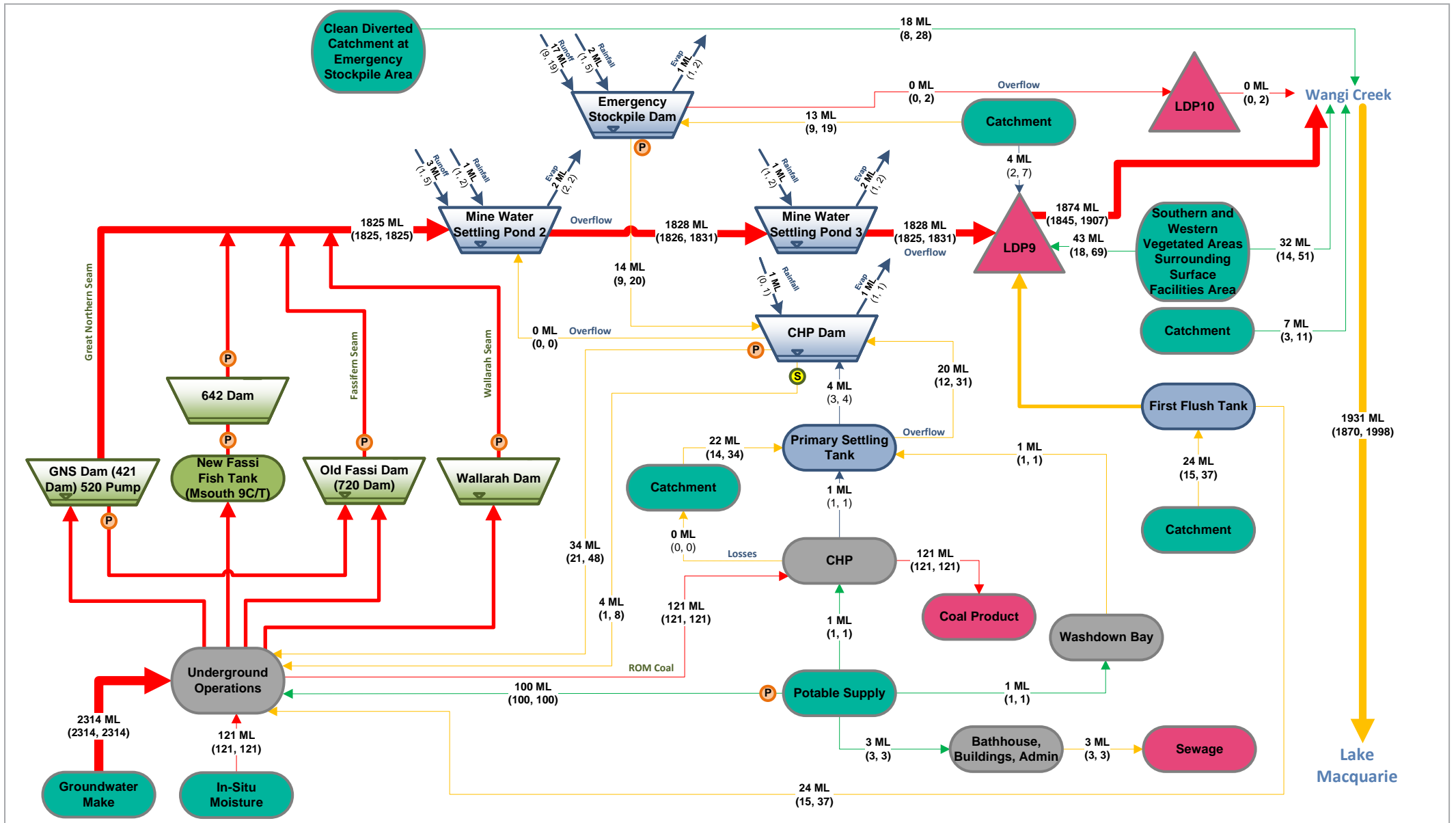
Centennial Coal Company Limited
 Myuna Colliery
 Annual water balance - 2021
Water management schematic
 Existing conditions (2021)

Project No. 12569542
 Revision No. 0
 Date 24/03/2022

FIGURE 1

Created by: Tyler Tinkler

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Centennial Coal Company Limited
 Myuna Colliery
 Annual water balance - 2021
Water management schematic
 Future conditions (2022)

Project No. 12569542
 Revision No. 0
 Date 24/03/2022

FIGURE 2
 Created by: Tyler Tinkler

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3.5.2 Discharge frequency

Discharges through LDP 10 have occurred due to heavy rainfall. The frequency and magnitude of discharges from LDP 10 are expected to remain rainfall-dependant for the life of the site.

The percentiles of the range of daily flow rates predicted to pass through LDP 9 under existing and future conditions are presented in Figure 3-11 below. For clarity, the results are shown on a single graph with the current EPL limit of 13 ML/day. Discharges of approximately 7.2 ML/day and 7.8 ML/day for existing and future conditions respectively, consisting predominantly of groundwater make, were modelled to occur for over 80% of days. Discharge greater than this is attributable to the variation in direct rainfall and runoff contributing to storages due to the wide range of possible rainfall conditions modelled.

The maximum discharge modelled was approximately 31 ML/day for both existing and future conditions. The maximum discharge under both existing and future conditions was modelled to occur on less than 0.1% of days. Discharges greater than the current EPL limit of 13 ML/day were predicted to occur on less than 2% of days in the year for both existing and proposed conditions.

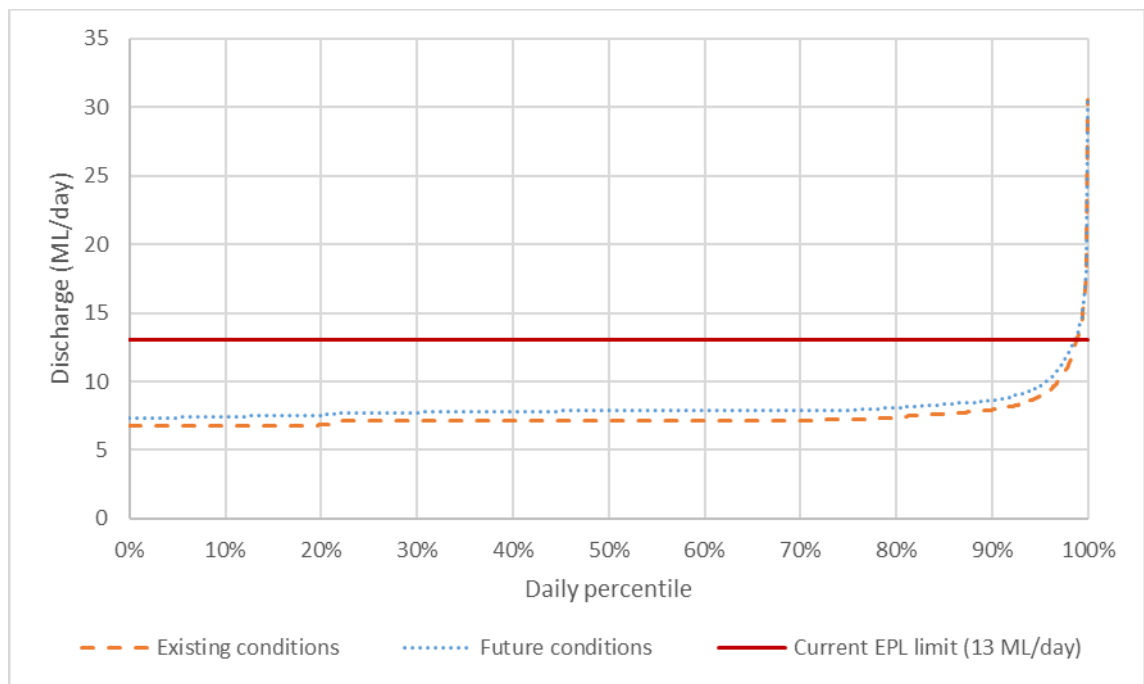


Figure 3-11 Predicted daily discharges from LDP 9

4. Monitoring requirements

4.1 Inspections

Site inspections are completed by the Centennial Myuna Environment and Community Coordinator and occur weekly and following rainfall events exceeding 40mm in 24 hours.

An example of a self-audit is undertaking the following activities:

- Walking around the site systematically.
- Inspecting water management and sediment control structures for capacity, structural integrity, and effectiveness.
- Recording and reporting on the condition of each water management and sediment control structure in place.
- Recording where around the site sediment is deposited.

Maintenance of the water management and sediment control structures will be implemented when visual defects are observed.

4.2 Surface water monitoring

Surface water quality at Myuna Colliery is currently monitored at the following locations:

- Upstream – located on Wangi Creek approximately 500 m upstream of LDP 9.
- Downstream – located on Wangi Creek approximately 180 m downstream of LDP 9.
- Wangi Lake – located in Lake Macquarie.

The locations of surface water quality monitoring sites are shown in Figure 4-1. All sites are monitored monthly. Water quality parameters are summarised in Table 4-1.

Table 4-1 Surface water quality monitoring parameters

Location	Frequency	Parameter
Upstream, Downstream, Wangi Lake	Quarterly	Physicochemical - EC, pH, TSS, turbidity. Nutrients - Total phosphorus. Cations - Calcium, magnesium, potassium, sodium, sulphur. Metals (dissolved and total) - Aluminium, antimony, arsenic, barium, boron, cadmium, cobalt, copper, iron, lithium, manganese, molybdenum, nickel, selenium, titanium, vanadium, zinc Other parameters - Oil and grease, silica. TPH (Downstream)
T2-5m, T2-10m,	Quarterly As per EPL366 requirements	¹ Manganese (2 samples at each location)

¹Manganese monitoring at T2 5m and T2 10m is completed to satisfy EPL366 Condition 8 E.1, which is subject to change.

There is no flow rate monitoring at Wangi Creek. Contribution of discharges to Wangi Creek is monitored through LDP 9 and LDP 10.

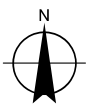


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LEGEND

- Licensed Discharge Point
- Surface Water Monitoring Location
- Surface Facilities Area
- Watercourse
- Footprint

Paper Size A4
 0 55 110 220 330 440
 Metres
 Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56



**Centennial
Myuna**

Centennial Myuna Pty Ltd
Water Management Plan

Surface water quality
monitoring locations

Job Number	1
Revision	1
Date	1 Dec 2021

Figure 4-2

4.3 Groundwater monitoring

4.3.1 Underground water quality data

The water quality of groundwater transferred from the underground workings to the surface is assessed as required. Monitoring of coal seam aquifers is not possible via boreholes as typically seen at other Centennial sites. This is due to the location of the workings which are primarily under Lake Macquarie or urban residential properties.

With the nature of the groundwater environment and the dominance of Lake Macquarie effecting both groundwater inflow and quality to Myuna Colliery, and the fact that there are no bores within or in close vicinity of the site, recording standing levels within the underground storages is the most appropriate way to monitor groundwater inflows and provide observational data for re-calibrating and updating the hydrogeological model for Myuna.

4.3.2 Underground water transfers

Daily monitoring of the following underground water transfers is undertaken:

- Supply of potable water to mining equipment within the Myuna workings.
- Transfer of water from underground storage area to mine water settling ponds.

Annual monitoring of water levels within the underground storage area will also be undertaken.

4.3.3 Alluvial groundwater monitoring

The groundwater monitoring network at Myuna includes ten shallow alluvial monitoring bores. These alluvial bores were installed in July 2012. Groundwater level monitoring at these locations commenced in November 2017 and was sampled on monthly basis until June 2023. To date (June 2023) there has been no significant change to groundwater levels due to mining activities, as predicted in the EIS and the GHD Hydrogeological Model (2016). Myuna will continue to measure and sample groundwater levels (mAHD) and water quality parameters (pH), quarterly as of Q3 2023. Details of the groundwater monitoring bores are provided in Table 4-2 and locations are shown in Figure 4-2.

Table 4-2 Groundwater monitoring bore details

Bore	Easting	Northing	Bore depth ¹ (m)	TOC (m AHD)	Groundwater level July 2012 (m AHD)
MW01	366421.196	6340666.725	6	20.6	19.357
MW05	366382.919	6340757.928	18.5	20.6	13.229
MW06	366352.036	6340702.937	13	20.6	13.211
MW07	366099.275	6340745.900	8.5	25.8	22.134
MW08	366166.975	6340855.902	9	24.6	21.364
MW09	366358.936	6340904.374	11	19.4	17.272
MW10	366253.961	6341072.879	10	30.1	24.666
MW11	366298.845	6341178.276	7	14.4	12.306
MW12	366523.721	6340866.437	7	9.3	6.779
MW13	366673.814	6340926.691	8	5	0.53

Notes:

TOC: Top of casing

1. Measured from TOC

4.4 Discharge water monitoring

4.4.1 Surface water discharge flows

Myuna Colliery has recently established monitoring at LDP 10 and LDP 9. The discharge monitoring program is outlined in Table 4-3.

Table 4-3 Discharge Volume monitoring

Location	Frequency	Monitoring device
LDP 10	Daily during discharge	Level sensor
LDP 9	Daily during discharge	Continuous electronic flow meter

4.4.2 Surface water discharge quality

Table 4-4 outlines the discharge water quality monitoring requirements for Myuna Colliery, which fulfils the specifications of EPL 366. *EPL366 requires a monthly sample during discharge, as of September 2022.

Table 4-4 Discharge quality monitoring

Location	Frequency	Parameters
LDP 10	Daily during discharge	Oil and grease, pH, TSS.
LDP 9	Monthly	Oil and grease, pH, TSS.

4.5 Watercourse stability monitoring

Centennial Myuna monitor the extent of channel incision at the downstream extent of reach W2, as shown in Figure 4-3. In the event of substantial incision of a channel (as defined by formation of a head-cut greater than 0.3 m high), structural intervention is likely to be required to stabilise the waterway. Channel incision will be monitored visually during inspections and in accordance with the triggers and actions stipulated within the stream health trigger action response plan (refer to Section 6). Channel incision inspections at the downstream extent of reach W2 will typically occur at least once every six months or during routine water quality sampling events at nearby monitoring locations.

Stream health and channel stability inspections will also be undertaken in areas along reaches W1, W2 and W3 annually. Visual monitoring of watercourses is to be carried out by suitably qualified professionals to identify any instabilities that may form because of discharge activities.

Inspections will identify if any of the following potential impacts occur within the creek lines or immediate catchment flow paths:

- Change in stream bed or bank conditions.
- Incision or head cut development.
- Ponding (particularly 'out of channel' ponding).
- Step changes in bed profile.



- Any notable/indicative changes in stream vegetation.

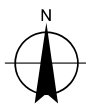
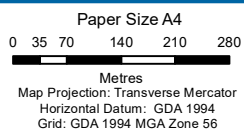
The monitoring locations for assessing watercourse stability (W1, W2, and W3) are presented in Figure 4-3.



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LEGEND

-  Groundwater Monitoring Location
-  Surface Facilities Area



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Water Management Plan

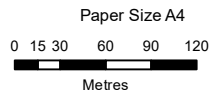
Job Number	1
Revision	1
Date	1 Dec 2021

Groundwater monitoring locations **Figure 4-2**

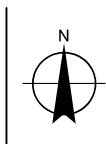
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Data source: © LPMA: DCTB & DTDB, 2007/2012; AECOM: Aerial & LDP data, 2009. Centennial: Monitoring, 2012; ESRI: Imagery, 2016. Created by:



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56



LEGEND

- Surface Water Monitoring Location
- Licensed Discharge Point
- Surface Facilities Area
- Waterways
- 10m Contours



Centennial Myuna Pty Ltd
 Water Management Plan

Job Number |
 Revision | 1
 Date | 1 Dec 2021

Watercourse geomorphic
 stability monitoring locations

Figure 4-1

5. Baseline data

5.1 Surface water flow

Myuna Colliery do not currently undertake flow monitoring of Wangi Creek or any other waterway. Contribution of discharges to Wangi Creek is monitored through LDP 9 with discharges from LDP 10.

Discharge monitoring at LDP 9 between 2013 and 2017 is provided in Figure 5-1.

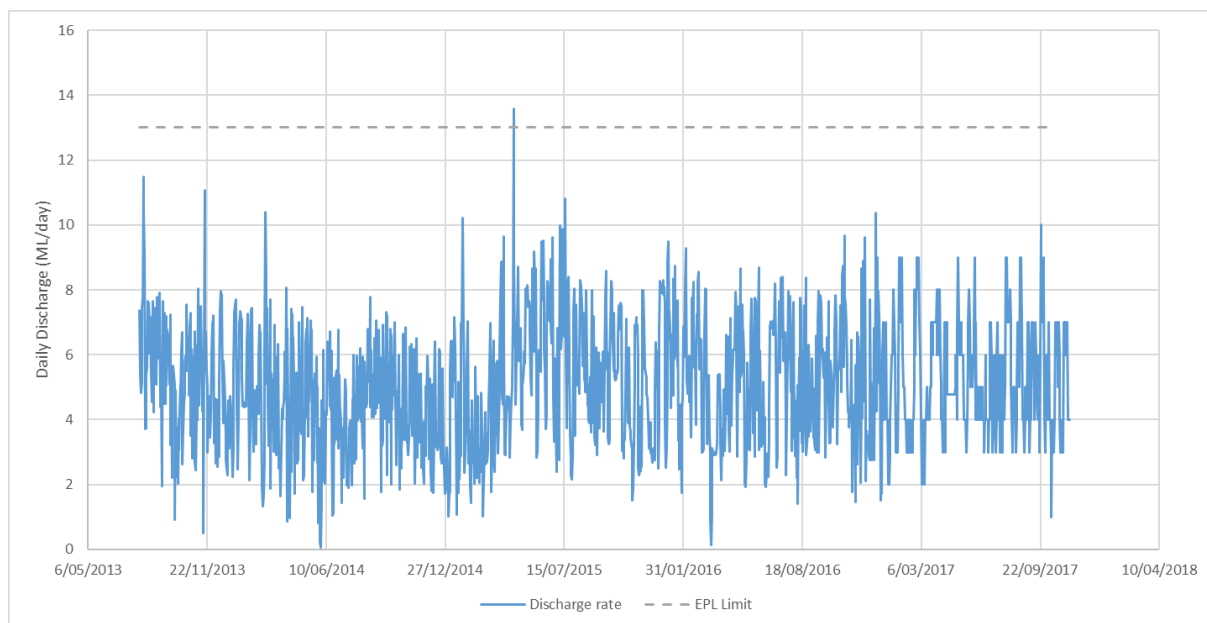


Figure 5-1 LDP 9 daily discharges between 2013 and 2017

The discharge limit for LDP 9 is 13 ML/day. From historical monitoring, one event has occurred that exceeded this limit in 2015. This event was because of a large rainfall event (299.2 mm in three days) in April, which increased the stored volume in the mine water settling ponds, resulting in an increased discharge volume. More details have been defined within the Annual Review completed for that year. Typically, daily discharge volumes as part of normal operation range between 3 and 8 ML/day

Potential water loss from waterways that exist above areas of mining are monitored through the assessment of alluvial monitoring bores.

5.2 Surface water quality

A surface water quality assessment was undertaken by GHD (2015b) for the following locations, as shown in Figure 4-1:

- Upstream.
- LDP 9.
- Downstream.
- Wangi Lake.

Summary statistics for these sites have also been provided in Appendix A. Time series graphs for selected water quality parameters monitored at LDP 9 over the period January 2011 to December 2015 are provided in 0. The EPL limits for oil and grease, pH and TSS specified by EPL 366 for LDP 9 discharges are also presented in the relevant figures. In cases where results were

less than the limit of reporting (LOR), the relevant LOR value has been plotted. Below is a summary of the baseline water quality data from January 2011 to December 2014.

5.2.1 Upstream

Water quality results for the Upstream site on Wangi Creek indicates the water is slightly acidic with elevated levels of TSS, turbidity and total phosphorus having been reported in recent samples.

Relatively low concentrations of the major ions have been recorded at the Upstream site.

Most results for dissolved and total metals were generally reported to be below the LOR, except for aluminium, barium, iron, manganese, nickel, titanium, and zinc.

Data from the Upstream monitoring location was used, in conjunction with ANZECC (2000) guidance, to develop site-specific trigger values (SSTVs). Further details on SSTVs are provided in Section 6.1.1.

5.2.2 LDP 9

Based on the available water quality data for the monitoring period, the water sampled at LDP 9 is slightly alkaline with low levels of TSS, turbidity and oil and grease. All parameters were within the limits specified by EPL 366 during the 24 monthly monitoring events, from March 2013 to February 2015. EC has not been addressed since the receptor is a marine environment.

Most total phosphorus results have been reported to be below the LOR for the most recent data.

Concentrations of the major ionic species were generally greater than those recorded at the Upstream monitoring site.

For assessed dissolved and total metals, most parameters were generally found to be below the LOR for the most recent data, except for barium, boron, iron, and manganese. Barium, boron, and manganese concentrations at LDP 9 were generally elevated compared to the Upstream monitoring site, however iron results were generally lower.

5.2.3 Downstream

Downstream monitoring results followed similar trends to LDP 9 results. The water sampled at the Downstream monitoring site was slightly alkaline, with low levels of TSS, turbidity and oil and grease. Levels of pH were within SSTVs, with the majority of TSS and turbidity results also below SSTVs. One sampling event in April 2013 recorded TSS and turbidity levels exceeding SSTVs. However, as the results for the Upstream monitoring site and LDP 9 discharge do not show the same increase in TSS and turbidity, these results are anomalous.

Most total phosphorus results were found to be at or below the LOR for the Downstream monitoring site, however the SSTV of 0.035 mg/L was found to be exceeded in approximately 18% of sampling events during the 24 monthly monitoring events.

Results for the major ions at the Downstream site indicated a similar range as for LDP 9 discharge.

Dissolved and total metal results at the Downstream monitoring site followed similar trends to LDP 9 discharge. Most metals were found to be below the LOR and relevant SSTVs for 24 monitoring events. Recent exceedances of SSTVs at the Downstream site have been reported for dissolved barium, boron, and silver.

Dissolved barium and boron results have consistently been detected at the Downstream site and exceeded SSTVs. Concentrations for both barium and boron at this site are similar in range to the results reported for LDP 9 discharge, which is elevated compared to the Upstream monitoring site.

The SSTV for silver was exceeded on three occasions during the 24 months; however, no dissolved silver has been detected at the Downstream monitoring site since March 2014. Dissolved silver at the Upstream monitoring site and in LDP 9 discharge has not been detected in any monitoring events, with all samples reported to be below the LOR. This indicates that the dissolved silver detected at Downstream was not associated with the upstream conditions or discharges from Myuna Colliery.

Overall, median concentrations during the 24 months of monitoring at site Downstream are below SSTVs except for dissolved barium and boron. These concentrations are most likely attributable to the mine water discharge at LDP 9, although it is noted that dissolved boron concentrations are higher in Wangi Lake.

5.2.4 Wangi Lake

Water quality results for Lake Macquarie from the Wangi Lake monitoring site indicate that the water is slightly alkaline, with very low levels of TSS, turbidity and oil and grease reported.

Total phosphorus results were mostly reported to be at or below the LOR and like the results in Wangi Creek and LDP 9 discharge.

The major ionic species concentrations were slightly elevated compared to the LDP 9 and Downstream site results.

Many dissolved and total metal results were found to be at or below the LOR for the Wangi Lake site during monthly monitoring events, except for barium, boron, and molybdenum. Barium concentrations within Lake Macquarie were reported to be lower than the results recorded within Wangi Creek at the Upstream, LDP 9 and Downstream monitoring locations. Boron and molybdenum concentrations at the Wangi Lake site were reported to be elevated compared to all three Wangi Creek monitoring sites, indicating these parameters may be associated with background levels in Lake Macquarie rather than discharge from Myuna Colliery.

5.3 Groundwater levels and quality

5.3.1 Underground extractions

GHD (2017) has recently undertaken an assessment of the long-term daily underground extraction rate from Myuna Colliery. Daily transfer volumes over the period 2011 to 2015 are shown in Figure 5-2 and ranged from 0 ML/day to 13.6 ML/day. Review of the extraction data indicates that approximately 40% of the extracted volumes are from the Wallarah Seam workings. Note that extraction volumes overestimate groundwater inflows into the mine since they also include potable water transfers to the mine (GHD, 2017).

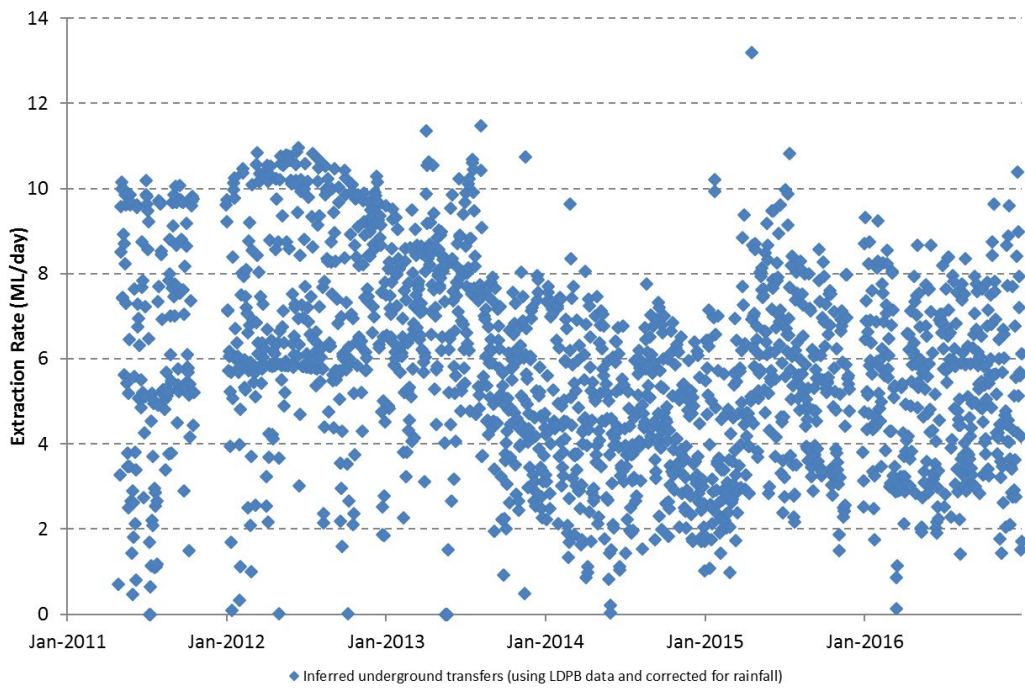


Figure 5-2 Daily total underground water extraction (inferred from LDP 9 (formerly LDP B) discharge volumes)

Visual inspection of the trend in Figure 5-2 indicates that extraction from the underground workings was decreasing from mid-2013 to 2014. Extraction rates began to increase in 2015. This is most likely attributable to the storage of groundwater inflows within old workings and/or underground dams rather than the immediate extraction of groundwater inflows.

Annual extraction volumes between 2011 and 2022 are listed in Table 5-1. Based on these recorded volumes, Centennial Myuna has consistently met Condition 17 of bore licence 20BL172565, and WAL4380 which limits the annual extraction of groundwater to 4,380 ML (GHD, 2017).

Table 5-1 Annual transfers of water from the underground workings

Year	Annual volume (ML)
2011	2,047
2012	2,580
2013	2,281
2014	1,614
2015	1,930
2016	1,902
2017	1,747
2018	1,923
2019	1,864
2020	1,893
2021	1,949
2022	1,840

5.3.2 Underground water storages

The underground water storages in the Wallarah Seam, the Great Northern Seam and the Fassifern Seam have been surveyed in February 2022 by Centennial Myuna. Based on assumptions around seam height, water storage areas and recovery rate, an underground stored volume can be determined. Table 5-2 provides the assumed underground storage volume, in 2022.

The hydrogeological model developed for Myuna Colliery assumes that the volumes of each of these storages are relatively constant. Follow up survey is to be conducted as part of the annual review of the site water balance to determine whether storage volumes have changed, and the hydrogeological model recalibrated as required.

Table 5-2 Underground water storage volumes – February 2022

Seam	Water storage volume (ML)
Walarah Seam	1,381
Great Northern Seam	1,045
Fassifern Seam	2,184

5.3.3 Groundwater quality

The water quality of underground water storages was sampled for 2 years from 2014-16. Generally, the water was slightly alkaline and saline. Generally, the underground water from the Fassifern Seam has a higher EC and dissolved iron concentration than the other seams. Underground water from the Great Northern Seam generally has lower dissolved manganese concentrations. Baseline water quality monitoring of the metals iron, manganese, barium and boron were taken from the three seams from 2014 – 2016. As discussed in section 5.2 these were the four metals found in LDP 9 above the LOR. The influence of mining on alluvial groundwater quality has not been observed as predicted in the EA due to the limited hydraulic connection between the alluvium and the Approved Project, the type of mining and the proximity of bores to the underground workings.

Key monitoring results from both underground water storages and underground water transfers are provided in Appendix C.3

5.3.4 Alluvial Groundwater monitoring network

The groundwater monitoring network at Myuna Colliery includes ten alluvial monitoring bores. Baseline groundwater levels at these monitoring bores are shown in Table 4-2. Observed groundwater levels in Figure 24. show that groundwater levels are generally stable with minor fluctuations. Monitoring results for alluvial groundwater and reported and discussed in the annual review.

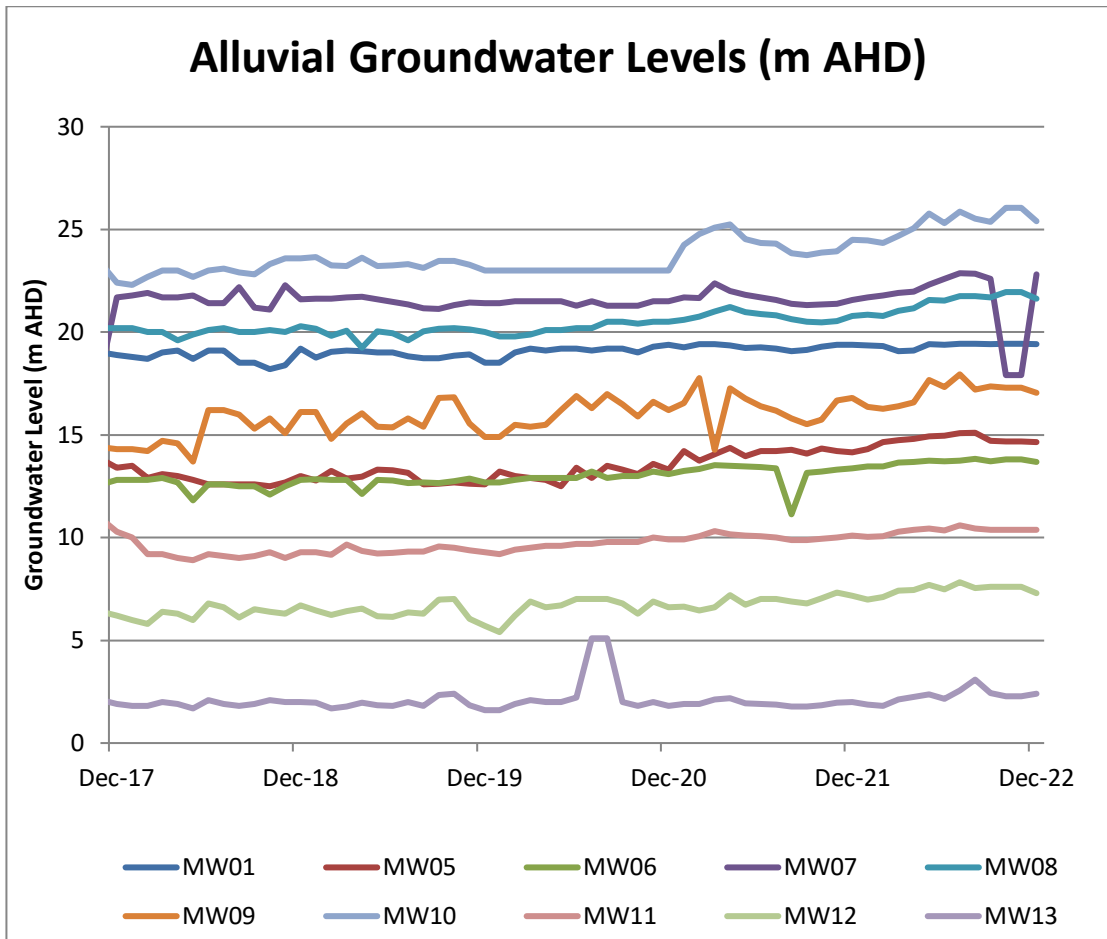


Figure 3 - Alluvial Groundwater Levels from December 2017 to December 2022 (m AHD).

5.4 Watercourse stability

Overall, Wangi Creek was defined as generally well vegetated and stable, although the creek is modified in places due to past disturbances (GHD, 2012a). The reaches inspected as part of the baseline assessment (W1, W2, W3, LDP 10 and LDP 9) were shown previously on Figure 4-3.

The five reaches are described in Table 5-3.

Table 5-3 Summary of baseline conditions of Wangi Creek

Reach identifier	Description
W1	This reach exhibits largely a natural channel of between 2 to 3 m and is generally 1 to 2 m deep. Banks are well-vegetated and there is no evidence of channel instabilities or significant bedload transport. At the downstream extent of this reach, a loose rock structure extends across the creek. Being like a rock grade control, this structure limits the potential for channel bed incision within the reach. Discharges from LDP 10 would enter this reach upstream of the rock structure.

Reach identifier	Description
W2	Downstream of the loose rock structure, the channel loses definition and Wangi Creek exhibits a swamp like environment. In this reach flows are dissipated across the entire valley floor which is well vegetated with <i>melaleuca sp.</i> and <i>gahnia sp.</i> There is largely no evidence of significant instabilities, erosion, or bedload transport in this reach. However, the downstream 20 to 30 m of the reach steepens as the streamline drops to converge with the LDP 9 channel. Along this section, there are a number (4 to 5) of low headcut features less than 0.1 m high. These are stabilised by tree roots and/or small logs. Future decay of the tree roots or logs could result in the reactivation of these headcuts resulting in channelisation of the reach.
W3	This reach exhibits a concrete lined channel invert up to 5 m wide and 1 to 2 m deep. Banks are generally graded and consist of cohesive fine-grained sediments. Given the concrete lining and grassed, graded banks, this reach is considered stable.
LDP 10	<p>The discharges from LDP 10 flow into an earthen channel confined and inset by 4 to 5 m within previously placed fill materials. The invert of this channel is generally 2 to 3 m wide and has a gentle gradient as evidenced by pooling along its extent. The upstream half of this reach is defined by the outlet of the Emergency Stockpile Dam which has created some instability in the channel cross section.</p> <p>Discharges from LDP 10 enter this reach at its upstream extent via a pipe connected to the sedimentation dam that services the emergency coal stockpile area.</p>
LDP 9	<p>Downstream of the LDP 9 discharge point, discharges flow through a piped network before outflowing into an earthen channel. This channel runs parallel to Wangi Creek in Reach W3 for approximately 200 m. The channel is constrained by fill materials along the left bank, which is steep and up to 4 – 5 m high. Along the left bank, a levee type structure exists which separates flows from the LDP 9 discharge channel from flows in Wangi Creek.</p> <p>Towards the upstream extent of this reach, a breach of a levee structure that had occurred in the past was repaired in October 2017. Due to extensive rainfall this has again been breached. Repair works are currently being scoped and due to be completed Mid 2023.</p>

The geomorphic assessment undertaken in 2012 as part of the Surface Water Management Plan (GHD, 2012a) described in Table 5-3 indicates that mine water discharges are not expected to have any significant impacts on the stability of Wangi Creek. Myuna Colliery will continue to monitor channel stability within Wangi Creek in accordance with the inspection process outlined in Section 4.5.

6. Response plans

6.1 Triggers

6.1.1 Surface water quality triggers

GHD (2015b) has undertaken a water quality assessment of background levels at surface water and mine discharge monitoring sites within and surrounding the Myuna Colliery (described in Section 5.1). The SSTVs for surface water sites at Wangi Creek, based on ANZECC (2000) guidelines and site-specific water quality monitoring data, are listed in Table 6-1 (GHD, 2015b).

Table 6-1 Site-specific trigger values for Wangi Creek (Downstream)

Parameter	Units	SSTV
Physicochemical parameters		
pH	pH unit	6.2–8.5
TSS	mg/L	77
Nutrients		
Total phosphorus	mg/L	0.035
Dissolved metals		
Aluminium	mg/L	0.724
Antimony	mg/L	0.27
Arsenic	mg/L	0.023
Barium	mg/L	0.04
Boron	mg/L	5.1
Cadmium	mg/L	0.0055
Cobalt	mg/L	0.001
Copper	mg/L	0.0013
Iron	mg/L	2.1
Lithium	mg/L	0.001
*Manganese	mg/L	0.66
Molybdenum	mg/L	0.023
Nickel	mg/L	0.07
Selenium	mg/L	0.01
Silica	mg/L	22.94
Titanium	mg/L	0.01
Vanadium	mg/L	0.1
Zinc	mg/L	0.016

*Manganese SSTV is as prescribed in the report titled 'Manganese Discharge from the Myuna Colliery ANZECC/ARMANZ Study' prepared by Hydrobiology Pty Ltd, dated March 2004, in

alignment with EPL366 Special Condition E1.1. Manganese is subject to additional monitoring through EPL366 Special Condition E1.1. Quarterly samples are taken from Wangi Bay, Lake Macquarie and provided to the EPA. Included in this is a trend analysis via graph presenting manganese monitoring results reported in accordance with condition E1 over a rolling 10 year period. This graph must also include relevant water quality guideline(s) for manganese. In the past 10 years (as of June 2023) there have been no exceedances of the water quality guidelines. These results are published in the Annual Review and Monthly Website Report which are both publicly available on the Centennial Myuna website.

6.1.2 Alluvial Groundwater levels

Groundwater level monitoring within alluvial aquifers commenced in November 2017 and completed monthly until and including December 2022. Results are reviewed against the trigger values listed in Table 6-2 below. Trigger values are based on baseline monitoring data and the 20th percentile levels. Monitoring will continue quarterly from June 2023 due to the limited influence observed on the alluvial groundwater levels from mining, which is complementary to the predictions of the Environmental Assessment for the project and hydrogeological model (Section 3.3.1). The areas where alluvial groundwater bores are located at Myuna Colliery are not planned to be undermined further at this stage.

Table 6-2 Alluvial Groundwater Trigger Levels

Monitoring Well Number	Boredepth ¹ (m)	TOC (m AHD ²)	Trigger Value (m AHD)
MW01	6	20.6	18.73
MW05	18.5	20.6	12.63
MW06	13	20.6	12.65
MW07	8.5	25.8	21.31
MW08	9	24.6	19.95
MW09	11	19.4	12.63
MW10	10	30.1	22.98
MW11	7	14.4	9.18
MW12	7	9.3	6.17
MW13	8	5	0.53

Notes: TOC: Top of casing, 1. Measured from TOC, 2. AHD – Australian height datum

6.1.3 Water Quality of Underground Water Storages

The water found within underground storages is a combination of surface water run-off, process water and infiltration of groundwater. Water quality within each seam is variable and heavily influenced by Lake Macquarie as this is the main source of water. The water from underground storages is pumped out to the surface into the surface dams and discharged through LDP 9. Water sampling at LDP 9 is a combination of the underground storage waters. Groundwater quality can be compared to the limits for EPL 366 for pH and TSS. Based on underground water quality sampling undertaken between 2014 and 2016, 20th and 80th percentiles were determined

for selected parameters monitored in each seam. These are provided in Table 6-2. All metal parameters are representative of filtered concentrations.

Table 6-2 Underground water storages quality ranges

Percentile	pH	EC (µS/cm)	TSS (mg/L)	Iron (mg/L)	Manganese (mg/L)	Barium (mg/L)	Boron (mg/L)
Fassifern Seam							
20th	7.4	48360	5	0.1	0.421	0.097	0.84
80th	7.8	49920	13.6	2.04	0.677	0.110	1.31
Great Northern Seam							
20th	7.6	40080	5	0.05	0.005	0.193	0.3
80th	8.1	41640	24	0.082	0.095	0.273	0.81
Wallarah Seam							
20th	6.8	35740	5	0.05	0.601	0.105	0.05
80th	7.7	40500	7	0.5	1.130	0.136	0.50

Above in Table 6-2 are the range of water qualities monitored within the underground over a period of two years. Underground water storages are pumped to the surface and regulated through LDP 9. If surface water quality is monitored outside of typical water quality criteria, the seam water quality would be tested as part of the investigation as to determine the source of the exceedance.

The values provided in Table 6-2 are intended to inform further management actions to mitigate risk of exceeding water quality limits at LDP 9.

6.1.4 Underground water management

Underground stored water is an issue of operational management with no specific level or volume trigger defined as part of the overall water management system. Monitoring will be undertaken to support calibration and validation exercises for the Hydrogeological Model.

6.1.5 Discharge triggers

Water quality monitoring data for LDP 10 and LDP 9 discharges are compared to EPL 366 concentration limits where applicable, as shown in Table 1-4. The discharge volume limit for LDP 9 as outlined by EPL 366, is 13 ML/day.

6.2 Performance criteria

Performance criteria have been developed based on baseline information and the approach presented within the Northern Operations RWMP.

6.2.1 Surface site operations

The performance criteria for on-site surface water management at Myuna Colliery is outlined in Table 6-3.

Table 6-3 On-site surface water management criteria

Aspect	Criteria
Surface storages	Storages sized in accordance with Landcom (2004) and DECC (2008) and maintained within the capacity of each storage.
Water quality management	Clean and dirty water separation.
Erosion and sediment control	<p>Minimising disturbance area.</p> <p>Pit top disturbance and other construction activities to be managed in accordance with the approach and guidelines outlined in the Northern Operations RWMP.</p> <p>Where construction works are significant an erosion and sediment control plan (ESCP) and construction environmental management plan will be prepared.</p>
Hydrocarbon management	Chemical and hydrocarbon storage to be in accordance Australian Standard AS1940:2017.

6.2.2 Watercourses

Criteria for the management of water quality within watercourses are provided in Table 6-4.

Table 6-4 Watercourse criteria

Aspect	Criteria
Watercourse quality	Below SSTVs provided in Table 6-1.

6.2.3 Groundwater environment

Based on the triggers derived in Section 5.3, Table 6-5 presents the groundwater management performance criteria for Myuna Colliery.

Table 6-5 Groundwater environment criteria

Aspect	Criteria
Alluvial Groundwater level	<p>No impact from mining to water level</p> <p>No complaints from surrounding groundwater users.</p>
Underground water quality	<p>No complaints from surrounding groundwater users.</p> <p>Discharge sampling at downstream within criteria</p>
Underground water level/storage	Within safe operating levels determined by the Myuna Colliery.

6.2.4 Discharge management

Discharge management includes both discharge volume and quality. The criteria applied for Myuna Colliery is presented in Table 6-6.

Table 6-6 Discharge management criteria

Aspect	Criteria
Discharge volume	Discharge is to only to occur in accordance with event-based criterion and the daily discharge limit specified in EPL 366.
Discharge quality	Discharge water quality must be less than EPL criteria provided in Table 1-4.

6.2.5 Stream health

The condition of riparian and in-stream vegetation and channel stability will be used during observation monitoring (in addition to the water quality criteria listed above in Table 6-1) to assess the health of Wangi Creek. The specific stream health assessment criteria (GHD, 2012a) to be followed during observation monitoring are detailed in Table 6-7.

Table 6-7 Stream health assessment criteria

Element	Parameter	Criteria
Riparian and in-stream vegetation	Vegetation condition – photographic log	Photographic log indicates that vegetation has not been detrimentally impacted over time.
Channel stability	Erosion – photographic log	Photographic log indicates occurrence of erosional processes has not occurred because of water discharges over time.
Watercourse subsidence	Subsidence – photographic log	Photographic log indicates no ponding, changes in stream bed or bank conditions, incision, head cut development, or surface cracking because of subsidence.

7. Site-specific reviews and reports

7.1 Hydrogeological model

Centennial Myuna will review the hydrogeological model for Myuna Colliery on an annual basis and update as necessary. The review has been previously undertaken in conjunction with the annual groundwater report which is no longer required due to the succession of Bore Licence 20BL173259, to WAL41560. Groundwater monitoring data will be used for verification of the hydrogeological model. If the review of monitoring data indicates trends that differ from the predictions of the hydrogeological model, then the hydrogeological model should be recalibrated using monitoring data. To date, the groundwater monitoring results have been in line with the predictions of the hydrogeological model and the project's Environmental Assessment.

7.2 Site water balance

Centennial Myuna will review the site water balance at least every three years or in response to significant changes to water management practices on site.

8. Exploration and Surveys

8.1 Background

Rockhead is the term used for the thickness of bedrock to the coal seam beneath soil cover at the bed of the lake. Understanding the rock depth and thickness is critical to Centennial Myuna's ongoing management of the risk of inrush into its underlying mining operations. Catastrophic inrush of water is a specified principal hazard under relevant safety legislation. All mines are required to address this risk through a Principal Hazard Management Plan. Given Myuna's location this under the Lake Macquarie this issue has relevance. Myuna has a responsibility under the Work Health and Safety Act to ensure, as far as reasonably practicable to ensure the safety of its workers. A significant amount of work has already been completed at Myuna Colliery to manage risks associated with mining beneath tidal waters and foreshore areas. The current mine planning parameters allow for first workings only, with conservative design of pillars providing significant safety factors for long term stability. The continued application of these design parameters for mining under the lake (to the 40 m rock head cover line) has been the major control for managing the risk of potential inrush at the mine.

To determine rockhead depth and thickness, ongoing survey and exploration activities are required to be carried out. These activities are necessary to:

- Enable the coal resource to be defined with greater accuracy.
- Gather information to complete a safe mine design.
- Provide information to assist with future mine planning and design.
- Gather geotechnical information related to strata type, strength, stability, and defects.
- Gather geological information related to the location and magnitude of geological structures.

The types of survey and exploration activities undertaken at Myuna include:

1. Magnetic surveys

Magnetic surveys are used to collect information on the intensity of the magnetic field across the area of interest. This information is used to identify where intrusions may occur within the coal seam. These surveys can be conducted via boat or an unmanned aerial vehicle, commonly referred to as a drone, is used to undertake these surveys. The drones are flown along survey lines at low altitudes (minimum 5 m above the water surface) and at low speeds (approximately 32 km/hr). The magnetic survey would provide exploration without the need for disturbance activities, with staff operating the drone making use of existing publicly accessible areas to launch the equipment.

2. Shallow Marine Survey

Shallow marine survey systems are used to determine physical properties of the sea floor and to image and characterise geological information a few metres below the sea floor. Specifically, this survey technique will be used by Centennial Myuna to provide a higher definition of rock head thickness above the coal seam and provide definition of the rock head features.

The shallow marine surveys are undertaken using a low impact survey method which uses a small boat towing survey equipment called a Sparker. Sound pulses bounce off the lake floor to help map the topography and composition of the lake floor. The acoustic energy is generated by a mechanical device meaning there is no explosive source used to generate energy. A Sparker

converts electrical energy into acoustic energy via the creation of a plasma bubble and the consequent generation of an acoustic pulse. This technique is used worldwide.

In Lake Macquarie similar survey methods are regularly used to monitor how the changing lakebed impacts on boat navigation in Swansea Channel. It is regularly used in Newcastle and Sydney harbours to assess water depth for dredging. Similar technologies are also used by marine scientists in sensitive marine environments, such as the Great Barrier Reef, to develop maps used to model ocean currents, storm surge inundation, and better understand ecosystem and biodiversity patterns on the seabed. These types of maps are widely used across all marine environments.

3. Rockhead drilling

Completed using a combination of rotary drilling methods in soils using HWT and HQ drill casings, and NMLC coring methods in rock; with the target being 1 m length of rock (with drilling ranging in depths of 30 to 40 m). This type of drilling is used to determine rockhead thickness and calibrate the shallow marine survey results. The drill rig would be transported to the relevant drilling location via a 20 tonne Jack-up barge, which would be held in position using spuds/jack-feet up to 30 m long. Jacks simply give the barge stability in water. The area of the barge represents a works site as if it were on land. The barge would remain on station (over borehole) each day / night and during weekends.

4. Surface to Seam Drilling

Completed using a combination of rotary drilling methods in soils using PW and HWT casing, and HQ coring methods in rock; with the target being Fassifern Seam, ranging in depths between 100 m and 170 m. This type of exploration is used to investigate coal quality. The drill rig would be transported to the relevant drilling location via a 20 tonne Jack-up barge, which would be held in position using spuds/jack-feet up to 30 m long. The barge would remain on station (over borehole) each day / night and during weekends.

8.2 Summary of Potential Impacts

8.2.1 Soil Impacts

The drilling programme is the only activity with the potential to impact estuarine sediments because of the anchoring of the barge and completion of drilling activities. Given the small diameter of the drill holes (approximately 100 mm), drilling would have a negligible impact on sub-surface soil structure. The completion of work from the barge would mean sub-surface disturbance is restricted to the area required for drilling as such any impacts would be localised.

8.2.2 Aquatic Ecology Impacts

The potential for benthic disturbance through direct removal of substrate only applies to drilling activities. Removal of these communities will result in the temporary loss of biodiversity from the impact areas however it is expected that biodiversity will not be permanently affected. Following the completion of the boreholes, the impacted seabed will be rapidly colonised by benthic species under a long-term natural recruitment process. It is expected that a mature community comparable to the one currently present, will be achieved within months of drilling activities being completed.

Indirect impacts may also occur to nearby communities, through the generation of turbid plumes and impacts of increased suspended sediment levels on filter-feeding organisms. These localised plumes are temporary and suspended sediments are expected to disperse rapidly.

8.2.3 Noise

Shallow marine surveys will generate underwater noise via the use of an acoustic signal (Squid 501). In addition, artificial noise will also be generated during vessel movements, and during drilling activities. Disturbance to marine fauna from above ground and underwater activities may occur in response to noise generated by these activities.

8.3 Exploration and Survey Management and Mitigation Measures

To manage impacts from the proposed survey and exploration activities, the following mitigation measures will be implemented.

8.3.1 General

All exploration and survey activities will be carried out within standard work hours as defined by the Interim Construction noise Guideline being:

- Monday to Friday: 7:00 am to 6:00 pm.
- Saturday: 8:00 am to 1:00 pm.
- Sundays and public holidays: no work.

8.3.2 Drilling

- Drilling will be conducted in accordance with Australian Standards (AS 1726:2017).
- No drilling in identified seagrass meadows or within 100m of identified artificial reefs.
- Drilling will be carried out using a method appropriate to the sediment characteristics within the site with the method reducing environmental impacts as far as practicable.
- Presence of marine mammals should be visually monitored by crew members for at least 30 minutes before the commencement of drilling, in particular within the shut-down zone (1 km), but also the observation zone (2 km) where possible - with observation continuing throughout operation.
- Drilling will be put on standby to shut down in the event a marine mammal is observed to come within the observation zone during operation. The drill rig will then be shut down if it comes within the shut-down zone, until such time that it leaves again.
- Waste drilling fluids will be captured and stored onboard for onshore disposal through registered according to legislative requirements
- Physical controls such as silt curtains and/or drill collars will be implemented to contain any disturbance of sediment.
- Drill holes will be rehabilitated in accordance with Departmental guidelines upon completion of drilling activities.

8.3.3 Shallow Marine Survey

- Shallow marine survey works will follow all relevant Legislation and Guidelines.
- Survey activities will implement mitigation measures outlined in EPBC Act Policy Statement 2.1 Part A (DEWHA, 2008) as appropriate for marine mammals.
- The interaction of all vessels with marine mammals will be compliant with Part 8 of the Environment Protection and Biodiversity Conservation (EPBC) Regulations (2000).
- The Australian Guidelines for Whale and Dolphin Watching (Commonwealth of Australia, 2017) for seafaring activities will also be implemented.
- All survey crew members will be briefed on EPBC Act Policy statement requirements, operations and stop work procedures, as well as low visibility procedures.
- Any other mitigation measures proposed by DPI-Fisheries will be implemented as appropriate in consultation with DPI-Fisheries (see Section 8.5 below).

The survey crew members will be following these mitigation and control procedures to avoid impact:

For Marine Mammals:

- Precaution zones will be implemented (Observation (3+ km) and Shut down (500 m)).
- Pre-start up visual observation of precaution zones (>30 mins before start).
- Survey line pass will not commence if marine mammals are within the low power or shut down zone within intended passage of vessel – alternate route will need to be selected.
- Crew will maintain vigilant observation for marine mammals within precaution zones and vessel planned path throughout shallow marine surveys.
- Survey array will be shut down if a marine mammal enters shut down zone.
- Any other mitigation measures proposed by DPI-Fisheries will be implemented as appropriate in consultation with DPI-Fisheries (see Section 8.5 below).

For dolphins and whales:

- Caution zone (300 m either side of whales and 150 m either side of dolphins) – vessels must operate at no wake speed in this zone.
- Caution zone must not be entered when calf (whale or dolphin) is present.
- No approach zone (100 m either side of whales and 50 m either side of dolphins) – vessels should not enter this zone and should not wait in front of the direction of travel or an animal or pod or follow directly behind.
- If there is a need to stop, reduce speed gradually.
- Do not encourage bow riding. If animals are bow riding, do not change course or speed suddenly.
- Any other mitigation measures proposed by DPI-Fisheries will be implemented as appropriate in consultation with DPI-Fisheries (see Section 8.5 below).

As noted above, many management measures reflect Commonwealth policy and guidelines for survey activities as they represent the most comprehensive recommendations for similar activities. As noted in Section 8.5 below, specific engagement with DPI-Fisheries will be

undertaken to identify any additional management and mitigation measures that should be taken into consideration by Centennial Myuna when carrying out exploration and survey activities on Lake Macquarie.

Should any unexpected impacts to marine species be identified during survey activities that could have been caused by the activities being undertaken, works will cease immediately. Works will not recommence unless Centennial, in consultation with DPI-Fisheries, are satisfied that impacts can be appropriately managed, and any additional management or mitigation measures are implemented where necessary.

8.4 Notifications

Communication regarding proposed exploration and survey activities will be undertaken to:

- Ensure that relevant stakeholders are informed about the proposal.
- Provide stakeholders with an opportunity to ask questions and to identify areas of concern with respect to the proposal.
- Allow Centennial Myuna to implement an approach to stakeholder communications that is transparent and timely.
- Effectively and proactively identify and manage issues and risks.
- Keep accurate records of consultation and communication with stakeholders.

Prior to exploration activities being undertaken, notifications regarding the proposed activities will be provided to stakeholders as identified in Table 8-1 below. The below Stakeholders are minimum notification requirements and additional stakeholders may also be notified as relevant.

Table 8-1 Exploration and Survey Stakeholder Notification

Stakeholder Group	Name
Government	Resources Regulator
	Department of Planning and Environment – Planning & Assessment Group
	Department of Primary Industries - Fisheries
	Roads and Maritime Services
	NSW National Parks and Wildlife Service
	Lake Macquarie City Council
	State MP
Lake Users	South Lake Macquarie Amateur Sailing Club
	Lake Macquarie Yacht Club
	Royal Motorboat Yacht Club Toronto
	Toronto Amateur Sailing Club
	Marmong Point Marina

Stakeholder Group	Name
	Teralba Amateur Sailing Club
	Speers Point Amateur Sailing Club
	Mannering Park Amateur Sailing Club
	Wangi Amateur Sailing Club
	Wangi RSL Fishing Club
	Wye Point Marina
	Lake Macquarie Game Fishing Club
Residents	Notification in local newspaper
Local Interest Group	Myuna Colliery Community Consultative Committee

8.5 Engagement

8.5.1 Department of Primary Industries – Fisheries

Specific engagement with Department of Primary Industries – Fisheries will be undertaken to identify any additional mitigation and management measures that should be considered as part of the exploration and survey programs. Any mitigation measures proposed by DPI-Fisheries will be implemented as appropriate in consultation with DPI-Fisheries

8.6 Information Availability

Information regarding any exploration and survey activities will be made available on the Centennial website (www.centennialcoal.com.au).

9. Action Plan

MP Section	Location	Requirement	Frequency
Inspection			
4.1	Surface pit top	Site inspections are completed by the Centennial Myuna Environment and Community Coordinator and occur at least weekly. Maintenance of the water management and sediment control structures will be implemented when visual defects are observed.	Weekly and following 40mm of rainfall in a day.
	Emergency Coal Stockpile Dam	An inspection of the Emergency Coal Stockpile Sediment Dam is to be carried out by an Engineer annually	Annually
Surface Water Quality			
4.2	Upstream, Downstream, Wangi Lake	Physicochemical - EC, pH, TSS, turbidity. Nutrients - Total phosphorus. Cations - Calcium, magnesium, potassium, sodium, sulphur. Metals (dissolved and total) - Aluminium, antimony, arsenic, barium, boron, cadmium, cobalt, copper, iron, lithium, manganese, molybdenum, nickel, selenium, titanium, vanadium, zinc Other parameters - Oil and grease, silica.	Quarterly
	T2-5m, T2-10m	Metals (dissolved) - Manganese (2 samples each)	Quarterly
Groundwater Monitoring			
4.3.1	Discharge pipes into Mine Dam 1	The water quality of groundwater transferred from the underground workings to the surface is assessed for: pH, total dissolved solids (TDS), TSS and turbidity.	As required
4.3.1	Underground water storages	The underground water storages are sampled and analysed for:	As required

MP Section	Location	Requirement	Frequency
		pH and TDS.	
4.3.2	Discharge pipes into Mine Dam 1	Daily monitoring of the transfer volume of water from underground storages to the mine water settling ponds.	Daily
4.3.2	Underground water storages	Annual monitoring of water levels within the underground storage area.	Annually
Alluvial Groundwater Monitoring			
4.3.3	MW01, MW05, MW06, MW07, MW08, MW09, MW10, MW11, MW12, MW13	Alluvial groundwater level (m AHD) and water quality monitoring for pH	Annually
Discharge Water Monitoring			
4.4.1	LDP 9	Volume (kL) - Discharge flow via continuous electronic flow meter	Continuously
4.4.1	LDP10	Volume (kL) - Level sensor	Daily during discharge
4.4.2	LDP 9	Physicochemical - Oil and grease, pH, TSS.	Monthly during discharge
		Nutrients - Total phosphorus. Cations - Calcium, magnesium, potassium, sodium, sulfur. Metals (dissolved and total) - Aluminium, antimony, arsenic, barium, boron, cadmium, cobalt, copper, iron, lithium, manganese, molybdenum, nickel, selenium, titanium, vanadium, zinc. Other parameters - silica.	Quarterly
		Metals (dissolved and total): chromium, cyanide (total), lead, mercury, Others: chlorine (total), cyanide (total), fluoride (total).	Quarterly
4.4.2	LDP 10	Physicochemical - Oil and grease, pH, TSS.	Daily during discharge
		Nutrients - ammonia (total), nitrogen (total), phosphorus (total). Cations - Calcium, magnesium, potassium, sodium, sulfur.	Monthly during any discharge

MP Section	Location	Requirement	Frequency
		<p>Metals (dissolved and total) - Aluminium, antimony, arsenic, barium, boron, cadmium, chromium, cobalt, copper, cyanide (total), iron, lithium, manganese, molybdenum, nickel, selenium, titanium, vanadium, zinc.</p> <p>Other parameters - chlorine (total), cyanide (total), fluoride (total), silica.</p>	
Watercourse Stability Monitoring			
4.5	Reaches W1, W2 and W3	Stream health and channel stability inspections will be undertaken in areas along reaches W1, W2 and W3 annually.	Every 6 months
Site Specific Reviews and Reports			
7.2	Hydrogeological Model	Review the hydrogeological model for Myuna Colliery on an annual basis and update as necessary.	Review Annually Update as necessary.
7.3	Site water balance	Centennial Myuna will review the site water balance at least every three years or in response to significant changes to water management practices on site.	Every 3 years or in response to significant changes
7.4	EPA Quarterly Report	In accordance with Special Conditions E1 of EPL 366 Myuna Colliery will submit a quarterly report to the Regional Manager, Hunter of the EPA.	As per EPL366 requirements (currently Quarterly)

10. References

AECOM (2011), *Myuna Colliery Extension of Mining Environmental Assessment*, prepared by AECOM Australia Pty Ltd for Centennial Myuna Pty Limited.

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Centennial Myuna Pty Ltd (2014) *Environmental Assessment Myuna Colliery*, Section 75W Modification to Project Approval PA 10_0080

DECC (2008), *Managing Urban Stormwater: Soils and Construction – Volume 2E Mines and quarries*, NSW Department of Environment and Climate Change.

GHD (2010) *Myuna Colliery – Water Management Assessment*, prepared by GHD Pty Ltd for Centennial Myuna Pty Ltd.

GHD (2012a) *Myuna Colliery – Surface Water Management Plan*, prepared by GHD Pty Ltd for Centennial Myuna Pty Ltd.

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GHD Pty Ltd (2012d) *Myuna Mine – Surface and Groundwater Response Plan*, prepared by GHD Pty Ltd for Centennial Myuna Pty Ltd.

GHD (2013a) *Myuna Colliery – Water Management Plan*, prepared by GHD Pty Ltd for Centennial Myuna Pty Ltd.

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GHD (2014a) *Myuna Colliery – Hydrogeological Model*, prepared by GHD Pty Ltd for Centennial Myuna Pty Ltd.

GHD (2014b) *Northern Operations Water and Salt Balance*, prepared by GHD Pty Ltd for Centennial Coal Company Limited.

GHD (2015b) *Myuna Colliery – ANZECC Water Quality Assessment*, prepared by GHD Pty Ltd for Centennial Myuna Pty Ltd.

GHD (2016) *Myuna Colliery Site Water Balance Update*, prepared by GHD Pty Ltd for Centennial Myuna Pty Ltd.

GHD (2017) *Myuna Colliery – Annual Groundwater Management Report*, prepared for 2016 by GHD Pty Ltd for Centennial Myuna Pty Ltd.

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NSW Department of Mineral Resources (1995), *Newcastle Coalfields Regional Geology 1:100,000 map*.

Appendices

Appendix A – Trigger Action Response Plans

TARP	TRIGGER	ACTIONS IF TRIGGER ACTIVATED	TO BE INFORMED
STOCKPILE / CHP DAM WATER LEVEL CAPACITY	<ul style="list-style-type: none"> Dam Levels <30% of Total Capacity 	<ul style="list-style-type: none"> No action required. 	
	<ul style="list-style-type: none"> Dam Levels 30 – 70% 	<ul style="list-style-type: none"> Check weather forecast Reduce water inflow rate where possible Check dewatering pumps 	Environmental Coordinator
	<ul style="list-style-type: none"> Dam Levels 70 – 99% 	<ul style="list-style-type: none"> Increase inspection frequency Reduce water inflow rate where possible Dam pit-top drains for temporary storage Treat water with flocculant in preparation for discharge Seek additional dewatering pumps 	Engineering Manager Environmental Coordinator
	<ul style="list-style-type: none"> Dam capacity exceeded 	<ul style="list-style-type: none"> Enact the PIRMP if material harm to the environment has occurred Contain or redirect water away from the dam Organise water sampling Downstream and at T-2 (5m) 	Mine Manager Engineering Manager Environmental Coordinator
EROSION AND SEDIMENT CONTROL	<ul style="list-style-type: none"> Sediment controls installed appropriately Ground stable and not vulnerable to erosion 	<ul style="list-style-type: none"> No action required 	

TARP	TRIGGER	ACTIONS IF TRIGGER ACTIVATED	TO BE INFORMED
	<ul style="list-style-type: none"> Disturbed ground not remediated and at risk of erosion 	<ul style="list-style-type: none"> Remediate ground and cover as soon as practical following disturbance 	Environmental Coordinator
	<ul style="list-style-type: none"> Erosion of areas due to rainfall and contained within dirty water system 	<ul style="list-style-type: none"> Install sediment control structures Divert water away from area if possible 	Environmental Coordinator
	<ul style="list-style-type: none"> Rainfall event has led to erosion and sediment laden water leaving site 	<ul style="list-style-type: none"> Enact the PIRMP if material harm to the environment has occurred Contain or redirect water away from the dam Organise water sampling 	Mine Manager Environmental Coordinator
CLEAN WATER DIVERSIONS	<ul style="list-style-type: none"> Clean water diverted around dirty water catchment 	<ul style="list-style-type: none"> No action required 	
	<ul style="list-style-type: none"> Clean water diversion partially blocked 	<ul style="list-style-type: none"> Monitor condition more frequently Organise maintenance contractor to clear blockage 	Environmental Coordinator
	<ul style="list-style-type: none"> Clean water entering dirty water system Clean water diversion blocked 	<ul style="list-style-type: none"> Clear blockage immediately Redivert clean water into dirty water system 	Environmental Coordinator
	<ul style="list-style-type: none"> Dirty water entering clean water system 	<ul style="list-style-type: none"> Enact the PIRMP if material harm to the environment has occurred Isolate dirty water source, if possible 	Environmental Coordinator Mine Manager
HYDROCARBON MANAGEMENT	<ul style="list-style-type: none"> Hydrocarbons stored in bunded areas Spill-kits stocked No spills Oil Mop separator systems operational 	<ul style="list-style-type: none"> No action required 	
	<ul style="list-style-type: none"> Hydrocarbon stored outside of bunded area Spill-kits needs to be restocked or not available Minor spill on surface area <20L 	<ul style="list-style-type: none"> Return hydrocarbon to bunded area Order or restock spill kits Remediate spill using MY-EWP-001 	Environmental Coordinator
	<ul style="list-style-type: none"> >20L oil spill onsite contained within dirty water management system Oil Mop separator not operational 	<ul style="list-style-type: none"> Remediate spill as per MY-EWP-001 Organise maintenance contractor to repair oil mop Organise waste contractor sucker truck to remove oily water 	Environmental Coordinator

TARP	TRIGGER	ACTIONS IF TRIGGER ACTIVATED	TO BE INFORMED
	<ul style="list-style-type: none"> Oil spill has migrated offsite 	<ul style="list-style-type: none"> Remediate spill as per MY-EWP-001 Enact the PIRMP if material harm to the environment has occurred 	<p>Mine Manager Environmental Coordinator</p>
DOWNSTREAM WATER QUALITY	<ul style="list-style-type: none"> Water quality at monitoring locations consistent with historical baseline or are below SSTVs provided in Table 6 1. 	<ul style="list-style-type: none"> No action required 	Environmental Coordinator
	<ul style="list-style-type: none"> Water quality is outside or above SSTVs downstream of operations for at least one parameter and one round. 	<ul style="list-style-type: none"> Review monitoring results and historic results to trend analyte in question. Review operational data and meteorological conditions Review meteorological conditions 	Environmental Coordinator
	<ul style="list-style-type: none"> Water quality is outside or above SSTVs downstream of operations for at least two parameters and more than one round. 	<ul style="list-style-type: none"> Organise resampling including at T2 – 5m and T2 – 10m 	Environmental Coordinator
	<ul style="list-style-type: none"> Repeated sampling shows elevated concentrations of water quality parameters above SSTV's for third consecutive round. 	<ul style="list-style-type: none"> Investigate source of exceedance and develop corrective action plan Enact the PIRMP if material harm to the environment has occurred If no material harm has occurred notify the relevant Government Agencies as soon as practicable 	<p>Environmental Coordinator Mine Manager</p>
LDP DISCHARGE	<ul style="list-style-type: none"> Discharge quality is within EPL limits Discharge volume <13,000kL for day 	<ul style="list-style-type: none"> No action required 	
	<ul style="list-style-type: none"> Low voltage alarm for LDP water volume monitor 	<ul style="list-style-type: none"> Check power supply Contact Contractor Source backup battery 	<p>Environmental Coordinator Electrical Engineering Coordinator</p>
	<ul style="list-style-type: none"> Discharge water quality is close to exceeding limits or shows measurements of oil and grease above the limit of measurable concentration. 	<ul style="list-style-type: none"> Investigate the source of change to water quality and create a corrective action plan Test duplicate oil and grease sample 	Environmental Coordinator

TARP	TRIGGER	ACTIONS IF TRIGGER ACTIVATED	TO BE INFORMED
	<ul style="list-style-type: none"> Discharge water exceeds EPL limits for water quality or volume Failure of volume monitoring equipment or missed water quality sample 	<ul style="list-style-type: none"> Cease pumping or reduce pumping rates Enact the PIRMP if material harm to the environment has occurred If no material harm has occurred notify the relevant Government Agencies as soon as practicable 	<p>Environmental Coordinator Mine Manager</p>
WATER COURSE INSTABILITIES	<ul style="list-style-type: none"> Watercourse monitoring indicates no areas of instabilities from visual inspections. 	<ul style="list-style-type: none"> No action required 	
	<ul style="list-style-type: none"> Significant rainfall event 	<ul style="list-style-type: none"> Complete watercourse monitoring 	Environmental Coordinator
	<ul style="list-style-type: none"> Watercourse monitoring indicates one or more areas of minor instabilities in watercourses 	<ul style="list-style-type: none"> Review historical monitoring records. Investigate the factors contributing to the instability, which may include advice from technical specialists. Implement corrective actions as required as soon as practicable to stabilise the surface and/or watercourses based on the outcomes of the investigation. Increase monitoring frequency and undertake additional monitoring where relevant. 	Environmental Coordinator
	<ul style="list-style-type: none"> Watercourse monitoring indicates one or more areas of major instabilities in watercourses, causing sediment loads to migrate and or impact to riparian vegetation. 	<ul style="list-style-type: none"> Where possible isolate areas of instability and implement remediation measures to stabilise surface and/or watercourse. Implement corrective/preventative actions based on the outcomes of the investigation and/or additional monitoring. Prioritise actions based on the risk to the environment and likelihood of further impact. 	<p>Environmental Coordinator Mine Manager</p>
RIPARIAN VEGETATION	<ul style="list-style-type: none"> No significant change in vegetation quality or extent compared with previous monitoring results. 	<ul style="list-style-type: none"> No action required. 	
	<ul style="list-style-type: none"> Bushfire 	<ul style="list-style-type: none"> Complete inspection when safe 	Environmental Coordinator
	<ul style="list-style-type: none"> Visual inspections show change in extent and density of vegetation not specific to season. Trend increased of exotic species. 	<ul style="list-style-type: none"> Investigate source of weeds, treat and control. Review weed management process. 	Environmental Coordinator

TARP	TRIGGER	ACTIONS IF TRIGGER ACTIVATED	TO BE INFORMED
	<ul style="list-style-type: none"> Visual inspections show significant change in extent and density of instream vegetation because of clearing or impact. 	<ul style="list-style-type: none"> Visual inspections show significant change in extent and density of instream vegetation because of clearing or impact. Enact the PIRMP if material harm to the environment has occurred If no material harm has occurred notify the relevant Government Agencies as soon as practicable 	<p>Environmental Coordinator Mine Manager</p>
ALLUVIAL GROUNDWATER	<ul style="list-style-type: none"> Water levels consistent with baseline or are above trigger values No complaints from adjacent bore owners regarding groundwater 	<ul style="list-style-type: none"> No action required. 	
	<ul style="list-style-type: none"> Complaint from adjacent bore owners regarding groundwater level or quality 	<ul style="list-style-type: none"> Review subsidence monitoring results 	
	<ul style="list-style-type: none"> Water levels below trigger levels for two consecutive monitoring events at one or more location. 	<ul style="list-style-type: none"> Undertake investigation to determine if the change in groundwater level is due to mining related activity. Review recent monitoring results and any relevant operational data (e.g. mining activities, meteorological data). 	<p>Environmental Coordinator</p>
	<ul style="list-style-type: none"> Investigation into Red Trigger identifies that change in groundwater quality level is due to mining related activity. 	<ul style="list-style-type: none"> Enact the PIRMP if material harm to the environment has occurred If no material harm has occurred notify the relevant Government Agencies as soon as practicable 	<p>Environmental Coordinator Mine Manager</p>

Appendix B - Consultation outcomes



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Water Management Plan, Condition 22, Schedule 3	Sufficient (Yes/No/Partial)	Document reference and comment	Action Required	Company Response
(a) The Applicant must prepare and implement a Water Management Plan for the surface facilities sites to the satisfaction of the Secretary and in consultation with DPE Water, Resources Regulator, and LMCC. This plan must: be prepared by suitably qualified and experienced persons whose appointment has been approved by the Secretary;	YES	Section 1 The original WMP was prepared to the satisfaction of the Secretary in consultation with DPE Water, the Resources Regulator and LMCC. This revision incorporates updates made to EPL 366 and includes improvements identified as part of the independent audit process.	None	N/A
(b) be submitted for approval to the Secretary within 7 months of the date of this approval; and	YES	Section 1.2.1 Modification 3 was approved on 25 November 2022. This revision to the WMP has been provided within 7 months of the modification approval.	None	N/A
(c) include: <ul style="list-style-type: none"> • a Site Water Balance; • an Erosion and Sediment Control Plan. • a Surface Water Management Plan; 	Partial	The Erosion and Sediment Control Plan is not attached to the Plan	Attach the Erosion and Sediment Control Plan to this WMP.	ESCP Attached



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<ul style="list-style-type: none"> • a Groundwater Monitoring Program; and • a Surface and Ground Water Response Plan. 				
Water Management Plan, Condition 23, Schedule 3	Sufficient (Yes/No/Partial)	Document reference and comment	Action Required	Company Response
The Site Water Balance must: <ul style="list-style-type: none"> (a) include details of: <ul style="list-style-type: none"> • sources and security of water supply; • water use on site; • water management on site; • any off-site water transfers; • groundwater transfers from the underground operations to the surface; and 	Partial	Section 3.6 addresses site water balance but does not indicate security of water supply. Are groundwater make values consistent with predictions for the project stage? Table 3-3 includes Total Inputs and Total Output values however these do not reflect the component values. Figure 3-11 and index for Figure 5-2 identify LDP B. Section 3.6.2 discusses discharge frequency due to heavy rainfall Section 4.3.2 discusses underground water transfers	Add commentary on water security reference the site water balance. Check water volumes and totals in Table 3-3. Revise discharge location IDs in Table 3-3 for consistency. Update Figures 3-11 and 5-2 titles and figure index.	Added in Section 3.4.3 Figures and tables have been reviewed and updated where required
(b) investigate and implement all reasonable and feasible	YES	Section 3.5. Periodical review, consistent with adaptive management best practice should be	Commit to periodic investigation of	Added in section 3.4



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measures to minimise potable water use from the town water supply and to reuse and recycle water.		undertaken to identify opportunities to reduce potable water demands.	reasonable and feasible measures to minimise potable water onsite.	
Water Management Plan, Condition 24, Schedule 3	Sufficient (Yes/No/Partial)	Document reference and comment	Action Required	Company Response
The Erosion and Sediment Control Plan must: (a) be consistent with the requirements of the Managing Urban Stormwater – Soils and Construction, Volume 2E: <i>Mines and Quarries</i> (DECC 2008), or its latest version);	Partial	Section 3.2.6 indicates progressive rehabilitation however a schedule of rehabilitation monitoring, triggers and management of erosion are not clear. The Erosion and Sediment Control Plan is not appended to the WMP therefore this condition cannot be fully assessed.	Append the Erosion and Sediment Control Plan to the WMP.	ESCP Attached
(b) identify activities that could cause soil erosion and generate sediment particularly in relation to activities near waterways;	Partial	Section 8.2 provides a summary of potential impacts, however, as the Erosion and Sediment Control Plan is not appended to the WMP this condition cannot be fully assessed.	Append the Erosion and Sediment Control Plan to the WMP, including details of erosive and sediment generating activities near waterways.	



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<p>(c) describe the location, function, and capacity of erosion and sediment control structures;</p>	<p align="center">Partial</p>	<p>Section 5.2 and Section 9, however as the Erosion and Sediment Control Plan is not appended to the WMP this condition cannot be fully assessed.</p>	<p>Append the Erosion and Sediment Control Plan to the WMP, including the location function and capacity of sediment control structures</p>	<p align="center">ESCP Attached</p>
<p>(d) describe what measures would be implemented to maintain the structures over time; and</p>	<p align="center">Partial</p>	<p>Section 4.1 broadly discusses inspection of sediment control structures, however as the Erosion and Sediment Control Plan is not appended to the WMP this condition cannot be fully assessed.</p>	<p>Append the Erosion and Sediment Control Plan to the WMP, including which measures would be implemented to maintain structures over time.</p>	
<p>(e) describe the sediment and erosion control measures to be implemented for all activities undertaken at the site.</p>	<p align="center">Partial</p>	<p>Section 6.2.1, Table 6-3. provides for construction works which may generate sediment or erosion, requiring an erosion and sediment control plan (ESCP) and construction environmental management plan will be prepared for significant construction works, however as the Erosion and</p>	<p>Append the Erosion and Sediment Control Plan to the WMP, including sediment and erosion control measures for all</p>	



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<i>Water Management Plan, Condition 25, Schedule 3</i>	Sufficient (Yes/No/Partial)	Document reference and comment	Action Required	Company Response
		Sediment Control Plan is not appended to the WMP this condition cannot be fully assessed.	activities undertaken at the site.	
The Surface Water Management Plan must:	YES	Section 5 includes baseline data. Contribution of discharges to Wangi Creek is monitored through LDP 9 with discharges from LDP 10. Discharge monitoring at LDP 9 between 2013 and 2017 is provided in Figure 5-1.	None	N/A
(a) include detailed baseline data on surface water flows and quality of Wangi Creek;				
(b) provide a geomorphic description of Wangi Creek up and downstream of the mine water discharge point;	YES	Table 5-3	None	N/A
(c) detail surface water quality and stream health assessment criteria, including trigger levels for investigating any potentially adverse surface water impacts;	Partial	Tables 6-1 (surface water quality parameters) and Table 6-7 (stream health) In Table 6-1, the surface water trigger value for manganese has been increased from 0.095mg/L to 0.66 mg/L without justification. The ANZECC trigger value for species protection for manganese in marine environments is 80 µg/L (0.08mg/L), however the presented criteria are higher than this.	Provide justification or reasons for the increase to manganese trigger value for Wangi Creek. Define which species protection	Note added to table 6-1 regarding Mn. The 2015 Water



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		<p>Section 5.2.1 highlights that data from the Upstream monitoring location was used, in conjunction with ANZECC (2000) guidance, to develop site-specific trigger values (SSTVs), however the adopted trigger values do not present which level of species protection are applied or implicit in the site-specific trigger values (i.e. 80, 90, 95 or 99% level of species protection as part of ANZECC criteria), nor whether <i>marine</i> or <i>freshwater</i> criteria are applied to the Wangi Creek location. Likewise, it's unclear which trigger values are adopted from ANZECC or adjusted based on monitoring.</p>	<p>level has been selected for the location, with justification, for each SSTV.</p> <p>Define if marine or freshwater ANZECC trigger values are used for the Wangi Creek surface water monitoring location.</p> <p>Add some contextual detail to section 6.1 on the selection of the site-specific trigger value criteria, as the GHD 2015b reference is not provided in full as an appendix to the WMP.</p>	<p>Quality Report (GHD 2015b) attached.</p>
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(d) provide a program to monitor: <ul style="list-style-type: none"> • surface water discharges from the surface facilities sites; • stream health, channel stability, water flows and water quality within Wangi Creek; and • water quality of Lake Macquarie; 	YES	Section 4 provides monitoring requirements. Note there is no flow rate monitoring at Wangi Creek. Contribution of discharges to Wangi Creek is monitored through LDP 9	None	N/A
(e) investigate mitigation and management measures to prevent/limit any incision and degradation of the channel of Wangi Creek from mine discharge water;	YES	Section 4.5	None	N/A
(f) include a detailed review of water management at the Myuna Colliery surface facilities site, with particular reference to the water storages within the dirty water management system and in consultation with EPA, to:	YES	Section 3.2 details surface water management , including dirty water management in section 3.2.4. Table 3-1 identifies water management structures including the CHP Dam.		N/A



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<ul style="list-style-type: none">• determine whether the capacity, integrity, retention time and management of the dirty water storages (particularly the CHP Dam) are sufficient to ensure that water discharged from the site meets all relevant ANZECC water quality criteria, including for metals and suspended solids;• assess all reasonable and feasible options for reducing salt load and/or salt concentration for discharges into Wangi Creek;• assess appropriate options to improve storage and retention times in accordance with The Blue Book - Managing Urban Stormwater (MUS): Soils and Construction (Landcom); and• propose upgrades of the dirty water storages sufficient				
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<p>that discharges meet all relevant ANZECC criteria; and</p> <ul style="list-style-type: none"> propose any other appropriate changes to the water management system; and 				
<p>(g) identify and assess practical measures to minimise potable water consumption, maximise recycled water use and improve the management of sewage and surface rainfall runoff for the project, including quantifying the abatement potential of identified measures and their related costs and benefits.</p> <p>Note: The Secretary may require the Applicant to implement upgrades and other changes identified under paragraph (f), in accordance with condition 4 of schedule 2. EPA may also require</p>	<p>YES</p>	<p>See Condition 23 (b), schedule 3 comments.</p>	<p>No further actions.</p>	<p>N/A</p>



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measures to be implemented under the terms of the site's environment protection licence.				
Water Management Plan, Condition 26, Schedule 3	Sufficient (Yes/No/Partial)	Document reference and comment	Action Required	Company Response
The Groundwater Monitoring Program must include: (a) baseline data of groundwater levels (including alluvial and weathered rock aquifers), yield and quality in the region, and any privately owned groundwater bores that may be affected by mining operations on site;	Partial	Section 2.4 provides groundwater user and bore database information. While section 2.4 indicates that <i>most</i> bores are on the eastern side of Lake Macquarie, the WMP does not identify how many privately owned bores make up the remaining bores, nor their proximity to the site. The WMP states that bore details are provided in the Northern Operations RWMP. Details pertinent to the approval condition should be easily accessible, ideally in one reference document. Section 6.1.2 notes that alluvial groundwater level monitoring has been undertaken since November 2017, and trigger level values are provided in Table 6-2, derived from baseline monitoring and the 20 th percentile levels. Baseline groundwater quality triggers (named underground water quality) are shown in a second	<ul style="list-style-type: none"> Ensure that the Northern Operations RWMP contains bore information; levels, yield and quality, for any privately owned groundwater bores that may be affected by mining operations. Revise the baseline bore information of the WMP as appropriate. 	Section 2.4 updated. Note that no privately owned groundwater bores were noted as potentially impacted by mining operations.



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		Table 6-2. Likely typographical error in Table naming.	<ul style="list-style-type: none">• Revise text in section 2.4 to indicate how many/which privately owned bores are affected by site mining operations including associated baseline groundwater data.• Revising Table numbering and in-text references to associated triggers.	Updated table numbering
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<p>(b) groundwater assessment criteria based upon analysis of baseline data for groundwater, surface water, including trigger levels for investigating any potentially adverse groundwater impacts; and</p>	<p align="center">NO</p>	<p>See above for schedule 3, condition 25 (c). Section 6.1.1 includes surface water quality triggers, including an increase in trigger level for manganese, however no justification has been provided for an increase in the analyte.</p> <p>Table 6-1 details site specific trigger values for Wangi Creek (only). Section 6.1.2, Table 6-2, provides assessment criteria for alluvial groundwater trigger levels.</p> <p>Section 6.1.3 notes that baseline groundwater quality data for each seam was collected between 2014 and 2016. Water quality ranges for the 20th and 80th percentile values for some analytes are provided, however it is not stated which is the action level or which level would trigger investigation into potentially adverse groundwater impacts. <i>Table 6-2 - Underground water quality ranges</i> (Table 6-3) provides water quality ranges for iron, manganese, barium and boron in addition to the pH, EC and TSS required by the EPL366, however, it is unclear why only these 4x metals carry a quality range.</p>	<p>See above action for schedule 3, condition 25 (c).</p> <p>Provide commentary on the selected or omitted metals analysed as part of the baseline groundwater data collection.</p> <p>State which values are to be used for trigger values and commit to groundwater quality investigation levels for potentially adverse groundwater impacts.</p>	<p>Section 5.3.3 updated regarding groundwater quality and metals analysed.</p>
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		Section 6.2.3 maintains that underground groundwater quality performance criteria will use complaints from surrounding groundwater users as the criteria for environmental assessment. Consultation on the original WMP noted that this was not sufficient.	Review underground groundwater data quality and provide water quality triggers for analytes measured as part of baseline monitoring.	Noted in sections 5.3 and discussed further in section 6.1.3
(c) a program to monitor and/or validate the impacts of the project of alluvial and coal seam aquifers, any groundwater bores.	Partial	Section 4.3 (Groundwater monitoring) provides a program to monitor, however this is proposed to reduce from monthly to annually (section 4.3.3), which is not consistent with the recommendations made in the independent environmental audit, to reduce monitoring to quarterly. Section 7.1 notes that the hydrogeological model will be reviewed annually and that groundwater monitoring data will be used to verify the model.	Revise frequency of monitoring consistent with the independent environmental audit.	Updated to quarterly in line with audit recommendations.
<i>Water Management Plan, Condition 27, Schedule 3</i>	Sufficient (Yes/No/Partial)	Document reference and comment	Action Required	Company Response
The Surface and Ground Water Response Plan must describe what measures and/or procedures would be implemented to:	YES	Section 6 details response plans <ul style="list-style-type: none"> - Table 6-3 On-site surface water management criteria - Table 6-7 Stream health assessment criteria 		N/A



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(a) respond to any exceedances of the surface water, stream health, and groundwater assessment criteria; and		- Table 6-5 Groundwater environment criteria		
(b) mitigate and/or offset any adverse impacts on riparian vegetation located within and adjacent to the site.	YES	Section 6.	None	N/A
General Comments			Action Required	Company Response
The Department note that the applicant has received approval from the NSW EPA to vary two water related conditions of EPL no. 366 on 15 September 2022, as follows: <i>M2.3 - Amend the monitoring frequency for Point 9 from daily to monthly. Separate tables have also been established for Points 9 and 10.</i> <i>M2.4 - Removed the condition as monitoring frequency is specified in condition M2.3 tables.</i>			None	N/A
Appointment of Experts letter dated 23/05/2012			None	N/A
Table 1-2 references Mod 1 conditions, however, Modification 3 has been approved. Table 1-2. The word “particular” has been omitted from Schedule 3, condition 25(f) text, however, does form part of the approval condition.			Revise Table 1-2 to reflect the contemporary approval conditions.	Updated.
“DPIE Water” reference used.			Update abbreviation	Updated.
NSW Department of Primary Industries – Water (DPI-Water) reference used within introduction.			Update reference	Updated.



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<p>The Department note that Appendix D title references licenced discharge point B however the location title has been updated to “LDP 9” on the charts within Appendix D.</p>	<p>Update Appendix D to align with the current location identification within the WMP and EPL366</p>	<p>Updated to include note regarding LDP 9 / LDP B</p>
<p>Table 3-1 indicates that First Flush Tank (GPT) outflows to the CHP Dam or directly to LDP9. However, Figure 3-1 indicates that the First Flush Settlement Tank flows to the CHP Dam. Table 3-1 also references LDP A as an outflow location.</p>	<p>Check Table 3-1 for outflow locations and check for accuracy and consistency of Figure 3-1 against water flows. Update LDP location name to reflect contemporary location identification.</p>	<p>Reviewed table and text and updated</p>
<p>Table 3-2 references location LDP B. Please update to contemporary location identification. LDP B is also written as a “proposed” location. If the location is now in use for the planned or proposed use, please revise Table 3-2.</p>	<p>Update table 3-2 to reflect clean water diversions in place rather than planned</p>	<p>Text updated</p>



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<p>Section 3.2.4 – Dirty Water Management, subsection “Emergency Stockpile Dam” management references LDP A in revised text.</p>	<p>Please check for consistency of discharge locations between the WMP text, WMP figures and the varied EPL.</p>	<p>Text updated</p>
<p>Tables 4-2 and 6-2 contain altered bore information, including Table 6-2 presenting MW09 at 5.1 m AHD. This does not appear to correspond with the elevations of surrounding bores (MW05 and MW08). The monitoring well location IDs marked on Figure 4-2 do not appear to match Table 4-2, for example, location easting/northings presented for MW09 in Table 4-2 appear to be for MW13 per figure 4-2. Likewise, easting/northings presented for MW13 in Table 4-2 appear to be for MW12 per Figure 4-2. The corresponding TOC values are carried forward to Table 6-2. Trigger levels are therefore presented which do not appear to reflect historical sampling and location information.</p>	<ul style="list-style-type: none"> • Check Table 4-2 TOC elevations and trigger water levels (mAHD) are accurate. • Check Location IDs in Figure 4-2. • Check Table 6-2 for accuracy. Revise presented water level trigger values for each location. 	<p>Table has been reviewed and updated.</p>



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	<ul style="list-style-type: none"> • Check monitoring well location IDs across text, figures and tables of the WMP for consistency. 	
<p>Table 4-4 does not specify the frequency of discharge quality monitoring. Text in 4.4.1 regards the surface water <i>discharge monitoring program</i> should include reference to both volume and quality tables</p>	<p>Please update Table 4-4 to reflect the revised EPL; i.e., Monthly during discharge at location LDP 9 and daily during discharge at LDP 10.</p>	<p>Text in Table 4-4 updated to reflect EPL366.</p>
<p>Context on water levels is not provided in the WMP. Discussion on reducing water level monitoring from monthly to annually is not provided. The independent audit recommendation included a reduction in groundwater monitoring from monthly to quarterly.</p>	<p>If changes to water level monitoring are proposed, please provide references and justification for the change.</p>	<p>Text updated in Section 6.1.2</p>



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<p>Erosion and Sediment Controls per schedule 3, condition 24 are not adequately outlined in Sections 3 and 5 as referenced. Section 5 addresses baseline data. The erosion and sediment control plan is not attached to the WMP version so controls and erosion management as part of the approval conditions are not clear.</p>	<p>Append the Erosion and Sediment Control Plan and evidence how the erosion and sediment control conditions are met.</p>	<p>ESCP Attached</p>
<p>Section 5.3.4 references water levels in Table “4-22”, however the table is not within the WMP. Typographical error needs revising.</p>	<p>Revise reference and add the observed groundwater levels to the WMP, commenting if these are in line with baseline water levels.</p>	<p>Section 5.3.4 text updated</p>
<p>Details pertinent to the approval conditions for Water Management should be easily accessible, ideally in one reference document. The Water Management Plan for the site should include the details necessary to transparently manage the Water Management Plan elements of the approval.</p>	<p>Revise the WMP to allow easy reference to the required water management related information.</p>	<p>Section 9 – Action Plan WAL Licence attached</p>



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		EPL 366 Licence Attached
The TARP tables have been removed from the appendices in favour of including management criteria, monitoring information or management actions in the text of the WMP, however there are unclear lines of investigation which are provided in the usual TARP format. For example, it is unclear what the trigger and monitoring rate will be for groundwater quality. Management steps or actions for any triggered action levels are not provided, so as a Plan, the WMP does not yet meet the intended purpose of being a plan for managing water related components of the approval.	Change ground water info to mine water or omit Update water security Update tarp to remove unneeded info	TARP Attached
Other Agency Comments	Action Required	Company Response
N/A. The WMP was prepared in consultation with the relevant agencies. This revision builds on outcomes of the sites independent audit processes and approved EPL variation.		N/A

Comment	Response
NSW Department of Planning and Environment - letter dated 11 October 2017 (responses to components deemed as not satisfactory)	
<p>Baseline surface water quality data is included in Section 5 of the Myuna WMP (upstream, LDP 9, downstream and Wangi Lake).</p> <p>No information on baseline surface water flow monitoring, however it is noted that flow monitoring has recently commenced at LDPs.</p> <p><i>Include baseline flow monitoring data in the Myuna WMP.</i></p>	<p>Comments added to Section 4.2 and 5.1.</p>
<p>Section 5.3 of the Myuna WMP includes a very general description of the stability of Wangi Creek. Note: incomplete sentence (1st para).</p> <p><i>Include a more detailed geomorphic description of Wangi Creek up and downstream on the mine water discharge point.</i></p>	<p>Paragraph updated to include more detail on the baseline conditions. Refer to Table 5-3 which details the outcomes of the geomorphic assessment.</p>
<p>General description of baseline groundwater quality included in Section 5.2.2. of the Myuna WMP. Considered inadequate. No data on baseline groundwater levels or yield.</p> <p><i>Include baseline data on groundwater levels, yield, and quality in the Myuna WMP</i></p>	<p>Additional information added to Section 5.3</p>
<p>No groundwater assessment criteria included in Section 6.1 (Triggers) of the Myuna WMP. The groundwater TARP at Appendix C indicates that groundwater level and quality triggers are based on complaints from adjacent bore owners and/or a statistically significant change in quality/depth of groundwater.</p> <p>Triggers cannot be determined without baseline data. Groundwater triggers should be better defined</p> <p><i>Include groundwater assessment criteria in the Myuna WMP and reflect this in the TARP.</i></p>	<p>Information added to sections 0 and Error! Reference source not found. in addition to a review of Section 6.2.3.</p> <p>Groundwater level criteria unable to be determined until a statistically valid set of data is gathered from alluvial monitoring bores.</p>
<p>Groundwater monitoring described in Section 4.3 of the Myuna WMP.</p> <p>Section 4.3.3 “recommends” monthly monitoring from 10 alluvial monitoring bores.</p>	<p>Section updated with current commitments to monitoring</p>

Comment	Response
<p><i>Remove recommendations for monitoring and include clear commitments of what will be done.</i></p>	
<p>Surface water quality, discharge and stream health triggers and performance criteria included in Sections 6.1 and 6.2 of the Myuna WMP respectively. These criteria form the basis of the TARPs provided in Appendix C. Considered adequate.</p> <p>Refer to comments on groundwater assessment criteria above.</p> <p><i>Include groundwater assessment criteria in the Myuna WMP and reflect this in the TARP.</i></p>	<p>Information added to sections 0 and Error! Reference source not found. in addition to a review of Section 6.2.3.</p> <p>Groundwater level criteria unable to be determined until a statistically valid set of data is gathered from alluvial monitoring bores.</p>
<p>The Myuna WMP would benefit from a document control register to record the document, approval, and circulation details.</p>	<p>Addressed</p>
<p>NSW Department of Planning and Environment – Division of Resources and Geoscience - letter dated 10 October 2017</p>	
<p>Myuna Colliery must ensure that the Myuna Colliery Water Management Plan and the Mining Operations Plan (MOP) are consistent. Mining activities must be conducted in accordance with an approved MOP</p>	<p>Noted, however the management requirements relevant to closure (indicated below in points a and b) are not relevant to the current stage of the operations. These aspects have not been included in the plan at this stage to provide focus to the key issues and risks requiring management that are of relevance.</p>
<p>The Myuna Colliery Management Plan should:</p> <p>a) determine (with reference to the groundwater assessment) the likelihood and associated impacts of groundwater accumulating and subsequently discharging (e.g. acid or neutral mine drainage) from the underground workings should dewatering of workings be suspended or at the cessation of mining; and</p>	<p>This information is currently not relevant for the Water Management Plan in the Projects current stage. During the stages of the operation’s transition towards closure (within the last 5 years of production) these aspects will be incorporated into the plan.</p>
<p>b) consider the likely controls required to either prevent or mitigate against these impacts as part of the closure plan for the site.</p>	<p>The current phase of the Project does not warrant the discussion of these aspects in the Water Management Plan. During the stages of the operation’s transition towards closure (within the last 5 years of production) these aspects will be incorporated into the plan</p>

Appendix C – Baseline surface and groundwater water quality data

Table C-1 Statistical summary for water quality monitoring at site Upstream (July 2012 to February 2015)

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Physicochemical parameters						
EC	µS/cm	24	137	731	241	306
pH	pH units	24	5.7	6.7	6.1	6.4
TSS	mg/L	24	5	490	19.5	77
Nutrients						
Total phosphorus	mg/L	24	0.01	0.26	0.02	0.04
Major ions						
Calcium	mg/L	24	2	4	3	3
Magnesium	mg/L	24	2	6	5	6
Potassium	mg/L	24	2	3	2	3
Sodium	mg/L	24	21	52	37	45
Sulfur	mg/L	24	1	9	3	4
Filterable/dissolved metals						
Aluminium	mg/L	24	0.05	1.38	0.34	0.72
Antimony	mg/L	24	0.001	0.01	0.001	0.01
Arsenic	mg/L	24	0.001	0.01	0.001	0.005
Barium	mg/L	24	0.025	0.046	0.037	0.040
Boron	mg/L	24	0.05	0.07	0.05	0.05
Cadmium	mg/L	24	0.0001	0.001	0.0001	0.0005
Cobalt	mg/L	24	0.001	0.01	0.001	0.005
Copper	mg/L	24	0.001	0.01	0.001	0.002
Iron	mg/L	24	0.5	7.5	1.1	2.1
Lithium	mg/L	24	0.001	0.004	0.003	0.003
Manganese	mg/L	24	0.028	0.187	0.060	0.095
Molybdenum	mg/L	24	0.001	0.01	0.001	0.001
Nickel	mg/L	24	0.001	0.01	0.001	0.001
Selenium	mg/L	24	0.01	0.1	0.01	0.05
Silica	mg/L	24	13.5	25.6	20.1	22.9
Titanium	mg/L	24	0.01	0.1	0.02	0.06
Vanadium	mg/L	24	0.01	0.1	0.01	0.01
Zinc	mg/L	24	0.005	0.05	0.012	0.016
Total metals						
Aluminium	mg/L	24	0.32	4.05	1.14	1.93

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Antimony	mg/L	24	0.001	0.01	0.001	0.005
Arsenic	mg/L	24	0.001	0.01	0.001	0.002
Barium	mg/L	24	0.031	0.136	0.043	0.058
Boron	mg/L	24	0.05	0.06	0.05	0.05
Cadmium	mg/L	24	0.0001	0.001	0.0001	0.0001
Cobalt	mg/L	24	0.001	0.01	0.001	0.001
Copper	mg/L	24	0.001	0.01	0.002	0.004
Iron	mg/L	24	0.8	163.0	5.6	21.4
Lithium	mg/L	24	0.002	0.01	0.003	0.004
Manganese	mg/L	24	0.029	0.247	0.071	0.127
Molybdenum	mg/L	24	0.001	0.01	0.001	0.001
Nickel	mg/L	24	0.001	0.01	0.001	0.002
Selenium	mg/L	24	0.01	0.1	0.01	0.01
Silica	mg/L	24	16.9	33.4	21.8	25.1
Titanium	mg/L	24	0.001	0.07	0.001	0.010
Vanadium	mg/L	24	0.01	0.1	0.01	0.01
Zinc	mg/L	24	0.005	0.24	0.016	0.023
Other parameters						
Oil and grease	mg/L	24	2	3	2	2

Table C-2 Statistical summary for water quality monitoring at site LDP 9 (March 2013 to February 2015)

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Physicochemical parameters						
EC	µS/cm	24	31,700	46,700	43,350	44,720
pH	pH units	24	7.6	7.8	7.7	7.8
TSS	mg/L	24	5	28	7	9
Nutrients						
Total phosphorus	mg/L	24	0.01	0.07	0.02	0.05
Major ions						
Calcium	mg/L	24	596	910	743	789
Magnesium	mg/L	24	905	1,370	1,150	1,234
Potassium	mg/L	24	152	247	186	210
Sodium	mg/L	24	6,400	10,000	8,340	9,000

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Sulfur	mg/L	24	377	686	547	609
Filterable/dissolved metals						
Aluminium	mg/L	24	0.01	0.01	0.01	0.01
Antimony	mg/L	24	0.001	0.01	0.010	0.010
Arsenic	mg/L	24	0.001	0.01	0.010	0.010
Barium	mg/L	24	0.111	0.301	0.147	0.178
Boron	mg/L	24	0.05	1.04	0.73	0.88
Cadmium	mg/L	24	0.0001	0.0027	0.0010	0.0010
Cobalt	mg/L	24	0.001	0.01	0.010	0.010
Copper	mg/L	24	0.001	0.066	0.010	0.010
Iron	mg/L	24	0.1	0.5	0.5	0.5
Lithium	mg/L	24	0.332	0.619	0.491	0.544
Manganese	mg/L	24	0.206	0.762	0.450	0.656
Molybdenum	mg/L	24	0.001	0.01	0.010	0.010
Nickel	mg/L	24	0.001	0.01	0.010	0.010
Selenium	mg/L	24	0.01	0.1	0.10	0.10
Silica	mg/L	24	9.8	17.0	13.4	15.7
Titanium	mg/L	24	0.1	0.1	0.1	0.1
Vanadium	mg/L	24	0.01	0.1	0.10	0.10
Zinc	mg/L	24	0.050	0.073	0.050	0.050
Total metals						
Aluminium	mg/L	24	0.01	0.46	0.01	0.01
Antimony	mg/L	24	0.001	0.01	0.010	0.010
Arsenic	mg/L	24	0.001	0.01	0.010	0.010
Barium	mg/L	24	0.116	0.304	0.152	0.187
Boron	mg/L	24	0.50	1.06	0.74	0.91
Cadmium	mg/L	24	0.0001	0.0031	0.0001	0.0001
Cobalt	mg/L	24	0.001	0.01	0.010	0.010
Copper	mg/L	24	0.003	0.075	0.010	0.010
Iron	mg/L	24	0.59	1.5	0.88	1.09
Lithium	mg/L	24	0.372	0.921	0.514	0.577
Manganese	mg/L	24	0.229	0.741	0.480	0.689
Molybdenum	mg/L	24	0.001	0.01	0.010	0.010
Nickel	mg/L	24	0.001	0.01	0.010	0.010

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Selenium	mg/L	24	0.01	0.1	0.10	0.10
Silica	mg/L	24	9.2	17.6	14.1	15.6
Titanium	mg/L	24	0.01	0.1	0.10	0.10
Vanadium	mg/L	24	0.01	0.1	0.10	0.10
Zinc	mg/L	24	0.050	0.103	0.050	0.052
Other parameters						
Oil and grease	mg/L	24	2	3	2	2

Table C-3 Statistical summary for water quality monitoring at site Downstream (March 2013 to February 2015)

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Physicochemical parameters						
EC	µS/cm	24	13,200	45,700	40,700	44,080
pH	pH units	24	7.3	8.1	7.7	7.8
TSS	mg/L	24	5	88	8	11
Nutrients						
Total phosphorus	mg/L	24	0.01	0.13	0.02	0.05
Major ions						
Calcium	mg/L	24	209	938	709	760
Magnesium	mg/L	24	322	1,270	1,120	1,206
Potassium	mg/L	24	61	237	174	203
Sodium	mg/L	24	2,160	9,290	7,925	8,726
Sulfur	mg/L	24	147	675	526	571
Filterable/dissolved metals						
Aluminium	mg/L	24	0.01	0.1	0.10	0.10
Antimony	mg/L	24	0.001	0.01	0.010	0.010
Arsenic	mg/L	24	0.001	0.01	0.010	0.010
Barium	mg/L	24	0.051	0.391	0.139	0.173
Boron	mg/L	24	0.18	1.08	0.68	0.86
Cadmium	mg/L	24	0.0001	0.01	0.010	0.010
Cobalt	mg/L	24	0.001	0.01	0.010	0.010
Copper	mg/L	24	0.001	0.01	0.010	0.010
Iron	mg/L	24	0.01	0.5	0.50	0.50
Lithium	mg/L	24	0.100	0.600	0.479	0.507

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Manganese	mg/L	24	0.194	0.809	0.371	0.595
Molybdenum	mg/L	24	0.001	0.01	0.010	0.010
Nickel	mg/L	24	0.001	0.01	0.010	0.010
Selenium	mg/L	24	0.01	0.1	0.10	0.10
Silica	mg/L	24	9.2	16.7	12.6	15.4
Titanium	mg/L	24	0.01	0.1	0.10	0.10
Vanadium	mg/L	24	0.01	0.1	0.10	0.10
Zinc	mg/L	24	0.031	0.058	0.050	0.050
Total metals						
Aluminium	mg/L	24	0.01	1.24	0.10	0.26
Antimony	mg/L	24	0.001	0.01	0.010	0.01
Arsenic	mg/L	24	0.001	0.01	0.010	0.010
Barium	mg/L	24	0.057	0.298	0.153	0.179
Boron	mg/L	24	0.05	1.00	0.74	0.91
Cadmium	mg/L	24	0.0001	0.0027	0.0010	0.0010
Cobalt	mg/L	24	0.001	0.01	0.010	0.010
Copper	mg/L	24	0.001	0.01	0.010	0.010
Iron	mg/L	24	0.52	2.14	1.17	1.40
Lithium	mg/L	24	0.117	0.789	0.492	0.546
Manganese	mg/L	24	0.225	0.826	0.402	0.623
Molybdenum	mg/L	24	0.001	0.01	0.010	0.010
Nickel	mg/L	24	0.001	0.01	0.010	0.010
Selenium	mg/L	24	0.01	0.1	0.10	0.10
Silica	mg/L	24	10.0	17.6	14.6	16.0
Titanium	mg/L	24	0.01	0.1	0.10	0.10
Vanadium	mg/L	24	0.01	0.1	0.10	0.10
Zinc	mg/L	24	0.048	0.073	0.050	0.052
Other parameters						
Oil and grease	mg/L	24	2	3	2	2

Table C-4 Statistical summary for water quality monitoring at site Wangi Lake (July 2012 to February 2015)

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Physicochemical parameters						

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
EC	µS/cm	24	23,700	56,300	51,350	52,940
pH	pH units	24	7.7	8.2	8.0	8.1
TSS	mg/L	24	5	16	6	7
Nutrients						
Total phosphorus	mg/L	24	0.01	0.12	0.02	0.05
Major ions						
Calcium	mg/L	24	202	478	423	461
Magnesium	mg/L	24	612	1,480	1,285	1,382
Potassium	mg/L	24	246	631	465	513
Sodium	mg/L	24	5,140	13,400	11,250	12,040
Sulfur	mg/L	24	458	1,220	972	1,062
Filterable/dissolved metals						
Aluminium	mg/L	24	0.1	0.16	0.10	0.10
Antimony	mg/L	24	0.001	0.01	0.010	0.010
Arsenic	mg/L	24	0.001	0.01	0.010	0.010
Barium	mg/L	24	0.001	0.021	0.011	0.013
Boron	mg/L	24	0.23	5.14	3.93	4.64
Cadmium	mg/L	24	0.0001	0.0027	0.0010	0.0010
Cobalt	mg/L	24	0.001	0.01	0.010	0.010
Copper	mg/L	24	0.001	0.08	0.010	0.010
Iron	mg/L	24	0.1	0.5	0.50	0.50
Lithium	mg/L	24	0.091	0.245	0.183	0.201
Manganese	mg/L	24	0.01	0.019	0.010	0.010
Molybdenum	mg/L	24	0.001	0.017	0.014	0.016
Nickel	mg/L	24	0.001	0.01	0.010	0.010
Selenium	mg/L	24	0.01	0.1	0.10	0.10
Silica	mg/L	24	0.1	3.9	0.1	1.3
Titanium	mg/L	24	0.1	0.1	0.1	0.1
Vanadium	mg/L	24	0.01	0.1	0.10	0.10
Zinc	mg/L	24	0.05	0.05	0.05	0.05
Total metals						
Aluminium	mg/L	24	0.01	0.36	0.10	0.13
Antimony	mg/L	24	0.001	0.01	0.010	0.010
Arsenic	mg/L	24	0.001	0.01	0.010	0.010

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Barium	mg/L	24	0.010	0.02	0.012	0.014
Boron	mg/L	24	2.27	6.04	3.86	4.78
Cadmium	mg/L	24	0.0001	0.003	0.0010	0.0010
Cobalt	mg/L	24	0.001	0.01	0.010	0.010
Copper	mg/L	24	0.001	0.077	0.010	0.010
Iron	mg/L	24	0.01	0.52	0.50	0.52
Lithium	mg/L	24	0.100	0.300	0.181	0.201
Manganese	mg/L	24	0.001	0.023	0.010	0.010
Molybdenum	mg/L	24	0.001	0.019	0.014	0.015
Nickel	mg/L	24	0.001	0.01	0.010	0.010
Selenium	mg/L	24	0.01	0.1	0.10	0.10
Silica	mg/L	24	0.1	3.9	0.1	1.34
Titanium	mg/L	24	0.001	0.1	0.10	0.10
Vanadium	mg/L	24	0.01	0.1	0.10	0.10
Zinc	mg/L	24	0.05	0.06	0.05	0.05
Other parameters						
Oil and grease	mg/L	24	2	2	2	2

Table C-10-1 Underground water storages – water quality data (2014 to 2016)

Location	Date	pH	EC (µS/cm)	TDS (mg/L)	TSS (mg/L)	Turbidity (NTU)	Fe (filt) (mg/L)	Mn (filt) (mg/L)	Ba (filt) (mg/L)	B (filt) (mg/L)
2014 Data										
720 Dam	28/03/2014	7.77	48200	ND	ND	ND	<0.05	0.755	0.11	0.84
324 Dam	3/04/2014	7.54	37000	ND	ND	ND	<0.05	0.843	0.124	<0.05
325 Dam	3/04/2014	7.95	30700	ND	ND	ND	<0.05	0.022	0.164	<0.05
930 Dam	24/09/2014	8.07	19300	ND	6	ND	ND	ND	ND	ND
2015 Data										
324 Dam	18/12/2015	7.63	ND	ND	<5	18.1	<0.50	0.709	ND	ND
720 Dam	18/12/2015	7.82	ND	ND	13	2.7	<0.10	0.157	ND	ND
642 Dam	18/12/2015	8.06	ND	ND	90	33.9	<0.05	0.007	ND	ND
421 Dam	18/12/2015	7.96	ND	ND	88	55.7	<0.05	<0.001	ND	ND
2016 Data										
324 Dam	31/03/2016	7.73	ND	ND	<5	ND	<0.5	0.17	0.099	<0.5
720 Dam	5/04/2016	7.59	ND	ND	14	ND	<0.1	0.62	0.096	1.43
421 Dam	20/04/2016	8.14	ND	7190	17	ND	ND	0.008	0.279	0.17
642 Dam	22/04/2016	8.02	ND	22300	24	ND	<0.05	0.005	0.585	0.38
324 Dam	22/06/2016	7.5	ND	25120	5	ND	ND	ND	ND	ND
421 Dam	22/06/2016	8.2	ND	6770	19	ND	ND	ND	ND	ND
720 Dam	28/06/2016	8	ND	28000	14	ND	ND	ND	ND	ND
642 Dam	29/06/2016	8	ND	13970	15	ND	ND	ND	ND	ND
642 Dam	15/09/2016	7.9	ND	29840	ND	ND	ND	ND	ND	ND
421 Dam	15/09/2016	8.2	ND	6340	ND	ND	ND	ND	ND	ND
324 Dam	15/09/2016	7.8	ND	21680	ND	ND	ND	ND	ND	ND

Location	Date	pH	EC (µS/cm)	TDS (mg/L)	TSS (mg/L)	Turbidity (NTU)	Fe (filt) (mg/L)	Mn (filt) (mg/L)	Ba (filt) (mg/L)	B (filt) (mg/L)
720 Dam	15/09/2016	7.8	ND	30800	ND	ND	ND	ND	ND	ND
324 Dam	15/11/2016	7	ND	26300	ND	ND	ND	ND	ND	ND
720 Dam	17/11/2016	7.5	ND	35240	ND	ND	ND	ND	ND	ND
421 Dam	17/11/2016	7.9	ND	12880	ND	ND	ND	ND	ND	ND
642 Dam	17/11/2016	7.6	ND	32040	ND	ND	ND	ND	ND	ND

Notes:

720 Dam – underground storage dam within the Fassifern Seam / 324 Dam – underground storage dam within the Wallarah Seam

325 Dam – underground storage dam within the Wallarah Seam / 930 Dam – underground storage dam within the Fassifern Seam

642 Dam – underground storage dam within the Great Northern Seam / 421 Dam – underground storage dam within the Great Northern Seam

ND – no data

Table C-10-2 Underground water transfers – water quality data (2014 to 2016)

Location	Date	pH	EC (µS/cm)	TDS (mg/L)	TSS (mg/L)	Turbidity (NTU)	Fe (filt) (mg/L)	Mn (filt) (mg/L)	Ba (filt) (mg/L)	B (filt) (mg/L)
2014 Data										
Fassi	29/09/2014	7.34	49100	ND	9	15.2	1.85	0.549	0.104	0.84
GN	29/09/2014	7.56	39600	ND	6	23.9	0.53	0.095	0.218	0.65
Fassi	1/10/2014	7.53	49600	ND	8	32.4	2.35	0.677	0.106	1.28
Walarah	1/10/2014	7.3	40400	ND	<5	16.6	0.46	1.21	0.144	0.54
GN	1/10/2014	7.68	40200	ND	<5	26.8	0.13	0.099	0.22	0.93
Fassi	2/10/2014	7.68	50000	ND	5	21.4	2.04	0.554	0.102	0.83
GN	2/10/2014	7.78	40400	ND	<5	0.9	<0.05	0.077	0.204	0.65
Fassi	3/10/2014	7.54	49000	ND	9	33	2.02	0.559	0.086	0.91

Location	Date	pH	EC (µS/cm)	TDS (mg/L)	TSS (mg/L)	Turbidity (NTU)	Fe (filt) (mg/L)	Mn (filt) (mg/L)	Ba (filt) (mg/L)	B (filt) (mg/L)
Wallarah	3/10/2014	7.34	40000	ND	7	16.2	<0.05	0.846	0.108	<0.05
GN	3/10/2014	7.73	45800	ND	8	9.6	<0.05	0.239	0.12	0.76
Fassi	8/10/2014	7.52	50300	ND	<5	23.8	3.04	0.692	0.098	1.24
Wallarah	8/10/2014	7.27	40900	ND	<5	15.2	0.34	0.905	0.116	0.49
GN	8/10/2014	7.64	40600	ND	<5	0.8	<0.05	0.077	0.198	0.88
2015 Data										
Fassi	16/12/2015	7.33	ND	ND	6	18.4	1.4	0.471	ND	ND
Wallarah	16/12/2015	6.79	ND	ND	<5	2.5	0.11	1.17	ND	ND
2016 Data										
Fassi	18/04/2016	7.7	ND	36300	<5	23.4	1.39	0.398	0.11	1.26
Wallarah	19/04/2016	6.82	ND	27500	<5	ND	<0.5	0.889	0.103	0.34
GN	19/04/2016	7.54	ND	26100	<5	ND	<0.5	0.056	0.186	0.71
Fassi	4/07/2016	7.4	ND	31140	19	ND	<0.05	0.421	0.136	1.35
GN	4/07/2016	8.1	ND	6430	5	ND	ND	0.005	0.269	0.18
Wallarah	5/07/2016	7	ND	25600	7	ND	ND	1.12	0.125	0.34
Wallarah	13/09/2016	6.7	ND	29340	12	19	ND	ND	ND	ND
Wallarah	17/11/2016	6.8	ND	26200	14	1.3	ND	ND	ND	ND
Fassi	24/11/2016	7.3	ND	30060	5	11	ND	ND	ND	ND
GN	25/11/2016	7.4	ND	25920	24	3.4	ND	ND	ND	ND

Notes:

Fassi – underground water transfer from the Fassifern Seam / Wallarah – underground water transfer from the Wallarah Seam

GN – underground water transfer from the Great Northern Seam / ND – no data

Appendix D – Myuna Colliery ANZECC Water Quality Assessment



Centennial Myuna Pty Ltd
Myuna Colliery
ANZECC Water Quality Assessment

May 2015

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Appendices

Appendix A – Time series graphs for Upstream, Downstream and LDP B monitoring sites

Appendix B – Time series graphs for Wangi Lake monitoring site

1. Introduction

1.1 Background

Myuna Colliery is an underground coal mine located on the western side of Lake Macquarie at Wangi Wangi, approximately 25 km south-west of Newcastle as shown in Figure 1-1. Development of Myuna Colliery commenced in 1979, with underground mining of the Wallarah, Great Northern and Fassifern coal seams using bord and pillar mining methods occurring since 1982. Centennial Myuna Pty Limited (Centennial Myuna) acquired Myuna Colliery in 2002 and has operated the site since that time. Currently Myuna Colliery has approval to extract up to 3 million tonnes per annum of mine coal, with all coal delivered by dedicated overland conveyor to Eraring Power Station, located approximately 5 km west of the surface facilities area at Myuna Colliery.

Water is required at Myuna Colliery for mining activities and is supplied by catchment runoff collected in surface water storages and potable water sourced from Hunter Water Corporation. Groundwater inflows into the underground mine workings are collected in underground storages to allow settling of fines prior to transfer to the surface and discharge off-site. Licensed water discharges occur through two licensed discharge points (LDPs) into Wangi Creek, which flows into Lake Macquarie.

1.2 Discharge locations

Environment Protection Licences (EPLs) are issued by the NSW Environment Protection Authority (EPA) under the *Protection of the Environment Operations Act 1997*. Licence conditions relate to pollution prevention and monitoring and can control the air, noise, water and waste impacts of an activity.

Myuna Colliery currently holds EPL 366, which includes requirements to monitor water quality and quantity of discharges from the site. Water is currently licensed to be discharged from the mine through the following LDPs:

- LDP A – Emergency discharge to Wangi Creek via the Emergency Coal Stockpile Dam.
- LDP B – Discharge of up to 13 ML/day to Wangi Creek via the Coal Handling Plant (CHP) Dam and Mine Water Settling Pond 3.

1.3 Wangi Creek

The surface facilities area at Myuna Colliery is located in the lower reaches of Wangi Creek. Water discharged from Myuna Colliery enters the estuarine reach of Wangi Creek before discharging into Lake Macquarie. Upstream of the surface facilities area, the creek is a freshwater environment. Adjacent to the surface facilities area, Wangi Creek is reasonably well-defined, with a width in the order of 5 m and vegetated invert of the creek.

Downstream of LDP A and LDP B, discharges flow through a piped network prior to outflowing into an earthen channel. This channel runs parallel to Wangi Creek for approximately 200 m. The channel is constrained by fill material along the left bank, which is steep and up to 4 m to 5 m high. Along the left bank, a levee type structure exists which separates flows from the LDP discharge channel and flows in Wangi Creek.

Wangi Creek is the only watercourse directly influenced by mine water discharge from Myuna Colliery. However, mine workings are located beneath several other watercourses as well as Lake Macquarie.



<p>1:100,000 for A4</p> <p>Map Projection: Universal Transverse Mercator Horizontal Datum: Geodetic Datum of Australia 1994 Grid: Map Grid of Australia, Zone 56</p>		<p>LEGEND</p> <ul style="list-style-type: none"> Existing Rail Watercourse Freeway Principal Road Secondary Road Watercourse Area Built up areas Nature Conservation Reserve State Forest Forest Or Shrub Myuna Underground Working 																
<p>© 2015. Whilst every care has been taken to prepare this map, GHD and Geoscience Australia make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.</p>	<table border="1"> <tr> <td>LOCATION</td> <td>Myuna</td> </tr> <tr> <td>SEAM</td> <td>Great Northern, Fassifern & Wallarah Seam</td> </tr> <tr> <td>DRAWN</td> <td>T.M</td> </tr> <tr> <td>CHECKED</td> <td>L.H</td> </tr> <tr> <td>APPROVED</td> <td>S.G</td> </tr> <tr> <td>SCALE</td> <td>refer to scalebar</td> </tr> </table>	LOCATION	Myuna	SEAM	Great Northern, Fassifern & Wallarah Seam	DRAWN	T.M	CHECKED	L.H	APPROVED	S.G	SCALE	refer to scalebar	<p>ANZECC Water Quality Assessment Myuna Colliery</p> <p>Locality Plan</p>	<table border="1"> <tr> <td>DATE</td> <td>15/05/2015</td> <td>Figure 1-1</td> </tr> </table>	DATE	15/05/2015	Figure 1-1
LOCATION	Myuna																	
SEAM	Great Northern, Fassifern & Wallarah Seam																	
DRAWN	T.M																	
CHECKED	L.H																	
APPROVED	S.G																	
SCALE	refer to scalebar																	
DATE	15/05/2015	Figure 1-1																

1.4 Scope of work

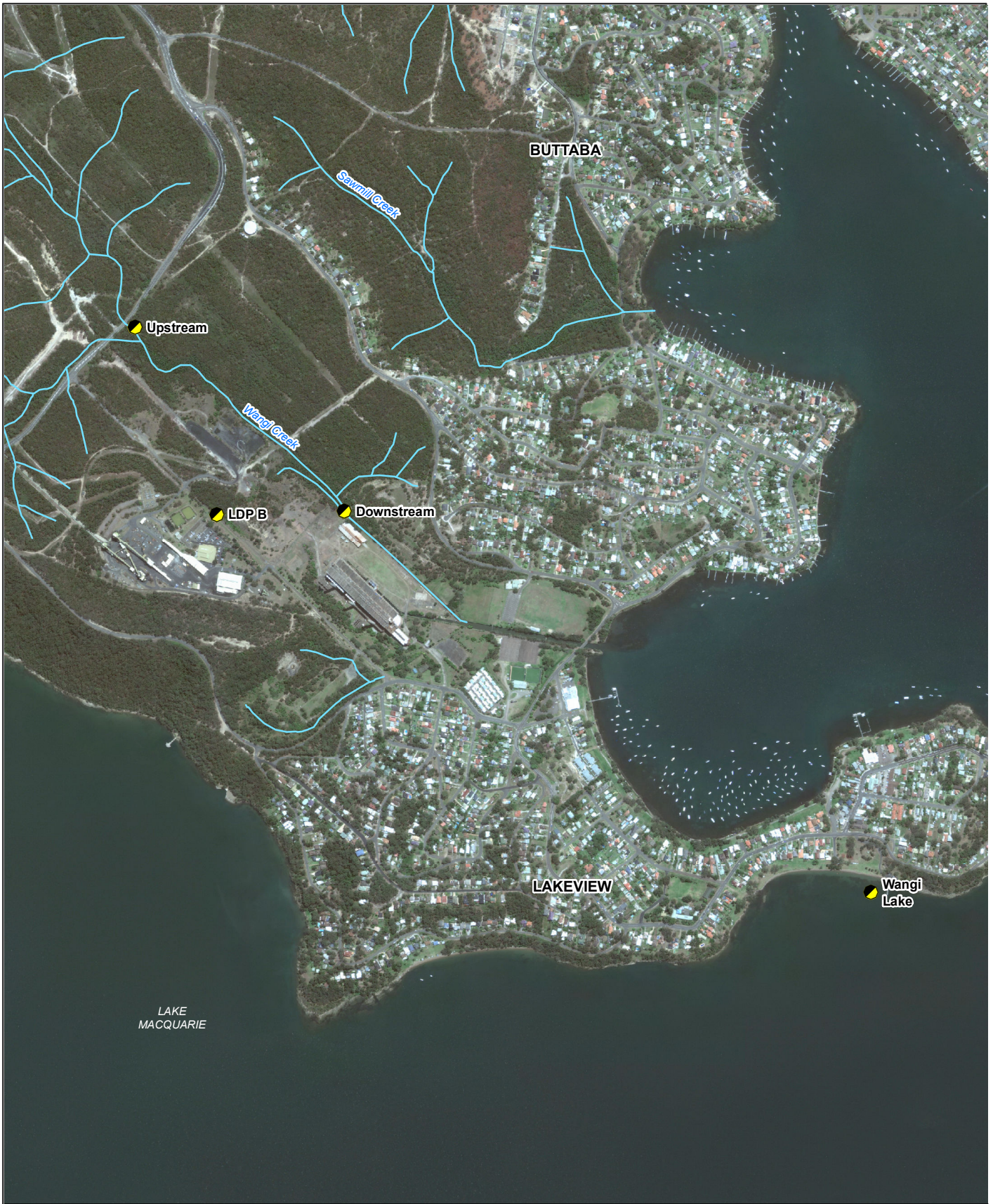
GHD Pty Ltd (GHD) was engaged by Centennial Myuna to undertake a water quality assessment of discharge from Myuna Colliery into Wangi Creek, with a particular focus on the concentrations of metals in water discharged from the mine site as required by Condition U1 of EPL 366.

The following monitoring points have been assessed, as shown in Figure 1-2:

- Upstream.
- LDP B.
- Downstream.
- Wangi Lake.

The scope of work for the water quality assessment includes:

- Collation and review of historical water quality data.
- Development of site-specific trigger values (SSTVs) in accordance with ANZECC (2000) methodology.
- Identify any additional parameters that may be considered appropriate for future water quality assessments.



<p>1:15,000 for A4</p> <p>Map Projection: Universal Transverse Mercator Horizontal Datum: Geodetic Datum of Australia 1994 Grid: Map Grid of Australia, Zone 56</p>		<p>LEGEND</p> <ul style="list-style-type: none"> Monitoring locations Streamlines 																
<p><small>© 2015. Whilst every care has been taken to prepare this map, GHD and Geoscience Australia make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.</small></p>	<table border="1"> <tr><td>LOCATION</td><td>Myuna</td></tr> <tr><td>SEAM</td><td>Great Northern, Fassifern & Wallarah Seam</td></tr> <tr><td>DRAWN</td><td>T.M</td></tr> <tr><td>CHECKED</td><td>L.H</td></tr> <tr><td>APPROVED</td><td>S.G</td></tr> <tr><td>SCALE</td><td>refer to scalebar</td></tr> </table>	LOCATION	Myuna	SEAM	Great Northern, Fassifern & Wallarah Seam	DRAWN	T.M	CHECKED	L.H	APPROVED	S.G	SCALE	refer to scalebar	<p align="center">ANZECC Water Quality Assessment Myuna Colliery</p> <p align="center">Monitoring locations</p>	<table border="1"> <tr> <td>DATE</td> <td>25/05/2015</td> <td>Figure 1-2</td> </tr> </table>	DATE	25/05/2015	Figure 1-2
LOCATION	Myuna																	
SEAM	Great Northern, Fassifern & Wallarah Seam																	
DRAWN	T.M																	
CHECKED	L.H																	
APPROVED	S.G																	
SCALE	refer to scalebar																	
DATE	25/05/2015	Figure 1-2																

2. Methodology

2.1 Data requirements

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) recommends that, for the purpose of deriving ambient concentrations and SSTVs, a sufficient amount of data needs to be collected and that it should characterise seasonal variations:

“A minimum of two years of continuous monthly data at the reference site is required before a valid trigger value can be established.”

The background/reference dataset currently available at the time of preparing this report has more than two years of monitoring data.

2.2 Trigger values

Trigger values may be derived from:

- ANZECC (2000) trigger values.
- Limits specified by relevant EPLs.
- SSTVs derived or recommended using site-specific water quality monitoring data.
- Local ecotoxicity data.

ANZECC (2000) defines trigger values as:

“...the concentrations (or loads) of the key performance indicators measured for the ecosystem, below which there exists a low risk that adverse biological (ecological) effects will occur. They indicate a risk of impact if exceeded and should ‘trigger’ some action, either further ecosystem specific investigations or implementation of management/remedial actions.”

Many trigger values can be found in ANZECC (2000) which are usually derived from ecotoxicity studies (for toxicants) or from background assessments (for nutrients and physicochemical parameters) and are not specific to the site studied. These trigger values should be considered as default trigger values (DTVs) and their suitability should be verified by establishing local background conditions.

2.2.1 ANZECC (2000) default trigger values

DTVs were selected from ANZECC (2000), with site-derived trigger values preferred to regionally-derived trigger values. Within the ANZECC (2000) guidelines, Wangi Creek falls into different categories of ecosystem protection depending upon the parameter reviewed, as identified in Table 2-1.

Table 2-1 Protection categories

Parameter	Category
Physicochemical	Aquatic ecosystem protection, ecosystem type estuaries, NSW (ANZECC, 2000; Section 8.2.2.1).
Nutrients	Aquatic ecosystem protection, ecosystem type estuaries, NSW (ANZECC, 2000; Section 8.2.2.1).
Metals and other toxicants	‘Marine’ category (ANZECC, 2000, Table 3.4.1), with 95% species protection for slightly-moderately disturbed ecosystems.

A list of DTVs available for adoption to assess water quality in the absence of adequate reference site monitoring data is presented in Table 2-2. The list is reflective of the parameters most commonly monitored at Myuna Colliery and specified in EPL 366.

Table 2-2 ANZECC (2000) default trigger values

Parameter	Trigger value	Additional information
Physicochemical parameters		
pH	7.0–8.5	Estuarine trigger value for NSW (Table 8.2.8).
TSS	6,000 µg/L	Estuarine trigger value for NSW (Table 8.2.12).
Nutrients		
Total phosphorus	35 µg/L	Estuarine trigger value for NSW (Table 8.2.3).
Filterable/dissolved metals		
Aluminium*	50 µg/L	Marine low reliability trigger value (Section 8.3.7.1).
Antimony	270 µg/L	Marine low reliability trigger value (Section 8.3.7.1).
Arsenic*	2.3 µg/L (As (III))	Marine low reliability trigger value (Section 8.3.7.1) for As (III).
	4.5 µg/L (As (V))	Marine low reliability trigger value (Section 8.3.7.1) for As (V).
Boron	5100 µg/L	Marine low reliability trigger value (Section 8.3.7.1).
Cadmium	5.5 µg/L	Marine trigger value for 95% species protection (Table 3.4.1).
Cobalt	1 µg/L	Marine trigger value for 95% species protection (Table 3.4.1).
Copper	1.3 µg/L	Marine trigger value for 95% species protection (Table 3.4.1).
Iron	300 µg/L	Canadian guideline trigger value as recommended by ANZECC (2000; section 8.3.7.1).
Molybdenum	23 µg/L	Marine low reliability trigger value (Section 8.3.7.1).
Nickel	70 µg/L	Marine trigger value for 95% species protection (Table 3.4.1).
Vanadium	100 µg/L	Marine trigger value for 95% species protection (Table 3.4.1).
Zinc	15 µg/L	Marine trigger value for 95% species protection (Table 3.4.1).

Note: no trigger values are indicated in ANZECC 2000 or Canadian Guidelines (CCME 1999) for marine waters for conductivity, barium, lithium, manganese, selenium or titanium

* High reliability trigger value for marine water not available.

2.2.2 Environment Protection Licence Limits

Concentration limits specified by EPL 366 for Myuna Colliery which apply to LDP A and LDP B are presented in Table 2-3.

Table 2-3 EPL 366 discharge limits

Parameter	100 percentile concentration limit
Oil and grease	10,000 µg/L
pH	6.5–8.5
Total suspended solids (TSS)	50,000 µg/L

2.2.3 Site-specific trigger values

Derivation of site-specific trigger values

SSTVs have been derived based on a review of DTVs recommended by ANZECC (2000) and the 80th percentile (and 20th percentile for pH, which is reported as a range) of water quality data collected from a reference location upstream of Myuna Colliery, referred to as 'Upstream'. The highest value of the ANZECC (2000) DTV and the 80th percentile concentration at the reference site was selected as the SSTV for downstream monitoring.

Data below the limit of reporting

Where the analytical result was below the limit of reporting (LOR) for a parameter, then the detection limit was included in the calculation. This is one of the recommended approaches by ANZECC (2000, Section 6.2.1). It is understood that this approach has limitations, in particular when over 25% of data is below the detection limit. Where greater than 25% of values for a parameter in the reference site dataset were below the LOR, the lowest detection limit reported for that dataset has been used as the SSTV.

Major Cations

ANZECC/ARMCANZ (2000) does not report trigger values for sodium, potassium, magnesium and calcium and information on the toxicity of these major cations to Australian species is not available. They are naturally abundant in the coastal aquatic environment and since mine water is discharge to an estuarine / marine environment, these parameters are not considered to pose a high risk to aquatic species. Median concentrations of all cations, with the exception of calcium, at the Downstream site are consistent with or lower than that observed at the Lake Macquarie site which can be considered as a gauge of levels within the ultimate receiving system. Therefore it is recommended that EPL concentration limits are not determined for sodium, potassium, magnesium and calcium.

3. Upstream site

3.1 Site description

Monitoring location Upstream is considered to be the most representative of the background conditions of Wangi Creek and is located approximately 500 m upstream of LDP B.

3.2 Statistical summary

A statistical summary for monitoring location Upstream is provided in Table 3-1. Data is presented for the most recent 24 monthly monitoring events, from July 2012 to February 2015.

Table 3-1 Statistical summary for water quality monitoring at site Upstream

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Physicochemical parameters						
pH	pH units	24	5.7	6.7	6.1	6.4
TSS	µg/L	24	5,000	490,000	19,500	77,000
Conductivity	µS/cm	24	137	731	241	306.4
Nutrients						
Total phosphorus	µg/L	24	10	260	20	40
Major ions						
Calcium	µg/L	24	2,000	4,000	3,000	3,000
Magnesium	µg/L	24	2,000	6,000	5,000	6,000
Potassium	µg/L	24	2,000	3,000	2,000	3,000
Sodium	µg/L	24	21,000	52,000	37,000	45,000
Sulfur	µg/L	24	1,000	9,000	3,000	4,000
Filterable/dissolved metals						
Aluminium	µg/L	24	50	1,380	340	720
Antimony	µg/L	24	1	10	1	10
Arsenic	µg/L	24	1	10	1	5
Barium	µg/L	24	25	46	37	40
Boron	µg/L	24	50	70	50	50
Cadmium	µg/L	24	0.1	1	0.1	0.5
Cobalt	µg/L	24	1	10	1	5

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Copper	µg/L	24	1	10	1	2
Iron	µg/L	24	500	7,500	1,100	2,100
Lithium	µg/L	24	1	4	3	3
Manganese	µg/L	24	28	187	60	95
Molybdenum	µg/L	24	1	10	1	1
Nickel	µg/L	24	1	10	1	1
Selenium	µg/L	24	10	100	10	50
Silica	µg/L	24	13,500	25,600	20,050	22,940
Titanium	µg/L	24	10	100	20	60
Vanadium	µg/L	24	10	100	10	10
Zinc	µg/L	24	5	50	12	16
Total metals						
Aluminium	µg/L	24	320	4,050	1,140	1,930
Antimony	µg/L	24	1	10	1	5
Arsenic	µg/L	24	1	10	1	2
Barium	µg/L	24	31	136	43	58
Boron	µg/L	24	50	60	50	50
Cadmium	µg/L	24	0.1	1	0.1	0.1
Cobalt	µg/L	24	1	10	1	1
Copper	µg/L	24	1	10	2	4
Iron	µg/L	24	800	163,000	5,600	21,400
Lithium	µg/L	24	2	10	3	4
Manganese	µg/L	24	29	247	71	127
Molybdenum	µg/L	24	1	10	1	1
Nickel	µg/L	24	1	10	1	2
Selenium	µg/L	24	10	100	10	10
Silica	µg/L	22	16,900	33,400	21,800	25,100
Titanium	µg/L	24	1	70	1	10

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Vanadium	µg/L	24	10	100	10	10
Zinc	µg/L	24	5	240	16	23
Other parameters						
Oil and grease	µg/L	24	2,000	3,000	2,000	2,000

3.3 Site-specific trigger values

Calculated SSTVs for Wangi Creek are shown in Table 3-2. These SSTVs have been derived following the methodology specified by ANZECC (2000). Note that SSTVs are applied to downstream sites at the edge of the mixing zone and do not apply to mine water discharges. Therefore, they should not be used as concentration limits in EPLs. SSTV exceedances at a downstream monitoring site should be addressed in accordance with the Trigger, Action, Response Plan (TARP) to determine the source of the exceedance, any potential impacts of the exceedance and if any management actions are required.

The numbers in bold indicate the selected SSTV for each parameter. Where greater than 25% of values for a parameter in the Upstream dataset were below the LOR¹, the lowest detection limit reported for that dataset has been used as the SSTV.

¹ LORs varied depending on the method used by the laboratory due to the matrix of the sample (samples with high EC will have higher LOR)

Table 3-2 Selected site-specific trigger values for Wangi Creek

Parameter	Units	ANZECC (2000) DTV	Upstream 80th percentile	Selected SSTV
Physicochemical parameters				
pH	pH unit	7.0–8.5	6.2*–6.4	6.2–8.5
TSS	µg/L	6,000	7,700	7,700
Nutrients				
Total phosphorus	µg/L	35	1^	35
Filterable/dissolved metals				
Aluminium	µg/L	50	724	724
Antimony	µg/L	270	1^	270
Arsenic	µg/L	23	1^	23
Barium	µg/L	–	40	40
Boron	µg/L	5,100	50^	5,100
Cadmium	µg/L	5.5	0.1^	5.5
Cobalt	µg/L	1	1^	1
Copper	µg/L	1.3	1^	1.3
Iron	µg/L	300	2,100	2,100
Lithium	µg/L	–	1^	1
Manganese	µg/L	-	95	95
Molybdenum	µg/L	23	1^	23
Nickel	µg/L	70	0.001	70
Selenium	µg/L	-	10^	10
Silica	µg/L	-	22,940	22,940
Titanium	µg/L	–	10^	10
Vanadium	µg/L	100	10^	100
Zinc	µg/L	15	16	16

Note: No SSTV can be determined for conductivity as there is no ANZECC (2000) marine trigger value and the Upstream site is freshwater so not relevant to Wangi Creek downstream of the discharge

* 20th percentile result.

^ Lowest limit of reporting recorded.

3.4 Historical trends

Time series graphs for selected water quality parameters monitored at site Upstream are provided in Appendix A. In cases where results were less than the LOR, the relevant LOR value has been plotted. Elevated aluminium and iron show a highly mineralised catchment.

3.4.1 Physicochemical parameters

pH

The pH levels at the Upstream monitoring location indicated the water was slightly acidic, with samples ranging between 5.7 and 6.7. The low pH may account for the bioavailable zinc concentration being higher than the DTV.

Total suspended solids

Concentrations of TSS have generally been recorded below 50,000 µg/L. Since July 2014, three TSS recordings have exceeded 390,000 µg/L, with the maximum concentration reported as 490,000 µg/L in October 2014. Elevated TSS is usually related to rain events.

Electrical conductivity

Electrical conductivity ranged between 137 µS/cm and 731 µS/cm, though levels were generally 241 µS/cm. Electrical conductivity within this range indicates freshwater conditions at this Upstream site.

3.4.2 Nutrients

Total phosphorus

The maximum concentration of total phosphorus reported for the Upstream monitoring site was 260 µg/L in February 2011. All concentrations since February 2012 have been below 100 µg/L, with approximately half of all results at or below the LOR of 10 µg/L.

3.4.3 Major ions

The major ion concentrations at the Upstream site showed considerable variation, possibly due to rain events and upstream activities during the monitoring period. Concentrations of calcium and magnesium varied between 2000 µg/L and 9000 µg/L, with the majority of calcium results recorded below 5,000 µg/L. Potassium showed little variation with concentrations ranging between 2,000 µg/L and 3000 µg/L. In contrast sodium varied between 16,000 µg/L and 53,000 µg/L. The majority of sulfur concentrations were recorded below 10,000 µg/L, with a maximum result of 15,000 µg/L reported in April 2011.

3.4.4 Metals

Aluminium

Dissolved and total aluminium has been detected at the Upstream monitoring site for each monthly monitoring event from January 2011 to February 2015. Concentrations ranged between 50 µg/L and 1,380 µg/L for dissolved aluminium. These concentrations are higher than the DTV, indicating a highly mineralised catchment, with total aluminium concentrations generally found to be below 2,500 µg/L.

Antimony

All dissolved and total antimony concentrations reported at the Upstream monitoring site were at or below the LOR, which varied between 1 µg/L and 10 µg/L.

Arsenic

The majority of dissolved and total arsenic concentrations were found to be at or below the LOR, which varied between 1 µg/L and 10 µg/L. A maximum concentration of 2 µg/L for dissolved arsenic which is below the DTV and 4 µg/L for total arsenic was detected.

Barium

Dissolved and total barium has been detected at the Upstream monitoring site for each monthly monitoring event from January 2011 to February 2015. Generally, dissolved barium was found to range between 25 µg/L and 52 µg/L with a median of 37 µg/L, with total barium found to vary between 30 µg/L and 100 µg/L.

Boron

The majority of dissolved and total boron concentrations were reported to be at or below the LOR, which varied between 5 µg/L and 500 µg/L. Two samples of dissolved boron were above the detection limit, with 6 µg/L recorded in June 2012 and 7 µg/L recorded in March 2014. One sample of total boron was found to be above the detection limit, with 6 µg/L recorded in June 2014.

Cadmium

The majority of dissolved and total cadmium concentrations were reported to be at or below the LOR, which varied between 0.1 µg/L and 1 µg/L. Only one sample of dissolved cadmium was found to be above the detection limit, which was reported to be 0.2 µg/L in April 2011. Three samples of total cadmium were found to be above the detection limit in April, May and June 2011, with the maximum concentration of 0.5 µg/L reported in June 2011.

Cobalt

The majority of dissolved and total cobalt concentrations were reported to be at or below the LOR, which varied between 1 µg/L and 10 µg/L. Concentrations of cobalt detected were found to range between 2 µg/L and 3 µg/L for dissolved cobalt and between 2 µg/L and 5 µg/L for total cobalt.

Copper

The majority of dissolved and total copper concentrations were reported to be at or below the LOR, which varied between 1 µg/L and 2 µg/L. Dissolved copper concentrations were generally found to be below 2 µg/L, with total copper results detected below 5 µg/L.

Iron

Dissolved and total iron has been detected at the Upstream monitoring site for each monthly monitoring event from January 2011 to February 2015. Concentrations of dissolved iron were generally reported below 2,000 µg/L; however there was an increase in concentrations recorded during 2012, with a maximum concentration of 1,460 µg/L reported in March 2012. Total iron concentrations were reported to be greater than dissolved, with the majority of samples found to be below 35,000 µg/L. A maximum concentration of 163,000 µg/L of total iron was reported in October 2014.

Lithium

Dissolved lithium concentrations between January 2011 and February 2015 have fluctuated between 1 µg/L and 6 µg/L, with a median value of 3 µg/L. Concentrations of total lithium have ranged between 2 µg/L and 10 µg/L with a median value of 3 µg/L.

Manganese

Dissolved and total manganese has been detected at the Upstream monitoring site for each monthly monitoring event from January 2011 to February 2015. Concentrations of dissolved

manganese were generally reported below 250 µg/L, with total manganese concentrations ranging between 22 µg/L and 278 µg/L.

Molybdenum

All dissolved and total molybdenum concentrations reported at the Upstream monitoring site were at or below the LOR, which varied between 1 µg/L, 5 µg/L and 10 µg/L.

Nickel

Approximately half of dissolved and total nickel concentrations were reported to be at or below the LOR, which varied between 1 µg/L, 5 µg/L and 10 µg/L. Detected concentrations of dissolved nickel were found to be below 3 µg/L, recorded in 2011 and 2012. Total nickel concentrations ranged between 2 µg/L and 6 µg/L.

Selenium

All dissolved and total selenium concentrations reported at the Upstream monitoring site were below the LOR, which varied between 10 µg/L and 100 µg/L.

Silica

Dissolved silica at the Upstream site was recorded between 13,500 µg/L and 26,800 µg/L with median values of 20,300 µg/L. Total silica ranged between 16,900 µg/L and 33,400 µg/L with median level of 21,800 µg/L. There has been a slight increase in silica in 2014, though this trend is most obvious in total concentrations as the bulk of the data have only been recorded between 2013 and 2014.

Titanium

Approximately half of dissolved titanium concentrations were reported to be below the LOR, which varied between 1 µg/L, 10 µg/L and 100 µg/L. Detected concentrations of dissolved titanium were found to range between 20 µg/L and 70 µg/L. The majority of total titanium concentrations were reported to be at or below the LOR, which varied between 1 µg/L, 5 µg/L and 10 µg/L. Two samples of total titanium were reported to be above the detection limit, with 20 µg/L recorded in July 2011 and 70 µg/L reported in December 2012.

Vanadium

All dissolved vanadium and the majority of total vanadium concentrations were reported to be at or below the LOR, which varied between 10 µg/L and 100 µg/L. Three samples of total vanadium were found to be above the detection limit, with 30 µg/L, 50 µg/L and 20 µg/L recorded in July, October and November 2014 respectively.

Zinc

Dissolved zinc concentrations for the Upstream monitoring site were generally found to vary between 5 µg/L (the LOR) and 23 µg/L. Two samples of dissolved zinc have been recorded to exceed 50 µg/L, in April 2011 and November 2014. Total zinc concentrations were found to generally range between 5 µg/L (the LOR) and 40 µg/L. The maximum concentration for total zinc of 240 µg/L was recorded in March 2013.

3.4.5 Other parameters

Oil and grease

The majority of total oil and grease concentrations were reported to be at or below the LOR of 2,000 µg/L at the Upstream monitoring site. A concentration of 3,000 µg/L was recorded on three occasions, in September 2011, May 2012 and November 2014.

4. Licensed Discharge Point B

4.1 Site description

As discussed in Section 1.2, Myuna Colliery has two operational LDPs licensed under EPL 366. LDP A is an emergency discharge point located on the outlet of the Emergency Coal Stockpile Dam. LDP B discharges mine water via the CHP Dam and Mine Water Settling Pond 3. Discharges from LDP A and LDP B enter an earthen channel that runs parallel to Wangi Creek for approximately 200 m.

4.2 Statistical summary

A statistical summary for monitoring at LDP B is provided in Table 4-1. Data is presented for the most recent 24 monthly monitoring events, from March 2013 to February 2015.

Table 4-1 Statistical summary for water quality monitoring at site LDP B

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Physicochemical parameters						
pH	pH units	24	7.6	7.8	7.7	7.8
TSS	µg/L	24	5,000	28,000	7,000	9,000
EC	µS/cm	24	31,700	46,700	43,350	44,720
Nutrients						
Total phosphorus	µg/L	24	10	70	20	50
Major ions						
Calcium	µg/L	24	596,000	910,000	743,000	789,000
Magnesium	µg/L	24	905,000	1,370,000	1,150,000	1,234,000
Potassium	µg/L	24	152,000	247,000	186,000	210,000
Sodium	µg/L	24	6,400,000	10,000,000	8,340,000	9,000,000
Sulfur	µg/L	24	377,000	686,000	547,000	609,000
Filterable/dissolved metals						
Aluminium	µg/L	24	10	10	10	10
Antimony	µg/L	24	1	10	10	10
Arsenic	µg/L	24	1	10	10	10
Barium	µg/L	24	111	301	147	178
Boron	µg/L	24	50	1,040	730	880
Cadmium	µg/L	24	0.1	2.7	1	1

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Cobalt	µg/L	24	1	10	10	10
Copper	µg/L	24	1	66	10	10
Iron	µg/L	24	100	500	500	500
Lithium	µg/L	24	332	619	491	544
Manganese	µg/L	24	206	762	450	656
Molybdenum	µg/L	24	1	10	10	10
Nickel	µg/L	24	1	10	10	10
Selenium	µg/L	24	10	100	100	100
Silica	µg/L	24	9,800	17,000	13,350	15,720
Titanium	µg/L	24	100	100	100	100
Vanadium	µg/L	24	10	100	100	100
Zinc	µg/L	24	50	73	50	50
Total metals						
Aluminium	µg/L	24	10	460	10	10
Antimony	µg/L	24	1	10	10	10
Arsenic	µg/L	24	1	10	10	10
Barium	µg/L	24	116	304	152	187
Boron	µg/L	24	500	1,060	740	910
Cadmium	µg/L	24	0.1	3.1	0.1	0.1
Chromium	µg/L	24	1	10	10	10
Cobalt	µg/L	24	1	10	10	10
Copper	µg/L	24	3	75	10	10
Iron	µg/L	24	590	1,500	880	1,090
Lithium	µg/L	24	372	921	514	577
Manganese	µg/L	24	229	741	480	689
Molybdenum	µg/L	24	1	10	10	10
Nickel	µg/L	24	1	10	10	10
Selenium	µg/L	24	10	100	100	100

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Silica	µg/L	24	9,200	17,600	14,100	15,620
Titanium	µg/L	24	10	100	100	100
Vanadium	µg/L	24	10	100	100	100
Zinc	µg/L	24	50	103	50	52
Other parameters						
Oil and grease	µg/L	24	2,000	3,000	2,000	2,000

4.3 Historical trends

Time series graphs for selected water quality parameters monitored at LDP B are provided in Appendix A. The limits for oil and grease, pH and TSS specified by EPL 366 for LDP B discharges (refer Section 2.2.2) are also presented in the relevant figures. In cases where results were less than the LOR, the relevant LOR value has been plotted.

4.3.1 Physicochemical parameters

pH

Levels of pH measured for LDP B discharge were found to range between 7.4 and 7.9, indicating slightly alkaline water. All reported pH results were within the range of 6.5 to 8.5 specified by EPL 366.

Total suspended solids

Concentrations of TSS have generally been recorded below 40,000 µg/L. Results indicate four occasions where TSS concentrations have been reported above the EPL limit of 50,000 µg/L, with the maximum concentration recorded as 96,000 µg/L in November 2011. All concentrations of TSS have been below the EPL 366 limit of 50,000 µg/L since April 2012.

Electrical Conductivity

Electrical conductivity between 2011 and 2014 ranged between 1,540 µS/cm and 48,200 µS/cm. This wide range of conductivity is reflective of freshwater to estuarine conditions with fluctuating influence of marine water from Lake Macquarie.

4.3.2 Nutrients

Total phosphorus

The maximum concentration of total phosphorus reported for LDP B was 150 µg/L in February 2011. All concentrations since January 2012 have been below 100 µg/L, with the majority of results at or below the LOR of 10 µg/L.

4.3.3 Major ions

Concentrations of calcium were recorded to range between 300,000 µg/L and 1,000,000 µg/L. Magnesium concentrations at LDP B were found to be between 900,000 µg/L and 1,400,000 µg/L for the majority of results. Concentrations of potassium were reported to range between 100,000 µg/L and 250,000 µg/L. Results for sodium at LDP B varied between 6,000,000 µg/L and 10,000,000 µg/L. The majority of sulfur concentrations were recorded between 400,000 µg/L and 700,000 µg/L.

4.3.4 Metals

Few metals were found in low concentrations in the discharge, however, the majority of metals were below detection limits.

Aluminium

The majority of dissolved and total aluminium concentrations have been reported to be at or below the LOR, which varied between 10 µg/L, 50 µg/L, 100 µg/L, 250 µg/L and 500 µg/L. Detected concentrations ranged between 20 µg/L and 80 µg/L for dissolved aluminium and between 110 µg/L and 470 µg/L for total aluminium.

Antimony

All dissolved and total antimony concentrations reported for LDP B were below the LOR, which varied between 1 µg/L, 5 µg/L and 10 µg/L.

Arsenic

All dissolved arsenic concentrations and the majority of total arsenic concentrations reported for LDP B were below the LOR, which varied between 1 µg/L, 5 µg/L, 25 µg/L, 10 µg/L and 5 µg/L. Two samples of total arsenic were found to be above the detection limit, with 15 µg/L and 31 µg/L recorded in November and December 2011 respectively.

Barium

Dissolved and total barium has been detected at LDP B for each monthly monitoring event from January 2011 to February 2015. Generally dissolved barium was found to be below 250 µg/L, with total barium found to vary between 100 µg/L and 320 µg/L.

Boron

Dissolved boron concentrations reported for LDP B were found to vary between 230 µg/L and 1,004 µg/L, with concentrations below the LOR of 50 µg/L on two occasions in September 2014 and February 2015. Total boron concentrations were found to generally range between 300 µg/L and 1,060 µg/L.

Cadmium

The majority of dissolved and total cadmium concentrations were reported to be at or below the LOR, which varied between 0.1 µg/L, 0.5 µg/L and 1 µg/L. Only one sample of dissolved cadmium was found to be above the detection limit, which was reported to be 2.7 µg/L in March 2013. Two samples of total cadmium were found to be above the detection limit in May 2011 and March 2013, with concentrations of 0.2 µg/L and 3.1 µg/L reported respectively.

Cobalt

All dissolved and total cobalt concentrations reported for LDP B were below the LOR, which was found to vary between 1 µg/L, 5 µg/L and 10 µg/L.

Copper

The majority of dissolved and total copper concentrations were reported to be at or below the LOR, which varied between 1 µg/L, 10 µg/L, 20 µg/L, 25 µg/L and 50 µg/L. Dissolved copper concentrations were generally detected below 3 µg/L, with a maximum concentration of 66 µg/L recorded in April 2013. The maximum total copper concentration was also recorded in April 2013, at 75 µg/L.

Iron

The majority of dissolved iron concentrations at LDP B were reported to be below the LOR, which varied between 50 µg/L, 100 µg/L, 250 µg/L and 500 µg/L. Detected concentrations of dissolved iron were generally below 400 µg/L, with a maximum concentration of 540 µg/L recorded in May 2013. The majority of total iron concentrations were found to vary between 260 µg/L (the LOR) and 1,500 µg/L, with a maximum concentration of 4,410 µg/L recorded in March 2012.

Lithium

Dissolved lithium concentration between 2011 and 2014 ranged between 203 µg/L and 921 µg/L with median concentrations of 508 µg/L. Total concentrations ranged between 226 µg/L and 828 µg/L with median concentrations of 489.5 µg/L.

Manganese

Dissolved and total manganese has been detected at LDP B for each monthly monitoring event from January 2011 to February 2015. Concentrations of both dissolved and total manganese were found to range between 80 µg/L and 800 µg/L.

Molybdenum

All dissolved and total molybdenum concentrations reported for LDP B were below the LOR, which varied between 1 µg/L, 5 µg/L and 10 µg/L.

Nickel

The majority of dissolved and total nickel concentrations reported for LDP B were at or below the LOR, which varied between 1 µg/L, 5 µg/L, 25 µg/L and 10 µg/L. One dissolved nickel sample was found to be above the detection limit, with 2 µg/L reported in November 2011. Two total nickel results were reported above the detection limit, with 14 µg/L and 2 µg/L recorded in May and June 2011 respectively.

Selenium

All dissolved and total selenium concentrations reported for LDP B were below the LOR, which varied between 10 µg/L, 50 µg/L and 100 µg/L.

Silica

Levels of dissolved silica were recorded at LDP B between 6,000 µg/L and 17,600 µg/L with median values of 13,700 µg/L. Total concentrations of silica ranged between 9,800 µg/L and 17,000 µg/L with median value of 13,350 µg/L.

Titanium

All dissolved titanium concentrations and the majority of total titanium concentrations for LDP B were reported to be below the LOR, which varied between 5 µg/L, 10 µg/L and 100 µg/L. Only one sample of total titanium was found to be above the detection limit, which was reported to be 20 µg/L in May 2011.

Vanadium

All dissolved and total vanadium concentrations reported for LDP B were below the LOR, which varied between 10 µg/L, 50 µg/L and 100 µg/L.

Zinc

The majority of dissolved and total zinc results for LDP B were found to be at or below the LOR, which varied between 5 µg/L, 50 µg/L and 52 µg/L. Dissolved and total zinc concentrations were generally found to be below 250 µg/L. The maximum result was recorded for dissolved zinc in

February 2011, where 290 µg/L was recorded. Concentrations of dissolved and total zinc have been reported at or below the LOR since May 2013.

4.3.5 Other parameters

Oil and grease

The majority of oil and grease results were reported to be at or below the LOR of 2,000 µg/L for LDP B. A concentration of 5,000 µg/L was recorded on one occasion in July 2011 and a concentration of 3,000 µg/L was recorded on three occasions, in May and June 2012 and November 2013. All reported oil and grease results were below the limit of 10,000 µg/L specified in EPL 366.

5. Downstream site

5.1 Site description

Monitoring site Downstream is located approximately 180 m downstream of the channel conveying LDP B discharge from Myuna Colliery.

5.2 Statistical summary

A statistical summary for monitoring location Downstream is provided in Table 5-1. Data is presented for the most recent 24 monthly monitoring events, from March 2013 to February 2015. The median values are compared to the SSTVs. Figures in bold exceed the SSTV.

Table 5-1 Statistical summary for water quality monitoring at site Downstream

Parameter	Units	SSTV	Count	Minimum	Maximum	50th percentile	80th percentile
Physicochemical parameters							
pH	pH units	6.2-8.5	24	7.3	8.1	7.7	7.8
TSS	µg/L	77,000	24	5,000	88,000	8,000	11,000
EC	µS/cm	-	24	13,200	45,700	40,700	44,080
Nutrients							
Total phosphorus	µg/L	35	24	10	130	20	50
Major ions							
Calcium	µg/L	-	24	209,000	938,000	709,000	760,000
Magnesium	µg/L	-	24	322,000	1,270,000	1,120,000	1,206,000
Potassium	µg/L	-	24	61,000	237,000	174,000	203,000
Sodium	µg/L	-	24	2,160,000	9,290,000	7,925,000	8,726,000
Sulfur	µg/L	-	24	147,000	675,000	526,000	571,000
Filterable/dissolved metals							
Aluminium	µg/L	724	24	10	100	100	100
Antimony	µg/L	270	24	1	10	10	10
Arsenic	µg/L	23	24	1	10	10	10
Barium	µg/L	40	24	51	391	139	173
Boron	µg/L	5,100	24	180	1,080	680	860

Parameter	Units	SSTV	Count	Minimum	Maximum	50th percentile	80th percentile
Cadmium	µg/L	5.5	24	0.1	10	1	1
Cobalt	µg/L	1.3	24	1	10	10	10
Copper	µg/L	1.3	24	1	10	10	10
Iron	µg/L	2,100	24	10	500	500	500
Lithium	µg/L	1	24	100	600	479	507
Manganese	µg/L	95	24	194	809	371	595
Molybdenum	µg/L	23	24	1	10	10	10
Nickel	µg/L	70	24	1	10	10	10
Selenium	µg/L	10	24	10	100	100	100
Silica	µg/L	22,940	24	9,200	16,700	12,550	15,400
Titanium	µg/L	10	24	10	100	100	100
Vanadium	µg/L	100	24	10	100	100	100
Zinc	µg/L	16	24	31	58	50	50
Total metals							
Aluminium	µg/L	-	24	10	1,240	100	260
Antimony	µg/L	-	24	1	10	10	10
Arsenic	µg/L	-	24	1	10	10	10
Barium	µg/L	-	24	57	298	153	179
Boron	µg/L	-	24	50	1,000	740	910
Cadmium	µg/L	-	24	0.1	2.7	1	1
Cobalt	µg/L	-	24	1	10	10	10
Copper	µg/L	-	24	1	10	10	10
Iron	µg/L	-	24	520	2,140	1,170	1,400
Lithium	µg/L	-	24	117	789	492	546
Manganese	µg/L	-	24	0.225	0.826	0.402	0.623
Molybdenum	µg/L	-	24	0.001	0.01	0.010	0.010
Nickel	µg/L	-	24	0.001	0.01	0.010	0.010
Selenium	µg/L	-	24	0.01	0.1	0.10	0.10

Parameter	Units	SSTV	Count	Minimum	Maximum	50th percentile	80th percentile
Silica	µg/L	-	24	10,000	17,600	14,550	15,980
Titanium	µg/L	-	24	10	100	100	100
Vanadium	µg/L	-	24	10	100	100	100
Zinc	µg/L	-	24	48	73	50	52
Other parameters							
Oil and grease	µg/L	-	24	2,000	3,000	2,000	2,000

5.3 Historical trends

Time series graphs for selected water quality parameters monitored at the Downstream monitoring location are provided in Appendix A. SSTVs (refer Section 3.3) are also presented in relevant figures. In cases where results were less than the LOR, the relevant LOR value has been plotted.

5.3.1 Physicochemical parameters

pH

Monitoring of pH at the Downstream location indicated that the water was slightly alkaline, with samples ranging between 7.2 and 8.1. All samples were found to be within the SSTVs of 6.2 to 8.5.

Total suspended solids

Results for TSS were generally below 40,000 µg/L at the Downstream monitoring site. One sample was reported above the SSTV of 77,000 µg/L, with 88,000 µg/L recorded in April 2013. A one off exceedance such as this will be unlikely to cause adverse environmental harm and is likely related to a rainfall event. The median TSS concentration of the most recent 24 months monitoring was below the SSTV.

Electrical conductivity

Electrical conductivity between January 2011 and February 2015 varied between 13,200 µS/cm and 48,200 µS/cm. The high variability in EC at this site demonstrates the variable tidal influence from Lake Macquarie. The median EC of 40,600 µS/cm confirms the status of Wangi Creek at the Downstream site as an estuarine environment. For this reason, EC has not been compared to values collected at the Upstream site.

5.3.2 Nutrients

Total phosphorus

The majority of total phosphorus results were found to be at or below the LOR, which varied between 10 µg/L, 20 µg/L and 50 µg/L. Detected samples of total phosphorus have exceeded the SSTV of 35 µg/L on nine occasions (representing approximately 18% of all monitoring samples). The maximum concentration of total phosphorus for the Downstream monitoring location was 140 µg/L, reported in January and March 2011. The elevated phosphorous detected in 2011 was likely sourced from the LDP B. However, the median total phosphorus concentration of the most recent 24 months monitoring was below the SSTV.

5.3.3 Major ions

The major ions were elevated at the Downstream site when compared to the Upstream site and may be sourced from the LDP B discharge. However, EC levels indicate that this site is tidally influenced and, therefore cations may be elevated due to the influence of water from Lake Macquarie.

Concentrations of calcium at the Downstream monitoring site were found to vary between 200,000 µg/L and 1,000,000 µg/L. Magnesium concentrations for the Downstream monitoring site were found to be between 900,000 µg/L and 1,300,000 µg/L for the majority of results. Concentrations of potassium were reported to generally range between 100,000 µg/L and 200,000 µg/L, with results showing a general increase in concentration since 2013 although this trend has not been assessed statistically. Results for sodium at the Downstream monitoring site largely varied between 6,000,000 µg/L and 10,000,000 µg/L. The majority of sulfur concentrations were recorded between 400,000 µg/L and 700,000 µg/L.

5.3.4 Metals

Aluminium

The majority of dissolved and total aluminium results were reported to be at or below the LOR, which varied between 10 µg/L, 50 µg/L, 100 µg/L mg/L and 250 µg/L. Detected concentrations ranged between 30 µg/L and 50 µg/L for dissolved aluminium, with all results below the SSTV of 724 µg/L. Total aluminium concentrations generally ranged between 70 µg/L and 570 µg/L, with the maximum concentration of 1,240 µg/L recorded in April 2013.

Antimony

All dissolved antimony concentrations and the majority of total antimony concentrations reported at the Downstream monitoring site were below the LOR, which varied between 1 µg/L, 5 µg/L and 10 µg/L. All samples between November 2011 and May 2012 were below the SSTV on 270 µg/L.

Arsenic

The majority of dissolved and total arsenic concentrations reported for the Downstream monitoring site were found to be below the LOR, which varied between 1 µg/L, 5 µg/L, 25 µg/L, 10 µg/L and 50 µg/L. A concentration of 3 µg/L for dissolved arsenic was detected in May 2011, which is below the SSTV of 240 µg/L. One sample of total arsenic was found to be above the detection limit, with 30 µg/L recorded in December 2011.

Barium

Dissolved and total barium has been detected at the Downstream monitoring location for each monthly monitoring event from January 2011 to February 2015. Dissolved barium concentrations were generally found to range between 100 µg/L and 250 µg/L, with the majority of samples above the SSTV of 40 µg/L. Only one sample in October 2011 was reported to be below this SSTV. It follows that the median dissolved barium concentration of the most recent 24 months monitoring was above the SSTV and was sourced from the LDP B discharge. However, barium has low toxicity with cladoceran LC50 at 470,000 µg/L and it is unlikely that exceedances of the SSTV will cause adverse environmental impacts². Therefore, the SSTV for barium should be modified based on a review of barium toxicity in marine environments. Total barium was found to vary mostly between 100 µg/L and 250 µg/L.

Boron

² http://www.pesticideinfo.org/List_AquireAcuteSum.jsp?Rec_Id=PC41174&Taxa_Group=Zooplankton

Dissolved boron concentrations were found to vary between 200 µg/L and 1,100 µg/L, with concentrations not detected above the LOR of 500 µg/L on seven occasions between January 2011 and February 2015. All dissolved boron concentrations were recorded below the SSTV of 5,100 µg/L. Total boron concentrations were found to generally range between 400 µg/L and 1,000 µg/L.

Cadmium

The majority of dissolved and total cadmium concentrations were reported to be at or below the LOR, which varied between 0.1 µg/L, 0.5 µg/L and 1 µg/L. One sample of dissolved cadmium was detected in March 2013 with a concentration of 2.4 µg/L for , which is below the SSTV of 5.5 µg/L and the median cadmium concentration is below the SSTV. Two samples of total cadmium were found to be above the detection limit in May 2011 and March 2013, with concentrations of 0.2 µg/L and 0.27 mg/L reported respectively.

Cobalt

The majority of dissolved and total cobalt concentrations reported were below the LOR, which varied between 1 µg/L, 5 µg/L and 10 µg/L. A concentration of 2 µg/L for dissolved cobalt was detected in May 2011, which is above the SSTV of 1 µg/L. In the same month, total cobalt was detected at 3 µg/L. The median dissolved cobalt was above the SSTV due to the high detection limit.

Copper

The majority of dissolved and total copper concentrations were reported to be at or below the LOR, which varied between 1 µg/L, 10 µg/L, 20 µg/L and 25 µg/L. Detected samples of dissolved copper were found to exceed the SSTV of 1.3 µg/L on five occasions (representing approximately 10% of all monitoring samples). However, the median dissolved copper concentration is above the SSTV due to the high LOR. Total copper levels were generally detected below 3 µg/L, with a maximum concentration of 29 µg/L reported in October 2012.

Iron

The majority of dissolved iron concentrations at monitoring site Downstream were reported to be below the LOR, which varied between 50 µg/L, 250 µg/L and 500 µg/L. Detected concentrations of dissolved iron were generally below 500 µg/L, with a maximum concentration of 580 µg/L recorded in May 2013. All recorded dissolved iron concentrations were below the SSTV of 2,100 µg/L. The majority of total iron concentrations were found to vary between 260 µg/L (the LOR) and 2,000 µg/L, with a maximum concentration of 4,900 µg/L recorded in March 2012.

Lithium

Between January 2011 and Feb 2015, dissolved lithium concentrations ranged between 104 µg/L and 823 µg/L with median levels of 477 µg/L. Total lithium concentrations were between 117 µg/L and 821 µg/L with a median concentration of 477 µg/L. Lithium concentrations were above the SSTV at all sites due to the number of observations below the LOR. There has been less variability in lithium reported between May 2013 and February 2015.

Lithium has low toxicity with cladoceran LC50 at 33,000 µg/L in freshwater (Aral and Vecchio-Sadus 2008) and LC50 for a marine fish species at greater than 105,000 µg/L (Dwyer *et al.* 1992) also showed that there was no acute toxicity of striped bass observed in a test solution of simulated seawater with a lithium concentration of 6,870 µg/L over a 96 hour exposure. The reduction in the toxicity of lithium in seawater compared to freshwater can be attributed to the increase in hardness (Dwyer *et al.* 1992). Based on this information, it is unlikely that exceedances of the SSTV will cause adverse environmental impacts to the aquatic ecosystem at the Downstream site or further downstream and it is recommended that the SSTV be modified based on this information.

Manganese

Dissolved and total manganese has been detected at the Downstream monitoring location for each monthly monitoring event from January 2011 to February 2015. Concentrations of both dissolved and total manganese were found to range between 60 µg/L and 800 µg/L, with all dissolved manganese results recorded above the SSTV of 95 µg/L. Since there is no marine trigger value for manganese reported in ANZECC (2000), it is recommended that a literature review of manganese toxicity in marine environments be undertaken and the SSTV modified accordingly.

Molybdenum

The majority of dissolved and total molybdenum results were recorded to be at or below the LOR, which varied between 1 µg/L, 5 µg/L and 10 µg/L. Dissolved molybdenum was recorded above the detection limit on three occasions, with the maximum recorded concentration of 3 µg/L in May 2012 above the SSTV of 1 µg/L. The SSTV of 1 µg/L for dissolved molybdenum was exceeded on all three of these occasions, representing approximately 6% of sampling events. However, the median molybdenum concentration is below the SSTV and short term exceedances are unlikely to cause adverse environmental harm. Total molybdenum was detected on four sampling occasions, with the maximum concentration also recorded at 3 µg/L in May 2011 and May 2012.

Nickel

The majority of dissolved and total nickel concentrations reported for monitoring site Downstream were at or below the LOR, which varied between 1 µg/L, 5 µg/L, 25 µg/L and 10 µg/L. Two dissolved nickel samples were found to be above the detection limit, with 5 µg/L and 4 µg/L reported in February and May 2011 respectively. Both samples were below the SSTV of 70 µg/L for dissolved nickel. One total nickel sample was found to be above the detection limit, with 11 µg/L reported in May 2011.

Selenium

The majority of dissolved selenium and all total selenium concentrations reported for the Downstream monitoring site were at or below the LOR, which varied between 10 µg/L, 50 µg/L and 100 µg/L. One dissolved nickel sample was detected, with 20 µg/L recorded in May 2011, which is above the SSTV of 11 µg/L. The median concentration for selenium is above the SSTV due to the high LOR. Ultra-trace testing should be conducted to enable calculation of a more realistic SSTV.

Silica

Dissolved silica was recorded between 8,100 µg/L and 20,800 µg/L and total silica ranged between 6,020 µg/L and 17,600 µg/L. Median dissolved silica was below the SSTV of 22,940 µg/L at all occasions between January 2011 and February 2015.

Titanium

All dissolved titanium concentrations and the majority of total titanium concentrations reported at the Downstream monitoring site were below the LOR, which varied between 5 µg/L, 10 µg/L and 100 µg/L. The median concentration for vanadium is above the SSTV due to the high LOR. Three samples of total titanium were found to be above the detection limit, which was reported to be 20 µg/L in May and June 2011 and April 2013.

Vanadium

All dissolved and total vanadium concentrations reported at the Downstream monitoring site were below the LOR, which varied between 10 µg/L, 50 µg/L and 100 µg/L.

Zinc

The majority of dissolved and total zinc results for the monitoring location Downstream were found to be at or below the LOR, which varied between 5 µg/L, 50 µg/L and 52 µg/L. Dissolved zinc concentrations ranged between 31 µg/L and 176 µg/L, with the majority of results above the SSTV of 16 µg/L. However, concentrations of dissolved zinc have been reported at or below the LOR since October 2013. It must be noted that the LOR is above the SSTV and it must be assumed that the zinc concentrations are exceeding the SSTV on every sampling occasion. Ultra-trace testing should be conducted to allow calculation of more realistic SSTV. Total zinc results were found to vary from 5 µg/L to over 200 µg/L.

5.3.5 Other parameters

Oil and grease

The majority of oil and grease results were reported to be at or below the LOR of 2,000 µg/L at the Downstream monitoring site. A concentration of 3,000 µg/L was recorded on two occasions, in May 2012 and November 2013.

5.4 Summary

Several of the dissolved metals exceed the SSTV due to high LORs. The LOR for cobalt, copper, selenium, titanium and zinc must be reviewed and the required ultra-trace tests selected to ensure that the water quality meets the SSTVs. The SSTVs should be stated on the Chain of Custody form when the samples are sent to the laboratory to ensure that the correct tests are selected.

Low SSTVs have been calculated for some variables, including selenium and titanium, due to the number of observations below the LOR and the lack of default ANZECC trigger levels. These SSTVs should be recalculated following further analysis at lower detection limits as described above.

Due to the low toxicity of barium and lithium, it is suggested that the SSTV be reviewed.

The minimum zinc concentration detected at the Downstream monitoring site is above the SSTV. This requires further investigation.

6. Lake Macquarie site

6.1 Site description

The Wangi Lake monitoring site is located on Lake Macquarie approximately 2 km south-east of Myuna Colliery. This site is considered to be representative of the receiving environment of Lake Macquarie.

6.2 Statistical summary

A statistical summary for monitoring location Wangi Lake is provided in Table 6-1. Data is presented for the most recent 24 monthly monitoring events, from July 2012 to February 2015.

Table 6-1 Statistical summary for water quality monitoring at site Wangi Lake

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Physicochemical parameters						
pH	pH units	24	7.7	8.2	8.0	8.1
TSS	µg/L	24	5,000	16,000	6,000	7,000
EC	µS/cm	24	23,700	56,300	51,350	52,940
Nutrients						
Total phosphorus	µg/L	24	10	120	20	50
Major ions						
Calcium	µg/L	24	202,000	478,000	423,000	461,000
Magnesium	µg/L	24	612,000	1,480,000	1,285,000	1,382,000
Potassium	µg/L	24	246,000	631,000	465,000	513,000
Sodium	µg/L	24	5,140,000	13,400,000	11,250,000	12,040,000
Sulfur	µg/L	24	458,000	1,220,000	972,000	1,062,000
Filterable/dissolved metals						
Aluminium	µg/L	24	100	160	100	100
Antimony	µg/L	24	1	10	10	10
Arsenic	µg/L	24	1	10	10	10
Barium	µg/L	24	1	21	11	13
Boron	µg/L	24	230	5140	3930	4640
Cadmium	µg/L	24	0.1	2.7	1	1

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Cobalt	µg/L	24	1	10	10	10
Copper	µg/L	24	1	80	10	10
Iron	µg/L	24	100	500	500	500
Lithium	µg/L	24	91	245	183	201
Manganese	µg/L	24	10	19	10	10
Molybdenum	µg/L	24	1	17	14	16
Nickel	µg/L	24	1	10	10	10
Selenium	µg/L	24	10	100	100	100
Silica	µg/L	24	100	3900	100	1340
Titanium	µg/L	24	100	100	100	100
Vanadium	µg/L	24	10	100	100	100
Zinc	µg/L	24	50	50	50	50
Total metals						
Aluminium	µg/L	24	10	360	100	130
Antimony	µg/L	24	1	10	10	10
Arsenic	µg/L	24	1	10	10	10
Barium	µg/L	24	10	20	12	14
Boron	µg/L	24	2,270	6,040	3,860	4,780
Cadmium	µg/L	24	0.1	3	1	1
Cobalt	µg/L	24	1	10	10	10
Copper	µg/L	24	1	77	10	10
Iron	µg/L	24	10	520	500	520
Lithium	µg/L	24	100	300	181	201
Manganese	µg/L	24	1	23	10	10
Molybdenum	µg/L	24	1	19	14	15
Nickel	µg/L	24	1	10	10	10
Selenium	µg/L	24	10	100	100	100
Silica	µg/L	24	100	3,900	100	1,340
Titanium	µg/L	24	1	100	100	100

Parameter	Units	Count	Minimum	Maximum	50th percentile	80th percentile
Vanadium	µg/L	24	10	10	10	10
Zinc	µg/L	24	50	60	50	50
Other parameters						
Oil and grease	µg/L	24	2,000	2,000	2,000	2,000

6.3 Historical trends

Time series graphs for selected water quality parameters monitored at Wangi Lake are provided in Appendix B. In cases where results were less than the LOR, the relevant LOR value has been plotted.

6.3.1 Physicochemical parameters

pH

Levels of pH within Lake Macquarie recorded at the Wangi Lake site were consistently recorded between 7.7 and 8.2, indicating slightly alkaline water as would be expected in a marine system.

Total suspended solids

Approximately half of all TSS results were reported at or below the LOR of 5,000 µg/L for the Wangi Lake monitoring location. Detected concentrations of TSS were generally below 10,000 µg/L, with a maximum concentration of 16,000 µg/L recorded in February 2015. The maximum followed a rain event of approximately 15 mm observed a few days prior to sampling.

Electrical Conductivity

Electrical conductivity at the Wangi Lake site ranged between 23,700 µS/cm and 56,900 µS/cm between October 2011 and February 2015. The median value of 51,000 µS/cm indicates a marine environment.

6.3.2 Nutrients

Total phosphorus

The majority of total phosphorus results were found to be at or below the LOR, which varied between 10 µg/L, 20 µg/L and 50 µg/L. Concentrations of total phosphorus above the detection limit ranged between 20 µg/L and 130 µg/L.

6.3.3 Major ions

Calcium

The majority of calcium results were found to generally vary between 350,000 µg/L and 500,000 µg/L, with the maximum concentration of 817,000 µg/L recorded in December 2011.

Magnesium

Magnesium levels were found to be between 1,100,000 µg/L and 1,500,000 µg/L for the majority of results.

Potassium

Concentrations of potassium at the Wangi Lake monitoring site were reported to generally range between 390,000 µg/L and 550,000 µg/L.

Sodium

Results for sodium largely varied between 8,000,000 µg/L and 14,000,000 µg/L.

Sulfur

The majority of sulfur concentrations were recorded between 800,000 µg/L and 1,200,000 µg/L.

6.3.4 Metals

Due to the low metal concentrations detected in the LDP B discharge and at the downstream monitoring site any elevated metal concentrations detected at the Lake Macquarie site would not have originated from the LDP B discharge.

Aluminium

The majority of dissolved and total aluminium results were reported to be at or below the LOR, which was found to vary between 10 µg/L and 100 µg/L. Dissolved aluminium was reported to be above the detection limit on two sampling occasions, with 160 µg/L and 140 µg/L recorded in March 2013 and February 2015 respectively. Detected total aluminium concentrations were generally reported below 400 µg/L, with the maximum level of 600 µg/L recorded in August 2012.

Antimony

All dissolved and total antimony concentrations reported at the Wangi Lake monitoring site were at or below the LOR, which varied between 1 µg/L and 10 µg/L. One dissolved antimony result was recorded as 1,100 µg/L in July 2012, however as the total antimony result for the same sample was reported as less than 1 µg/L, this result is considered to be erroneous.

Arsenic

The majority of dissolved and total arsenic concentrations were found to be at or below the LOR, which varied between 1 µg/L and 10 µg/L. A maximum concentration of 2 µg/L for dissolved arsenic and 25 µg/L for total arsenic was detected.

Barium

For several monitoring events, dissolved and total barium concentrations at the Wangi Lake location have been at or below the LOR, which varied between 1 µg/L, 5 µg/L and 10 µg/L. Both dissolved and total barium concentrations were found to generally range between 10 µg/L and 20 µg/L. Maximum concentrations of 170 µg/L in April 2012 and 180 µg/L in December 2011 were recorded for dissolved and total barium respectively.

Boron

Dissolved boron concentrations reported for Wangi Lake were found to vary between 230 µg/L and 5,490 µg/L, with concentrations below the LOR of 50 µg/L on two occasions in October and December 2011. It is noted that dissolved boron concentrations at Wangi Lake generally exceeded concentrations reported at LDP B. Total boron concentrations were found to generally range between 2,270 µg/L and 6,040 µg/L, with one concentration recorded below the LOR of 50 µg/L in December 2011. This concurs with ANZECC (2000) that states that the average concentration of boron in marine waters is 5,100 µg/L.

Cadmium

The majority of dissolved and total cadmium concentrations were reported to be at or below the LOR, which varied between 0.1 µg/L and 1 µg/L. Two samples of dissolved cadmium was found to be above the detection limit, which were reported to be 0.2 µg/L in May 2012 and 2.7 µg/L in March 2013. Two samples of total cadmium were found to be above the detection limit in May 2012 and March 2013, with concentrations of 0.2 µg/L and 3 µg/L reported respectively.

Cobalt

All dissolved and total cobalt concentrations reported were below the LOR, which was found to vary between 1 µg/L and 10 µg/L.

Copper

The majority of dissolved and total copper concentrations were reported to be at or below the LOR, which varied between 1 µg/L, 10 µg/L and 20 µg/L. Dissolved copper concentrations were generally detected at levels below 20 µg/L, with a maximum concentration of 80 µg/L recorded in April 2013. The maximum total copper concentration was also recorded in April 2013, at 77 µg/L.

Iron

The majority of dissolved and total iron concentrations at the monitoring location Wangi Lake were reported to be below the LOR, which varied between 50 µg/L, 100 µg/L and 500 µg/L. Only one sample of dissolved iron was reported to be above the detection limit, which was recorded as 120 µg/L in February 2015. Three samples of total iron were found to be above the detection limit in October 2011, March 2012 and February 2015, with the maximum concentration of 2,080 µg/L reported in March 2012.

Lithium

Dissolved lithium concentrations ranged between 91 µg/L and 448 µg/L between October 2011 and February 2015. Total lithium ranged between 92 µg/L and 484 µg/L with a median value of 180 µg/L.

Manganese

The majority of dissolved and total manganese results have been recorded below the LOR, which varied between 1 µg/L and 10 µg/L. Concentrations of both dissolved and total manganese were found to generally range between 20 µg/L and 200 µg/L.

Molybdenum

For several monitoring events, dissolved and total molybdenum levels at the Wangi Lake location have been at or below the LOR, which varied between 1 µg/L and 10 µg/L. Both dissolved and total molybdenum concentrations were found to generally range between 10 µg/L and 20 µg/L.

Nickel

All dissolved and total nickel concentrations reported for the Wangi Lake site were below the LOR, which varied between 1 µg/L and 10 µg/L.

Selenium

All dissolved and total selenium concentrations reported for the Wangi Lake site were at or below the LOR, which varied between 10 µg/L and 100 µg/L.

Silica

Dissolved silica ranged between 100 µg/L and 15,000 µg/L with median concentrations of 850 µg/L. Apart from the one-off recording of 15,000 µg/L in December 2011 and 3,900 µg/L in March 2013, dissolved lithium concentrations at Wangi Lake have been below 2,200 µg/L. Total silica ranged between 500 µg/L and 5,300 µg/L with median levels of 700 µg/L.

Titanium

All dissolved and total titanium concentrations reported for the Wangi Lake site were below the LOR, which varied between 10 µg/L and 100 µg/L.

Vanadium

All dissolved and total vanadium concentrations reported for the Wangi Lake site were below the LOR, which varied between 10 µg/L and 100 µg/L.

Zinc

The majority of dissolved and total zinc concentrations at the monitoring location Wangi Lake were reported to be below the LOR, which varied between 50 µg/L and 52 µg/L. Only one sample of dissolved zinc was reported to be above the detection limit, which was recorded as 6 µg/L in May 2012. Three samples of total zinc were found to be above the detection limit in December 2011, May 2012 and February 2015, with the maximum concentration of 79 µg/L reported in December 2011.

6.3.5 Other parameters

Oil and grease

The majority of oil and grease results were reported to be at or below the LOR of 2,000 µg/L at the Wangi Lake monitoring site. A concentration of 3,000 µg/L was recorded on one occasion, in May 2012.

7. Summary

7.1 Upstream site

Water quality results for the Upstream site on Wangi Creek indicated the water is slightly acidic with elevated levels of TSS and total phosphorus reported in recent samples. Rainfall was received in the study area on the day of or immediately preceding sampling for the last four sampling events which may explain these results.

Relatively low concentrations of the major ions have been recorded at the Upstream site.

The majority of results for dissolved and total metals were generally reported to be below the LOR, with the exception of aluminium, barium, iron, manganese, nickel, titanium and zinc, indicating a highly mineralised catchment.

Data from the Upstream monitoring location was used to develop SSTVs in conjunction with the DTVs recommended by ANZECC (2000).

7.2 Licensed Discharge Point B

Based on the available water quality data for the monitoring period, the water sampled at LDP B is slightly alkaline with low levels of TSS, metals and oil and grease. All parameters were within the limits specified by EPL 366 for the most recent 24 monthly monitoring events, from March 2013 to February 2015. Electrical conductivity (EC) has not been addressed in this assessment since the receptor is a marine environment.

The majority of total phosphorus results have been reported to be below the LOR for the most recent data.

Concentrations of the major ionic species were generally greater than those recorded at the Upstream monitoring site.

For assessed dissolved and total metals, the majority of parameters were generally found to be below the LOR for the most recent data, with the exception of barium, boron, iron and manganese. Barium, boron and manganese concentrations at LDP B were generally elevated compared to the Upstream monitoring site, however iron results were generally lower.

7.3 Downstream site

Downstream monitoring results followed similar trends to LDP B results. The water sampled at monitoring site Downstream was slightly alkaline, with low levels of TSS, metals and oil and grease. Levels of pH were within SSTVs, with the majority of TSS results also below SSTVs. One sampling event in April 2013 recorded TSS levels exceeding SSTVs. However, as the results for the Upstream monitoring site and LDP B discharge show the same increase in TSS, these results are considered to be anomalous.

The majority of total phosphorus results were found to be at or below the LOR for the Downstream monitoring site, however the SSTV of 35 µg/L was found to be exceeded in approximately 18% of sampling events in the most recent 24 monthly monitoring events. The median total phosphorus concentration of the most recent 24 months monitoring was below the SSTV.

Results for the major ions at the Downstream site indicated a similar range as for LDP B discharge.

Dissolved and total metal results at the Downstream monitoring site followed similar trends to LDP B discharge. The majority of metals were found to be below the LOR and relevant SSTVs

for the most recent 24 monthly monitoring events. Recent exceedances of SSTVs at the Downstream site have been reported for dissolved barium and lithium.

Dissolved barium concentrations have consistently been detected in exceedance of the SSTV at the Downstream site. Concentrations for barium at this site are similar in range to the results reported for LDP B discharge, which is elevated compared to the Upstream monitoring site. However as noted previously, the concentrations detected are unlikely to cause adverse environmental harm.

As discussed previously the LOR is above the SSTV for several metals and it must be assumed that the SSTV is exceeded on all monitoring occasions. Lithium is one such example where the number of observations below the LOR meant that this was adopted as the SSTV. However, median lithium at the downstream site in the last 24 months is consistent with levels at LDP B and higher than levels at either the Upstream or the Wangi Lake site. Therefore, it is likely that elevated concentrations of dissolved lithium are attributable to the Myuna Colliery discharge. However, as toxicity of lithium is low, the current concentrations of lithium are not likely to have adverse impacts on aquatic ecology.

Overall, median concentrations of the most recent 24 months monitoring at site Downstream are below SSTVs, with the exception of dissolved barium, lithium, manganese and zinc which recorded elevated concentrations. Not all these elevated concentrations are attributable to the mine water discharge at LDP B, and are due to high LORs. It is noted that dissolved boron concentrations are higher at Wangi Lake as would be expected in a marine system.

7.4 Lake Macquarie site

Water quality results for Lake Macquarie from the Wangi Lake monitoring site indicate that the water is slightly alkaline, with very low levels of TSS and oil and grease reported.

Total phosphorus results were mostly reported to be at or below the LOR and similar to the results in Wangi Creek and LDP B discharge.

The major ionic species concentrations were slightly elevated compared to the LDP B and Downstream site results.

The majority of dissolved and total metal results were found to be at or below the LOR for the Wangi Lake site over the most recent 24 monthly monitoring events, with the exception of barium, boron and molybdenum. Boron and molybdenum concentrations at the Wangi Lake site were reported to be elevated compared to all three Wangi Creek monitoring sites, indicating these parameters may be associated with background levels in Lake Macquarie rather than discharge from Myuna Colliery. Further, Barium concentrations within Lake Macquarie were reported to be lower than the results recorded within Wangi Creek at the Upstream, LDP B and Downstream monitoring locations thus supporting the conclusion above that discharges from LDP B are not increasing concentrations in Lake Macquarie.

7.5 Recommendations

7.5.1 Future monitoring

It is recommended that the current sampling program for water quality at sites Upstream, LDP B, Downstream and Wangi Lake continues as well as to provide information on the background levels of Wangi Creek and monitor potential impacts of discharge from Myuna Colliery.

It is recommended that the LOR for each analyte be specified on the chain of custody form accompanying the samples to the laboratory to determine if the SSTV is met.

If it is shown that the following analytes are below the SSTVs, it is recommended that they are removed from the monitoring program, as they are consistently reported to be below the LOR:

- Antimony;
- Cobalt;
- Selenium;
- Titanium;
- Vanadium.

7.5.2 Literature review

It is recommended that a literature investigation of toxicity studies be undertaken to assess the potential impacts of barium, lithium and manganese concentrations on the downstream environment so that the SSTVs for these parameters can be modified to reflect environmental harm.

7.5.3 Ecotoxicological assessment

If the zinc concentrations are above the SSTV after application of the lower LORs, it is recommended that screening tests using a marine alga growth inhibition bioassay be conducted on the downstream site to determine if zinc is having an adverse impact on the site. An Upstream sample and an LDP B sample would need to be included in the program.

7.5.4 Review of water quality assessment

A review of this report and recalculation of the SSTVs is recommended to be undertaken annually to include the 24 most recently collected observations.

8. References

ANZECC (2000), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Aral H. and Vecchio-Sadus A. 2008. Toxicity of lithium to humans and the environment – A literature review. *Ecotoxicology and Environmental Safety*. 70(3):349-356.

Dwyer F.J., Buech S.A., Ingersoll C.G. and Hunn J.B. 1992. Toxicity of trace element and salinity mixtures to striped bass (*Morone saxatilis*) and *Daphnia magna*. *Environmental Toxicology and Chemistry* 11:513-520.

Appendices

Appendix A – Time series graphs for Upstream, Downstream and LDP B monitoring sites

Physicochemical parameters

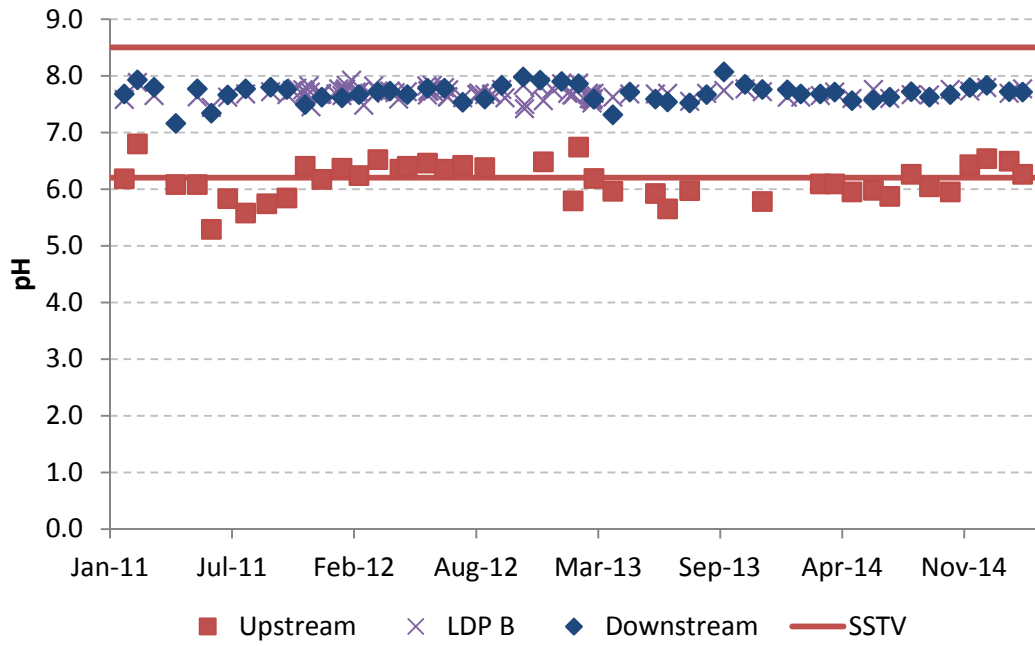


Figure A-1 pH recorded at monitoring Upstream, LDP B and Downstream sites

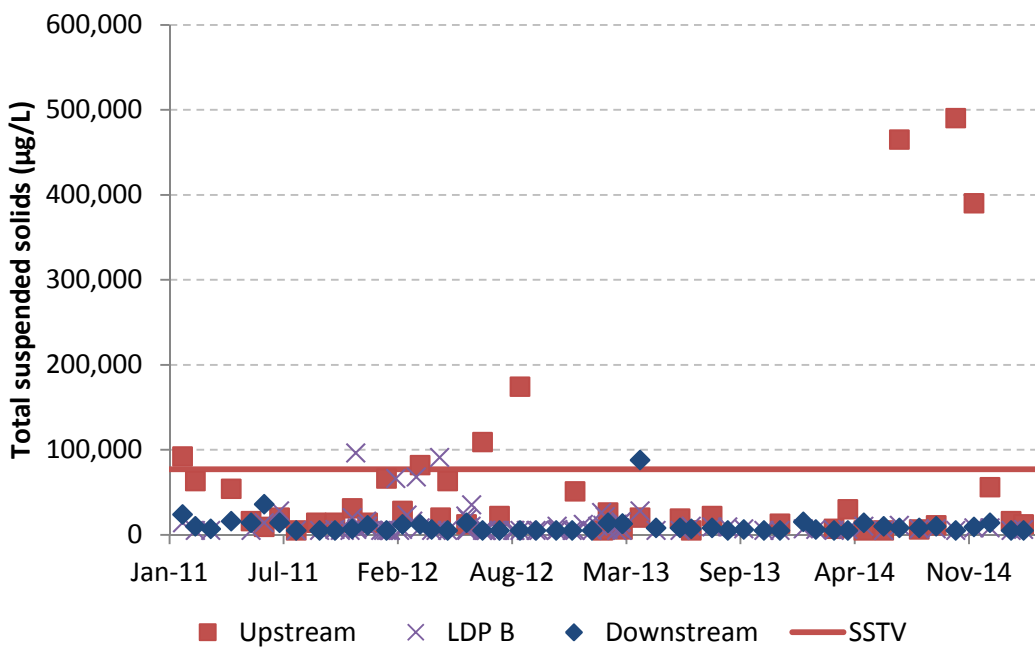


Figure A-2 Total suspended solids recorded at monitoring Upstream, LDP B and Downstream sites

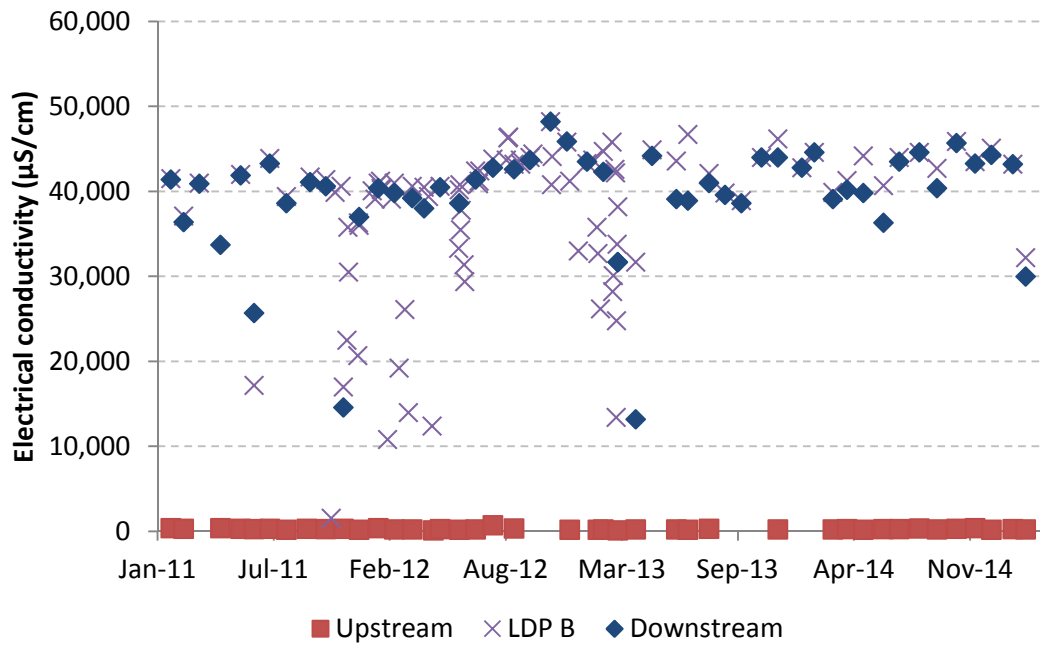


Figure A-2 Electrical conductivity recorded at monitoring Upstream, LDP B and Downstream sites

Nutrients

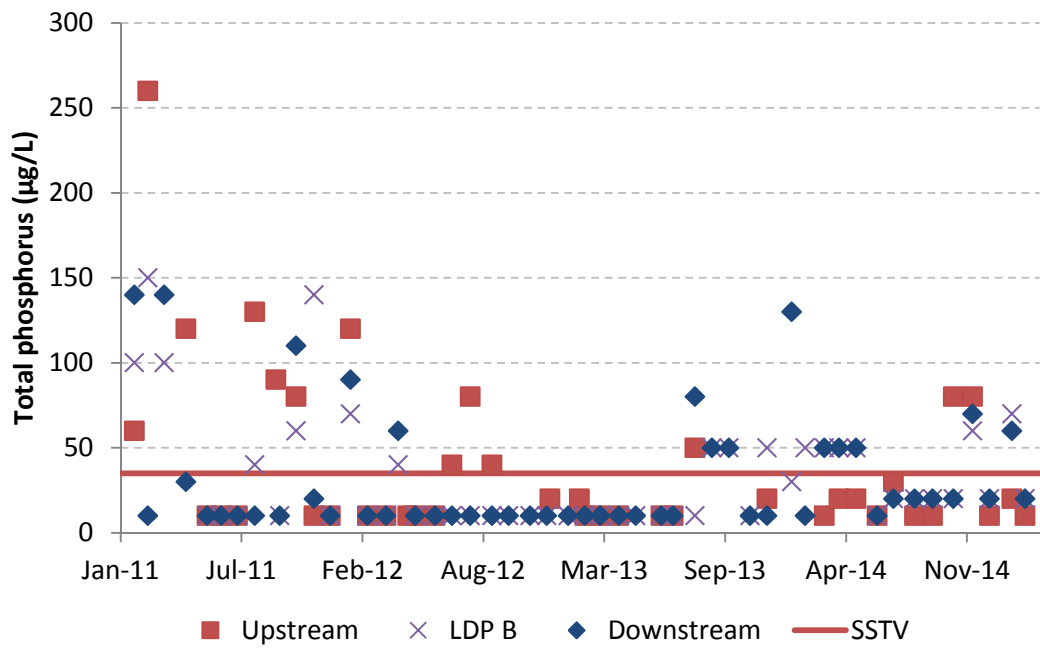


Figure A-4 Total phosphorus recorded at monitoring Upstream, LDP B and Downstream sites

Major ions

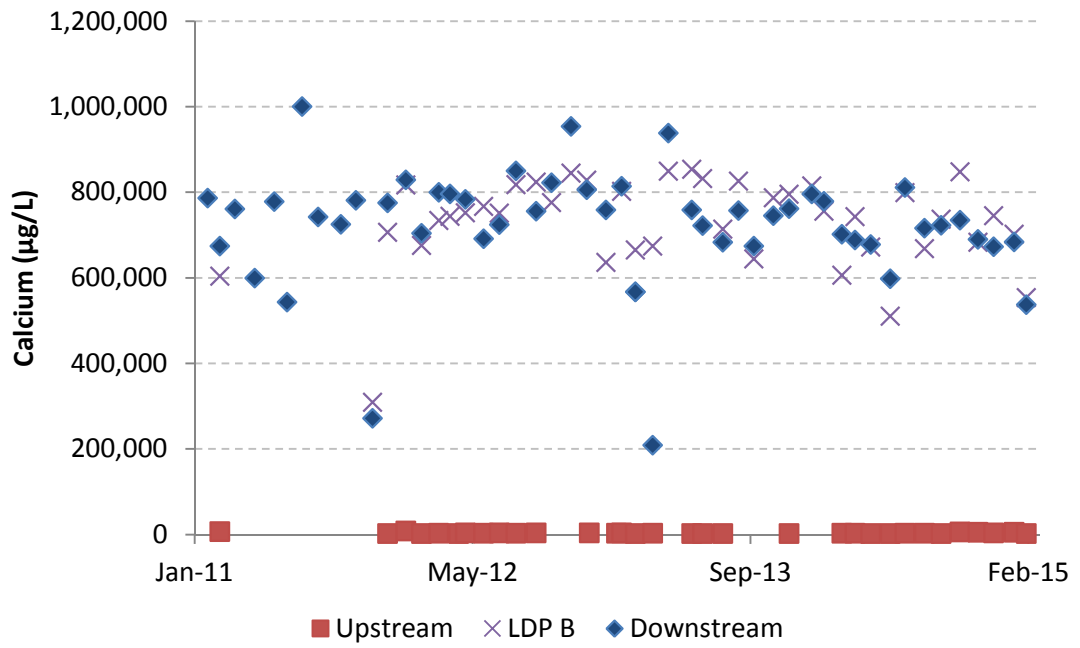


Figure A-5 Calcium recorded at monitoring Upstream, LDP B and Downstream sites

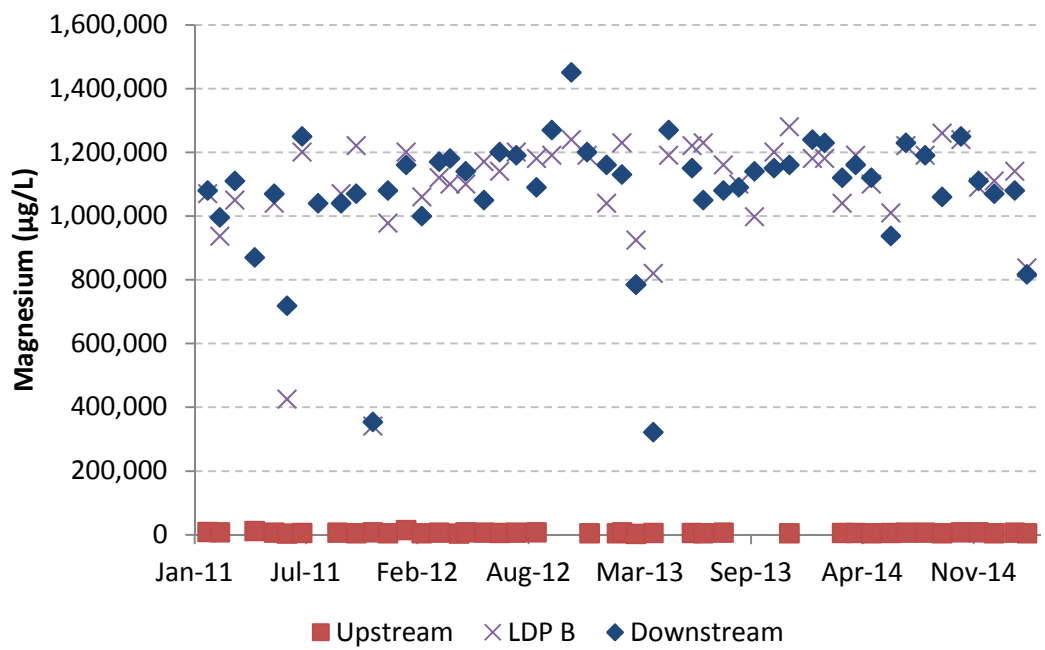


Figure A-6 Magnesium recorded at monitoring Upstream, LDP B and Downstream sites

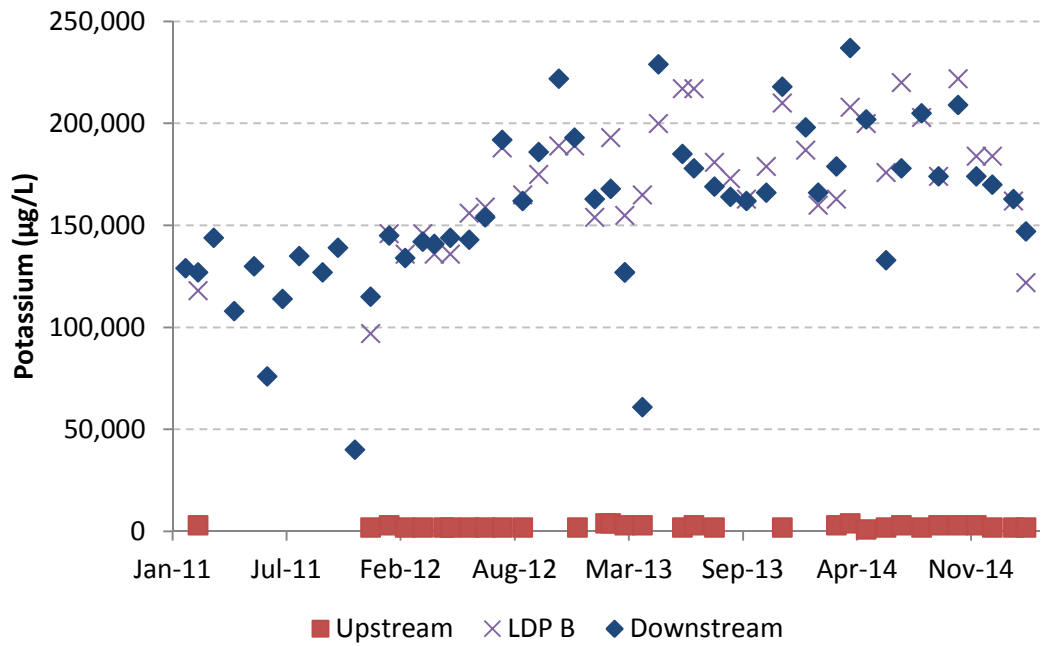


Figure A-7 Potassium recorded at monitoring Upstream, LDP B and Downstream sites

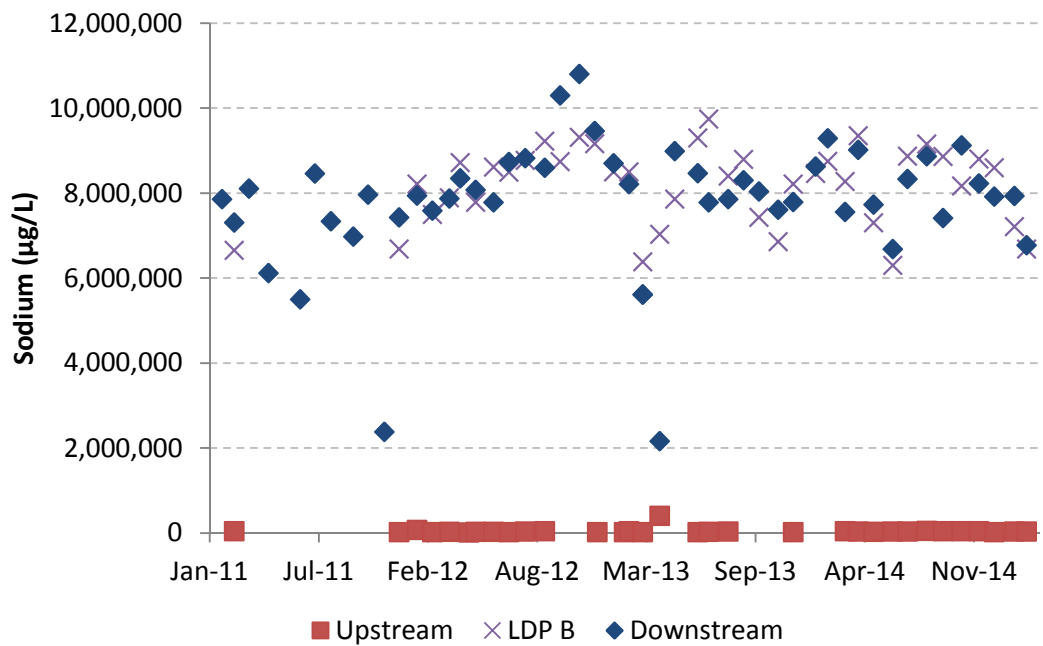


Figure A-8 Sodium recorded at monitoring Upstream, LDP B and Downstream sites

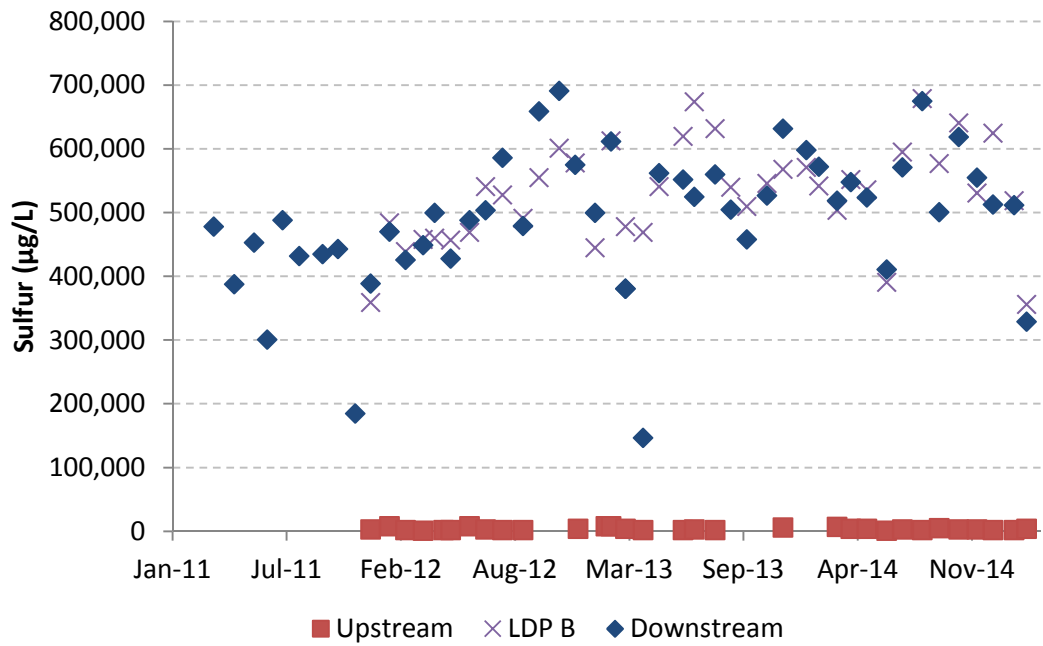


Figure A-9 Sulfur recorded at monitoring Upstream, LDP B and Downstream sites

Metals

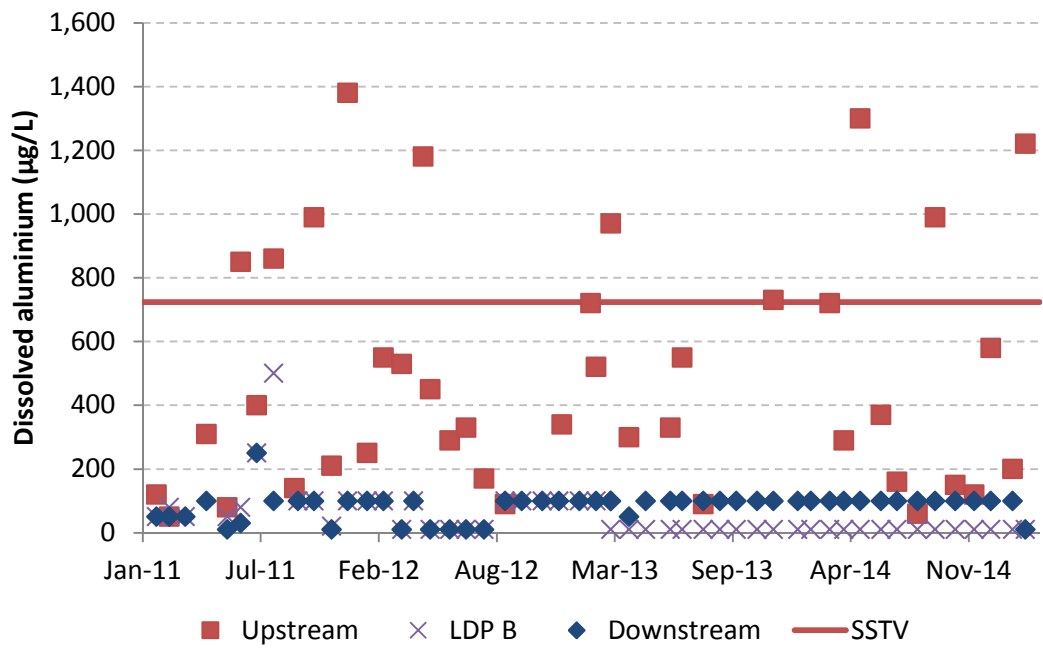


Figure A-10 Dissolved aluminium recorded at monitoring Upstream, LDP B and Downstream sites

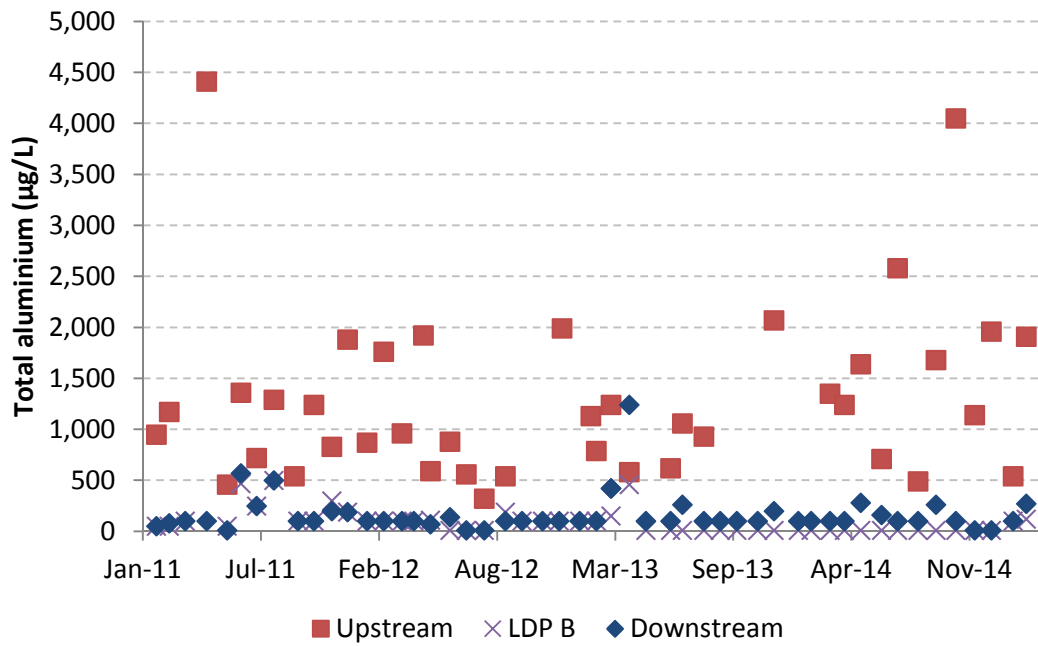


Figure A-11 Total aluminium recorded at monitoring Upstream, LDP B and Downstream sites

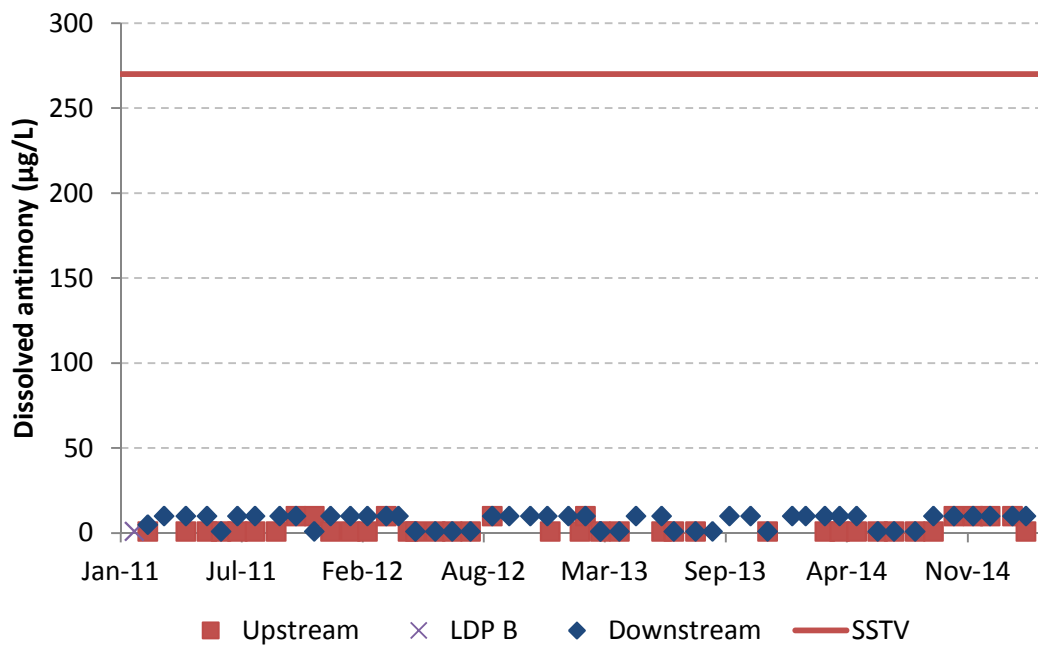


Figure A-12 Dissolved antimony recorded at monitoring Upstream, LDP B and Downstream sites

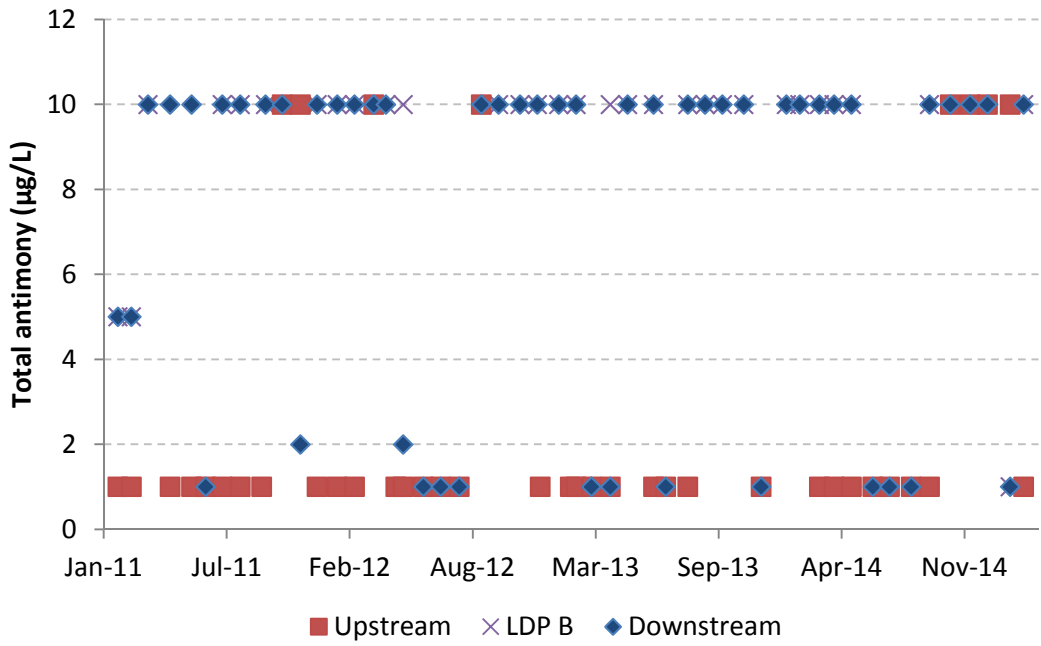


Figure A-13 Total antimony recorded at monitoring Upstream, LDP B and Downstream sites

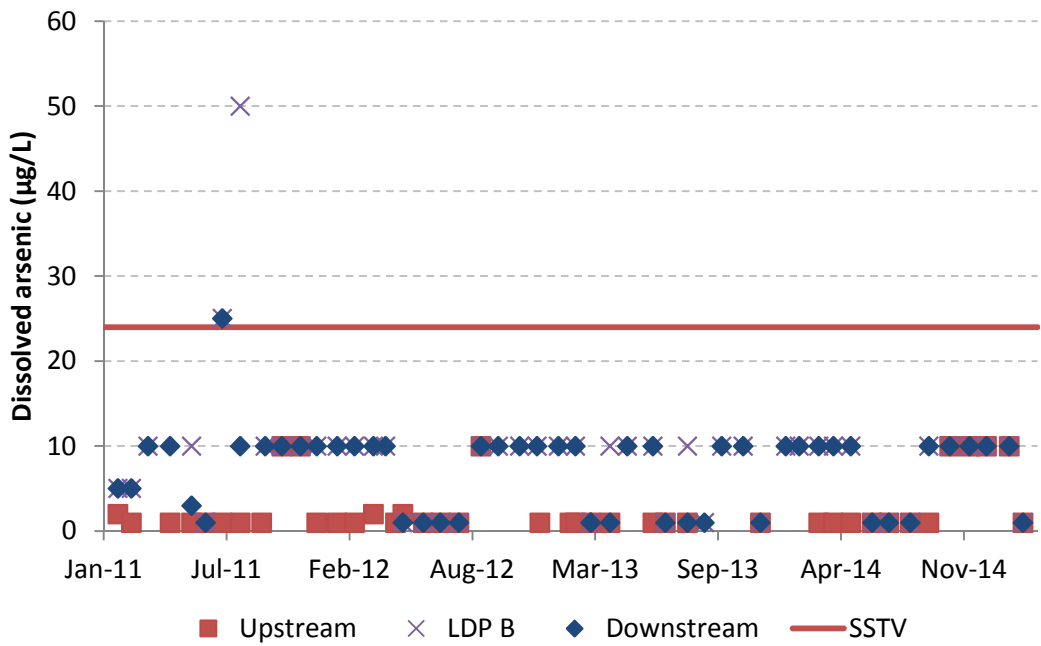


Figure A-14 Dissolved arsenic recorded at monitoring Upstream, LDP B and Downstream sites

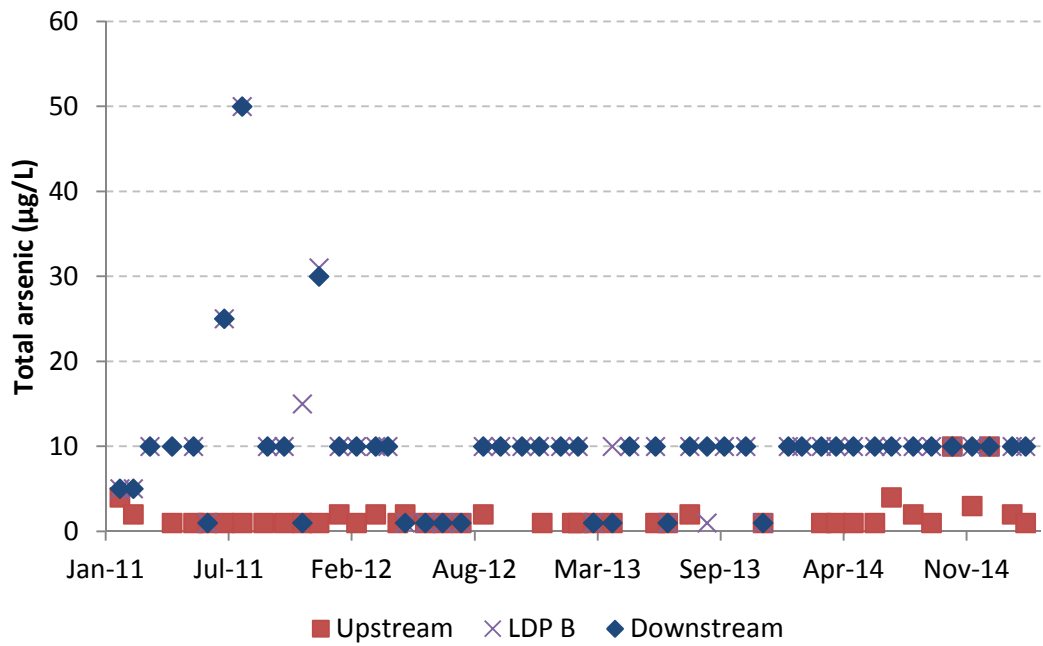


Figure A-15 Total arsenic recorded at monitoring Upstream, LDP B and Downstream sites

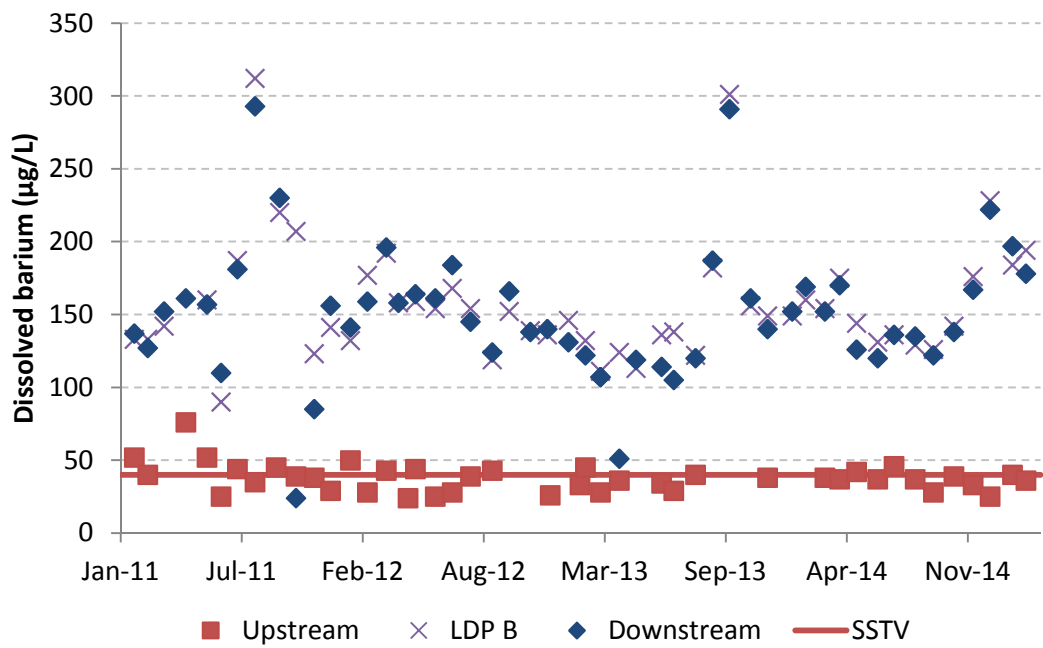


Figure A-16 Dissolved barium recorded at monitoring Upstream, LDP B and Downstream sites

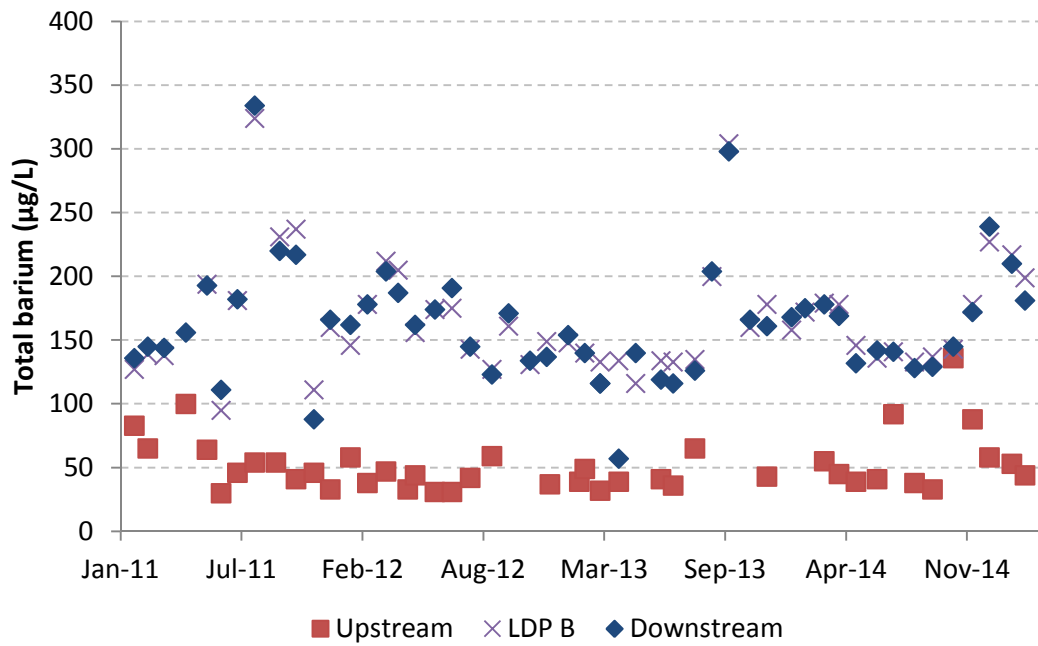


Figure A-17 Total barium recorded at monitoring Upstream, LDP B and Downstream sites

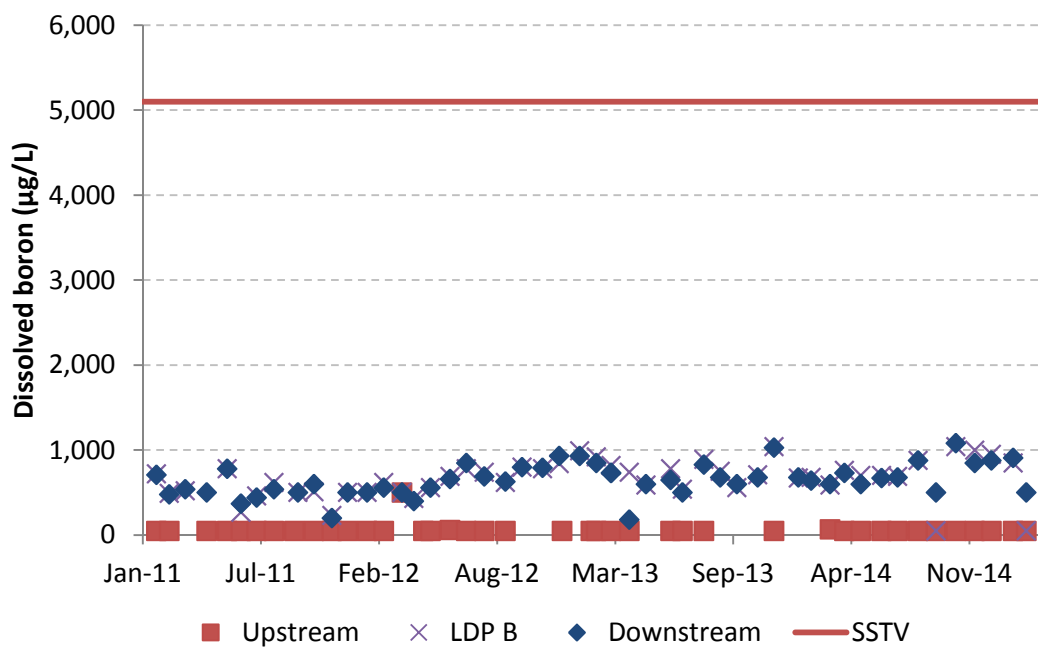


Figure A-20 Dissolved boron recorded at monitoring Upstream, LDP B and Downstream sites

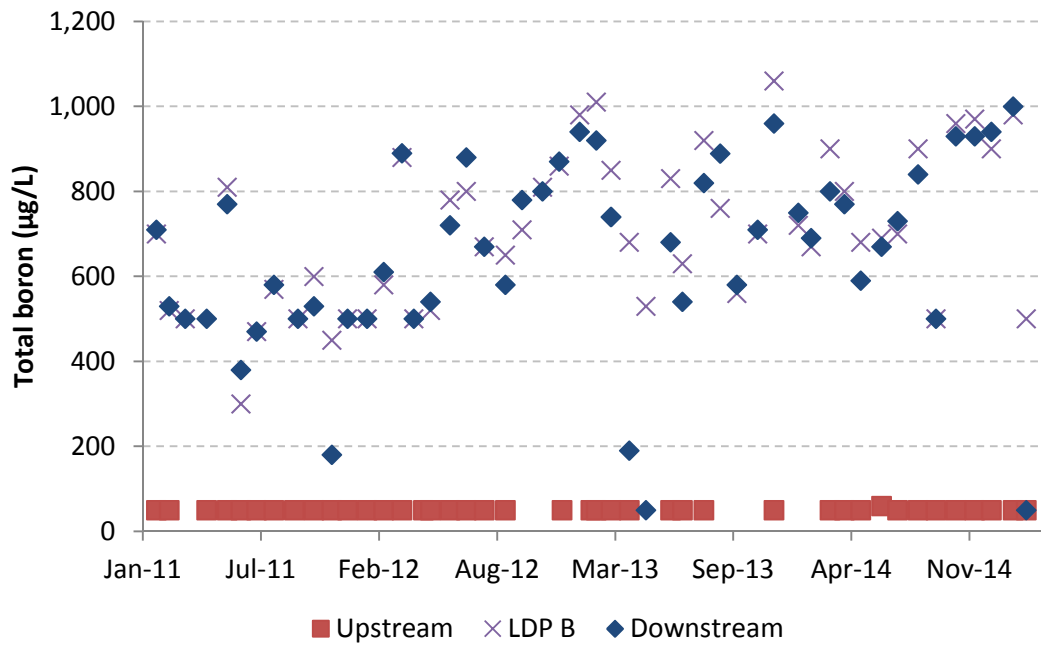


Figure A-21 Total boron recorded at monitoring Upstream, LDP B and Downstream sites

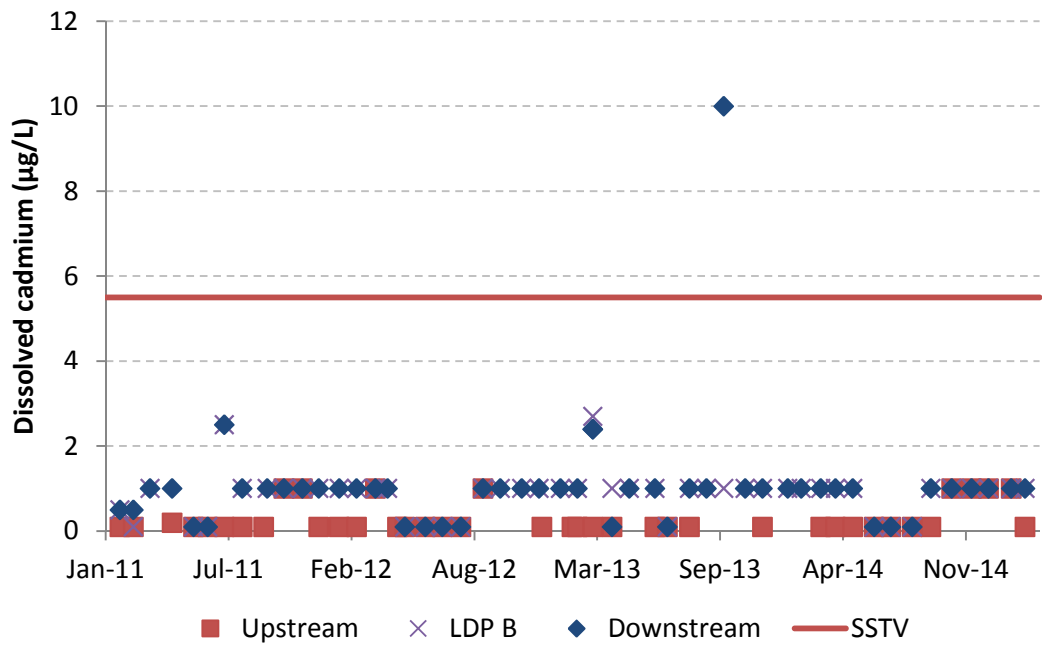


Figure A-22 Dissolved cadmium recorded at monitoring Upstream, LDP B and Downstream sites

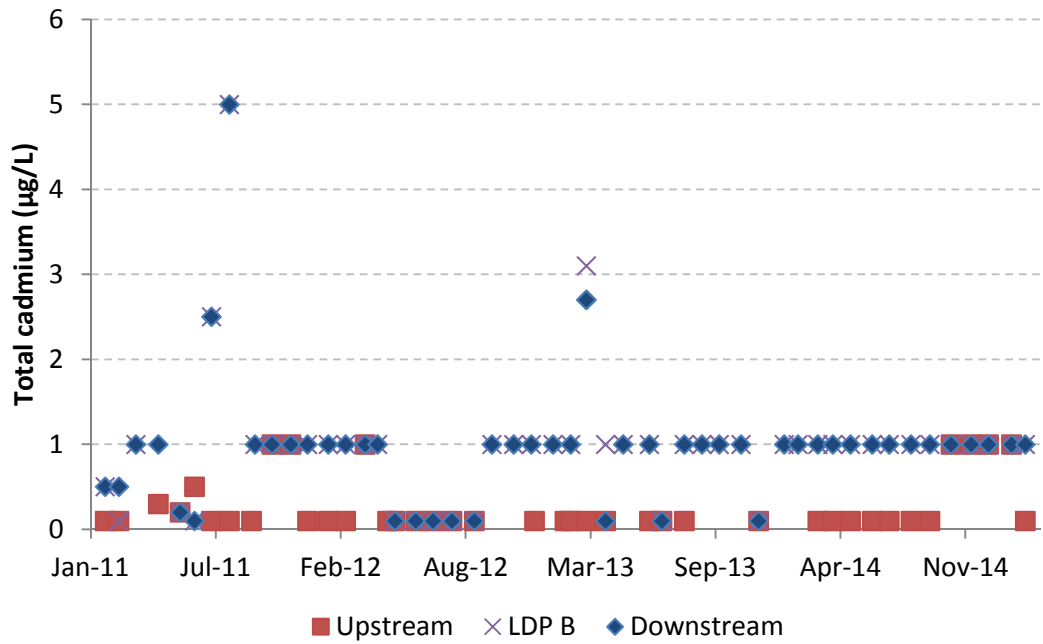


Figure A-23 Total cadmium recorded at monitoring Upstream, LDP B and Downstream sites

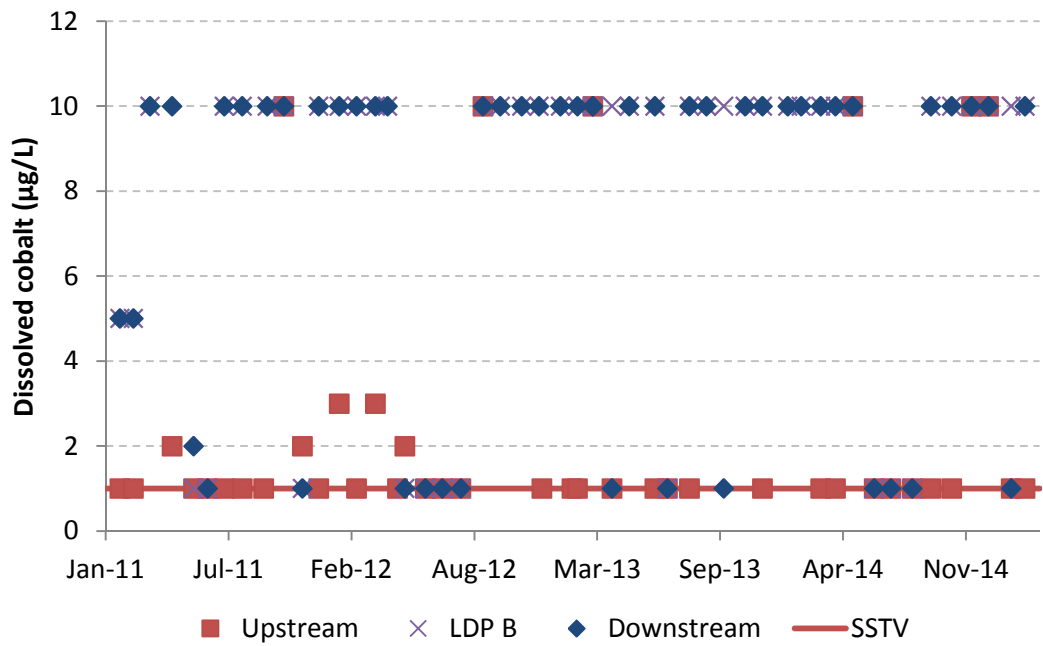


Figure A-26 Dissolved cobalt recorded at monitoring Upstream, LDP B and Downstream sites

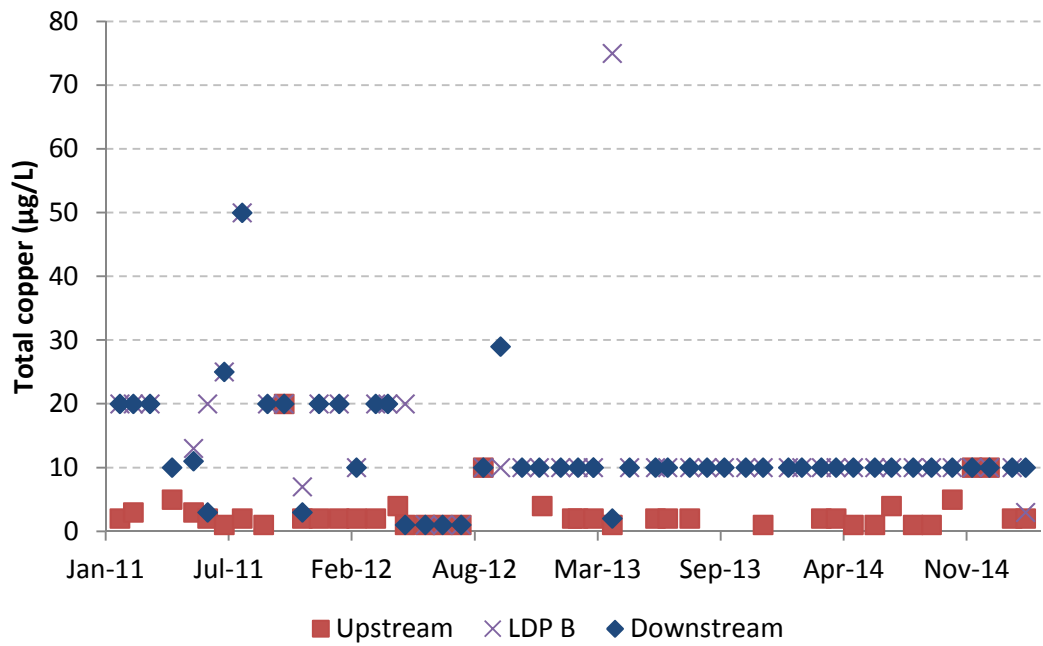


Figure A-29 Total copper recorded at monitoring Upstream, LDP B and Downstream sites

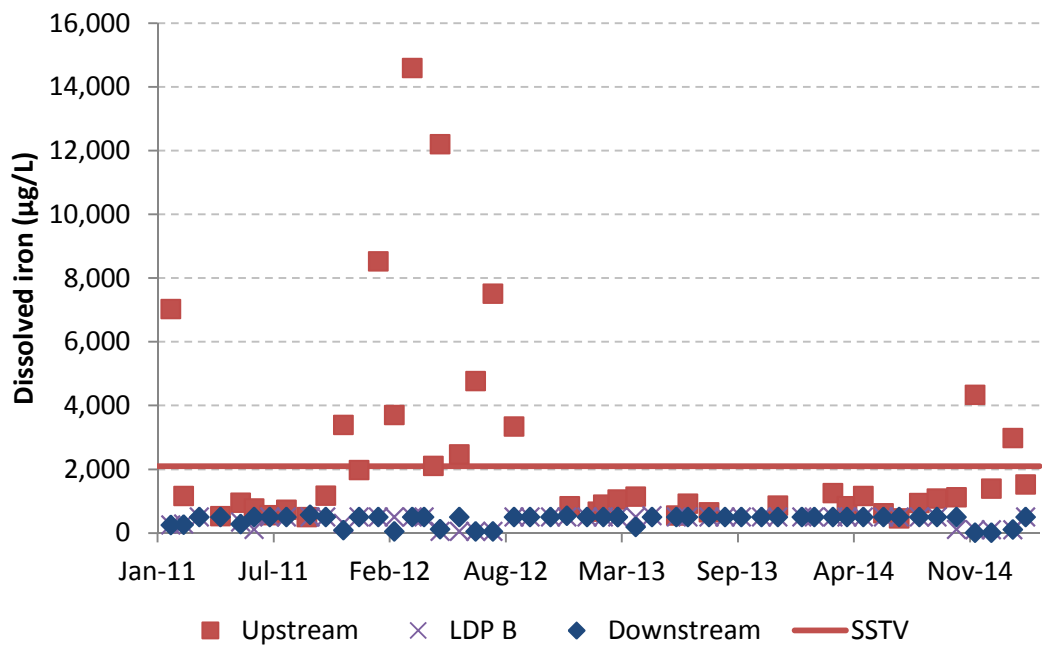


Figure A-30 Dissolved iron recorded at monitoring Upstream, LDP B and Downstream sites

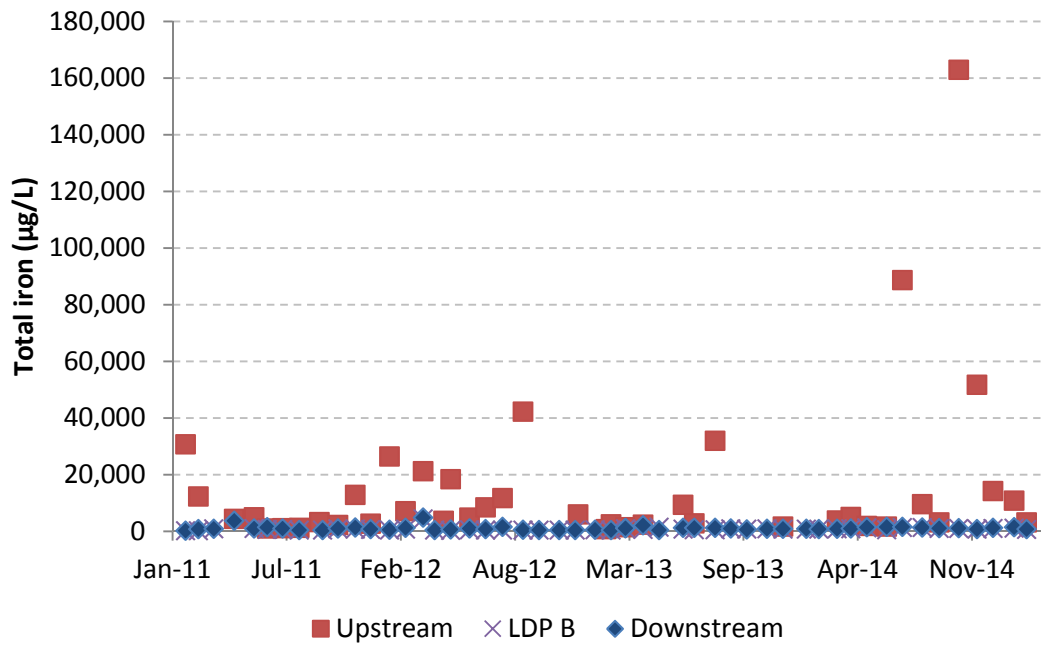


Figure A-31 Total iron recorded at monitoring Upstream, LDP B and Downstream sites

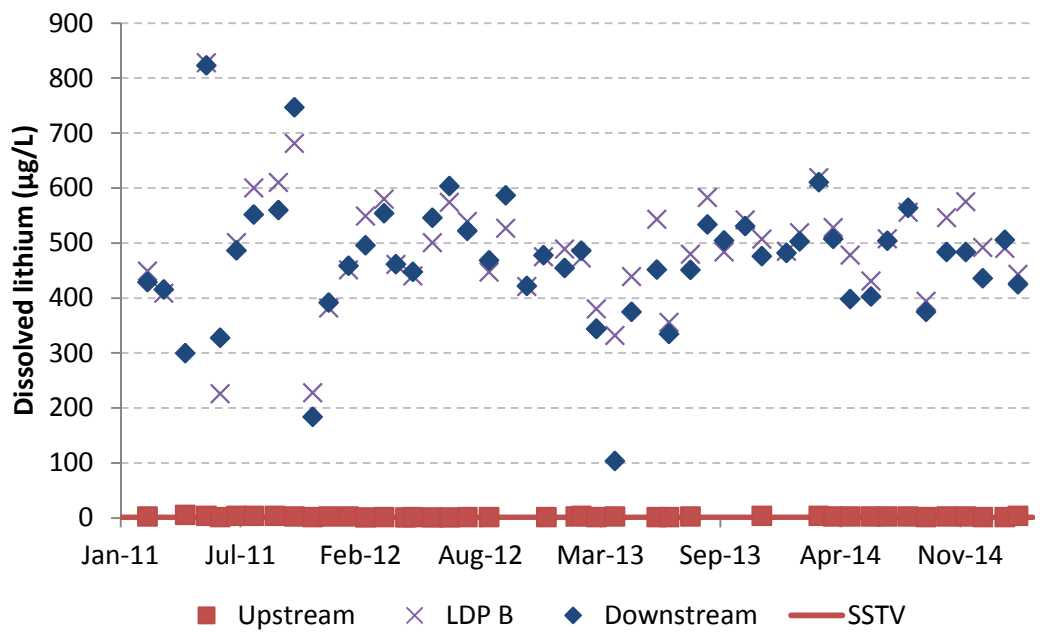


Figure A-32 Dissolved lithium recorded at monitoring Upstream, LDP B and Downstream sites

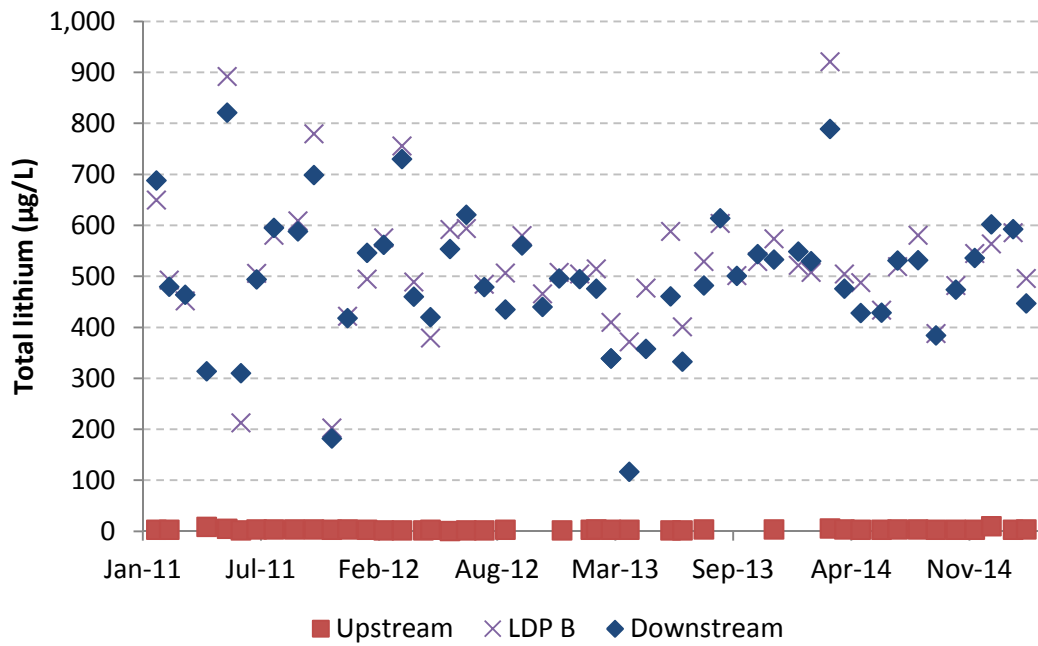


Figure A-33 Total lithium recorded at monitoring Upstream, LDP B and Downstream sites

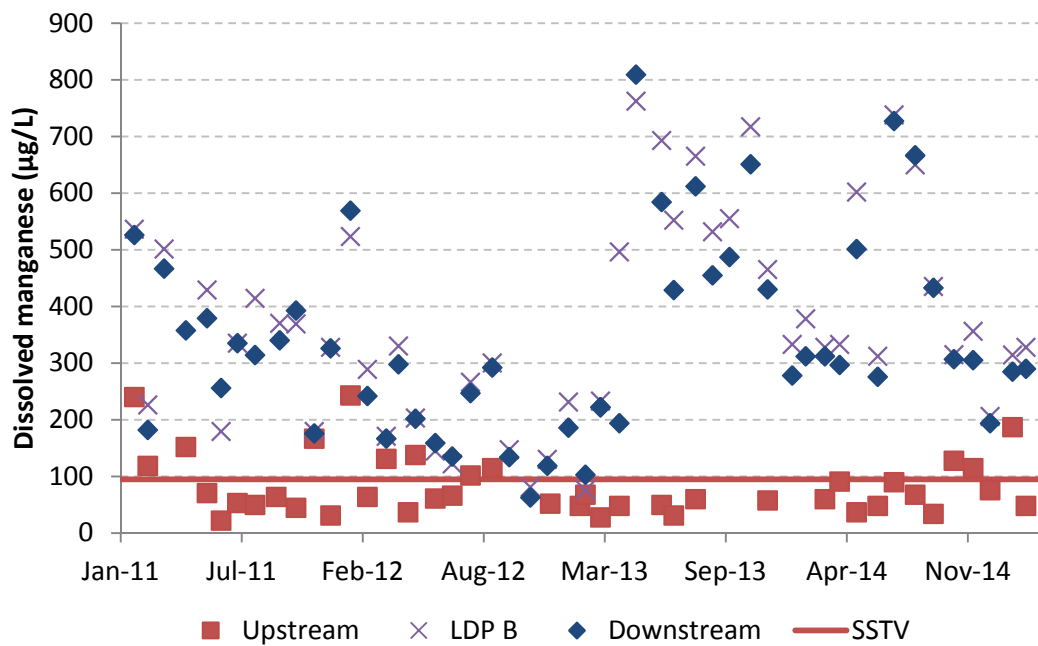


Figure A-34 Dissolved manganese recorded at monitoring Upstream, LDP B and Downstream sites

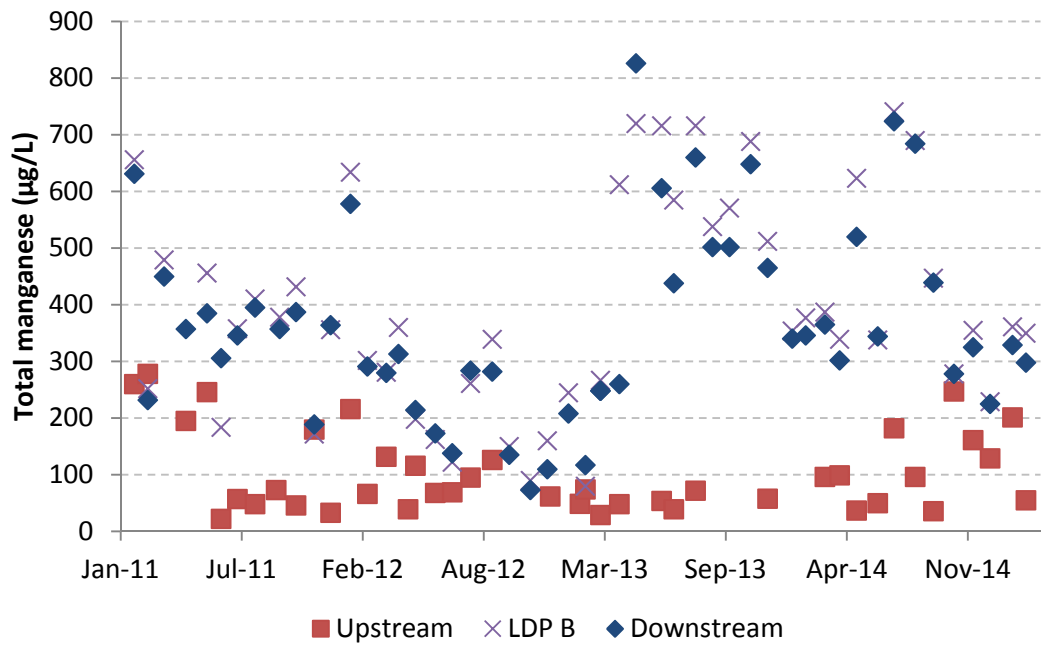


Figure A-35 Total manganese recorded at monitoring Upstream, LDP B and Downstream sites

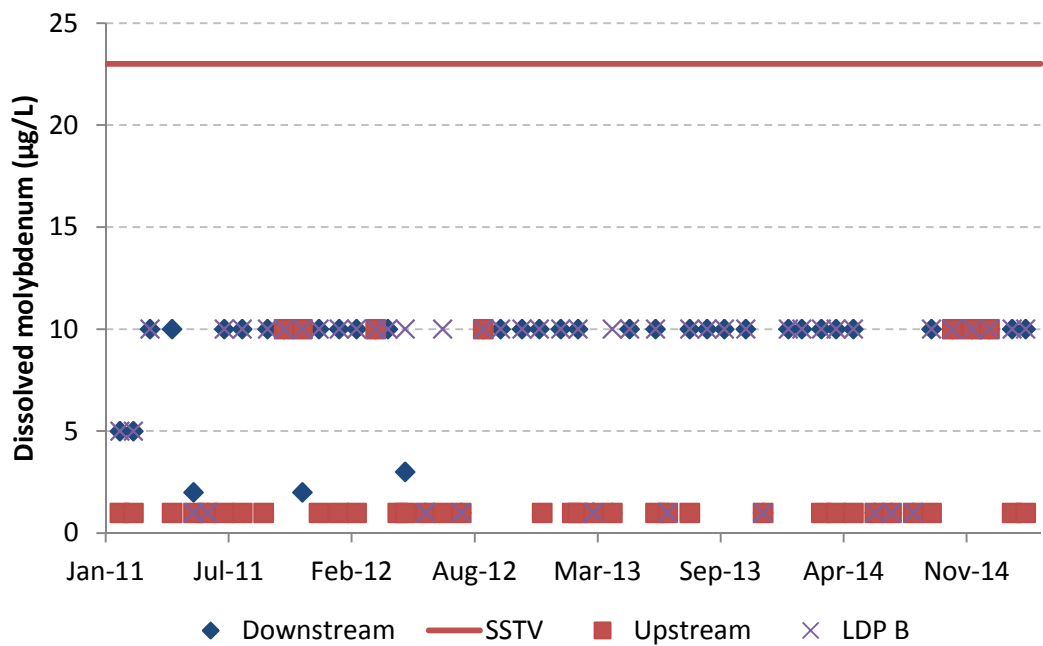


Figure A-38 Dissolved molybdenum recorded at monitoring Upstream, LDP B and Downstream sites

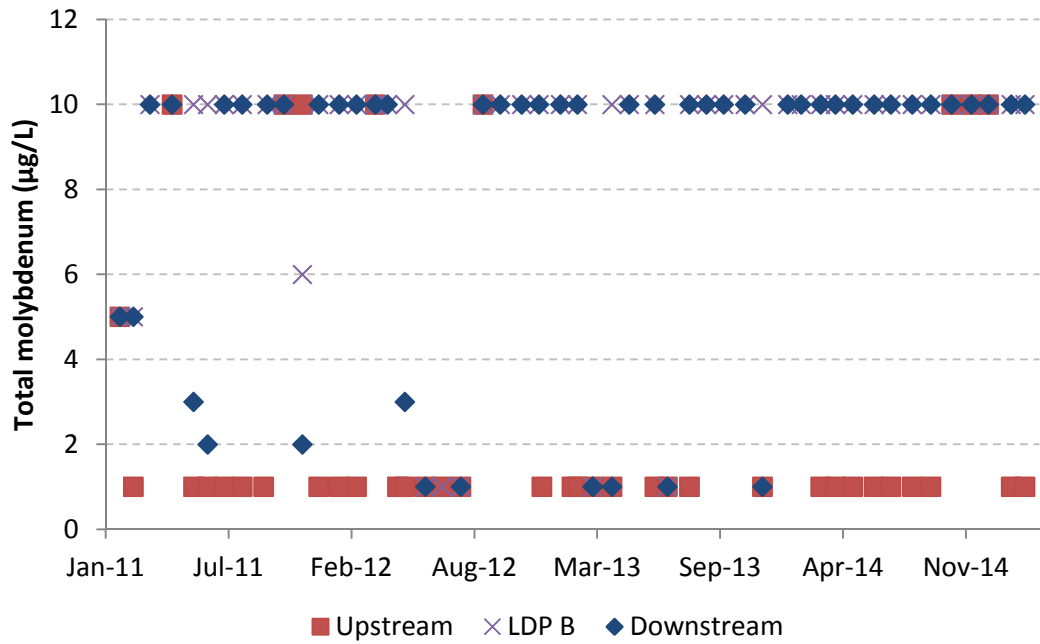


Figure A-39 Total molybdenum recorded at monitoring Upstream, LDP B and Downstream sites

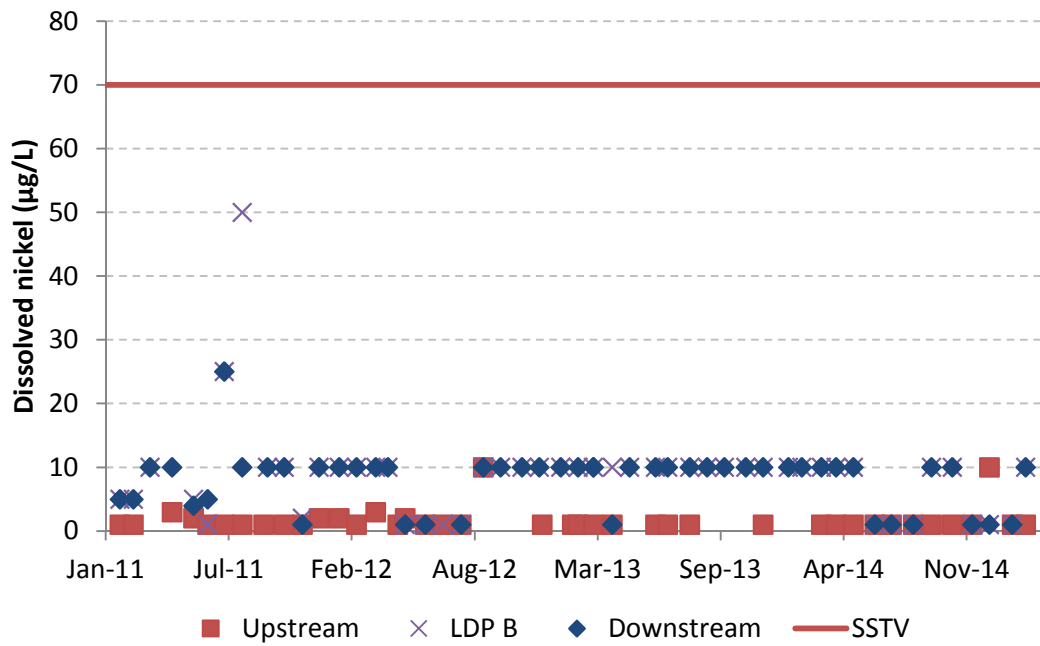


Figure A-40 Dissolved nickel recorded at monitoring Upstream, LDP B and Downstream sites

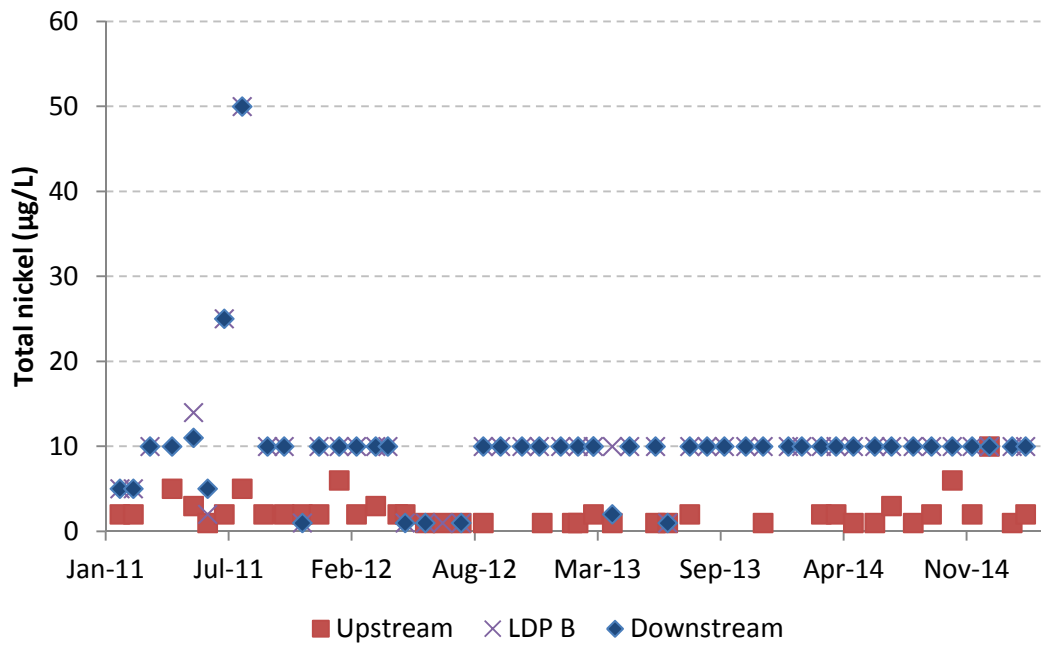


Figure A-41 Total nickel recorded at monitoring Upstream, LDP B and Downstream sites

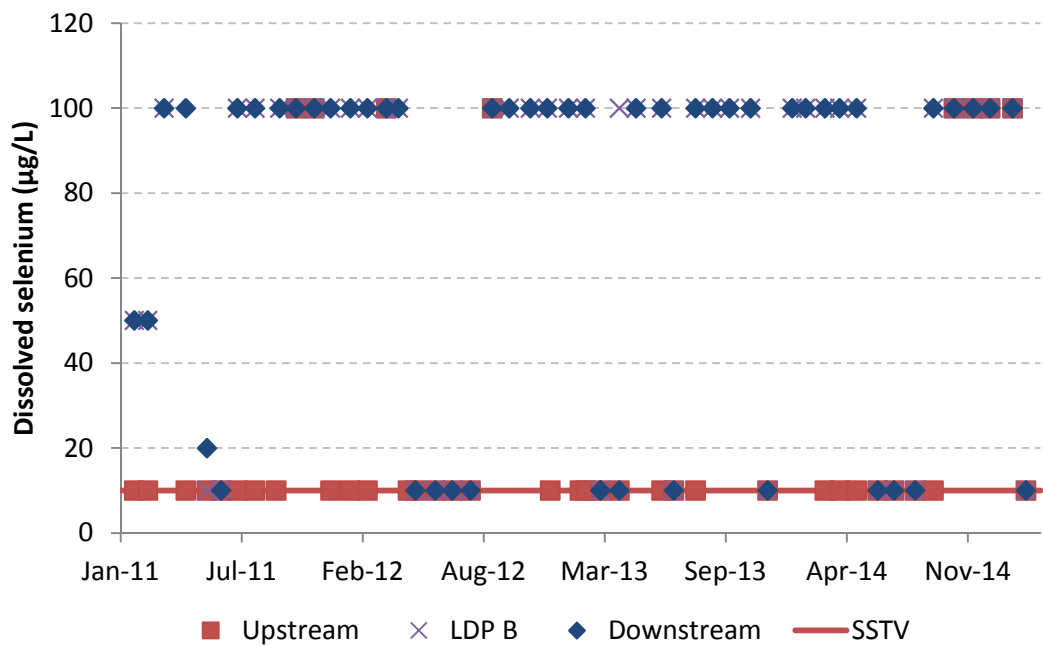


Figure A-42 Dissolved selenium recorded at monitoring Upstream, LDP B and Downstream sites

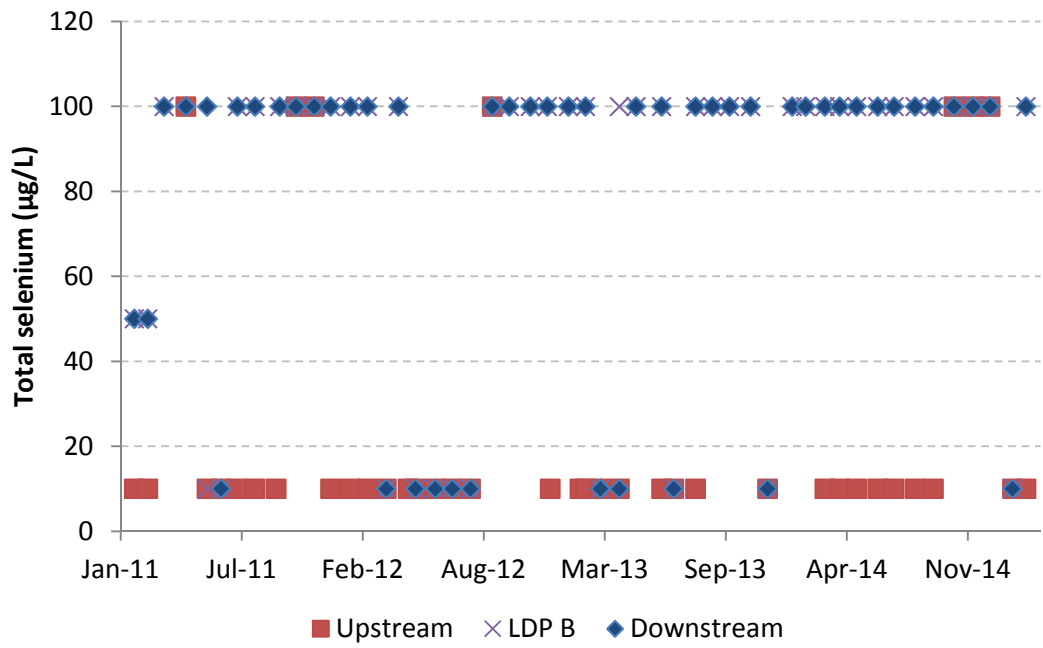


Figure A-43 Total selenium recorded at monitoring Upstream, LDP B and Downstream sites

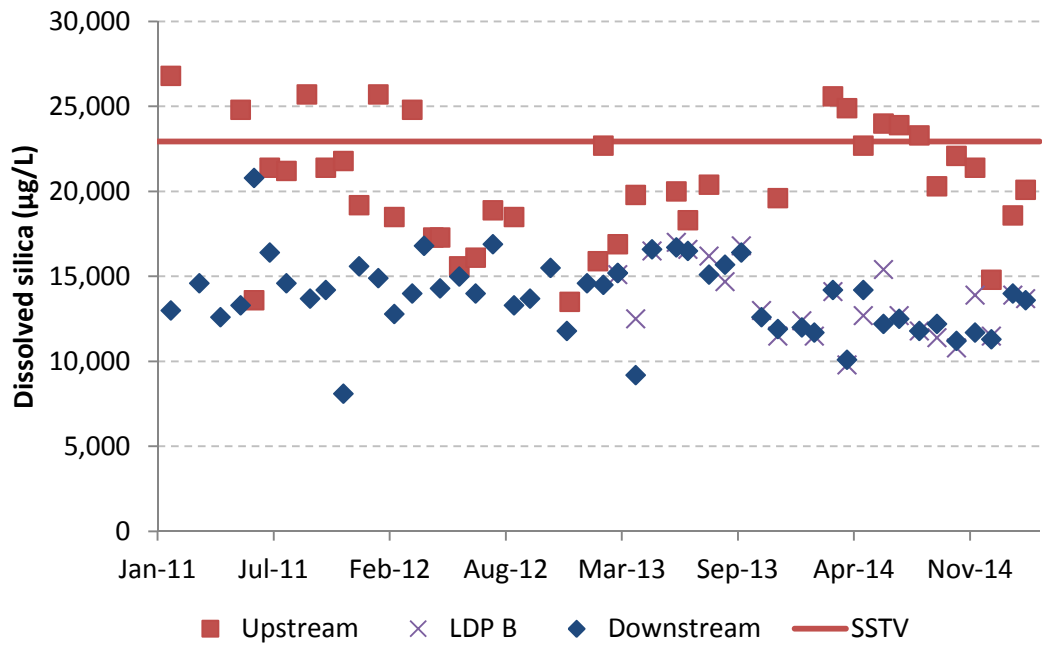


Figure A-46 Dissolved silica recorded at monitoring Upstream, LDP B and Downstream sites

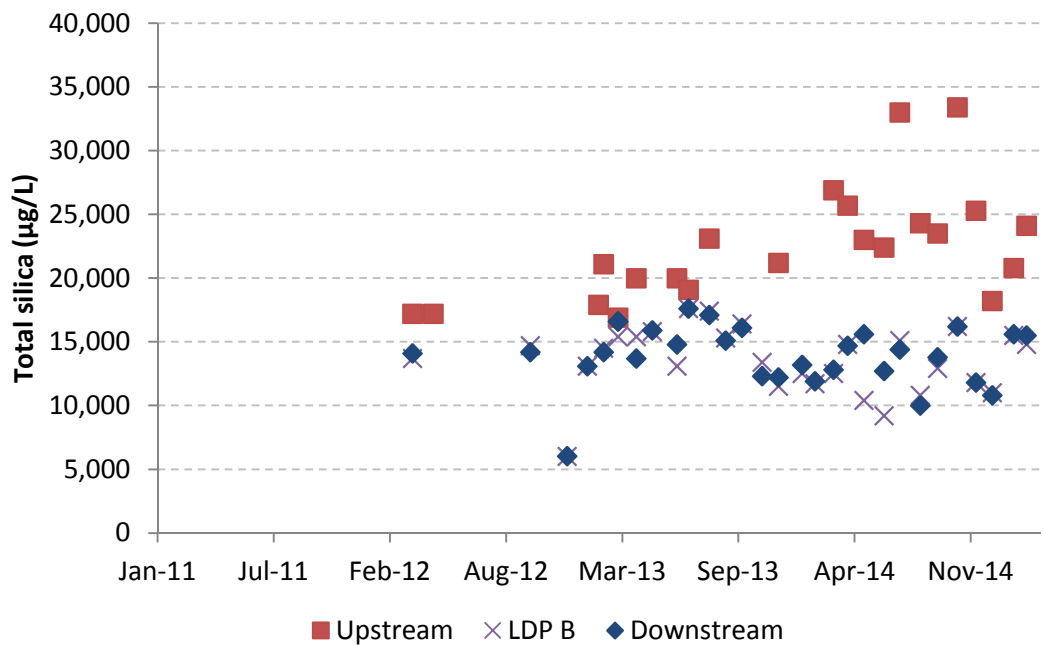


Figure A-47 Total silica recorded at monitoring Upstream, LDP B and Downstream sites

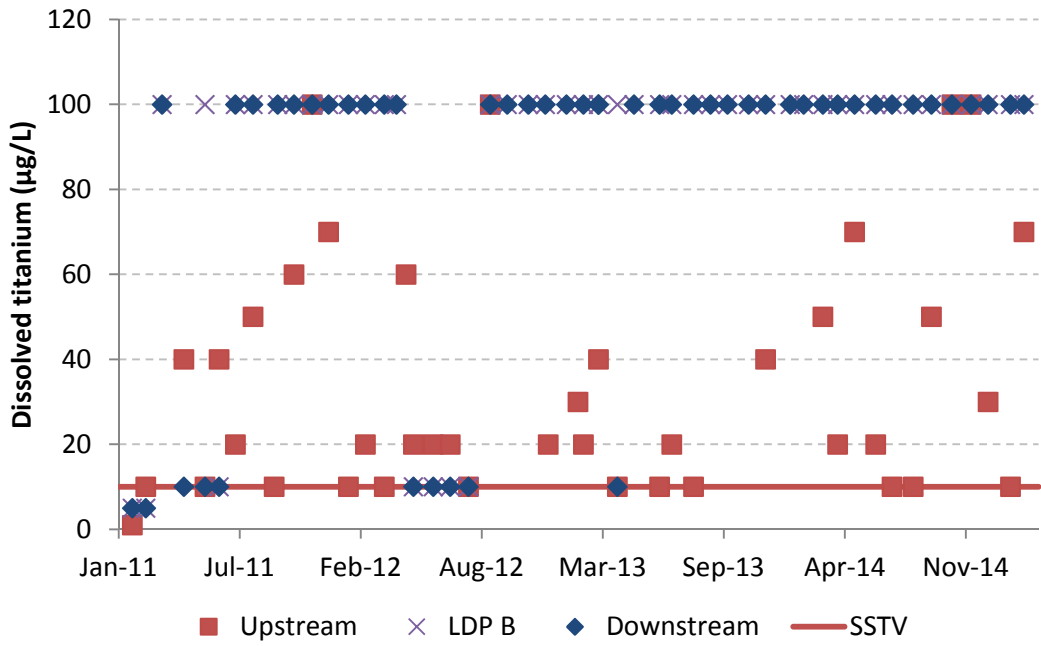


Figure A-48 Dissolved titanium recorded at monitoring Upstream, LDP B and Downstream sites

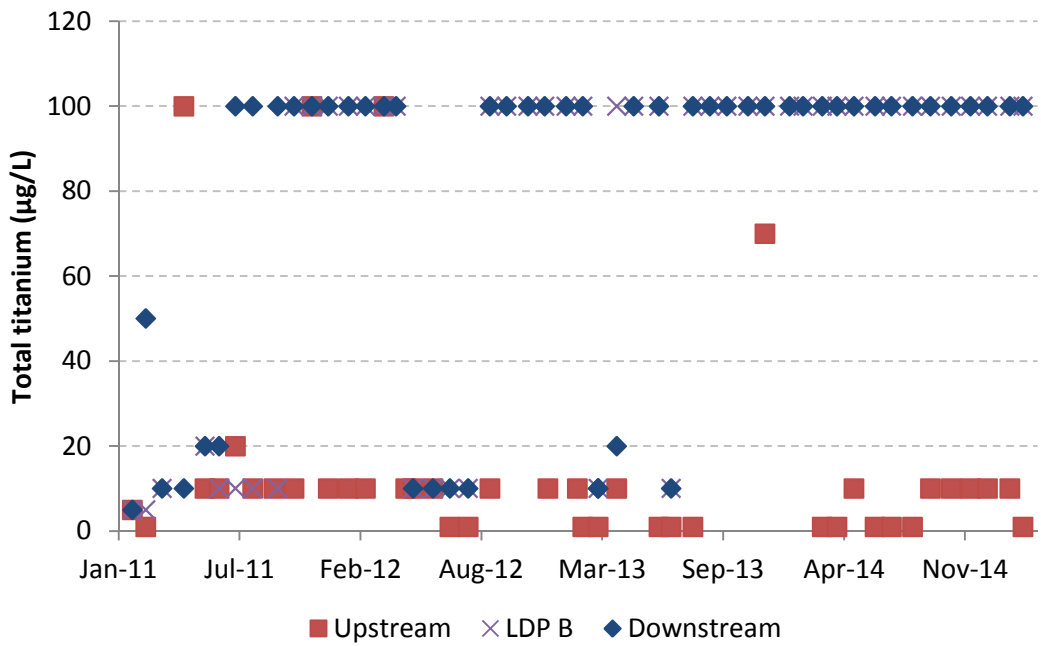


Figure A-49 Total titanium recorded at monitoring Upstream, LDP B and Downstream sites

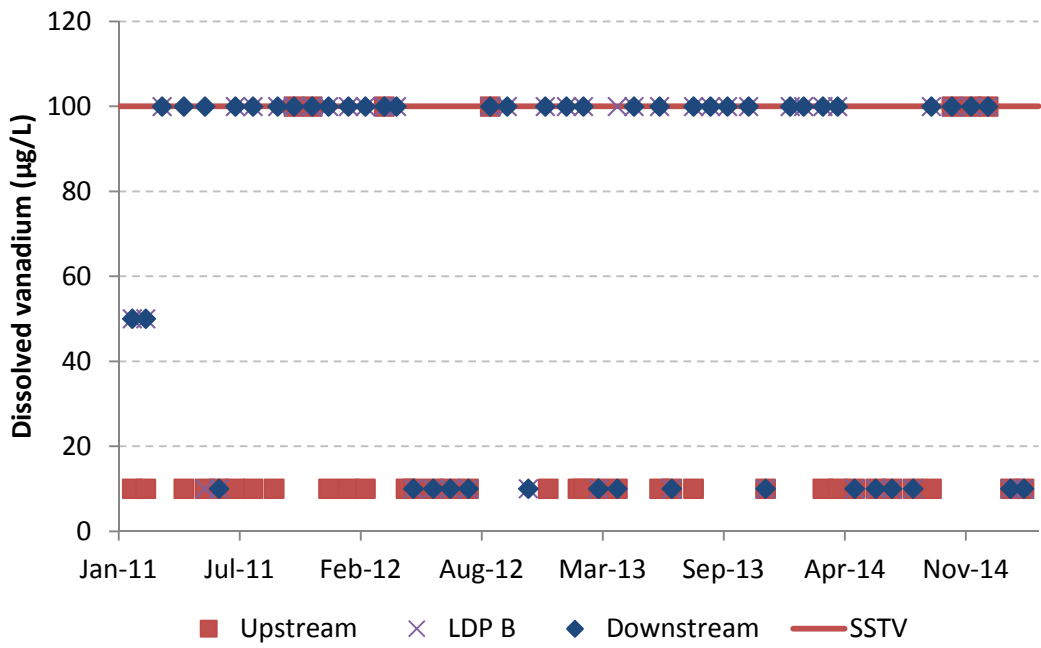


Figure A-50 Dissolved vanadium recorded at monitoring Upstream, LDP B and Downstream sites

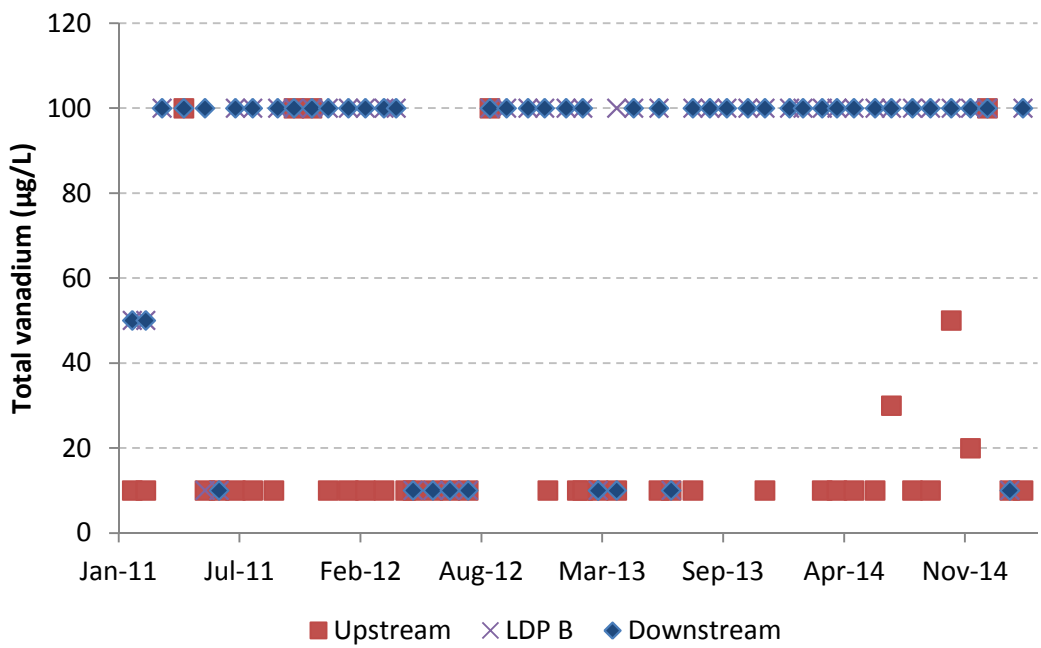


Figure A-51 Total vanadium recorded at monitoring Upstream, LDP B and Downstream sites

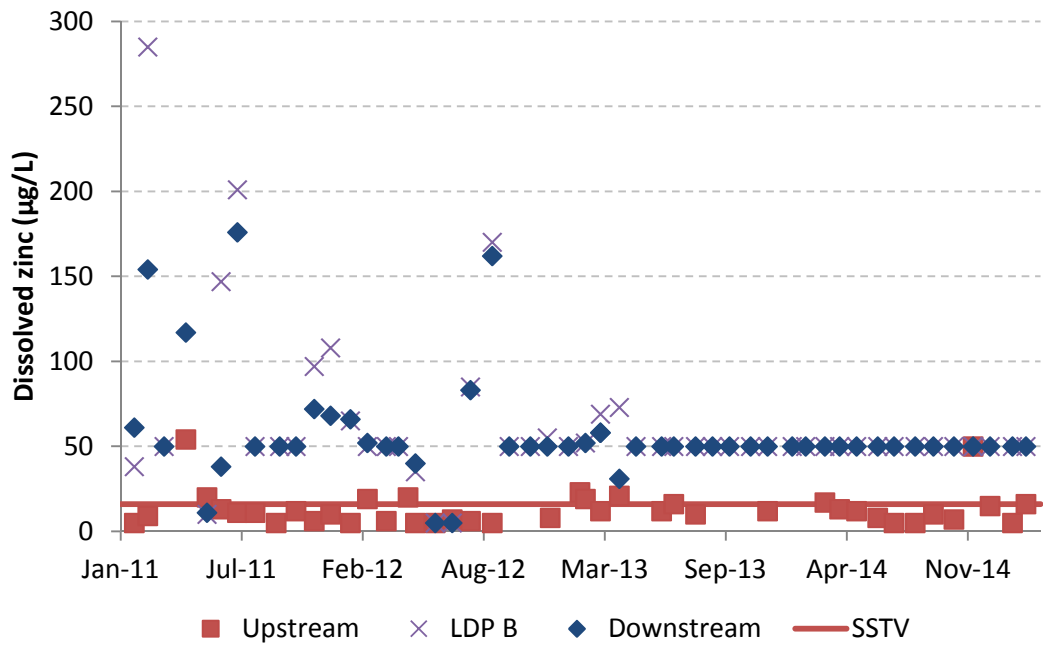


Figure A-52 Dissolved zinc recorded at monitoring Upstream, LDP B and Downstream sites

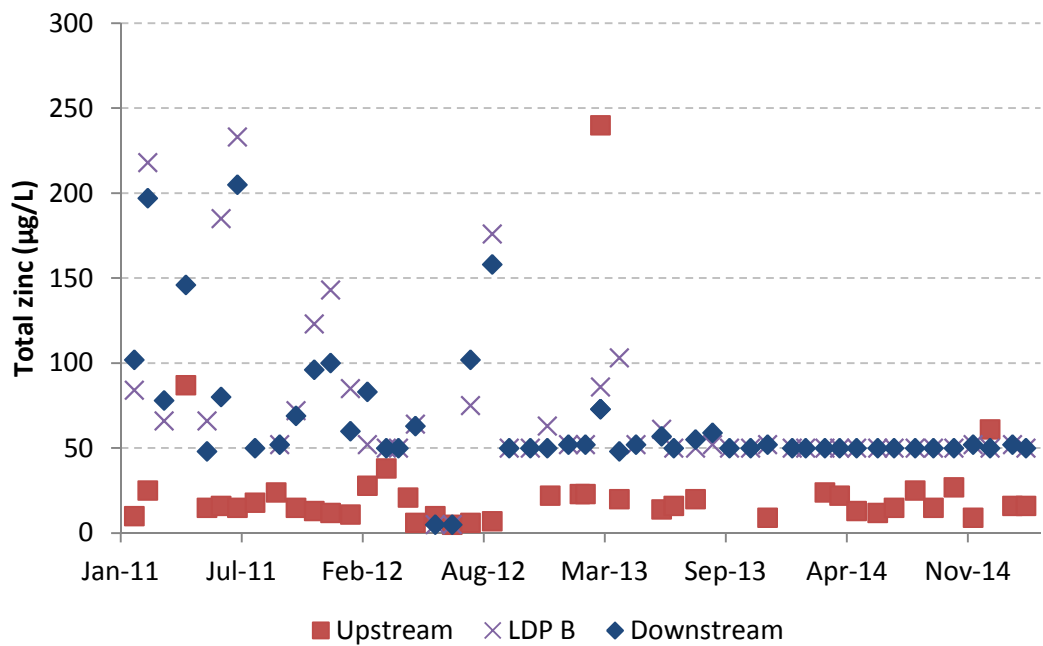


Figure A-53 Total zinc recorded at monitoring Upstream, LDP B and Downstream sites

Other parameters

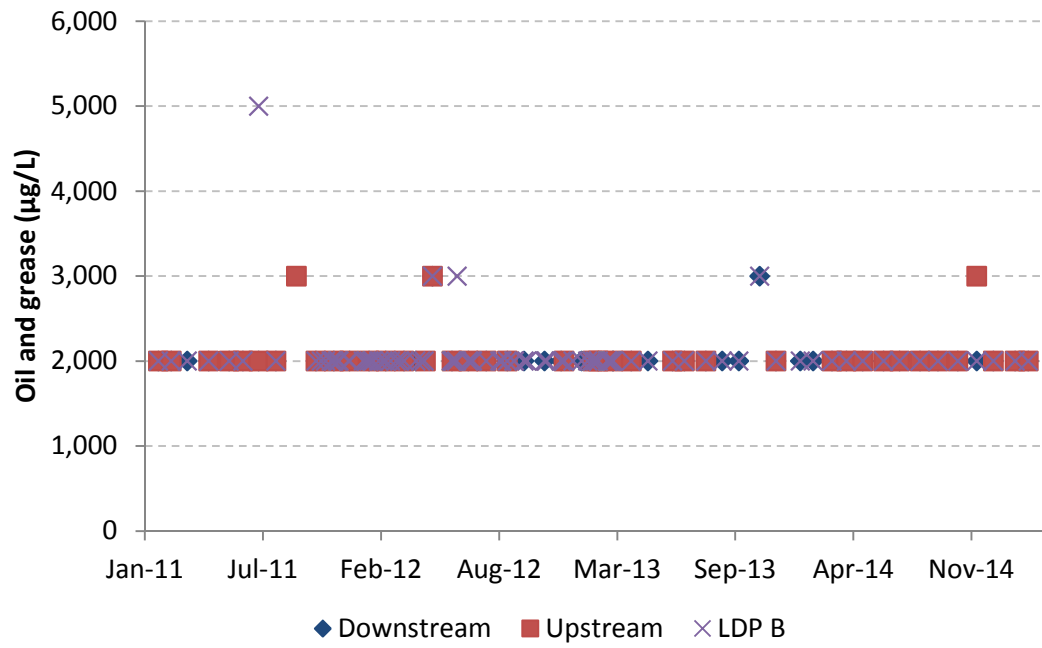


Figure A-54 Oil and grease recorded at monitoring Upstream, LDP B and Downstream sites

Appendix B – Time series graphs for Wangi Lake monitoring site

Physicochemical parameters

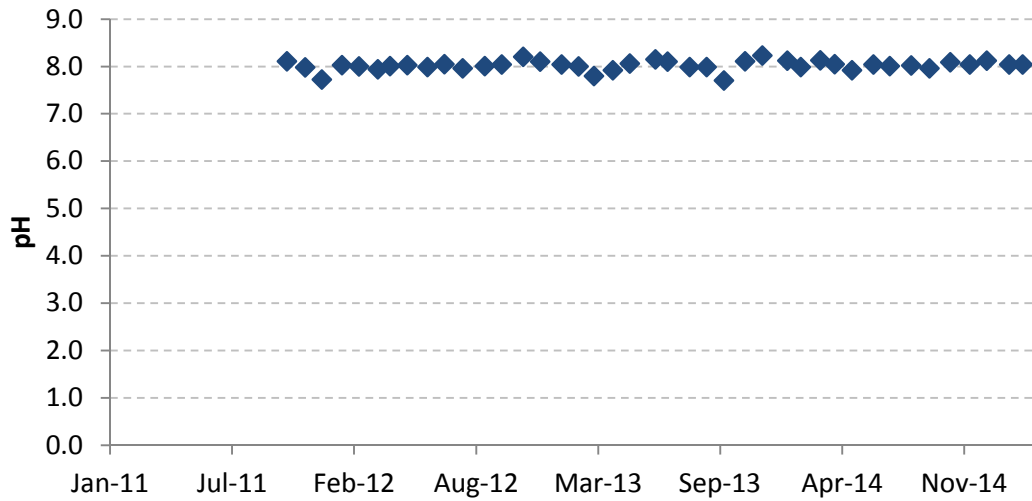


Figure B-1 pH recorded at monitoring site Wangi Lake

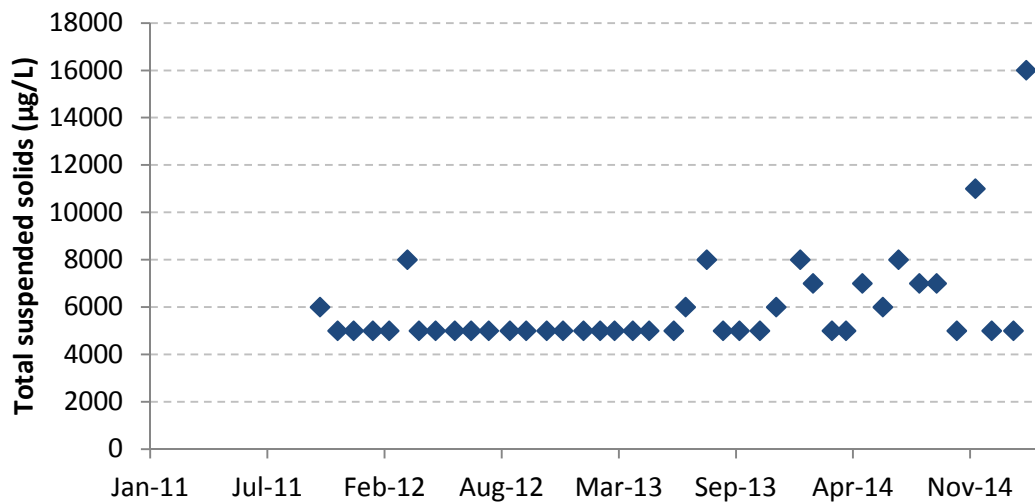


Figure B-2 Total suspended solids recorded at monitoring site Wangi Lake

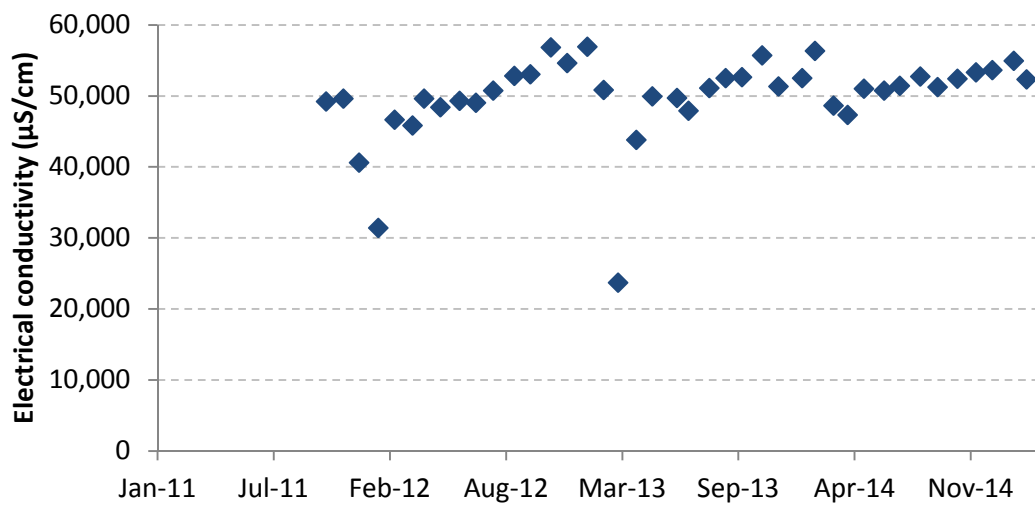


Figure B-2 Electrical conductivity recorded at monitoring site Wangi Lake

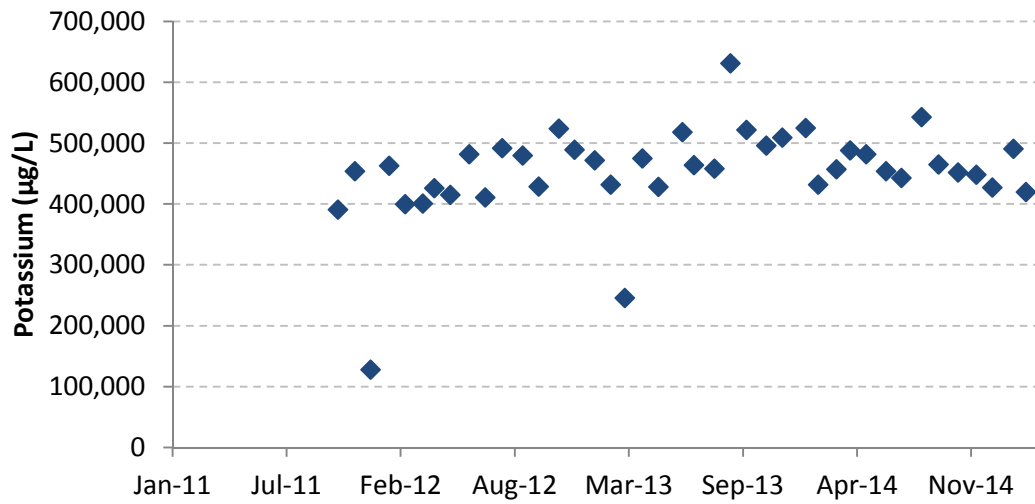


Figure B-7 Potassium recorded at monitoring site Wangi Lake

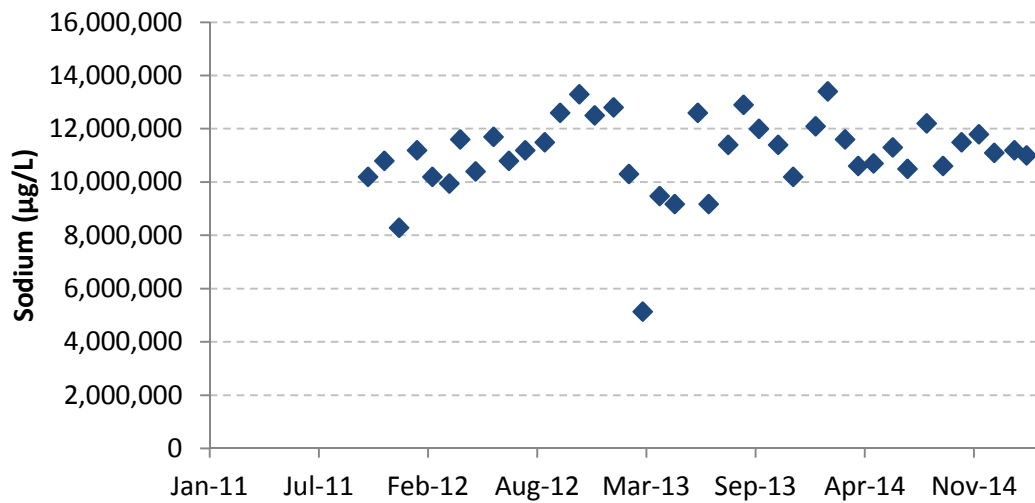


Figure B-8 Sodium recorded at monitoring site Wangi Lake

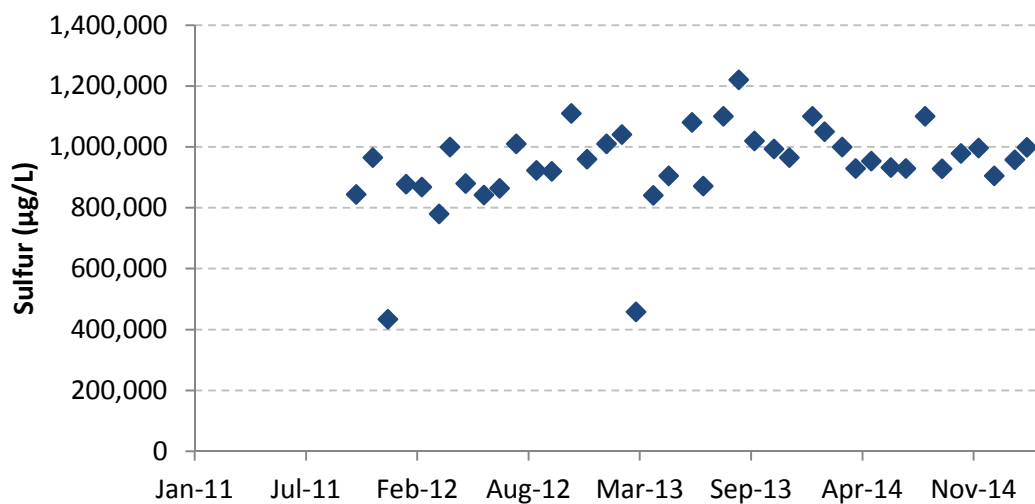


Figure B-9 Sulfur recorded at monitoring site Wangi Lake

Metals

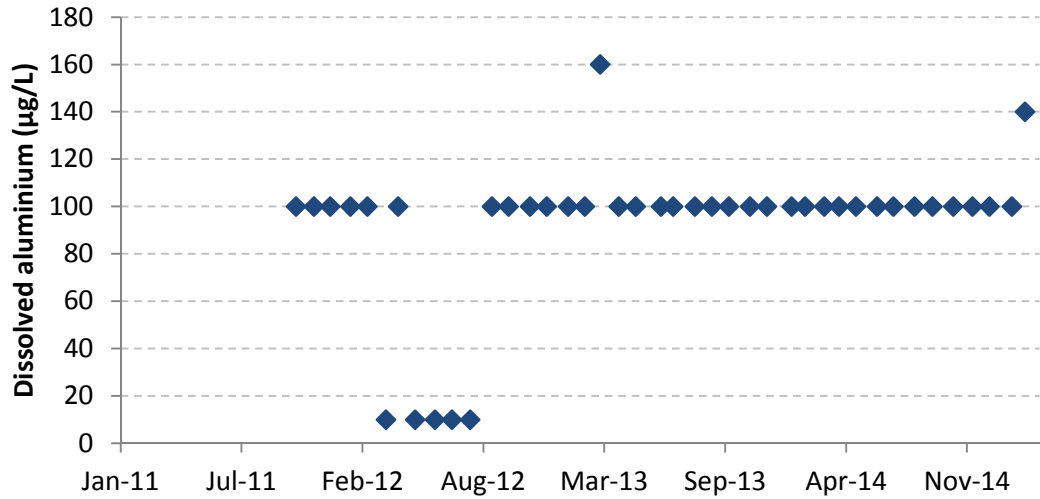


Figure B-10 Dissolved aluminium recorded at monitoring site Wangi Lake

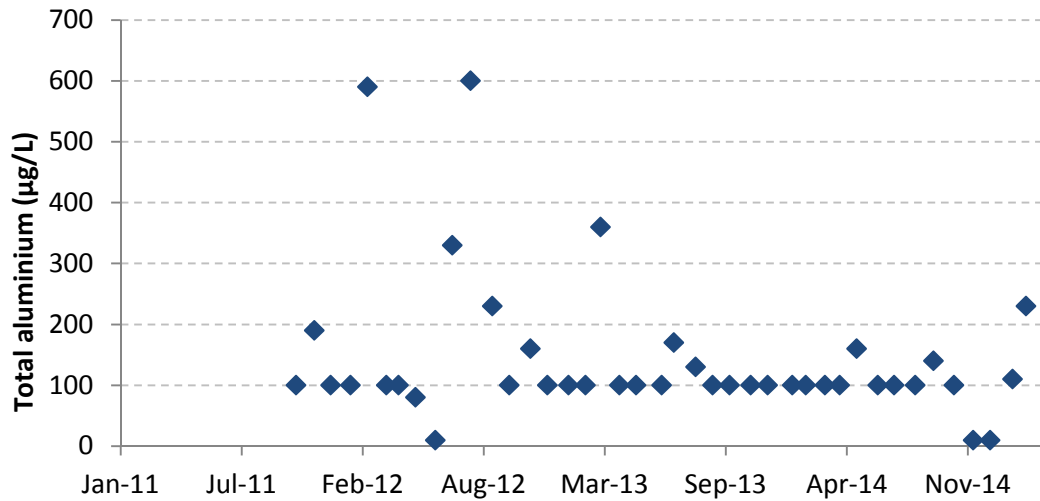


Figure B-11 Total aluminium recorded at monitoring site Wangi Lake

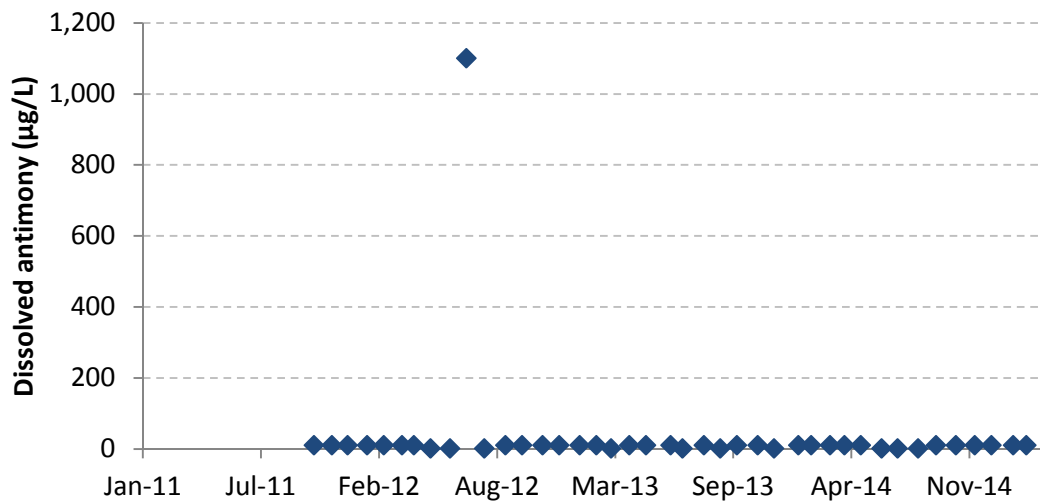


Figure B-12 Dissolved antimony recorded at monitoring site Wangi Lake

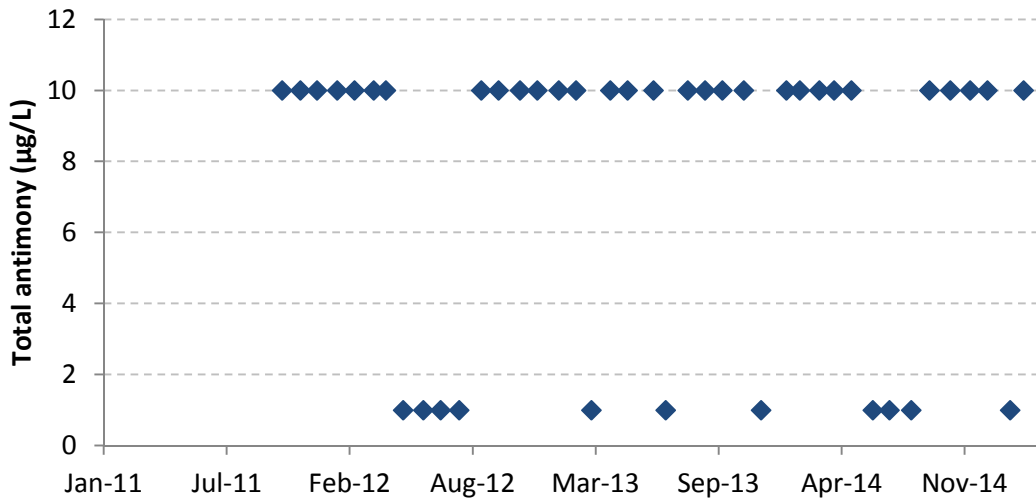


Figure B-13 Total antimony recorded at monitoring site Wangi Lake

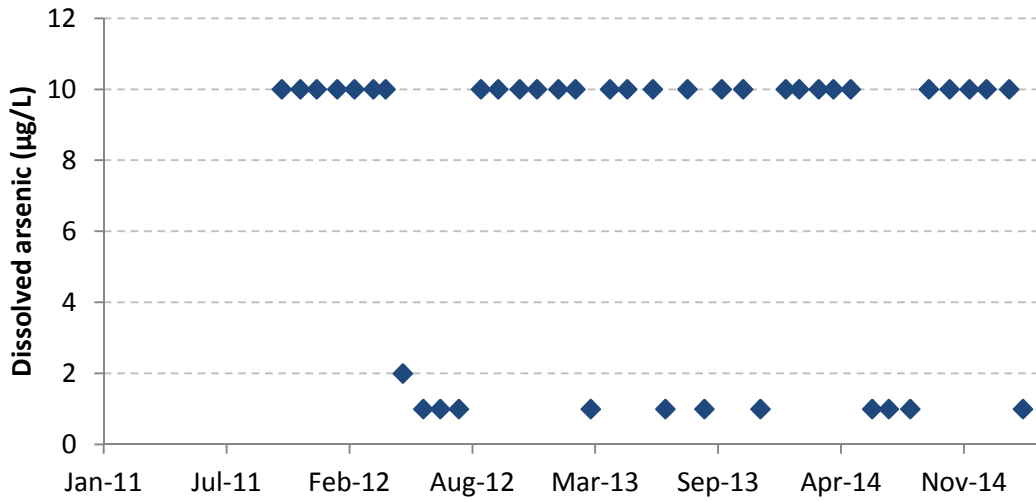


Figure B-14 Dissolved arsenic recorded at monitoring site Wangi Lake

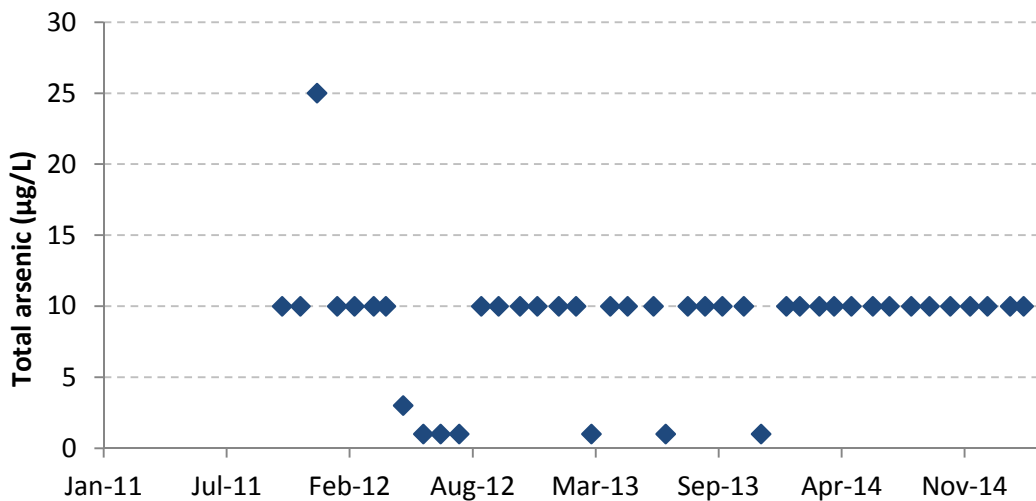


Figure B-15 Total arsenic recorded at monitoring site Wangi Lake

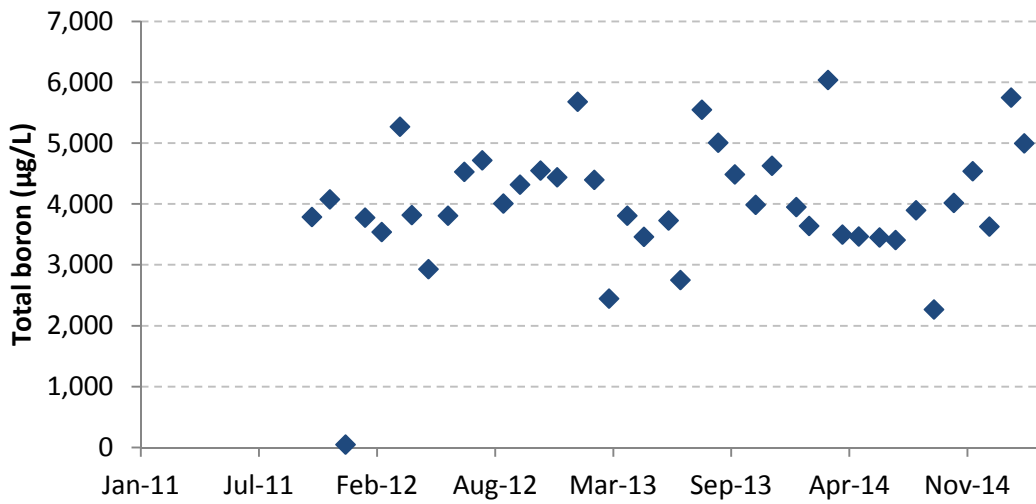


Figure B-21 Total boron recorded at monitoring site Wangi Lake

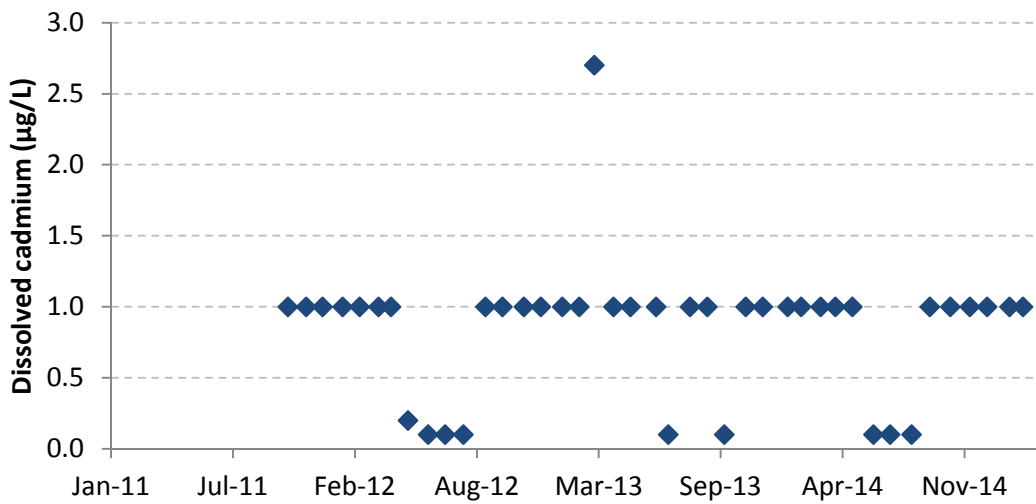


Figure B-22 Dissolved cadmium recorded at monitoring site Wangi Lake

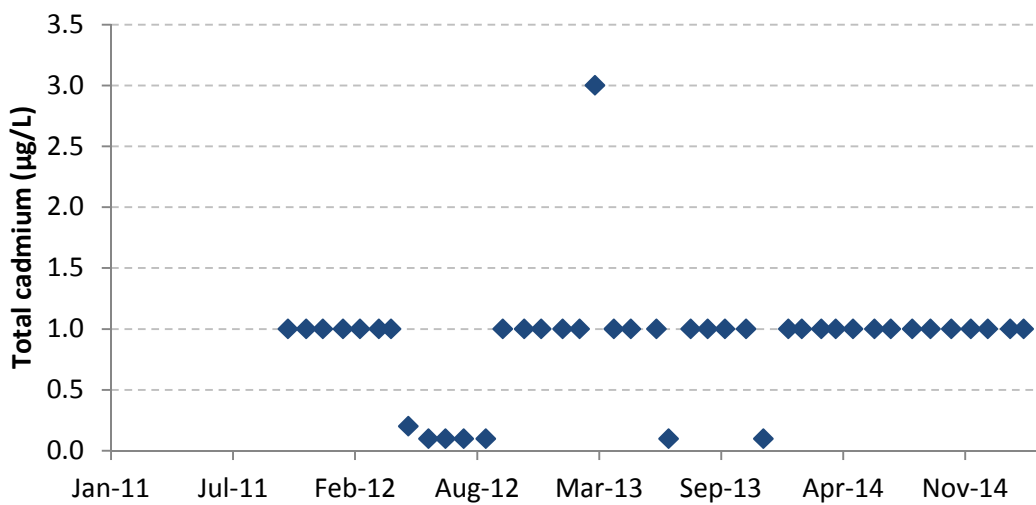


Figure B-23 Total cadmium recorded at monitoring site Wangi Lake

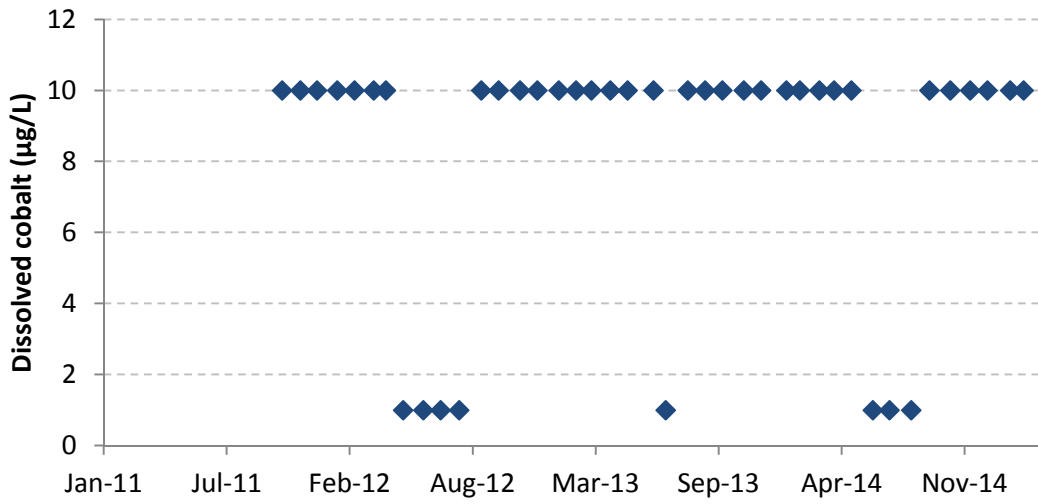


Figure B-26 Dissolved cobalt recorded at monitoring site Wangi Lake

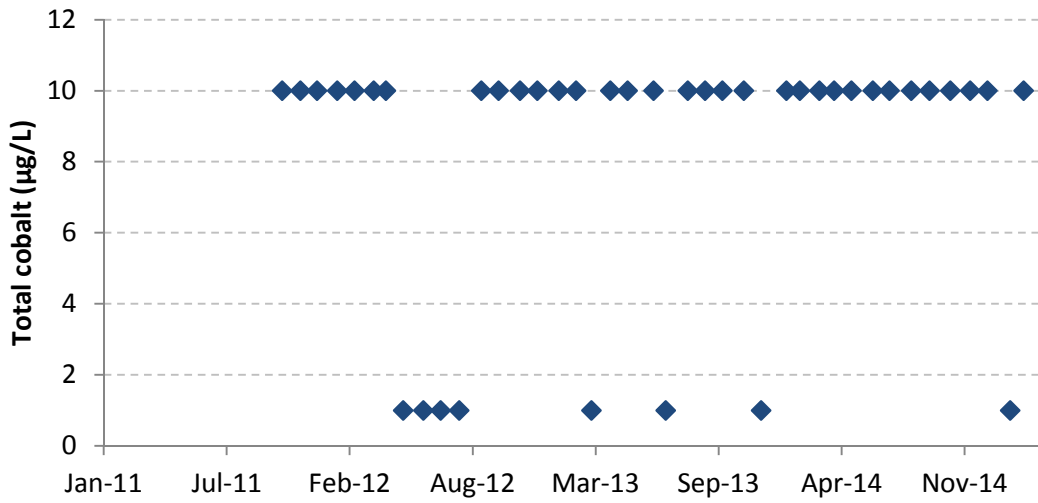


Figure B-27 Total cobalt recorded at monitoring site Wangi Lake

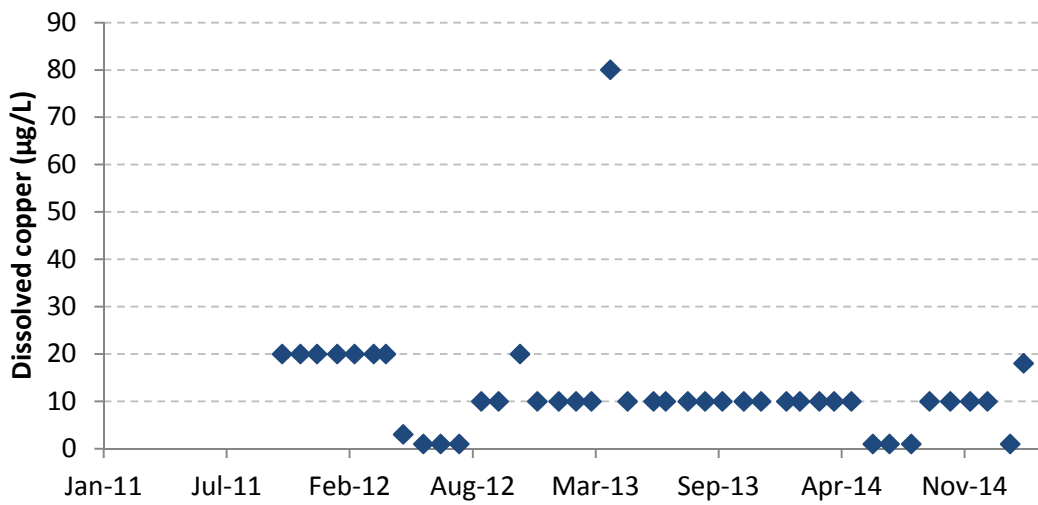


Figure B-28 Dissolved copper recorded at monitoring site Wangi Lake

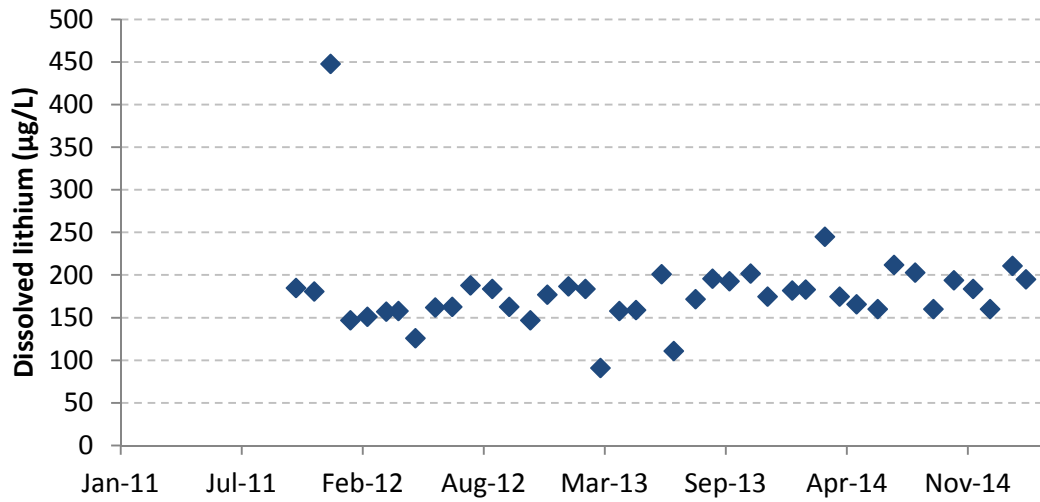


Figure B-32 Dissolved lithium recorded at monitoring site Wangi Lake

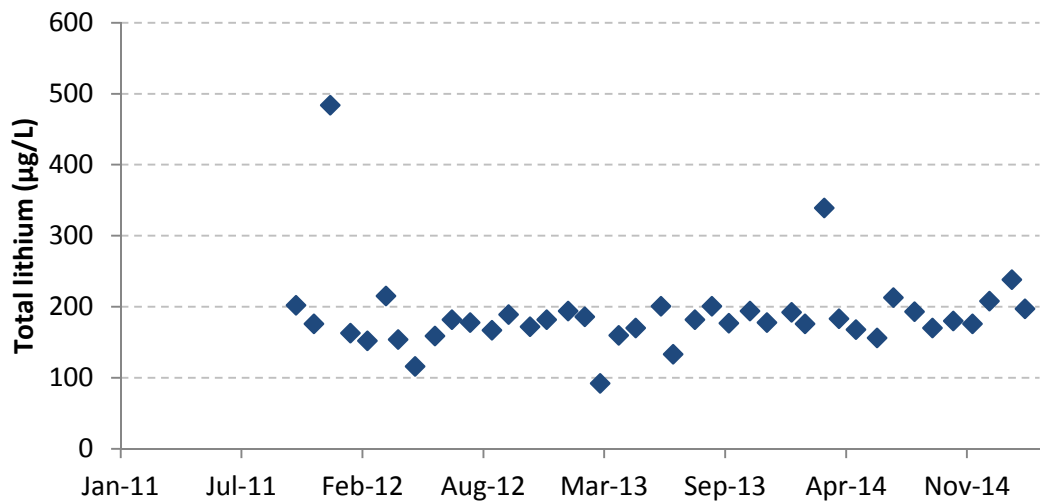


Figure B-33 Total lithium recorded at monitoring site Wangi Lake

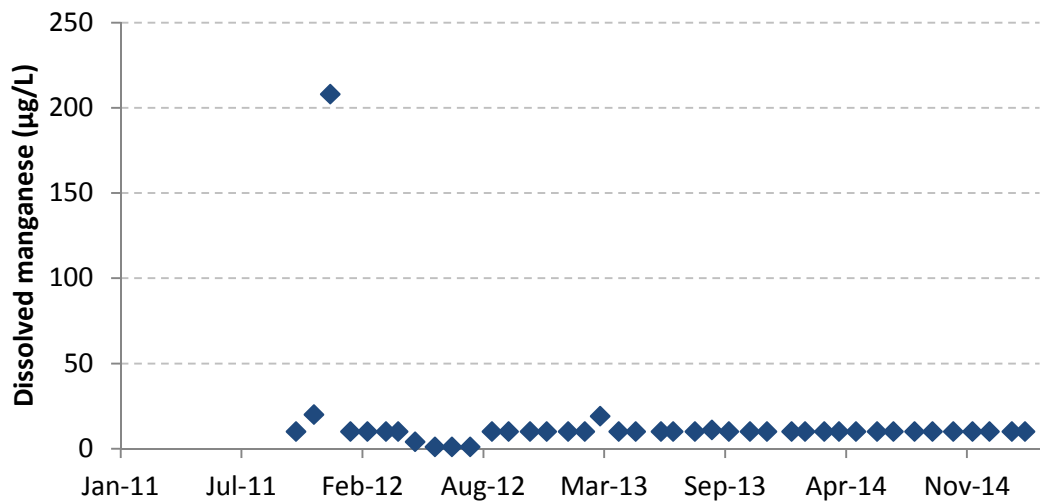


Figure B-34 Dissolved manganese recorded at monitoring site Wangi Lake

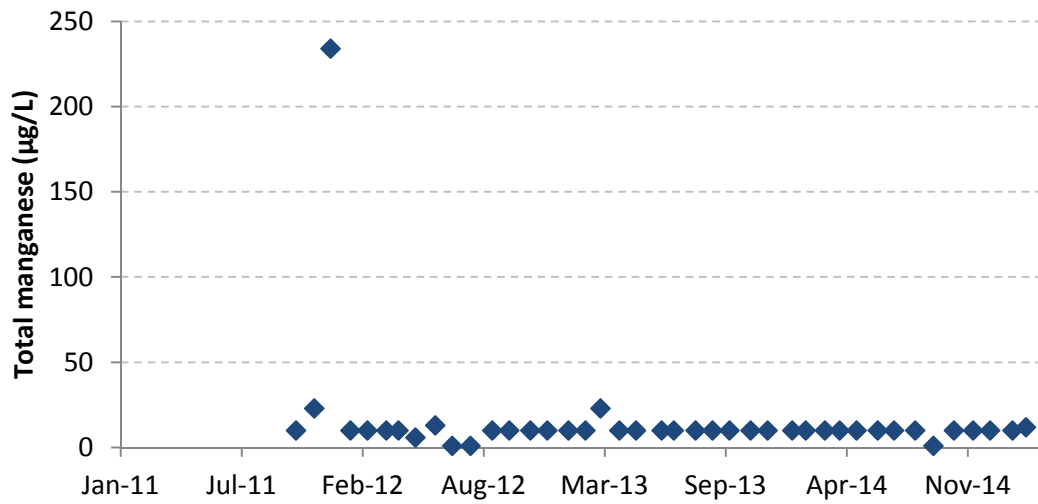


Figure B-35 Total manganese recorded at monitoring site Wangi Lake

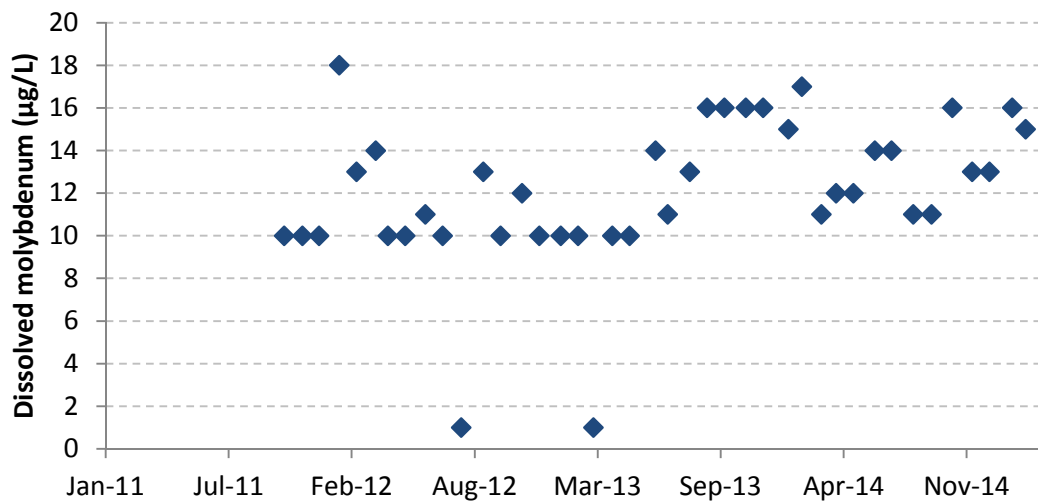


Figure B-38 Dissolved molybdenum recorded at monitoring site Wangi Lake

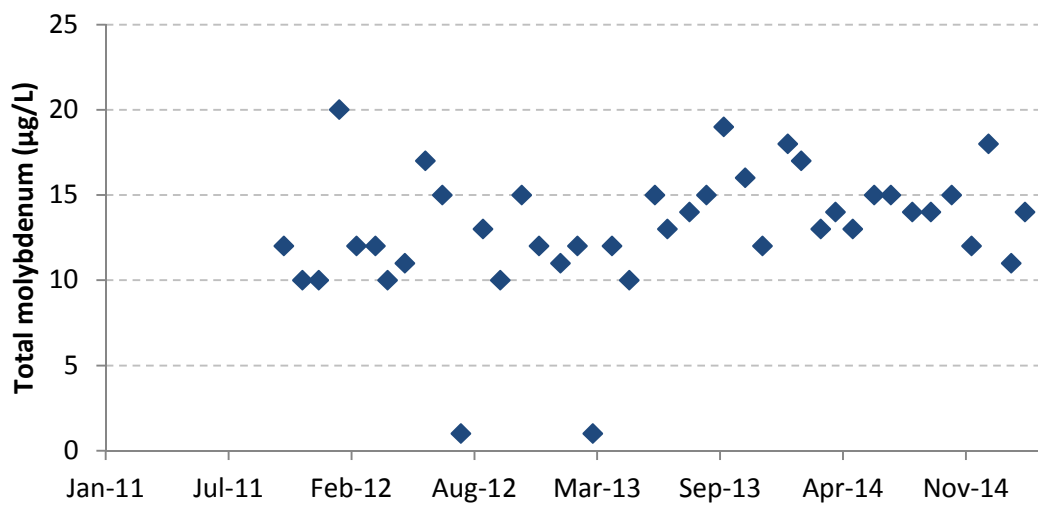


Figure B-39 Total molybdenum recorded at monitoring site Wangi Lake

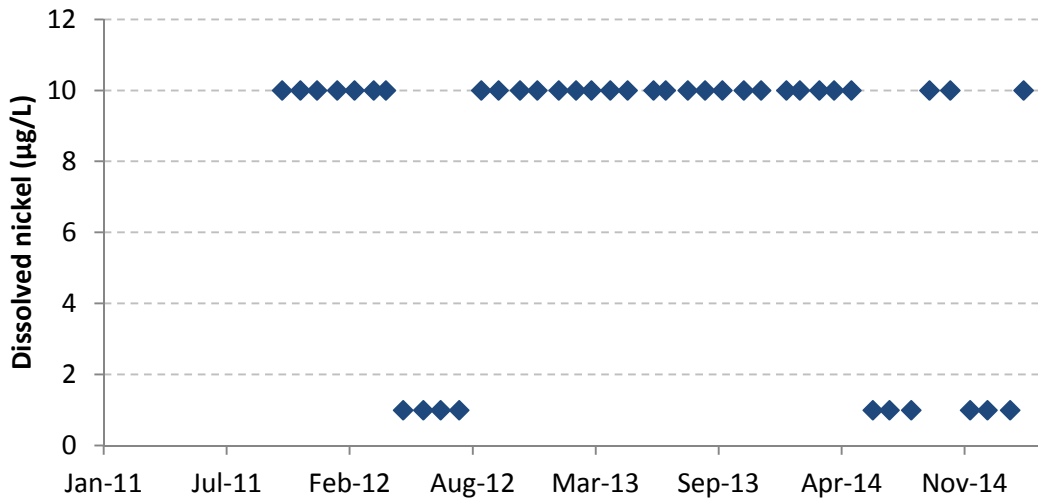


Figure B-40 Dissolved nickel recorded at monitoring site Wangi Lake

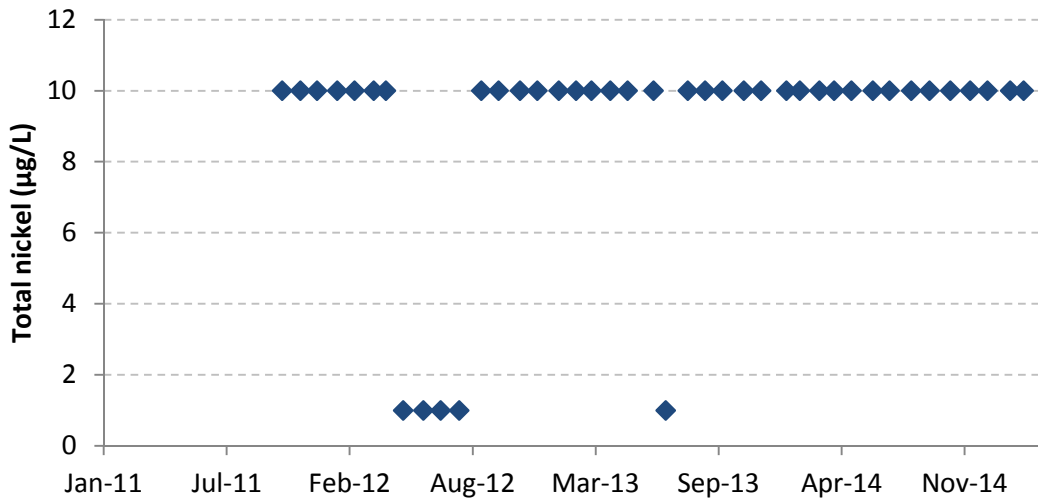


Figure B-41 Total nickel recorded at monitoring site Wangi Lake

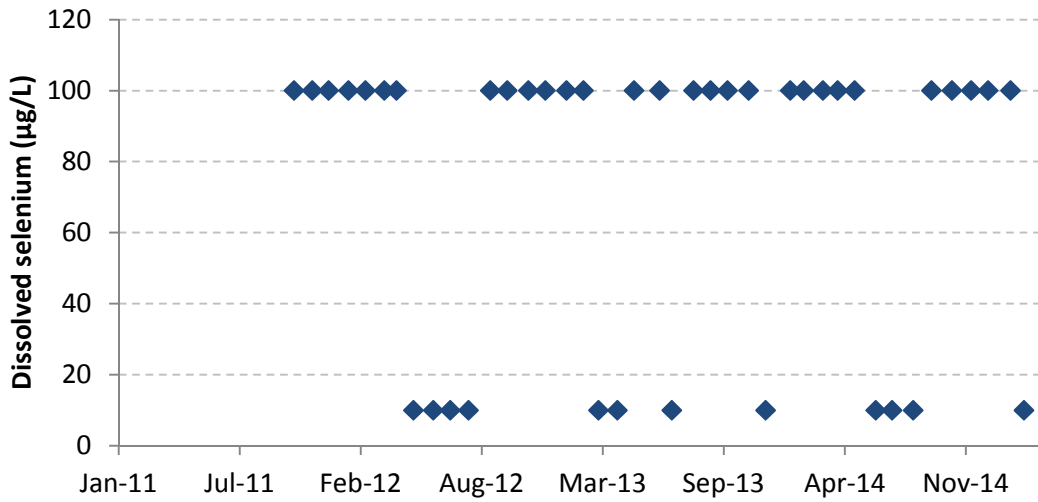


Figure B-42 Dissolved selenium recorded at monitoring site Wangi Lake

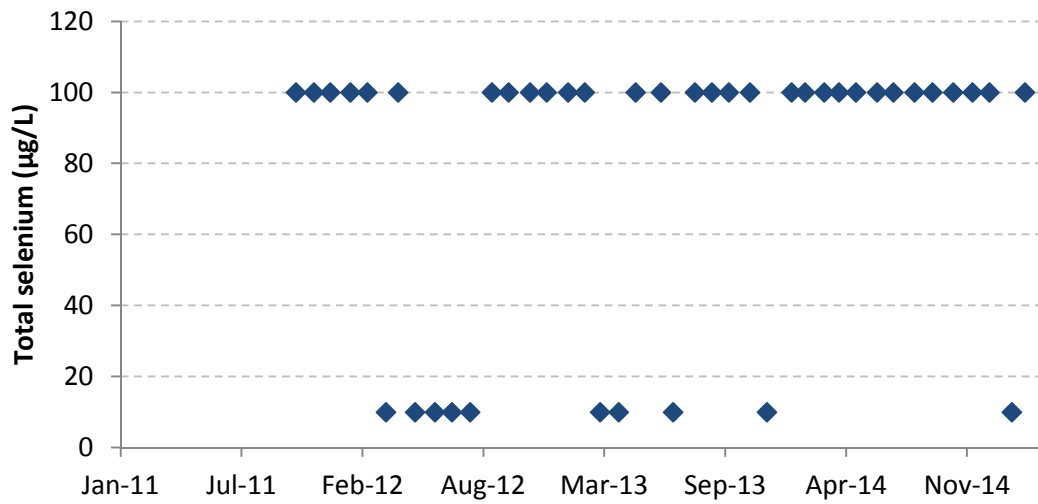


Figure B-43 Total selenium recorded at monitoring site Wangi Lake

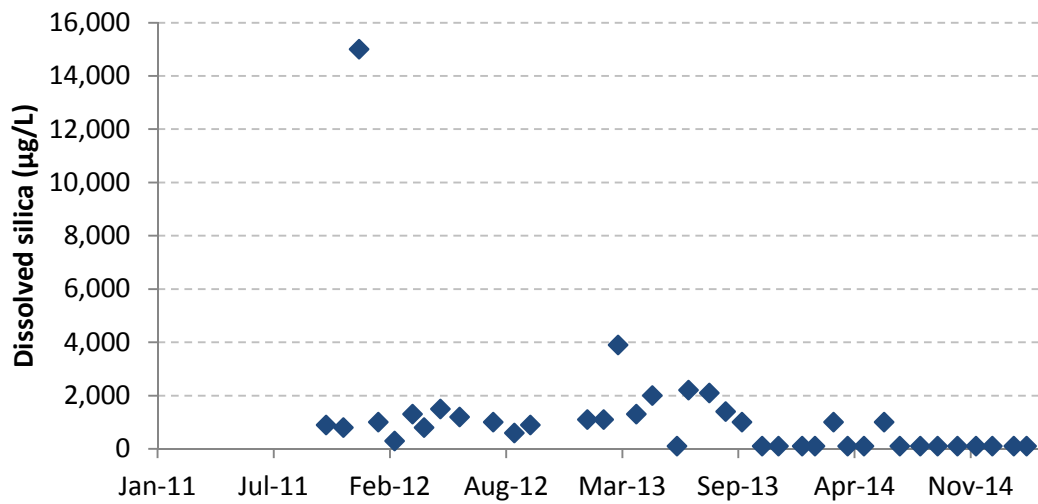
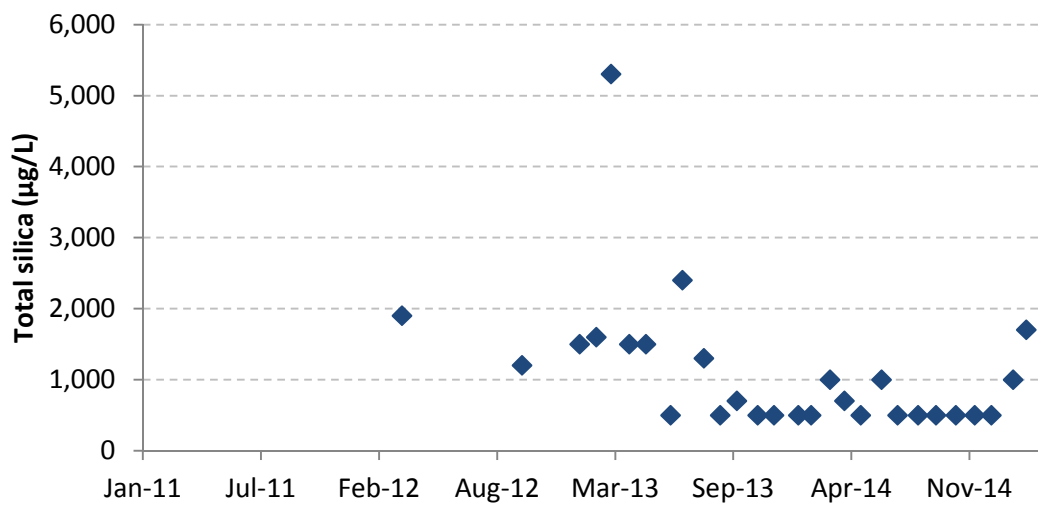


Figure B-44 Dissolved silica recorded at monitoring site Wangi Lake



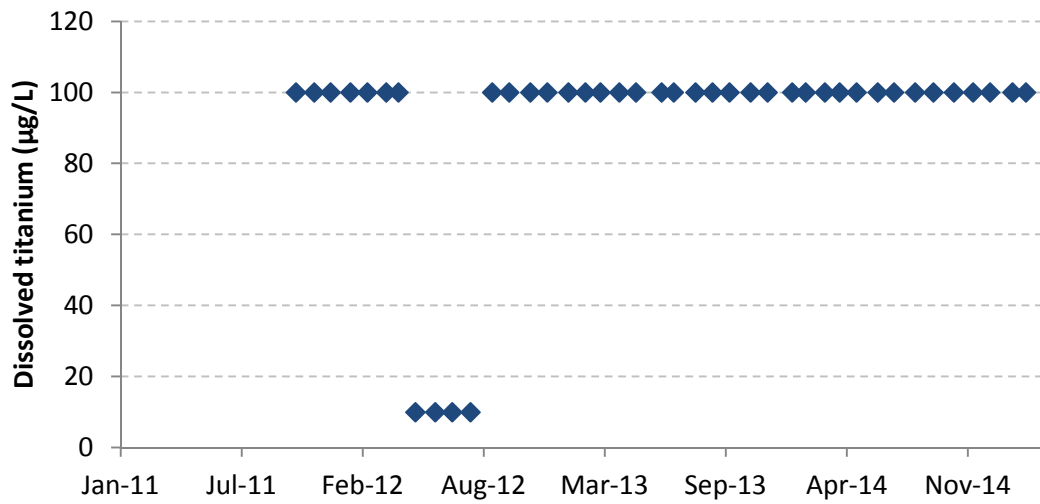


Figure B-48 Dissolved titanium recorded at monitoring site Wangi Lake

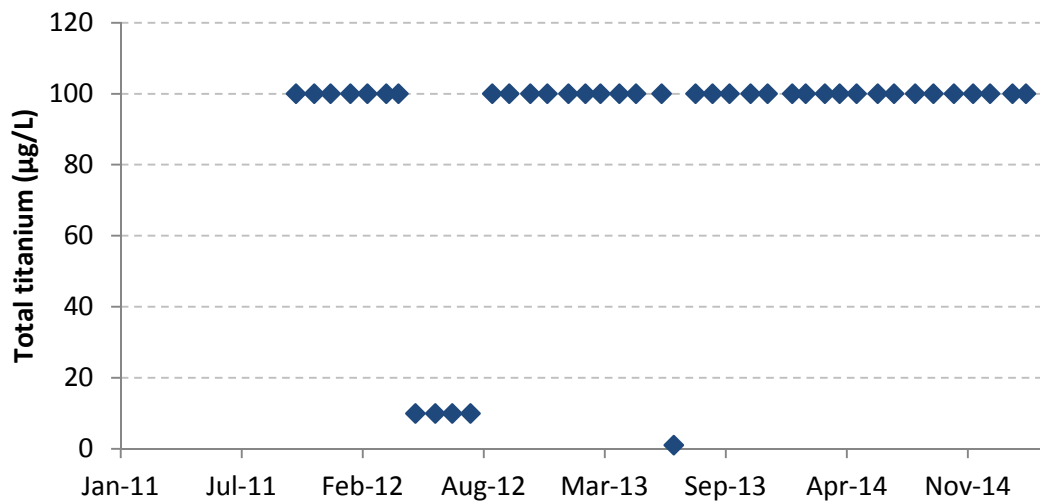


Figure B-49 Total titanium recorded at monitoring site Wangi Lake

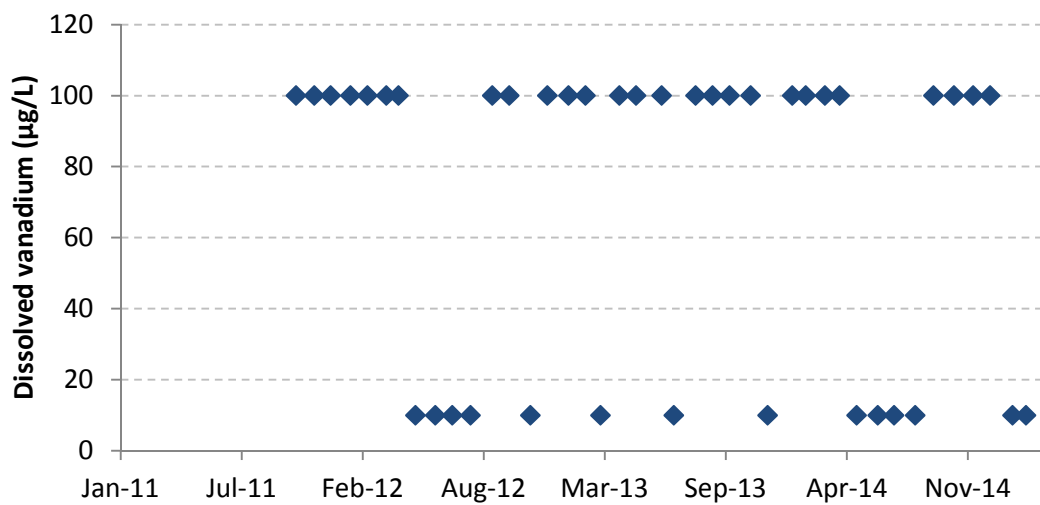


Figure B-50 Dissolved vanadium recorded at monitoring site Wangi Lake

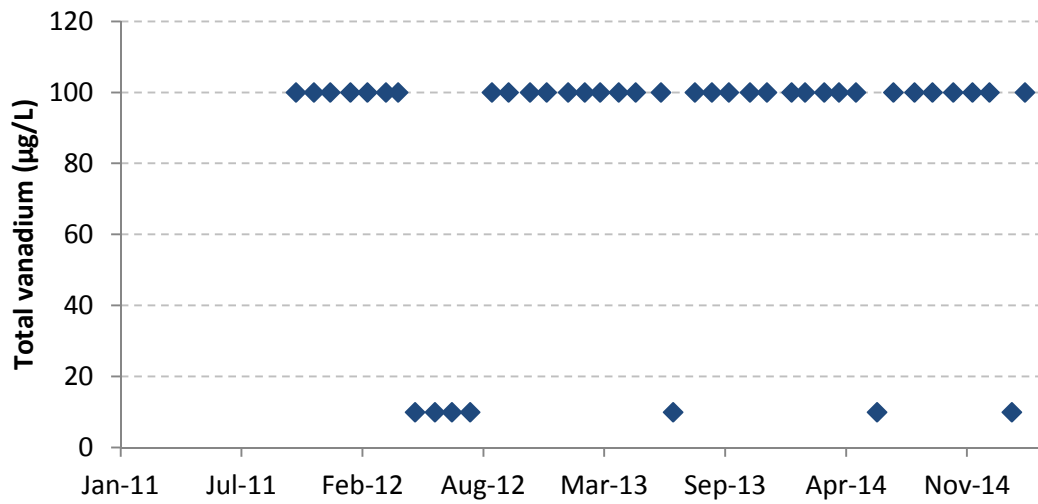


Figure B-51 Total vanadium recorded at monitoring site Wangi Lake

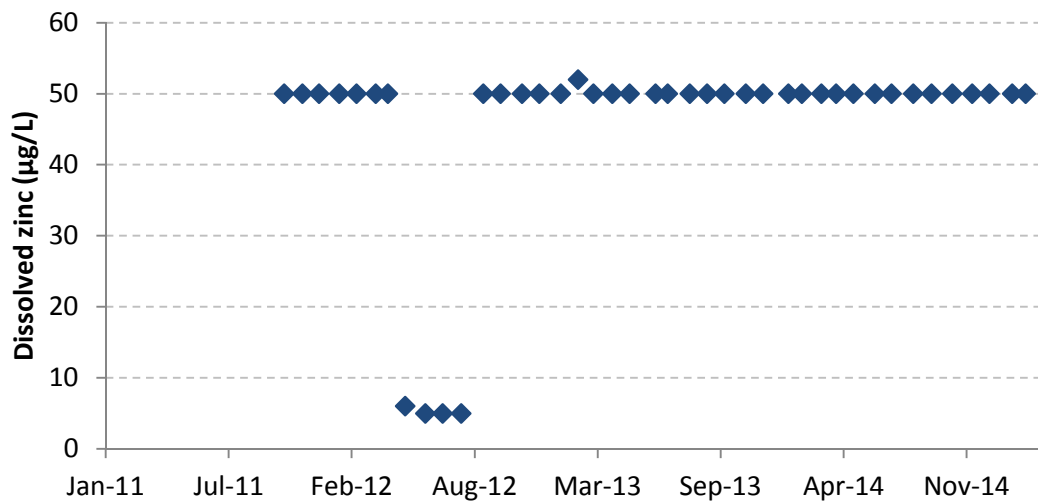


Figure B-52 Dissolved zinc recorded at monitoring site Wangi Lake

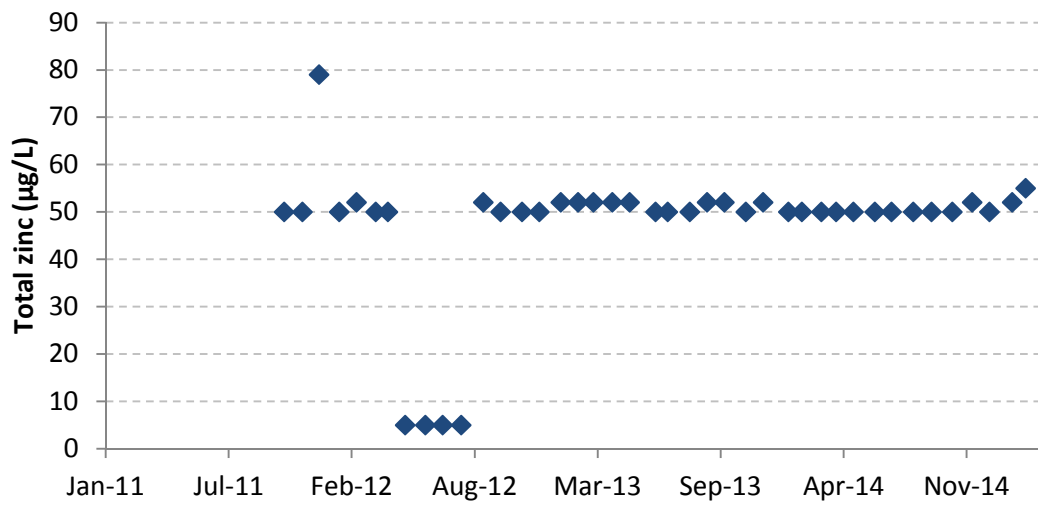


Figure B-53 Total zinc recorded at monitoring site Wangi Lake

Other parameters

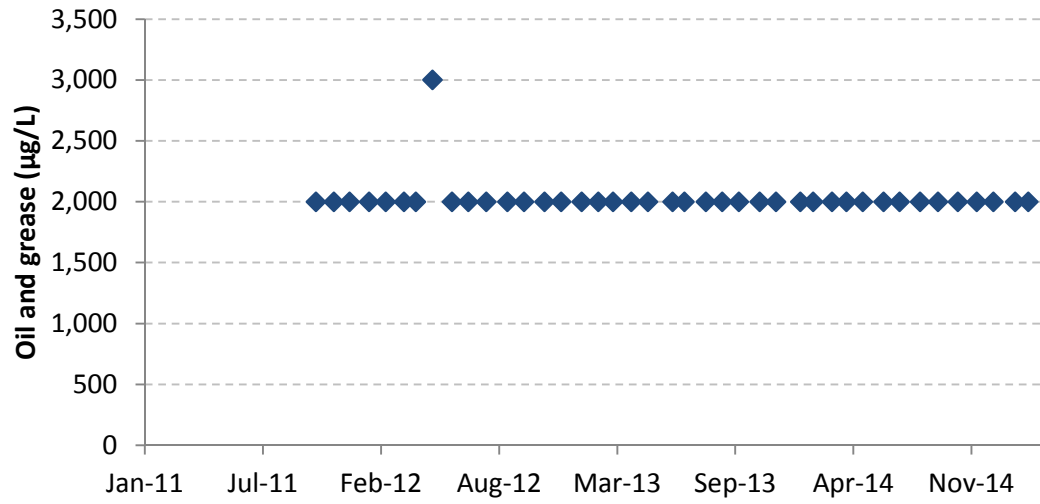


Figure B-54 Oil and grease recorded at monitoring site Wangi Lake

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Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
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Appendix E – Erosion and Sediment Control Plan



Centennial Myuna Pty Ltd

Erosion and Sediment Control Plan

June 2023

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Appendices

- A Sediment Basin Calculations**
- B Standard Erosion and Sediment Control Details**

Glossary

Aquifer	Underground water storage within either disturbed or undisturbed strata.
Average Recurrence Interval	A statistical estimate of the average period in years between the occurrence of a flood of a given size or larger, eg. floods with a discharge as big as, or larger than, the 100-year ARI flood event will occur on average once every 100 years. ARI is equal to the reciprocal of annual flood risk, e.g. an annual flood risk of 1/100 has an ARI of 100 years.
Bore	A constructed connection between the surface and a source of underground water that enables the underground water to be transferred to the surface either naturally or through artificial means.
Clean catchment areas	Catchments in which there are no exposed surfaces containing coal or mined carbonaceous material.
Clean water	Waters on the premises that have not come into physical contact with coal, or mined carbonaceous material.
Coal Handling Plant	A facility where coal is screened and prepared for transport off-site.
Dewatering	Transfer of water from underground workings to the surface.
Dirty catchment areas	Catchments in which coal mined carbonaceous materials are present or areas where the topsoil has been disturbed.
Dirty water	Water on the premises that has come into physical contact with coal, mined carbonaceous materials or otherwise contains elevated sediment load.
Fassifern Seam	Deepest coal horizon of the Permian Age Newcastle Coal Measures mined at Myuna, with an average depth of 140 metres.
Great Northern Seam	Lies above the Fassifern seam in the Newcastle Coal Measures and has an average depth of 120 metres.
Groundwater	Water held in an aquifer, excluding the underground water stored within mined workings of a coal seam.
Horizontal hydraulic conductivity	The ease with which water can move through pores or fractures within rock or sediment.
Hydrogeology	The area of geology that deals with the distribution and movement of groundwater in soils and rocks of the earth's crust.
Infiltration	Natural flow of surface water through ground surfaces as a result of rainfall events.
Licensed Discharge Point	A location where Myuna Colliery discharges water in accordance with conditions stipulated within the site Environment Protection Licence.

Oil Water Separator	Device designed to separate oil and suspended solids from water.
Approved Project Area	Encompasses Mining Lease 1370, a portion of Consolidated Coal Lease 762 and the Mining Purpose Lease 334.
Project	Extension of underground coal mining and associated activities at Myuna Colliery within the Project Application Area for up to 21 years.
Run of Mine	Raw coal production (unprocessed).
Specific storage	The amount of water that a portion of an aquifer releases from storage, while remaining fully saturated.
Surface Facilities Area	Comprises surface land containing mining and non-mining infrastructure.
Surface Water	Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks and drainage lines.
Temporary storage	Volume of storage available within a dam between the permanent water level and the overflow level.
Underground water	Water stored in underground aquifers. During the mining process a proportion of this water is released and managed by the underground settling and pumping system.
Wallarrah Seam	Uppermost coal horizon of the Permian Age Newcastle Coal Measures, with an average depth of 80 metres.

Abbreviations

AHD	Australian Height Datum
ARI	Average recurrence interval
BOM	Bureau of Meteorology
Centennial	Centennial Coal Company Limited
Centennial Myuna	Centennial Myuna Pty Limited
CHP	Coal handling plant
DPIE -Water	Department of Planning and Environment – Water
RR	Department of Regional NSW – Resource Regulator
EPA	Environment Protection Authority
EPL	Environment protection licence
ESCP	Erosion and sediment control plan
ha	Hectare
HWC	Hunter Water Corporation
kL/day	Kilolitre per day
km	Kilometre
L/s	Litre per second
LDP	Licensed discharge point
LMCC	Lake Macquarie City Council
LOR	Limit of reporting
m	Metre
mg/L	Milligram per litre
ML	Megalitre
ML/day	Megalitre per day
ML/year	Megalitre per year
mm	Millimetre
Mtpa	Million tonnes per annum
NTU	Nephelometric turbidity unit
OEH	Office of Environment and Heritage
PIRMP	Pollution Incident Response Management Plan

1. Introduction

Myuna Colliery is an underground coal mine owned and operated by Centennial Myuna Pty Limited (Centennial Myuna), a wholly owned subsidiary of Centennial Coal Company Limited (Centennial). Myuna Colliery's Surface Facilities Area is in Wangi Wangi on the western side of Lake Macquarie, 25 km south-west of Newcastle, as shown in Figure 1.1.

On 27 February 2012 Centennial Myuna received approval for the Myuna Coal Project under Part 3A of the Environmental Planning and Assessment Act 1979. The new approval (PA 10_0080) allowed for the continuation of mining at the Myuna Colliery at a maximum extraction rate of 2 Mtpa of ROM coal for a period of 21 years up to 31 December 2032. On 27 February 2015, Centennial Myuna was granted a modification to this approval (MOD 1) which allowed for an increased rate of production up to a maximum of 3 Mtpa and an increase in personnel from 210 to up to 300 full time employees. Mining of three seams, the Wallarah, Great Northern and Fassifern coal seams

1.1 Commission and Scope

GHD Pty Ltd was commissioned by Centennial Myuna Pty Ltd to prepare a Water Management Plan for the Myuna Colliery and includes an Erosion and Sediment Control Plan (this Plan).

This Erosion and Sediment Control Plan (ESCP) is a component of the Myuna Colliery Water Management Plan and is a requirement under the Project Approval 10_0080.

The scope of the Plan includes:

- Definition of activities that could cause soil erosion and generate sediment at the Colliery.
- Definition of the location, function and capacity of erosion and sediment control structures that exist for the Colliery.
- Definition of the management and maintenance systems in place for Erosion and Sediment Control structures that exist within the Colliery.
- Definition of the location, function and capacity of erosion and sediment control structures that are to be implemented for the Colliery.

The ESCP must be implemented in conjunction with the Water Management Plan (WMP) to maximise the effectiveness of all erosion and sediment control measures.

1.2 Control Plan Objectives

This ESCP has been prepared accordance with Schedule 3, Condition 24 of the Project Approval and ongoing consultation with:

- NSW Office of Water (NOW).
- Department of Trade and Investment – Division of Resources and Energy.
- Lake Macquarie City Council (LMCC).

The conditions of Schedule 3 are shown in **Table 1-1** along with the section(s) of this report where these objectives are addressed.

FIGURE 1.1

Table 1-1 Relevant Project Approval Conditions

Consent Requirements	Condition	Where address within this Report
Centennial Myuna Project Approval 10_0080, Schedule 3, Condition 24	The Erosion and Sediment Control Plan must:	
	(a) Be consistent with the requirements of the Managing Urban Stormwater – Soils and Construction, Volume 2E: Mines and Quarries (DECC 2008), or its latest version).	This Document
	(b) Identify activities that could cause soil erosion and generate sediment particularly in relation to activities near waterways.	Section 2
	(c) Describe the location, function, and capacity of erosion and sediment control structures.	Section 3
	(d) Describe what measures would be implemented to maintain the structures over time.	Section 5.5
	(e) Describe the sediment and erosion control measures to be implemented for all activities undertaken at the site.	Section 3 and 5

1.3 Description of the Project

The Approved Project includes the extension of mining and coal handling activities at Myuna Colliery. The Approved Project will:

- Mine using bord and pillar methods in the Wallarah, Great Northern and Fassifern Seams for a further 21 years.
- Produce, handle and distribute to Eraring Power Station up to 3 million tonnes per annum (Mtpa) using existing infrastructure at Myuna Colliery.
- Continue the use of ancillary infrastructure and services for a further 21 years.
- Upgrade the water management system currently present.
- Rehabilitate the Surface Facilities within 5 years of completion of mining.

1.4 Environmental Protection Licence

- Myuna Colliery currently holds Environment Protection Licence (EPL) 366, which includes requirements to monitor water quality and quantity of discharges from the site. Water is currently licensed to be discharged from the mine through two licensed discharge points (LDPs):
 - LDP 10 (Formerly LDP A) – Emergency discharge to Wangi Creek via the Emergency Coal Stockpile Dam for event-based discharges where rainfall exceeds 140 mm in the preceding 24 hours.
 - LDP 9 (Formerly LDP B) – Discharge of up to 13 ML/day to Wangi Creek via the Mine Water Settling Pond 3.

1.5 Relevant Legislation

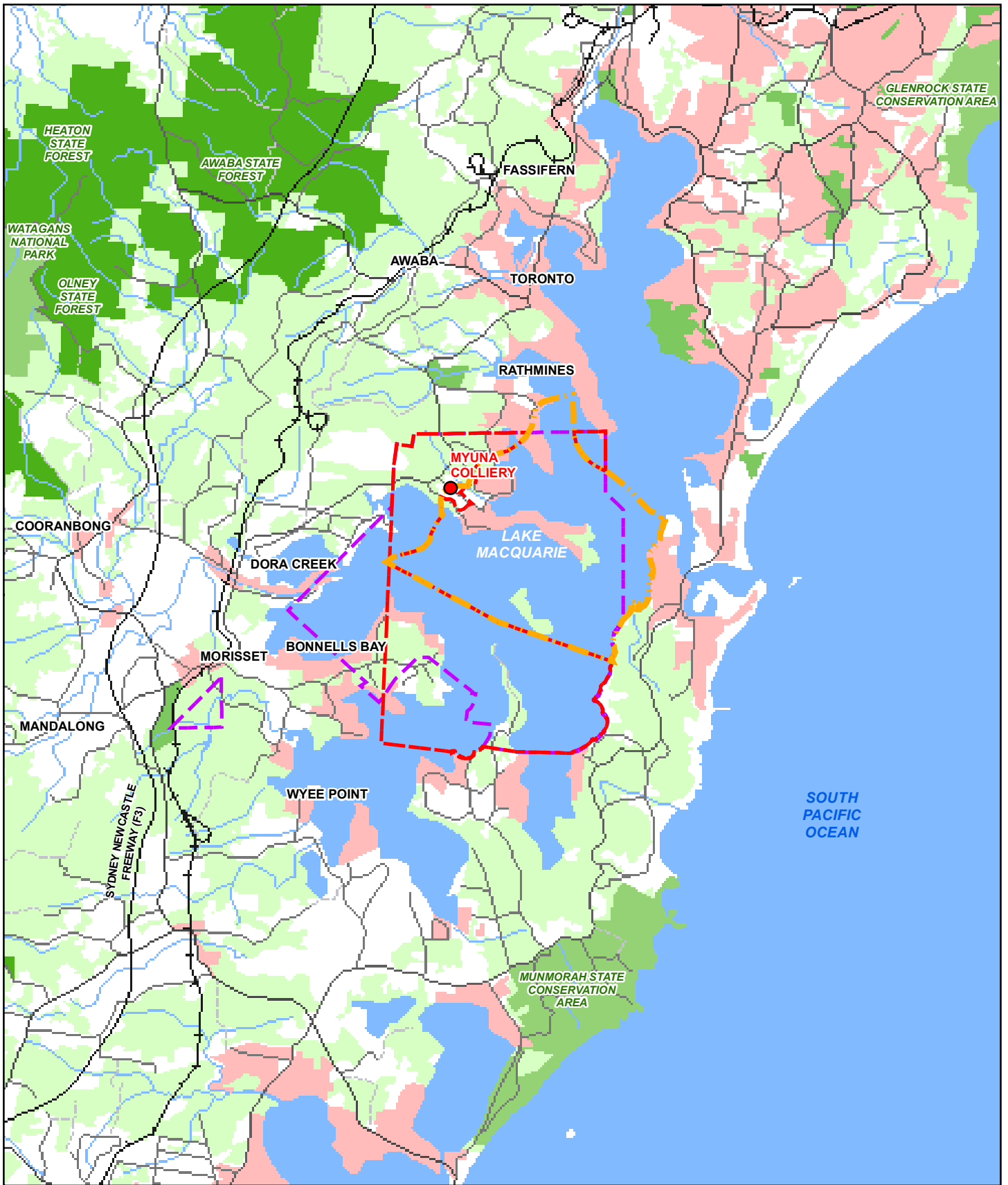
Legislative requirements, government policies and guidelines relating both erosion and sediment control and soil management techniques have been considered in the preparation of this ESCP. The key relevant pieces of legislation are:

- The Environmental Planning and Assessment Act 1979.
- The Water Management Act 1912.
- The Water Management Act 2000.
- The Protection of the Environment Operations Act 1997.

1.6 Relevant Guidelines

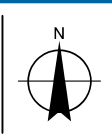
The key guidelines applicable to the development of erosion and sediment control measures for the site are:

- Managing Urban Stormwater: Soils and Construction, Volume 1 (Landcom, 2004) and Volume 2E – Mines and Quarries (Department of Environment and Climate Change, 2008).
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000).



—+— Existing Rail	■ Lake	■ Nature Conservation Reserve
— Principal Road	■ Built up areas	■ State Forest
— Secondary Road	■ Recreation area	■ Forest Or Shrub
— Minor Road		■ Myuna Colliery 1977 Development Consent SH110-148
--- Track		■ Project Application Area - Myuna Coal Mine MP10_0080 MOD1
— Watercourse		■ Mining Lease 1638

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Centennial Myuna Pty Ltd
 Water Management Plan
 Locality Plan

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Date	1 Dec 2021

Figure 1-1

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2. Myuna Colliery

2.1 Soils/Geology

The Surface Facilities Area is located within a natural depression in the landscape where the predominant soil landscape is the Awaba. As a majority of the Surface Facilities Area has hardstand as a ground cover erosion is limited.

Within the Approved Project Area, the Environmental Assessment (AECOM; 2011) identified three key soil landscapes including the Awaba, Doyalson and Wyong landscapes.

The Awaba and Doyalson landscapes are defined as erosional while the Wyong landscape is generally poorly drained floodplain and alluvial material, typically found within drainage lines and along the edges of Lake Macquarie (AECOM; 2011). A large majority of the soils in the nearby Wangi area are classed as belonging to the Awaba soil landscape.

2.2 Surface Facilities Area

The underground mining operations are supported by surface facilities. These surface facilities are located on Wangi Point Road and include administration buildings, workforce amenities, mining support infrastructure, coal storage, a Coal Handling Plant and maintenance and storage area. The location of these surface facility elements is provided on **Figure 2-1**.

2.3 Assessment Criteria for Surface Water Quality

The locations of existing and proposed LDPs are shown on **Figure 2-1**. The water quality concentration limits for the existing LDP009 and LDP0010 are summarised in **Table 2-1**.

Table 2-1 Water Quality Concentration Limits for EPL 366

Pollutant	Unit of Measure	Daily Concentration Limit, LDP 9	Daily Concentration Limit, LDP 10
Oil and Grease	mg/L	10 mg/L	10 mg/L
pH	pH	6.5 – 8.5	6.5 – 8.5
Total Suspended Solids	mg/L	50 mg/L	50 mg/L






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LEGEND

-  Licensed Discharge Point
-  Watercourse
-  10m Contours



Centennial Myuna

Centennial Myuna Pty Ltd
 Water Management Plan

Job Number | 22-18127-02
 Revision | A
 Date | 16 Jun 2023

**Surface Facilities Area and
 Licensed Discharge Points**

Figure 1-2

3. Water Management

This Water Management section will focus on clean and dirty water management at the surface. Clean water is defined as water from vegetated catchments and hardstand areas that do not involve processing and preparation of coal. Dirty water is defined as water from hardstand areas used for processing and preparation of coal, and coal stockpile areas.

The following sections outline the existing water management features current at Myuna Colliery. **Figure 3-1** indicates the overall water management schematic for Myuna Colliery.

3.1 Clean Water Management

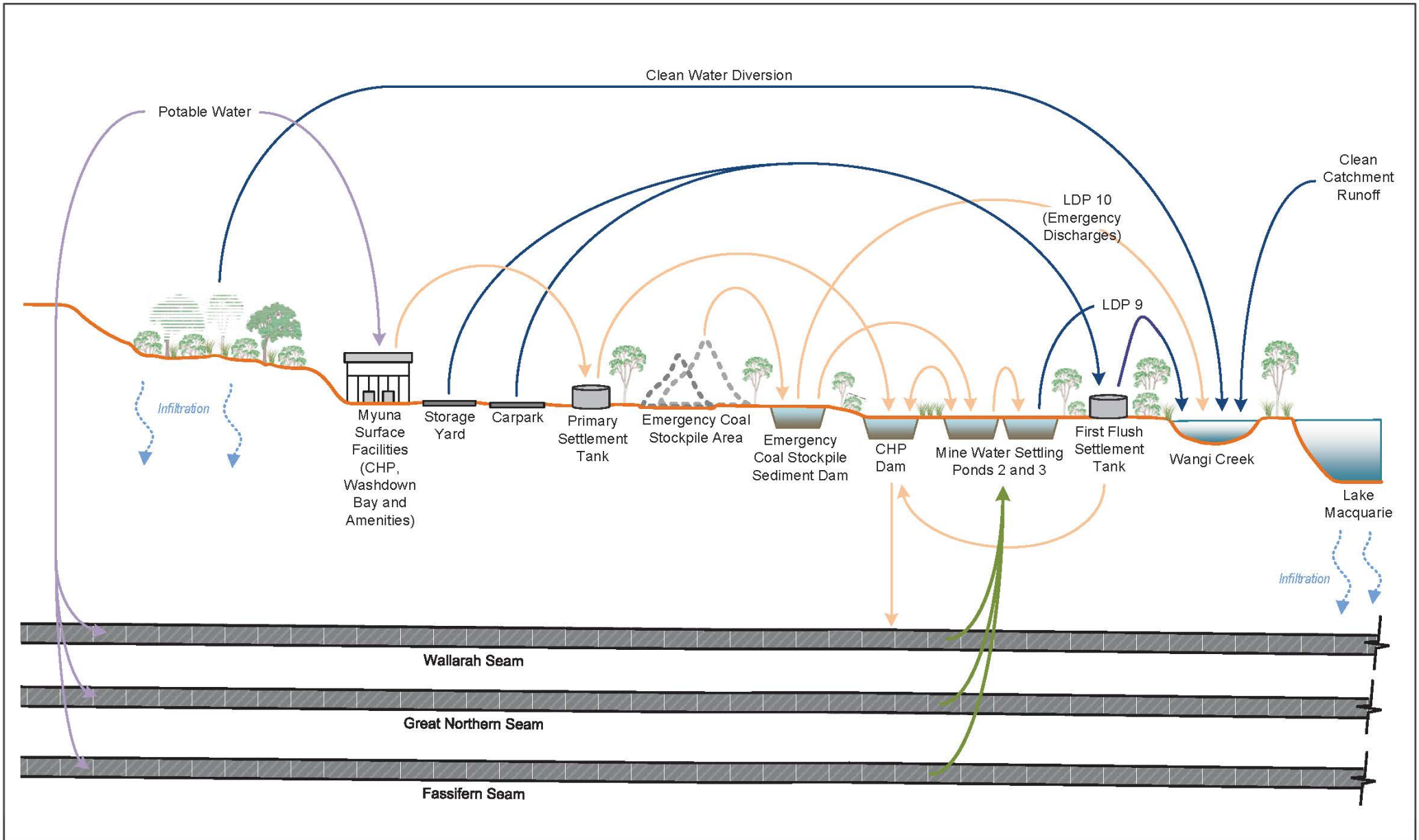
The following sections discuss the management of clean water relevant to each component within the Surface Facilities Area.

3.1.1 Buildings

Roof runoff from the administration and bathhouse buildings is captured and directed to the underground piped stormwater network and flows into the first flush settlement tank located north of the Surface Facilities Area. The workshop building roof water is conveyed to a piped stormwater network which conveys flow directly downstream to Wangi Creek. The first flush settlement tank (GPT) is either directed to the CHP Dam or LDP 9.

3.1.2 Hardstand Areas

Within the Surface Facilities Area, there are clean hardstand areas including the carpark and materials yard. Runoff from these areas is conveyed to the first flush settlement tank which can discharge to LDP 9. To maintain these hardstand areas as clean catchments, regular sweeping is undertaken, and these areas are also regularly inspected to ensure that they remain clean.

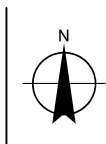


	Clean water	Groundwater	<small>© 2016. Whilst every care has been taken to prepare this figure, GHD make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the figure being inaccurate, incomplete or unsuitable in any way and for any reason.</small>	LOCATION Myuna	Centennial Myuna Pty Ltd Water Management Plan Water Management Schematic		Centennial Coal
	Potable water			SEAM NA			
	Dirty water			DRAWN SM			
	Groundwater			CHECKED TD			
				APPROVED LH		DATE June 2023	Figure 3-1
				SCALE NTS			



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LEGEND

- Licensed Discharge Point
- Dirty Water Catchments
- First Flush Tank
- Watercourse
- LDP9
- 10m Contours
- Wangi Creek



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Water Management Plan

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Clean Water Catchment Areas Figure 3-2

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3.1.3 Clean Water Diversions

The diversion of surrounding clean water catchments is an effective way of mitigating concentrated runoff away from areas of coal operations.

The clean water channels are constructed to convey the time of concentration, 20 year Average Recurrence Interval (ARI) storm event and are lined such that erosion within the channel is mitigated. The 20 year ARI design storm event is in line with the guidelines documented in *Managing Urban Stormwater, Volume 2e* (DECC; 2008), for non-erosive hydraulic capacity of drainage controls.

The topography surrounding the Surface Facilities Area makes the diversion of external clean catchment runoff critical to an effective water management system. Several clean water diversions have been implemented as part of the Approved Project.

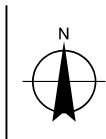
The clean water diversion locations are provided in **Figure 3-3**.

To determine the conveyance of the existing diversion structures, the catchment area and estimated runoff flow were determined using the Probabilistic Rational Method. The outcomes are provided in **Table 3-1**.



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LEGEND

- Licensed Discharge Point
- Clean Water Diversions
- Watercourse
- 10m Contours
- Clean Water Pit and Pipe Network



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 Water Management Plan

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Clean Water Diversion
 and Stormwater Network

Figure 3-3

Table 3-1 Clean Water Catchment Diversion Flows

Diversion Location	Purpose	Approximate Contributing Catchment Area (ha)	Estimated Channel Flow (20 year ARI, L/s)
Clean Water Diversion 1	Diverting the south eastern external catchment around the pit top to the clean water drainage network.	3.10	440
Clean Water Diversion 2	Diverting the southern external catchment to the clean water drainage network.	4.80	630
Clean Water Diversion 3	Diverting the western external catchment to the clean water drainage network.	1.10	180
Clean Water Diversion 4	Diverting the northern external catchment to clean water drainage network.	1.00	170
Clean Water Diversion 5	Diverting the northern external catchment to clean water drainage network.	3.40	470
Clean Water Diversion 6	Diverting the western catchment of the Coal Stockpile to Wangi Creek.	2.30	340
Clean Water Diversions 7	Diverting the western catchment of the Coal Stockpile to Wangi Creek.	0.50	90
Clean Water Diversion 8	Diverting the clean water from the internal Haul Road to Wangi Creek.	1.60	250
Clean Water Diversion 9	Diverting the north western external catchment to the clean water drainage network.	1.00	200

As indicated in **Table 3-1**, the clean water diversions cater for flows between 90 to 630 L/s in a 20 year ARI event storm. A number of these diversions convey flow to a drainage network to carry it to the identified discharge locations.

3.2 Dirty Water Management

Dirty water management structures are to be consistent with the requirements of Managing Urban Stormwater – Soils and Construction Volume 1 (Landcom, 2004) and Volume 2E: Mines and Quarries (DECC 2008).

Within the Surface Facilities Area there are two key areas where dirty water management is required to mitigate the risk of coal-laden water being discharged from the colliery downstream into Wangi Creek. These two areas can be identified as the CHP processing area and storage yard and the Emergency Stockpile Area.

Dirty water runoff from the CHP processing area and storage yard is directed through a series of open drains, and a drainage network to the Primary Settlement Tank. The Primary Settlement Tank has a limited volume and acts to capture large sediment material conveyed in runoff before discharging into the CHP Dam. The CHP Dam is where the settlement of coal material occurs. The sizing and recommended operation of the CHP Dam and Emergency Stockpile Dam are discussed in detail within Section 5.3.

The dirty water catchments are shown on **Figure 3-4** while the dirty water diversions are shown on **Figure 3-5**.

3.3 Water Management Structures

Details of the water management structures associated with the Myuna Colliery Surface Facilities Area are provided in **Table 3-2**. The capacity of clean water structures was not considered as part of this assessment as their respective catchment area contributing to each of the structures was not altered as a result of the Approved Project.

Table 3-2 Water Management Structures

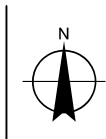
Location	Purpose	Water Type	Catchment Area (ha)	Capacity (ML)
Workshop Washdown Sump	Capture water from workshop washdown bay and remove hydrocarbons	Dirty	0.2	0.25
Primary Settlement Tank	Provides a primary capture and settlement function for the Coal Handling Plant Dam.	Dirty	2.84	0.04
First Flush Settlement Tank	Emergency fail safe for pollution events in carpark or hardstand	Clean or Dirty	2.43	0.30
Coal Handling Plant Dam	Receives water from the captured flow in the Primary Settlement Tank.	Dirty	0.93	1.05
Mine Water Settling Pond 2	Receives mine water from the underground, dewatering activities and overflows from the Coal Handling Plant Dam and	Clean (mine water)	0.1	1.80

Location	Purpose	Water Type	Catchment Area (ha)	Capacity (ML)
	some surrounding runoff.			
Mine Water Settling Pond 3	Receives overflows from Mine Water Settling Pond 2.	Clean	0.1	1.65
Emergency Coal Stockpile Sediment Dam	Receives dirty water from the Stockpile Area and provides a settlement function	Dirty	2.58	4.55



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LEGEND

- Licensed Discharge Point
- CHP Processing Area and Storage Yard
- Emergency Coal Stockpile Area
- Pit Top General
- 10m Contours
- Watercourse



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 Water Management Plan

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Date	1 Dec 2021

Dirty Water Catchment Areas **Figure 3-4**

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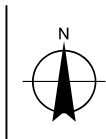
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Data source: © LPMA: DCTB & DTDB, 2007/2012; AECOM: LDP data, 2009. Nearmap: Aerial dated 20160504, extracted 20160720. Created by:








Paper Size A4
 0 12.525 50 75 100
 Metres




Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56



LEGEND

-  Dirty Water Pump Locations
-  Licensed Discharge Point

-  10m Contours
-  Transfer Pipeline
-  Dirty Water Pit and Pipe Network

-  Watercourse
-  Dirty Water Flow Paths
-  Injection Point



Centennial Myuna Pty Ltd
 Water Management Plan

Dirty Water Flow Paths
 and Pipe Network

Job Number
 Revision 1
 Date 1 Dec 2021

Figure 3-5

C:\GIS_Data\Maps\ARC\GIS\Deliverables\North\Myuna\WMP Site Updates 2021\WMP_007_DirtyWaterDiversions_1_20210817.mxd

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Data source: © LPMA: DCTB & DTDB, 2007/2012; AECOM: LDP data, 2009; Centennial: Drainage network, 2012; Nearamap: Aerial dated 20160504, extracted 20160720. Created by:

3.4 Existing Watercourses

There are named and un-named watercourses that either originate in or pass through the Approved Project Area. Each of these watercourses contributes to Lake Macquarie and the named watercourses include Sawmill and Wangi Creek.

Only Wangi Creek is directly influenced by discharge from the surface facilities area, however mine workings are located beneath several other watercourses as well as Lake Macquarie.

The Myuna Colliery Surface Facilities Area is in the lower reaches of Wangi Creek. Adjacent to the surface facilities area, Wangi Creek is reasonably well defined with a width in the order of 5 m and the invert of the creek is vegetated.

3.4.1 Works within the Riparian Zone

Any works with a defined riparian zone of a creek are to be carried out in accordance with the guidelines of Department of Water and Energy (2008). These guidelines focus on the following key requirements:

- Maintaining the natural geomorphic processes, through the accommodation of the existing watercourse, allow for natural movement of sediment, woody debris, and not allowing for an increase or the creation of scour and erosion within the existing watercourse.
- Maintain the existing watercourses hydrologic function through accommodation of low flows and not altering the natural bank full or flood flows.
- The use of scour protection when required for the protection of existing banks, using placed rock.
- Visual inspections and maintenance on the watercourse during the works.

4. Erosion and Sediment Control

4.1 General Erosion and Sediment Controls and Management Principles

Erosion and Sediment controls shall be implemented at all stages of the Colliery operations with implementation controls critical within the Colliery's construction and maintenance phases. Erosion and Sediment Controls will be designed and applied in accordance with the Soils and Construction, Managing Urban Stormwater, Volume 1, 'The Blue Book' (2008) guideline.

As Myuna Colliery only has mining operations underground, typical impacts from surface extraction such as topsoil stripping and minimal surface excavations do occur though are minimal and not undertaken for mining purposes. Erosion and sediment control requirements are therefore limited for the Colliery to include:

- Minimisation of disturbance footprints for activities such as the construction of surface infrastructure and site maintenance.
- Separation of clean and dirty water catchments runoff.
- The effective management and treatment of dirty water runoff from stockpile and processing areas.

4.2 Minimising Disturbance Footprints

A staged and progressive approach to disturbance activities is the best method of minimising disturbed areas. This can be achieved through keeping the disturbance area limited to the smallest practical area required at the time of the activity and limiting the time that the area is disturbed.

Erosion processes can be effectively managed with the use of groundcover. Groundcover can include the use of natural (such as mulch, grass seed and hydro-mulch) or artificial products (such as Jute-mesh, Geo-fabric and chemical soil stabilisers) to cover a disturbed surface protecting it from wind and water, the two agents of soil erosion.

4.3 Temporary Erosion and Sediment Control Measures

Prior to any construction activity, temporary erosion and sediment controls shall be installed. The following are temporary erosion and sediment controls that are currently being utilised at Myuna Colliery. The installation of these controls should be in accordance with the specification detailed in the Managing Urban Stormwater, Soils and Construction (2004) standard drawings attached in Appendix B.

4.3.1 Sediment Fence

Within the Surface Facilities Area where areas of small construction are required with limited disturbance, a Sediment Fence will be used effectively to manage sediment transport. Sediment Fences act to trap sediment that is mobilised from concentrated runoff across a disturbed area. The fence should only be temporary and should be maintained regularly.

Sediment Fences shall be installed on the contour and downstream of the disturbed surface. Fences shall not be located within concentrated flow paths but in positions where sheet flow is adequately filtered before leaving the site. Sediment fences shall be installed in accordance with the Sediment Fence Standard Drawing (SD6-8) (Landcom; 2004) attached in Appendix B.

4.3.2 Inlet Pit Protection

Where disturbance activities are around a stormwater drainage network of pits and pipes, it is recommended that sedimentation is controlled through the application of inlet pit protection measures. Pit protection measures provide a barrier for sediment laden runoff from entering a pit network and silting up the network of pipes. Inlet pit protection shall be installed in accordance with the Inlet Pit Protection Standard Drawing (SD6-11) (Landcom; 2004) attached in Appendix B.

4.3.3 Small Temporary Sediment Traps

In instances where temporary disturbance activities exceed the manageable capacity of sediment fences, it is recommended that small temporary sediment traps are installed. These traps can be implemented quickly from construction materials or simply from shaping an area of earth. It is expected that these small temporary sediment traps would be operated similar to a Type D Sediment Basin. A temporary sediment trap shall be installed in accordance with the type D sediment basin standard drawing (SD6-4) (Landcom; 2004) attached in Appendix B.

5. Implementation and Monitoring

5.1 Plan Implementation

The requirement for erosion and sediment control measures at Myuna Colliery are largely restricted to the Surface Facilities Area with only limited disturbance activities undertaken as part of daily mining operations.

The following sections outline a summary of the recommended mitigations measures to minimise erosion and sediment impacts during the operation of the Myuna Colliery.

5.2 Clean Water Management

5.2.1 Clean Water Diversions and Drainage Network

To maintain the nominated clean hardstand areas as clean catchments, regular sweeping of these areas will continue to be undertaken. These areas are also regularly inspected to ensure that they remain clean.

5.2.2 Rehabilitation of Drainage Lines

Where drainage lines are to be rehabilitated, stabilisation of the channel should be designed and installed such that the stabilisation will remain on long term basis. During the rehabilitation process, temporary erosion and sediment control measures need to be in place to mitigate the transport of sediment from the rehabilitation area.

5.3 Dirty Water Management

The current requirements from the consent conditions indicated in **Table 1-1** is that the Myuna Erosion and Sediment Control Plan will be consistent with the requirements of Managing Urban Stormwater – Soils and Construction, Volume 1 and Volume 2E: Mines and Quarries (Landcom 2004 and DECC 2008).

In determining the requirements for sediment capture within mining operations, Section 6 of the Department of Environment and Climate Change (DECC, now OEH) guidelines outlines that controls should be sized based on the length of disturbance, the type of sediment and sensitivity of the receiving environment. **Table 5-1** summarises the assessment criteria for sediment basin sizing for Myuna Colliery.

Table 5-1 Assessment Criteria for evaluating existing dirty water management storages as Sediment Basins

Purpose	Condition
Water Quality Treatment	90 th Percentile up to a 5 day Management Period
Duration of Disturbance	Greater than 3 years
Coefficient of Volumetric Runoff	0.9
Soil Erodibility Factor	0.05
Sensitivity of Receiving Environment	Standard
Sediment Retention Basin Type	D or F, to cater for settling of coal fines added by flocculent

5.3.1 CHP Dam

The CHP Dam captures runoff from the dirty water catchments as indicated in **Figure 3-4** and **Figure 3-5**. The dam is dewatered to the underground workings water storage by a submersible pump and drainage line. The CHP Dam is managed to prevent overflow into the settlement dams. If overflow occurs the water will mix with settling pond water before being discharged offsite through LDP 9 into Wangi Creek.

5.3.2 Emergency Stockpile Dam

The Emergency Coal Stockpile Dam captures runoff from the Emergency Coal Stockpile area as indicated in **Figure 3-4**. The dam is located within the western corner of the Emergency Stockpile Area which is bound by a bund approximately 1 m high and a storage depth of approximately 0.5 m. The Emergency Coal Stockpile area is used as a dam during an extreme rainfall event.

Dirty water that is captured in the Emergency Stockpile Dam is dewatered to either the CHP dam or directly into the underground workings. If the capacity of the dam is exceeded, then the dam will overflow into Wangi Creek via LDP 10.

5.4 Monitoring

To enable ongoing assessment of water quality discharged from Myuna Colliery, the existing monitoring program is recommended to be maintained. The minimum water quality assessment criteria is summarised in **Table 2-1**. The current monitoring program is outlined in **Table 5-2**.

Table 5-2 Surface Water Monitoring Program

Location	Frequency	Monitored Parameters
LDP 10	Daily During and Discharge	pH, TSS, oil and grease, EC, turbidity.
LDP 9	Monthly	pH, TSS, oil and grease, EC, turbidity.
LDP 9	Quarterly	Physicochemical - EC, pH, TSS, turbidity. Nutrients - Total phosphorus. Cations - Calcium, magnesium, potassium, sodium, sulphur. Metals (dissolved and total) - Aluminium, antimony, arsenic, barium, boron, cadmium, cobalt, copper, iron, lithium, manganese, molybdenum, nickel, selenium, titanium, vanadium, zinc Other parameters - Oil and grease, silica.
Upstream		
Downstream		
Wangi Lake		
T2 (5m) T2 (10m)	Quarterly	Manganese (dissolved)

The surface water monitoring locations for Myuna Colliery are indicated on **Figure 5-1**.

5.5 Maintenance

The maintenance program requirements are critical to providing certainty that structures do not fail and are operated as intended. To assist in the program of maintenance, regular site inspections and self-auditing must occur on site.

Site inspections, at a minimum, should be completed by the Environmental and Community Coordinator and occur:

- At least weekly.
- Immediately following rainfall events that exceed 40 mm in 24 hours.

Any issues identified during inspections are rectified as soon as is practicable.

The standard requirements for the maintenance of each of the site erosion and sediment control elements are detailed below.

Sediment trapped behind sediment fences or in stilling ponds or similar must be regularly cleaned out with material stockpiled in an appropriate area. Where there is a potential for sediment to migrate off the site, special consideration must be made to these areas to be certain that this risk is mitigated with the appropriate controls.

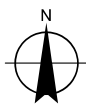


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LEGEND

- Licensed Discharge Point
- Surface Water Monitoring Location
- Watercourse
- Footprint
- Surface Facilities Area

Paper Size A4
 0 55 110 220 330 440
 Metres
 Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56



**Centennial
Myuna**

Centennial Myuna Pty Ltd
Water Management Plan

Surface water quality
monitoring locations

Job Number	1
Revision	1
Date	1 Dec 2021

Figure 4-2

The operation of clean water diversions and dirty water channels must be regularly inspected. Any low points within a channel where overtopping may occur in large events and the integrity of the channel could be at risk must be managed.

Pit protection measures and pipe and pit networks are to be checked regularly. During inspections an assessment of the pit protection measures effectiveness from indicators such as any visible flow paths should be undertaken. Pit protection measures should not create nuisance flooding or safety concerns. If such events occur then a different sediment control option will be evaluated.

The maintenance of all erosion and sediment control measures are required until disturbance activities and site rehabilitation are completed.

5.6 Reporting

Erosion and sediment issues at the site are reported at daily and weekly meetings and addressed or escalated as required.

5.7 Roles and Responsibilities

For members of the management team, there are varying responsibilities. These include:

- **Mine Manager:**
 - Manage operations and reporting undertaken in accordance with EPL 366.
 - Manage operations in accordance with the objectives of the Erosion and Sediment Control Plan.
 - Manage the resources available to site personnel to achieve the objectives of the Erosion and Sediment Control Plan.
- **Environmental and Community Coordinator:**
 - Assist the Mine Manager in complying with the requirements of EPL 366.
 - Investigate opportunities for improvement in water management including re-use and reduction initiatives.
 - Annual performance review for water management.
 - Annual reporting on issues of water management.
 - Update the Erosion and Sediment Control Plan with additional relevant information, as it becomes available.
 - Manage the relevant reporting, review and consultation conditions of the Project Approval.
 - Monthly internal report.
 - Reporting of breaches and discharge events.
- **Personnel:**
 - Will undertake operations in accordance with the objectives of the Erosion and Sediment Control Plan.
 - Report any areas where controls have become ineffective or have failed and areas they believe controls may be required.
- **Contractors:**
 - To ensure that operations are undertaken in accordance with the objectives of the Erosion and Sediment Control Plan.

- Report any areas where controls have become ineffective or have failed and any areas they identify where they believe controls may be required.

5.8 Training

Personnel are provided with instruction and training to possess the necessary skills and knowledge to competently perform their allotted tasks and to be aware of the associated hazards and risks to this Erosion and Sediment Control Plan.

5.8.1 Supplementary Training

On the job training is the preferred method, however this will be supplemented by other means whenever necessary. Where a need for specific training has been identified for personnel, such specific training will be either supplied or resourced.

5.8.2 Induction

New employees and contractors are required to complete an induction, which includes an environmental component that addresses the hazards and risks associated with the Myuna Colliery water management system.

5.9 Review

Myuna Colliery management team will review the performance and/or compliance of this Erosion and Sediment Control Plan to identify any issues that may affect the integrity and effectiveness of this Plan. A review should be undertaken on a period basis or as a result of:

- A statutory requirement.
- A regulatory requirement.
- Environmental change, or significant event.
- Significant discharge incident.
- Significant changes to water control structures.
- Decommissioning.

The objectives of an audit/review would be to:

- Maintain compliance with statutory requirements.

If changes to this Erosion and Sediment Control Plan are made, the following key personnel are, as a minimum, required to review the Erosion and Sediment Control Plan before finalisation:

- Mine Manager.
- Environmental and Community Coordinator.

6. References

- AECOM (2011), *Myuna Colliery, Extension of Mining, Environmental Assessment*, Feb 2011, Centennial Myuna
- Department of Environment and Climate Change, (2008), *Managing Urban Stormwater Volume 2E Mines and Quarries*
- Department of Environment and Heritage, (2000), *ANZECC / ARMICANZ 2000, National Water Quality Management Strategy: Australian and New Zealand guidelines for fresh and marine water quality* Canberra
- GHD, (2011), *Water Management Assessment, Myuna Colliery*
- Landcom (2004), *Managing Urban Stormwater: Soils and Construction Volume 1*, 4th Edition March 2004, NSW.
- Office of Environment and Heritage (NSW), 2011, *Environment Protection Licence Number 366 (EPL 366)*, 21 April 2011

Appendix A
Sediment Basin Calculations

Coal Handling Plant Dam
Emergency Stockpile Dam



Memorandum

Site Data Sheet

Site Name: Myuna Colliery
Site Location: Wangi Wangi
Rainfall Precinct: Wyong

Site area	Sub-catchments				Remarks
	CHP Dam 5-Day Rainfall	Emergency Stockpile Dam 5-Day Rainfall	CHP Dam 2-Day Rainfall	Emergency Stockpile Dam 2-Day Rainfall	
Total catchment area (ha)	3.1	2.33	3.1	2.33	
Disturbed catchment area (ha)	3.1	2.33	3.1	2.33	

Soil analysis (enter sediment type if known, or laboratory particle size data)

Sediment Type (C, F or D) if known:	D	D	D	D	From Appendix C (Landcom; 2004)
% sand (fraction 0.02 to 2.00 mm)					Soil texture should be assessed through mechanical dispersion only. Dispersing agents (e.g. Calgon) should not be used
% silt (fraction 0.002 to 0.02 mm)					
% clay (fraction finer than 0.002 mm)					
Dispersion percentage					E.g. enter 10 for dispersion of 10%
% of whole soil dispersible	0	0	0	0	See Section 6.3.3(e) (Landcom; 2004). Auto-calculated
Soil Texture Group	D	D	D	D	Automatic calculation from above

Rainfall data

Design rainfall depth (days)	5	5	2	2	See Sections 6.3.4 (d) and (e) (Landcom; 2004)
Design rainfall depth (percentile)	90	90	90	90	See Sections 6.3.4 (f) and (g) (Landcom; 2004)
x-day, y-percentile rainfall event	58.7	58.7	37.2	37.2	See Section 6.3.4 (h) (Landcom; 2004)
Rainfall R-factor (if known)		0	0	0	See Appendix B(Landcom; 2004)
IFD: 2-year, 6-hour storm (if known)	11.5	11.5	11.5	11.5	See IFD chart for the site

RUSLE Factors

Rainfall erosivity (R-factor)	2860	2860	2860	2860	Auto-filled from above RUSLE LS factor calculated for a high rill/interrill ratio.
Soil erodibility (K-factor)	0.05	0.05	0.05	0.05	
Slope length (m)	80	80	80	80	
Slope gradient (%)	1	1	1	1	
Length/gradient (LS-factor)	0.19	0.19	0.19	0.19	
Erosion control practice (P-factor)	1.3	1.3	1.3	1.3	
Ground cover (C-factor)	1	1	1	1	

22/15991/99054

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Calculations

Soil loss (t/ha/yr)	36	36	36	36	
Soil Loss Class	1	1	1	1	See Section 4.4.2(b) (Landcom; 2004)
Soil loss (m ³ /ha/yr)	28	28	28	28	
Sediment basin storage volume, m ³	15	11	15	11	See Sections 6.3.4(i) and 6.3.5 (e) (Landcom; 2004)

Total Basin Volume

Site	C _v	R _{x-day, y-%ile}	Total catchment area (ha)	Settling zone volume (m ³)	Sediment storage volume (m ³)	Total basin volume (m ³)
CHP Dam 5-Day Rainfall	0.90	58.7	3.1	1638	21	1659
Emergency Stockpile Dam 5-Day Rainfall	0.90	58.7	2.33	1231	16	1247
CHP Dam 2-Day Rainfall	0.90	37.2	3.1	1038	21	1059
Emergency Stockpile Dam 2-Day Rainfall	0.90	37.2	2.33	780	16	796



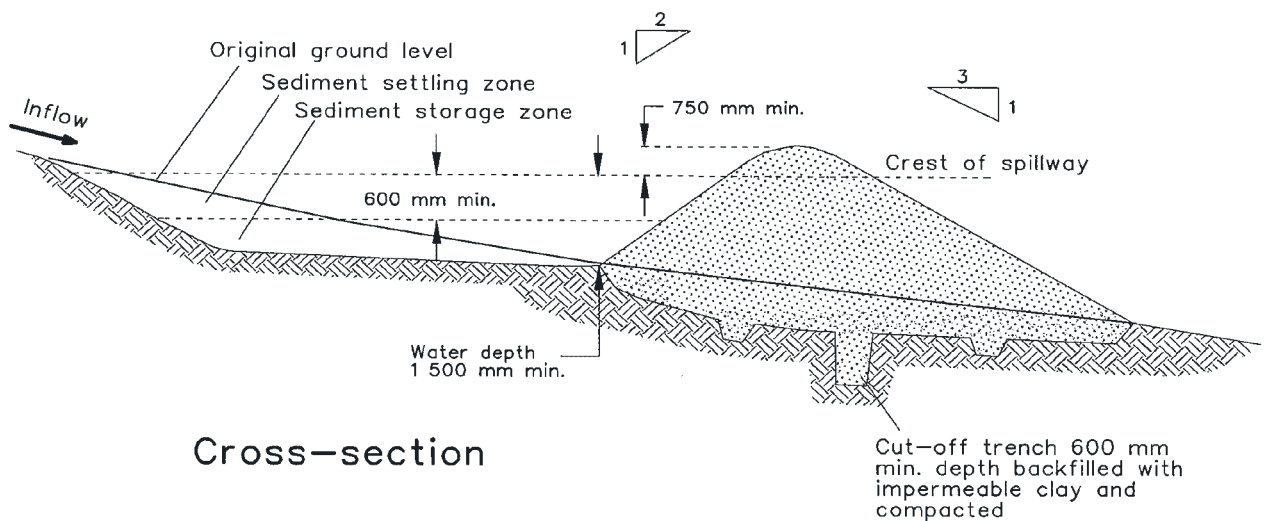
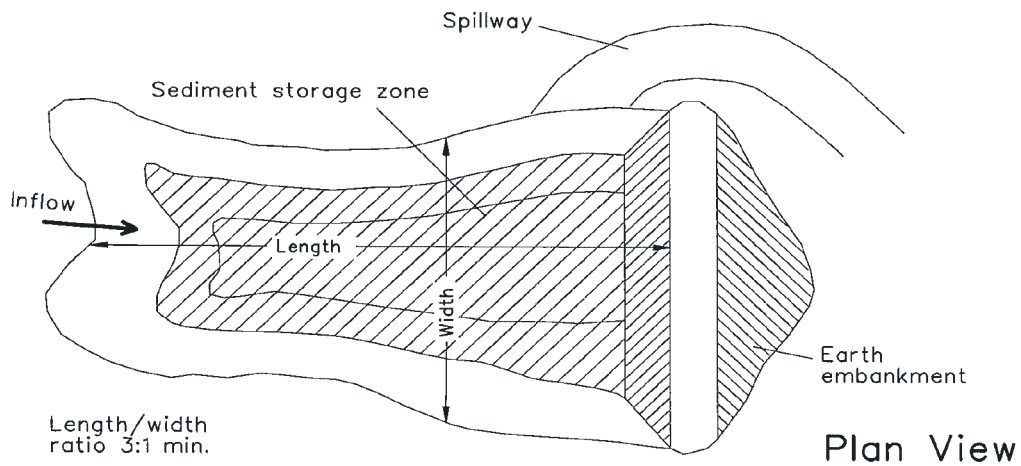
Appendix B

Standard Erosion and Sediment Control Details

SD 6-4 – Earth Basin – Wet (DECC; 2008)

SD 6-8 – Sediment Fence (DECC; 2008)

SD 6-11 – Mesh and Gravel Inlet Filter (DECC; 2008)



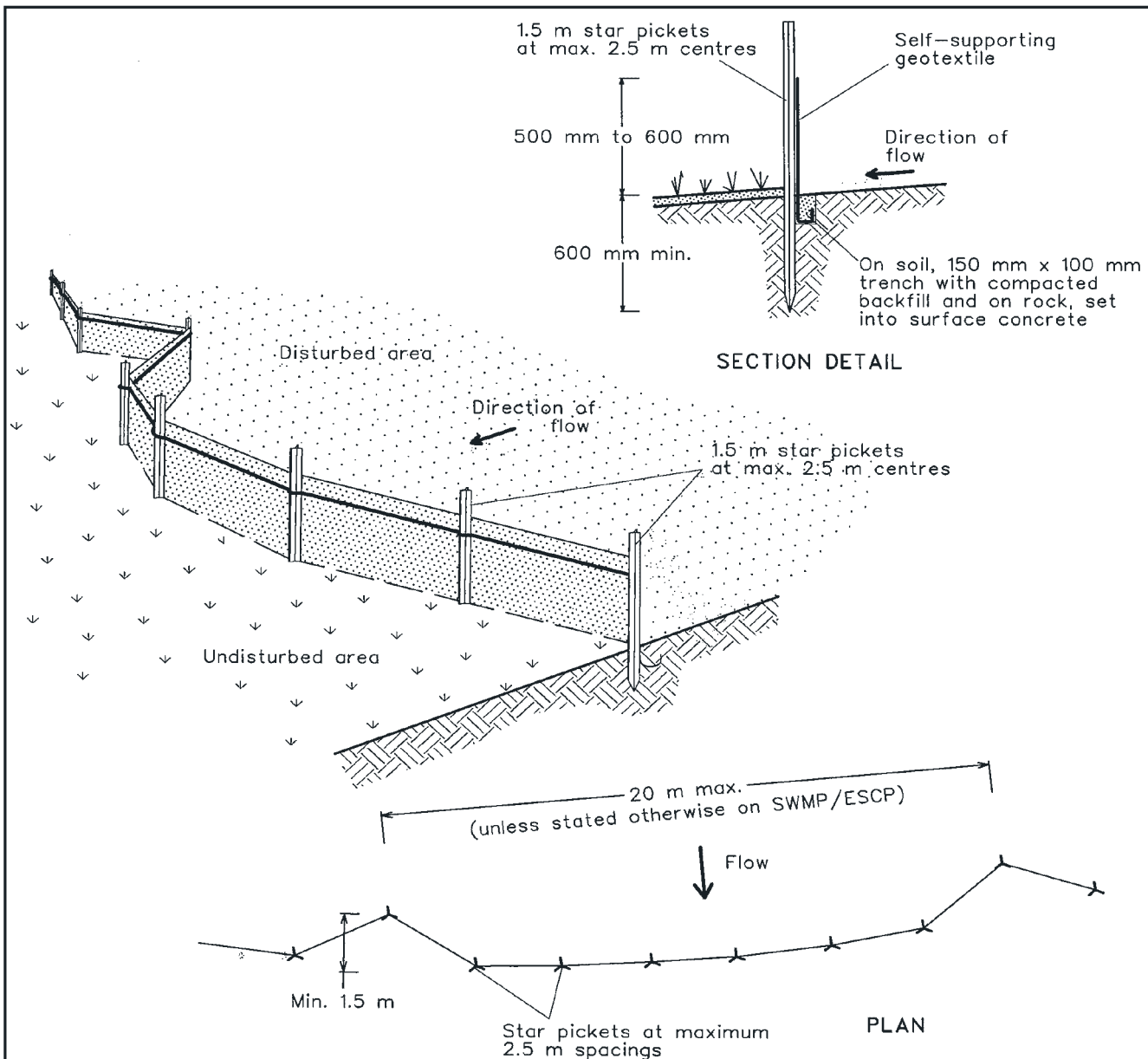
Construction Notes

1. Remove all vegetation and topsoil from under the dam wall and from within the storage area.
2. Construct a cut-off trench 500 mm deep and 1,200 mm wide along the centreline of the embankment extending to a point on the gully wall level with the riser crest.
3. Maintain the trench free of water and recompact the materials with equipment as specified in the SWMP to 95 per cent Standard Proctor Density.
4. Select fill following the SWMP that is free of roots, wood, rock, large stone or foreign material.
5. Prepare the site under the embankment by ripping to at least 100 mm to help bond compacted fill to the existing substrate.
6. Spread the fill in 100 mm to 150 mm layers and compact it at optimum moisture content following the SWMP.
7. Construct the emergency spillway.
8. Rehabilitate the structure following the SWMP.

EARTH BASIN - WET

(APPLIES TO 'TYPE D' AND 'TYPE F' SOILS ONLY)

SD 6-4

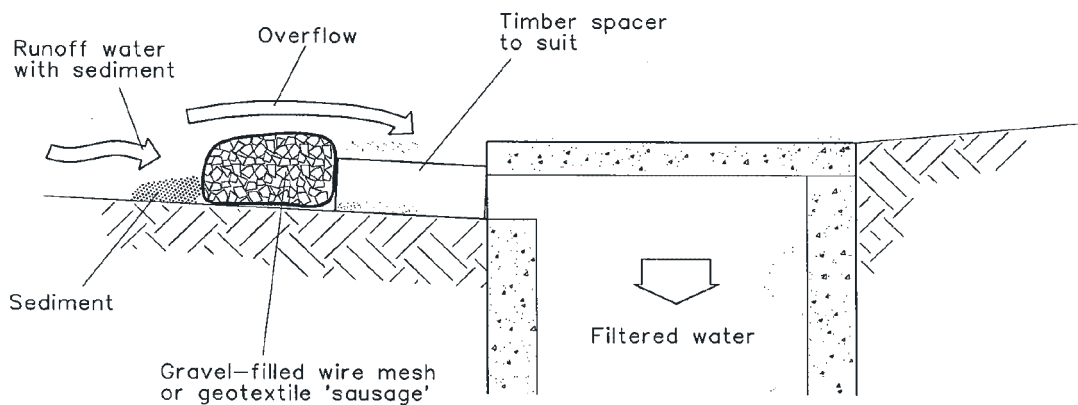
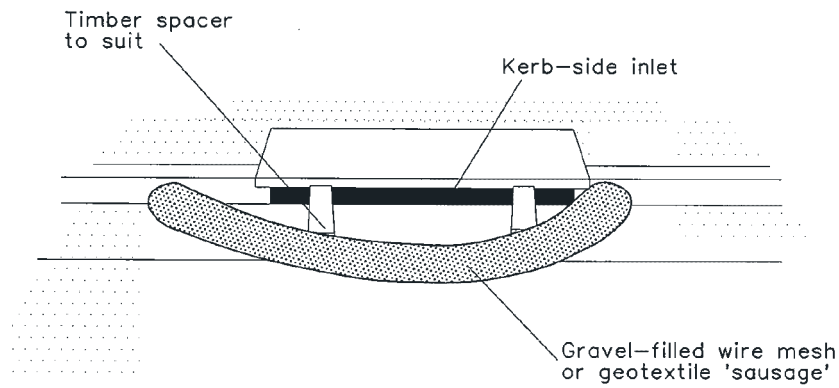


Construction Notes

1. Construct sediment fences as close as possible to being parallel to the contours of the site, but with small returns as shown in the drawing to limit the catchment area of any one section. The catchment area should be small enough to limit water flow if concentrated at one point to 50 litres per second in the design storm event, usually the 10-year event.
2. Cut a 150-mm deep trench along the upslope line of the fence for the bottom of the fabric to be entrenched.
3. Drive 1.5 metre long star pickets into ground at 2.5 metre intervals (max) at the downslope edge of the trench. Ensure any star pickets are fitted with safety caps.
4. Fix self-supporting geotextile to the upslope side of the posts ensuring it goes to the base of the trench. Fix the geotextile with wire ties or as recommended by the manufacturer. Only use geotextile specifically produced for sediment fencing. The use of shade cloth for this purpose is not satisfactory.
5. Join sections of fabric at a support post with a 150-mm overlap.
6. Backfill the trench over the base of the fabric and compact it thoroughly over the geotextile.

SEDIMENT FENCE

SD 6-8



NOTE: This practice only to be used where specified in an approved SWMP/ESCP.

Construction Notes

1. Install filters to kerb inlets only at sag points.
2. Fabricate a sleeve made from geotextile or wire mesh longer than the length of the inlet pit and fill it with 25 mm to 50 mm gravel.
3. Form an elliptical cross-section about 150 mm high x 400 mm wide.
4. Place the filter at the opening leaving at least a 100-mm space between it and the kerb inlet. Maintain the opening with spacer blocks.
5. Form a seal with the kerb to prevent sediment bypassing the filter.
6. Sandbags filled with gravel can substitute for the mesh or geotextile providing they are placed so that they firmly abut each other and sediment-laden waters cannot pass between.

MESH AND GRAVEL INLET FILTER

SD 6-11

This Erosion and Sediment Control Plan (“Report”):

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	L Hammersley	I Joliffe		S Gray		16/8/12
1	G Peard	K Fiatarone				15/6/23

Appendix F – Manganese Discharge from the Myuna Colliery ANZECC/ARMCANZ Study

Myuna Colliery - Centennial Coal

Manganese Discharge from the Myuna Colliery
ANZECC/ARMCANZ Study

March 2004



Manganese Discharge from the Myuna Colliery

ANZECC/ARMCANZ Study

Date Printed	March 2004
Title	Manganese Discharge from the Myuna Colliery, ANZECC/ARMCANZ Study
Job Number	CC/0401-Myuna-Mn
Status	Final
Client	Centennial Coal Pty Ltd/Myuna
Authors	Lévy V, Smith R, Stauber J, Binet M
File Name	Z:\Clients\Myuna Colliery\Reporting\Myuna 2003-03-10.doc
Authorised	Ross Smith



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EXECUTIVE SUMMARY

The following study presents the results of an investigation carried out into the potential impacts of mine-derived inputs of manganese to the receiving water ecosystems of Wangi Bay by Myuna Colliery (Lake Macquarie, NSW) through Wangi Creek. This study was initiated in part to address concerns of the EPA that were triggered by the levels of manganese released by the mine at the licensed discharge point, and the limited availability of data on the toxicity of manganese in marine environments.

This report is composed of two sections. The first section focuses on the current status of Wangi Bay, specifically the manganese content in water and sediments. The second section focuses on the toxicity of manganese and the derivation of a marine receiving water trigger value for manganese.

Current Status

Water and sediment samples were collected along 5 transects; 4 in Wangi Bay and 1 in Myuna Bay, a reference location. Selected water samples were analysed for colloidal and for “free/labile” manganese to facilitate assessment of the bioavailable fraction of total manganese.

The highest manganese concentrations were found for the transect extending along Wangi Creek. Longitudinal mixing was proven efficient with manganese concentrations recorded 200 m from the outlet (5-6.1 µg/L) being considerably lower than those near the outlet (31-340 µg/L). However, lateral mixing in the bay was shown to be incomplete.

Ultrafiltration of the sample and voltammetry analysis both confirmed that the colloidal fraction was negligible and that manganese was essentially present as hydrated and/or as very labile complexes, which constitute the most easily biologically assimilated fractions.

The manganese content of the sediments sampled in Wangi Bay could not be attributed to the colliery, as comparable amounts were recorded at the reference site in Myuna Bay and at other EPA monitoring sites.

This first section concluded that the impact of the mine can only be detected for the dissolved phase in the vicinity of the outlet.

Ecotoxicology

Toxicity tests were carried out on 5 taxonomic groups: a fish; an urchin; a prawn; an oyster; and an alga. These tests included acute and chronic toxicity tests. An acute to chronic ratio (ACR) derived from two of the test species was used to convert the acute test results to chronic no observed effect concentration (NOEC) equivalent



values. The combined set of NOEC values was used to derive a water quality trigger value of 660 µg/L using the methodology of ANZECC/ARMCANZ (2000). This was higher than the draft guideline value of 310 µg/L of WHO (2003 draft), but the latter figure was derived using an assumed essential metal ACR of 2 and conversion to NOEC-equivalent values via an application factor of 5, not measured NOEC values and a measured ACR. Furthermore, the draft WHO guideline was based on a data set that did not include fish test results. If the trigger value derived from the local species testing is used to assess the potential for environmental impacts, the measured manganese concentrations in Wangi Bay would all be acceptable.



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Abbreviation

ACR:	Acute to Chronic Ratio
ANZECC:	Australia and New Zealand Environment and Conservation Council
ARMCANZ:	Agricultural and Resource Management Council of Australia and New Zealand
DS:	Downstream of the Mine
DSWW:	Downstream of the Weir Wall
EC ₅₀ :	Effect Concentration
LC ₅₀ :	Lethal Concentration
IC ₅₀ :	Inhibition Concentration
ICP-AES:	Inductively Coupled Plasma- Atomic Emission Spectrophotometry
ICP-MS:	Inductively Coupled Plasma- Mass Spectrophotometry
LDP1:	Licensed Discharge Point 1
LOEC:	Lowest Observed Effect Concentration
LT ₅₀ :	Lethal Time
NOEC:	No Observed Effect Concentration
NSW-EPA:	New South Wales Environmental Protection Agency
OECD:	Organisation for Economic Cooperation and Development
SSD:	Species Sensitivity Distribution
T1 :	Transect 1
T2 :	Transect 2
T3 :	Transect 3
T4 :	Transect 4
TR :	Reference transect
TV:	Trigger Value
US:	Upstream
US-EPA:	United States Environmental Protection Agency
USWW:	Upstream of the Weir Wall
WHO:	World Health Organisation



1. BACKGROUND

1.1 Generalities

Myuna Colliery is located on the western side of Lake Macquarie (Figure 1, Figure 2), near the township of Wangi Wangi

The colliery is an underground mine; and the majority of its workings are located beneath Lake Macquarie (Figure 3). Historically, coal has been extracted from three seams, the Wallarah, the Great Northern and the Fassifern. Workings are currently consolidated in the Great Northern seam.



Figure 1: Aerial photograph of Lake Macquarie



Figure 2: Aerial photograph of the study area

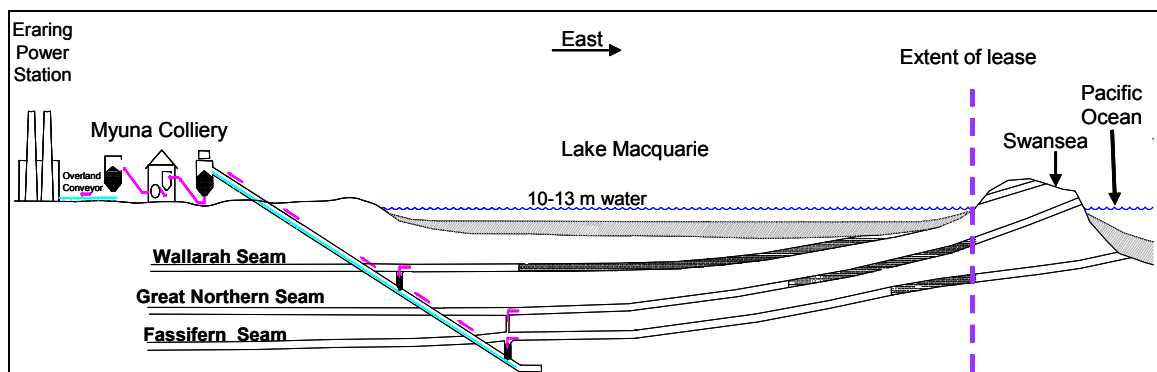


Figure 3: Myuna Colliery seam schematic

To recover the coal and maintain safe and efficient workings, the colliery must extract the water that ingresses into the underground workings. The water is discharged off site into Wangi Creek; an intermittent freshwater creek system located approximately 800 m upstream of Wangi Bay, Lake Macquarie. For the purpose of this report, Wangi Bay is considered the receiving environment for waters discharged from the Colliery.

The water pumped from the individual panels of the three seams contains levels of manganese ranging from 0 to 3.5 mg/L (Figure 4) and average values¹ of: 0.42, 0.94 and 1.20 mg/L for the Great Northern, Wallarah and the Fassifern seam respectively. Currently, the water discharged at the Licensed Discharge Point (LDP1) contains manganese levels typically up to 1 mg/L. However, higher levels of manganese have been reported in the past.

¹ Average value calculated from all data available between January 2001 and September 2003.

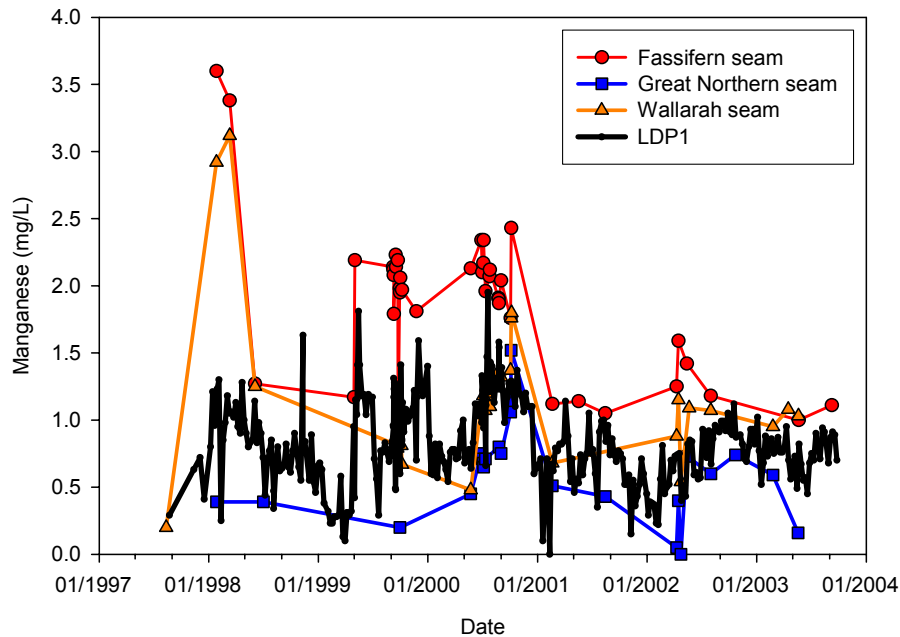


Figure 4: Total manganese concentration in the water pumped from the Fassifern, Great Northern and Wallarah seams and in the water released at LDP1

1.2 Scope

The colliery has been engaged in a pollution reduction program with the EPA since 1997, following elevated levels of manganese being noted in discharge from the Licensed Discharge Point.

In June 2002, investigations commenced into the potential mine-derived inputs of manganese to the receiving water ecosystems of Wangi Bay and Lake Macquarie; and to determine the mixing zone in Wangi Bay for waters discharged from the colliery.

From 2002 results, waters pumped from the colliery (LDP1 Site) contained filterable (<0.45 μm) manganese concentrations up to 990 $\mu\text{g/L}$, while a concentration of 40 $\mu\text{g/L}$ was recorded at the discharge point into Wangi Bay, and concentrations up to 280 $\mu\text{g/L}$ were recorded within Wangi Bay. These values exceed the Clean Waters Regulations 1972 limit and the ANZECC/ARMCANZ (2000) low reliability guideline:

- Under the Clean Water Regulations 1972, the receiving waters of Lake Macquarie are classified as class "C" (controlled) waters, and thereby the concentration of manganese is limited to 0.05 mg/L.
- The ANZECC/ARMCANZ (2000) low reliability trigger value for manganese in marine waters is 80 $\mu\text{g/L}$ (0.08 mg/L).



In January 2003, following the review of the November 2002 report, NSW EPA concluded that "...a more comprehensive monitoring program is needed that demonstrates no adverse environmental consequence of particular concentrations and loads of manganese within the receiving waters of Lake Macquarie"².

They also required "... a water quality monitoring program be conducted over a 12 month period to determine any impacts of filterable manganese discharges from the premises, on receiving waters."³

Which would lead to a review of "...the limits applied to licensed discharge point 1 for filterable manganese..." at the completion of the monitoring program.

These requirements induced a variation of the licence and modification of the "Pollution studies and reduction programs" and the "Special conditions" sections as listed below:

Assessment of Impact of Minewater Discharges on Receiving Waters

U1.1 The licensee must

- (a) *conduct a water quality monitoring program, in accordance with the ANZECC Guidelines for Fresh and Marine Water Quality (ANZECC 2000), that establishes the impacts of filterable manganese discharges on the receiving waters of Wangi Bay; and*
- (b) *submit a report to the Regional Manager, Hunter, that assesses the impacts of filterable manganese discharges from the premises, on the receiving waters of Wangi Bay.*

Completion Date: 1 May 2004

NOTE: *It is the EPA's intention to set discharge limits for filterable manganese at LDP1, based on the report referred to in (b), such that the requirements set out in the Clean Waters Regulation (1972) for Class C (Controlled) Waters are met.*

Additional monitoring

E1.1 For the period 16 January 2003 to 1 June 2004, the licensee must record the following monitoring information:

- (a) *the concentration of filterable manganese (mg/L) in the receiving waters, both upstream and downstream of water discharge point 1, measured at each location on a weekly basis; and*
- (b) *any visual impacts, such as any discolouration of receiving waters, evidence of precipitation or staining of any surfaces, downstream of water discharge point 1, by undertaking weekly inspections*

Note: *Any evidence of environmental harm must be immediately reported to the EPA.*

Several discussions between the EPA, Myuna Colliery and Hydrobiology (Mandalong meeting, July 2003; David Darvall, letter, August 2003 in Appendix A) and correspondence between Michael Warne and Ross Smith (telephone and e-mail) lead to the design of the following project plan:

² <http://www.epa.nsw.gov.au/PRPOEO/NOTICES/N1024904.DOC>:

³ <http://www.epa.nsw.gov.au/PRPOEO/NOTICES/N1024904.DOC>:



Chemistry

- Water sampling (manganese analysis) of on-land sites (upstream and downstream of the mine, upstream and downstream of the weir wall, licensed discharge point).
- Water sampling (manganese analysis) and depth profile (salinity, pH, and turbidity) for four transects in Wangi Bay and one transect in Myuna Bay.
- Sediment sampling (manganese analysis and particle size distribution) for four transects in Wangi Bay and one transect in Myuna Bay.
- Quantification of free and colloidal manganese by ultrafiltration for one transect.
- Quantification of labile and stable manganese by voltammetry for 3 samples.
- Manganese analysis in sediment pore water.

Ecotoxicology

- Comprehensive search of the literature in regards to manganese trigger values.
- Toxicity testing on 5 taxonomic species including: a fish larva (Australian bass); a sea urchin; a rock oyster; a tiger prawn; and a marine alga.
- Derivation of a trigger value.

2. MANGANESE

2.1 Sources of manganese

Manganese is the 10th most abundant element in the earth's crust (Post, 1999). It is a major constituent of basalt, olivines, pyroxenes and amphiboles, and a minor constituent of dolomite and limestone. Manganese is released in the aqueous environment through the weathering of rocks under acidic conditions.

2.2 Manganese in the environment

The fate of manganese in the environment is controlled by pH and redox conditions (Figure 5). Manganese is more soluble at low pH, low redox potentials and when complexed with organic acids such as humic and fulvic acid. Typically manganese is released as Mn(II) before being oxidised into Mn(IV). However, in the absence of an appropriate catalyst the oxidation of Mn(II) to Mn(IV) (with Mn(III) as an intermediate) is kinetically slow. At a pH of 8.4, Mn(II) solutions will remain unoxidised despite the presence of dissolved oxygen (Diem and Stumm; 1984). For the reaction to happen, the solution must be oversaturated in MnCO₃, Mn(OH), or contain "manganese bacteria" or other surface catalysts. Natural sea water is rich in bacteria and, therefore, will be favourable to the oxidation of manganese.

There are over 30 manganese oxide minerals. The most stable is pyrolusite, which is one of the three known mineral polymorphs of MnO₂ (Post, 1999). MnO₂ is the most commonly occurring oxide in nature. MnOOH and Mn₃O₄ have been identified in the



laboratory, but are relatively uncommon in natural conditions (Hajinikitas, 1996). Manganese oxides are present in soils and sediments and are known for their propensity to remove heavy metals by adsorption. In sea water, the conditions are mostly favourable to the deposition of manganese oxides as nodules, micro-concretions, coatings and crusts (Post, 1999). Manganese oxide nodules in the oceans have been extensively studied since their discovery in 1873 (Post, 1999).

At Eh and pH conditions commonly found in nature, Mn(II) is 10^6 - 10^7 times more soluble than Fe (II) and therefore, is more stable with respect to oxidation (Hajinikitas, 1996).

According to Hem (1985), manganese is often present at concentrations greater than 1 mg/L in streams that have received acid drainage from coal mines. As the pH rises, the manganese will slowly oxidise and precipitate. Under anoxic conditions, manganese is extracted from sediments rich in organic matter and will be present in the pore water. The reduction can be chemical (slow kinetics) or biological (faster kinetics).

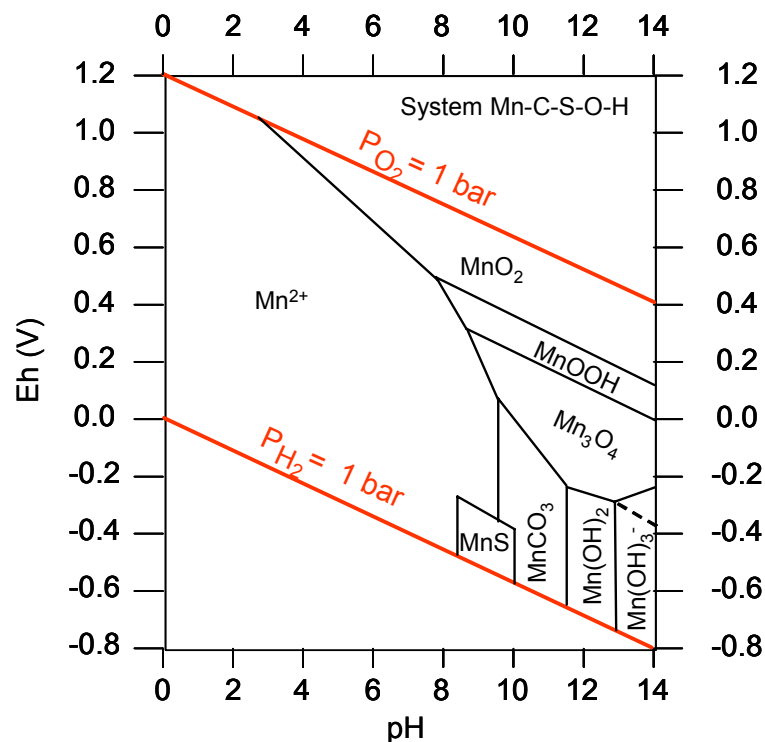


Figure 5: Pourbaix diagram of manganese

System Mn-C-S-O-H; Activities for dissolved species are $Mn = 10^{-6}$, $C = 10^{-3}$, $S = 10^{-3}M$

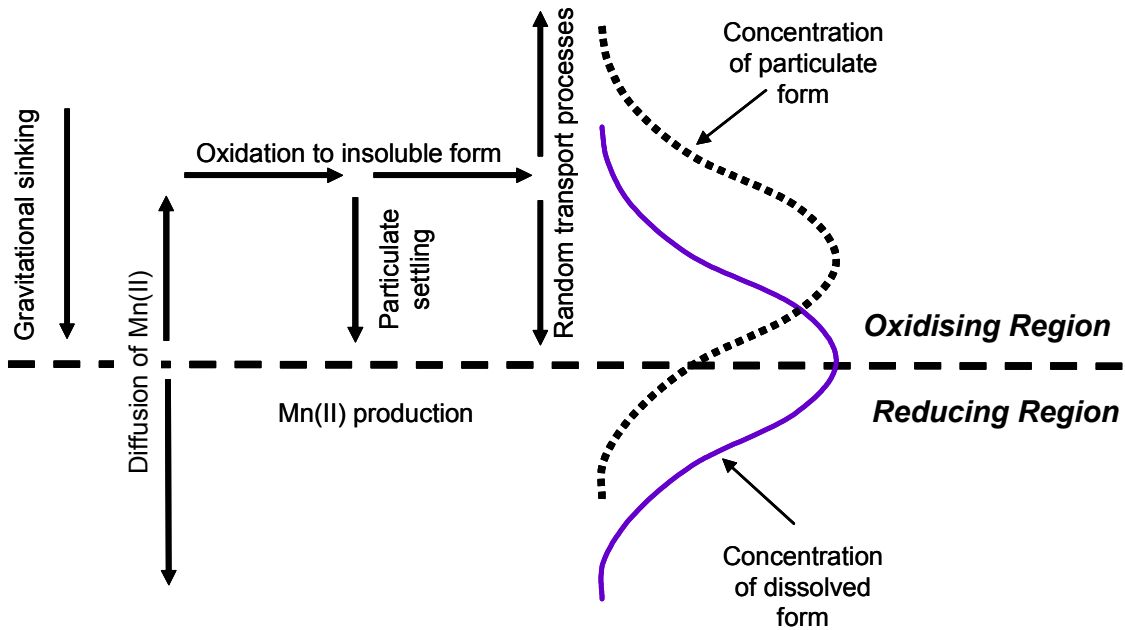


Figure 6: Concentration of dissolved and particulate manganese at the redox boundary formed in water columns, sediments or at the sediment-water interface (from Hajnikitas, 1996)

Manganese values for porewater and sediments found in the literature are collated in Table 1. These values show that manganese concentrations in the environment can be naturally high depending on the mineralogy of the background and in the case of pore water, much higher than the low reliability trigger value listed in the ANZECC/ARMCANZ (2000) guideline.

Table 1: Manganese values from literature

Author	Type	Value
Sea water		
US EPA (1984)	Seawater	0.4-10 µg/L
Porewater		
Stauber <i>unp.</i>	NSW Port	1.5 mg/L
Doyle <i>et al.</i> (2003)	Fennel Bay, Lake Macquarie	1-2.1 mg/L
Boucher and Watzin (1999)	Lake Champlain, USA	23.3-38.9 mg/L
Lewis and Landing (1991, 1992)	Anaerobic layers of open seawater, Saint Lawrence Gulf, Canada	0.5 mg/L
Sediments		
Roy and Crawford (1984)	Lake Macquarie	350-400 mg/kg
Sundby (1981)	Gulf of Saint Lawrence, Canada	1110-5580 mg/kg
Sundby (1977)	Gulf of Saint Lawrence, Canada	46500 mg/kg
Stauber <i>unp.</i>	Sediment in NSW port	345 mg/kg

Manganese is an essential element for aquatic organisms, which require it as a constituent or cofactor in numerous enzymes involved in photosynthesis, cholesterol and fatty acid synthesis, and general metabolism. Manganese is a constituent of



several metallo-enzymes including pyruvate carboxylase and superoxide dismutase, which are required to detoxify superoxide radicals, reactive byproducts of photosynthesis (Sunda and Huntsman, 1998). Manganese is required for the growth of all photosynthetic organisms as it is an essential component of Photosystem II. In addition, manganese has been shown to have a protective role in aquatic organisms, particularly algae, where it prevents the binding and uptake of a range of more toxic metals (Stauber and Florence, 1985).

Manganese is one of the least toxic metals to aquatic organisms. Manganese is generally regarded as non-toxic in colloidal form (MnO_2), whereas Mn^{2+} or organically-bound manganese is potentially bioavailable (Luoma, 1983).

2.3 Manganese in seawater, geochemical modelling using Minteq

The fate of manganese in seawater was investigated using the geochemical modelling software Minteq ver. 2.21. The software was run for a theoretical case using the water composition provided in Table 2 and for a range of manganese concentrations (0-1 mg/L), though only the results obtained for 0.2 mg/L and 1 mg/L are presented.

Table 2: Theoretical seawater composition

Compounds	Concentration (mg/L)
Ca^{2+}	412
Mg^{2+}	1290
Na^+	10800
Cl^-	19400
Alkalinity as HCO_3^-	140
SO_4^{2-}	2700
NO_3^-	0.29
pH	8.2

from Ball and Nordstrom, 1991

For a total dissolved manganese concentration of 0.2 mg/L and 1 mg/L the manganese compounds formed in solution will be as follow:

**Table 3: Manganese species distribution in the dissolved phase**

Compound	Mn _T = 0.2 mg/L	Mn _T = 1 mg/L
Mn ²⁺	69.3	71.8
MnCO ₃ (aq)	8.2	0.68
MnOH ⁺	0.1	0.12
MnCl ⁺	9.8	10.1
MnSO ₄ (aq)	11.9	12.5
MnHCO ₃ ⁺	0.7	0.05

According to the model, the manganese will remain in the dissolved phase. None of the probable manganese species in marine water are likely to precipitate without additional oxygen input through the diffusion of atmospheric oxygen in water or microbial catalysis.

2.4 Guidelines

2.4.1 ANZECC/ARMCANZ water quality guidelines

The ANZECC/ARMCANZ (2000) guidelines provide trigger values for toxicants at alternative levels of protection for both freshwater and marine water. The trigger values are ranked into three categories depending on their reliability, i.e. the number of studies available, the quality and suitability of the study and the number of species and taxonomic groupings tested.

Due to the small number of toxicity studies for manganese in seawater⁴, the ANZECC/ARMCANZ guidelines only provide a low reliability trigger value of 80 µg/L (Section 8.3.7 of the ANZECC/ARMCANZ guidelines, 2000). This value was derived from one set of data relating to a species of mollusc and “*should only be used as an indicative interim working level*” (ANZECC/ARMCANZ 2000, Appendix B). For comparison, the high reliability trigger value for freshwater for a 95% level of protection is 1900 µg/L; 24 times more than the one provided for seawater.

2.4.2 Other Guidelines

In France and New Caledonia, the effluent discharge criterion for manganese is 1 mg/L (Journal Officiel, 1998) although it is uncertain on what this limit is based.

The US EPA does not specify a limit for manganese for the protection of marine ecosystems, although an upper value of 1 mg/L has been suggested for freshwater biota protection (McKee and Wolf, 1963). This value was based on limited toxicity data and does not consider potential modifying factors such as water hardness. More

⁴ Toxicity data for six species from three taxonomic groups were available, which did not include fish. This did not meet the minimum data requirements for calculation of a high reliability, moderate reliability or interim trigger value, so a low reliability trigger value was calculated using an application factor approach.



recently, Stubblefield and Hockett (2000) derived criteria for protection of freshwater biota in Colorado waters, using standard US EPA procedures (US-EPA, 1985). Two criteria were derived:

- The criterion maximum concentration (acute) which was hardness corrected using an algorithm. This ranged from 2.4 mg/L at 50 mg CaCO₃/l hardness to 3.8 mg/L at a hardness of 200 mg CaCO₃/l.
- The criterion continuous concentration (chronic) which ranged from 1.3 to 2.1 mg/L over the hardness range 50-200 mg CaCO₃/l.

These values are similar to the freshwater trigger value of 1.9 mg/L given in the ANZECC/ARMCANZ guidelines (2000).

2.5 Manganese toxicity

2.5.1 Generalities

Manganese has consistently been shown to be one of the least toxic metals to marine biota. However, the effects of manganese on marine biota are not well documented. Reported LC₅₀/EC₅₀⁵ values range from: 1.5-6⁶ mg/L for algae, 5->40 mg/L for molluscs and echinoderms, and 52-75 mg/L for adult crustacea (Appendix C). No data on the toxicity of manganese to marine fish could be found in the literature.

Studies on the mechanism of manganese toxicity have only been carried out at concentrations well above levels found at even the most polluted sites, using freshwater biota. In algae, manganese can affect chlorophyll synthesis, while in fish, manganese disrupts carbohydrate metabolism, haematological parameters and sodium and calcium metabolism, ultimately leading to oxygen deprivation.

2.5.2 Algae

The toxicity of manganese to algae is confounded by the different culture media used in the toxicity tests. For example, Rosko and Rachlin (1975) showed that the 96-h EC₅₀ for manganese for the diatom *Nitzschia closterium* increased from 26 mg/L to 54 mg/L when the chelator, citric acid, was added to the culture media. Florence *et al.* (1994) found that growth of an Australian isolate of the same diatom species was also insensitive to manganese, with a 72 h EC₅₀ of >0.5 mg/L. Manganese was also of low toxicity to the marine diatoms *Ditylum brightwellii* and *Asterionella japonica*, with EC₅₀ values of 1.5 mg/L and 4.9 mg/L respectively (Canterford and Canterford, 1980; Fisher and Jones, 1981).

Ismail *et al.* (2002) found the golden alga *Isochrysis galbana* to be slightly more sensitive to manganese than the marine diatoms *Tetraselmis tetrahole*,

⁵ LC₅₀: the concentration lethal to 50% of the test population. EC₅₀: the concentration causing the measured effect to 50 % of the test population.

⁶ For tests without EDTA in the test medium.



Tetraselmis sp. and *Chaetoceros calcitrans*. The diatoms had similar sensitivities to that reported for *Nitzschia closterium*, with 96-h EC₅₀ values of 19-21 mg/L, compared with 7.2 mg/L for *Isochrysis galbana*.

Christensen *et al.* (1979) found a 50% reduction in cell volume of the green alga *Chlorella stigmatophora* at 50 mg/L (added as manganese chloride) in artificial seawater medium plus EDTA. They observed a strong antagonistic effect of manganese on lead toxicity, presumably due to competition for active sites. Rebhun and Ben-Amotz (1988) also showed that manganese protected against cadmium toxicity to the green alga *Dunaliella salina*. Cadmium competed with manganese for either a cell membrane site or intracellularly on a specific metal-enzyme, leading to symptoms of manganese deficiency such as chlorosis and interference with chloroplast membrane structure and electron transport in Photosystem II.

Manganese up to 50 µg/L was not toxic to natural populations of phytoplankton and nanoplankton from Zuari estuary, Goa, India. There was no decrease in photosynthesis (carbon assimilation), but small increases were observed at low manganese concentrations of 8 µg/L (Rajendran *et al.*, 1978).

Sediments collected from a port in NSW, Australia contained 345 mg/kg dry weight of manganese, with 1.5 mg/L in filtered pore waters. Despite this, the sediment was not toxic to the benthic marine alga *Entomoneis* cf. *punctulata* in a whole sediment toxicity test (Stauber, unpub). This test measures the decrease in enzyme activity (esterase) in the alga over a 3-24 h exposure. Adams (2000) showed that there was no effect on enzyme activity in this alga at concentrations up to 2.5 mg/L.

2.5.3 Invertebrates

With the exception of crab embryos, crustaceans have been reported to be insensitive to manganese. Liu and Chen (1987) determined the effect of three manganese oxidation states on the relative hatching percentage of cysts of the brine shrimp *Artemia salina* after 48 h exposure at 28°C. Of all the metals tested, manganese was the least toxic. Concentrations of 100 mg/L of Mn(II), Mn(IV) and Mn(VII) gave hatching rates 82 %, 69 % and 8 % of control respectively. However, the results were confounded by the precipitation of Mn(IV) at concentrations in excess of 10 mg/L.

In contrast, embryos of the brachyuran crab *Cancer anthonyi*, were sensitive to manganese (Macdonald *et al.*, 1988). Because this species broods embryos externally on the abdomen, the embryos are exposed to contaminants in waters and sediments continuously. Dissolved manganese concentrations of >100 mg/L gave 100 % mortality of crab embryos over 7 days. Concentrations of 0.01-10 mg/L gave 27-45 % mortality, but the response was not concentration-dependent over the full three orders of magnitude of test concentrations. Hatching of embryos was also decreased at manganese concentrations of 0.01-10 mg/L, compared with controls. Eggs of the crab *Carcinus maenas* accumulate manganese (and other metals) during



ovogenesis, and when the eggs are extruded manganese also adsorbs to the chitinous vitelline membrane (Martin, 1976). This bioconcentration of manganese may explain why crab embryos are killed and larval hatching is impaired at lower manganese concentrations compared with other invertebrates.

Molluscs and echinoderms are insensitive to manganese at environmentally relevant concentrations. Manganese had no effect on the settlement success of the oyster *Crassostrea gigas* and larval behaviour was not affected at concentrations of up to 20 µg/L (Watling, 1983). Manganese also had no effect on the filtering rate or mortality of the common cockle *Cerastoderma edule* (Naylor, 1989). Young and Nelson (1974) also found no effect on motility of sea urchin sperm at 0.14 mg/L. Sperm motility was only slightly affected at concentrations of manganese of 0.68 mg/L. Eisler (1977) found that the survival of the softshell clam *Mya arenaria* was not effected by manganese at concentrations of up to 300 mg/L after 96 h. However, after 168 h, the LC₅₀ value was 300 mg Mn/l, with no effect at 30 mg/L.

A sediment containing 345 mg/kg in manganese, collected from a NSW port, was not acutely toxic to the estuarine amphipod *Corophium* sp. over a 10 day exposure (Stauber, unpub.). In contrast, Doyle *et al.* (2003) found that manganese was strongly implicated as the cause of toxicity of porewater samples from Cockle Creek, Warners Bay, Broughton Point and Marks Point in Lake Macquarie, NSW. Total manganese concentrations in the pore waters ranged from 50-5272 µg/L, similar to the concentrations known to affect sea urchin larval development over 72 h (NOEC of 1.3 mg/L and EC₅₀ of 5.2 mg/L). When porewaters were spiked with additional manganese, toxicity was increased. However, the authors suggested that manganese in these sediments did not result from anthropogenic inputs, but was derived from natural sources.

2.5.4 Toxicity summary

A summary of all available data on the toxicity of manganese to marine species is given in Appendix C. Acute and chronic effects on marine organisms are generally only detectable at concentrations of manganese above 5 mg/L, well in excess of environmental manganese concentrations. Exceptions include one marine alga, with reported effects on growth at manganese concentrations of about 1 mg/L, and early life stages of one marine crab. Figure 7 shows that there is little overlap between concentrations of manganese in seawater, with those concentrations that cause effects in aquatic organisms. There is some overlap in sediment porewater concentrations and effects concentrations.

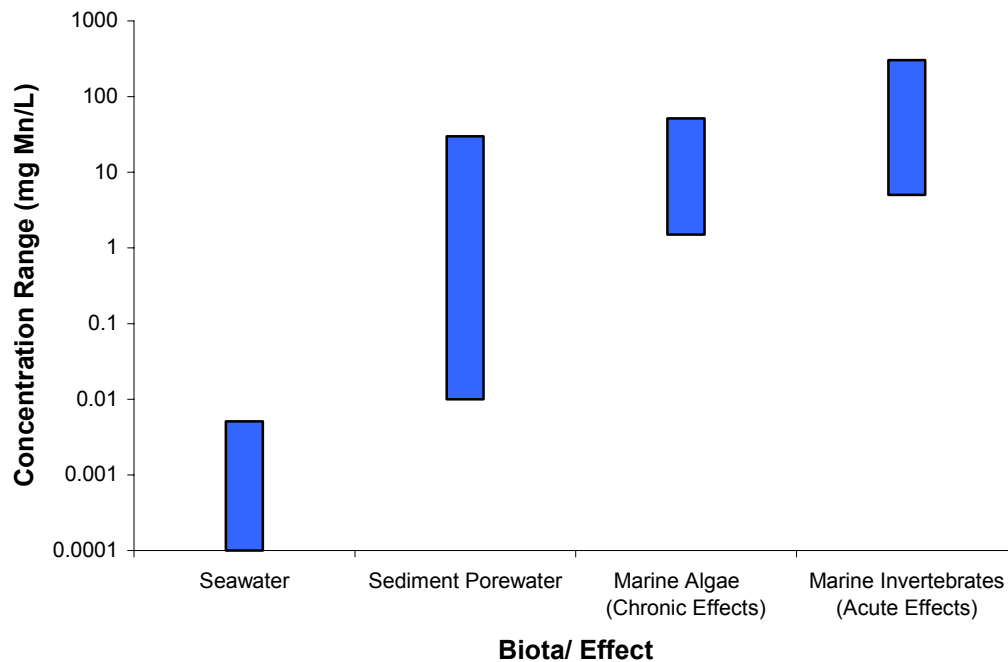


Figure 7: Comparison of manganese concentrations in waters and sediments with the concentration ranges known to elicit a toxic effect (EC₅₀) in marine organisms

2.5.5 Protective effect of manganese

For microalgae, manganese has been shown to have a protective effect against toxicity from other metals. For example, manganese (4 µg/L) ameliorated the toxicity of copper to the marine alga *Nitzschia closterium* (Stauber and Florence, 1985).

Manganese oxides are efficient scavengers of metals due to their low solubility and large surface area. However, Mn(II) is only oxidised slowly in seawater to MnO₂. Manganese added to seawater was found to remain as Mn(II) with only 10% oxidised over three months. However, in the presence of algae, Mn(II) may be oxidised at the cell surface to Mn(III), probably by superoxide. Manganese associated with the cells (as Mn(II) or Mn(III) hydroxides) adsorbed copper and prevented copper penetration into the cells.

For *Nitzschia closterium*, although there was competitive binding at the cell surface between copper and manganese, copper did not affect intracellular manganese. Manganese was also shown to be an effective scavenger of superoxide radicals produced in the chloroplast by the reduction of molecular oxygen. Manganese catalysed the dismutation of superoxide to H₂O₂ and O₂, providing further protection for the algal cell.

The potential toxicity of metals released from proposed submarine disposal of nickel tailings from a mine in South East Asia was recently investigated (Stauber and Adams, 1998, 2000). Although simulated tailings liquor contained up to 30 mg/L in



manganese, it was not toxic to the micro-algae *Nitzschia closterium*. Simulated tailings pore waters, containing up to 60 mg/L, were also not toxic to fertilisation in the sea urchin *Heliocidaris tuberculata*, after pre-exposure of sperm for 1 h (Stauber and Adams, 1998). This pore water contained high concentrations of a number of metals, so it is possible that manganese was also ameliorating the toxicity of other metals.

2.6 Manganese at Myuna Colliery – June/November 2002

The following paragraph provides a summary of the work completed by the colliery in 2002, to investigate some facets of the issue. The sites sampled for water quality included:

- Licensed Discharge Point 1 (LDP1),
- upstream of the colliery (US),
- downstream of the colliery (DS),
- upstream of the weir wall (USWW),
- downstream of the weir wall (DSWW),
- Pourmalong Creek,
- 5 transect sites in Wangi Bay (10, 25, 50, 100, 200 m),
- 1 reference site in Myuna Bay.

Water samples were collected from all sites. Sediments were collected at Pourmalong Creek, at the 5 transect sites in Wangi Bay, and at the Myuna Bay reference site. All sites are shown on Figure 8 and a summary of the data is given in Table 4. The complete set of data collected during this campaign is provided in Appendix D.

Table 4: Summary data from the 2002 study

Site	Dissolved Mn (µg/L)	pH	Conductivity (mS/cm)	Sediment Mn (mg/kg)
Upstream of the colliery	40	5.88	0.32	n.d. ⁷
LDP1	990	7.5	39.4	n.d.
Downstream of the colliery	910	7.7	38.5	n.d.
Upstream of the Weir Wall	940	7.70	38.3	n.d.
Downstream of the Weir Wall	150	8.00	47.6	n.d.
Canal Outlet	70	8.09	50.6	n.d.
10 m from the canal outlet	160	8.03	49.7	147
25 m from the Canal outlet	40	8.10	51.4	175
50 m from the Canal outlet	40	8.10	50.4	161
100 m from the Canal outlet	60	8.17	52.0	140
200 m from the Canal outlet	20	8.20	52	n.d.
Myuna Bay reference site	12.5	8.13	52	158
Pourmalong Creek	10	7.93	48.7	4

⁷ n.d.: not determined

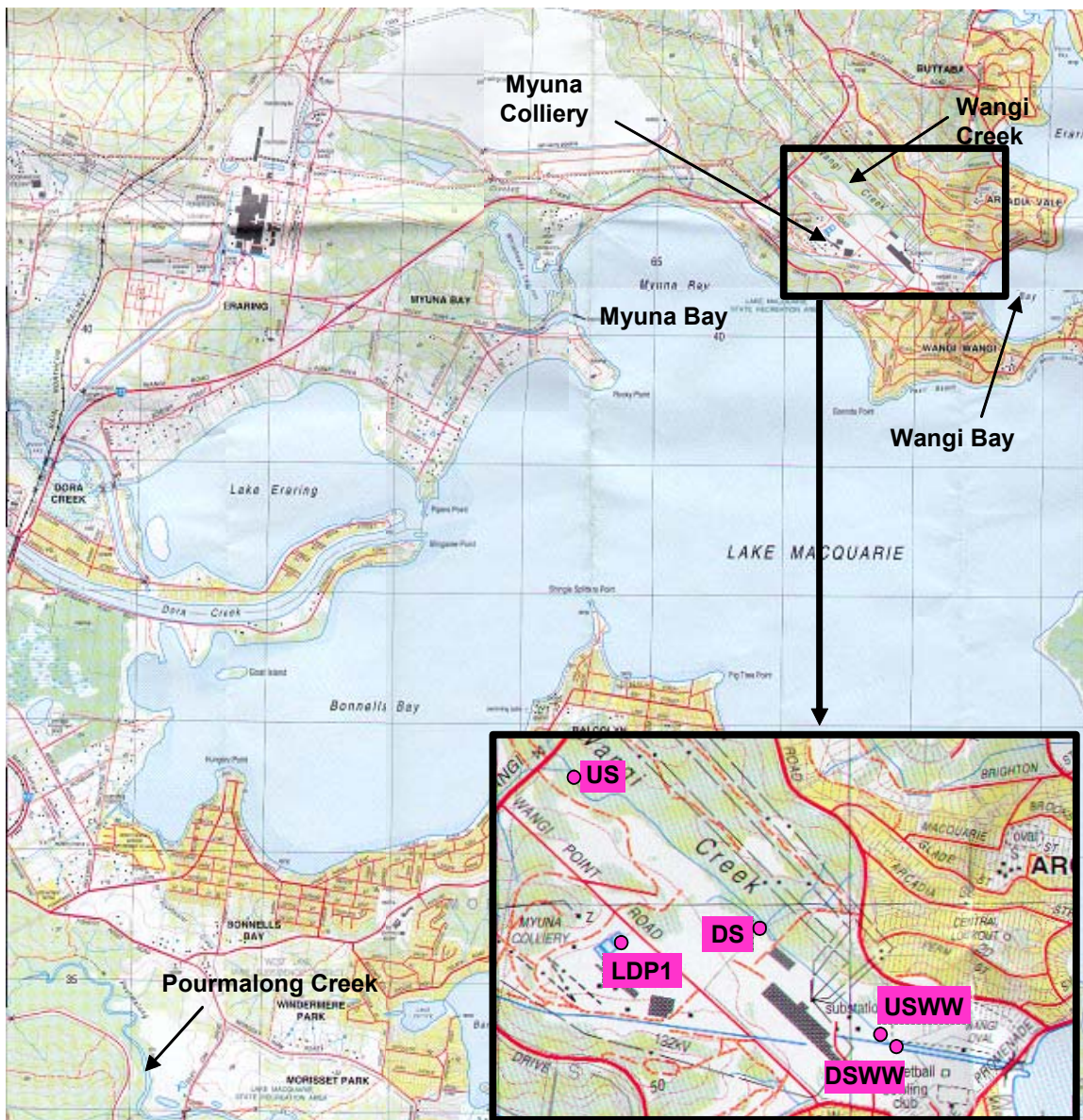


Figure 8: Sampling sites for November 2002

Reported on map IPI Swansea 9231-4N

The data collected during the November 2002 study showed a distinct decrease in manganese concentration between the LDP1 and the outlet of the creek in Wangi Bay, from 990 to 70 $\mu\text{g/L}$. However, there was little or no variation between LDP1 and upstream of the weir wall.

3. AUGUST 2003 CAMPAIGN - METHODOLOGY

The field work relevant to this study was carried out on the 21st and 22nd August 2003. The sampling campaign incorporated the sampling sites used during the 2002 study, allowing comparison with the data collected up to date.



3.1 Sampling

The sampling program was designed to identify the extent of the mixing area. The water samples were collected from:

- Wangi Creek; upstream (US) and downstream (DS) of the colliery, upstream (USWW) and downstream (DSWW) of the weir wall and at the licensed discharge point (LDP1)
- Wangi Bay, on four transects (T1, T2, T3, T4) of five samples (5, 10, 50, 100 and 200 m)
- Myuna Bay for reference on one transect (TR) of five samples (5, 10, 50, 100 and 200 m)

The complete list of sampling sites can be found in Appendix E. Their locations are shown in Figure 9.

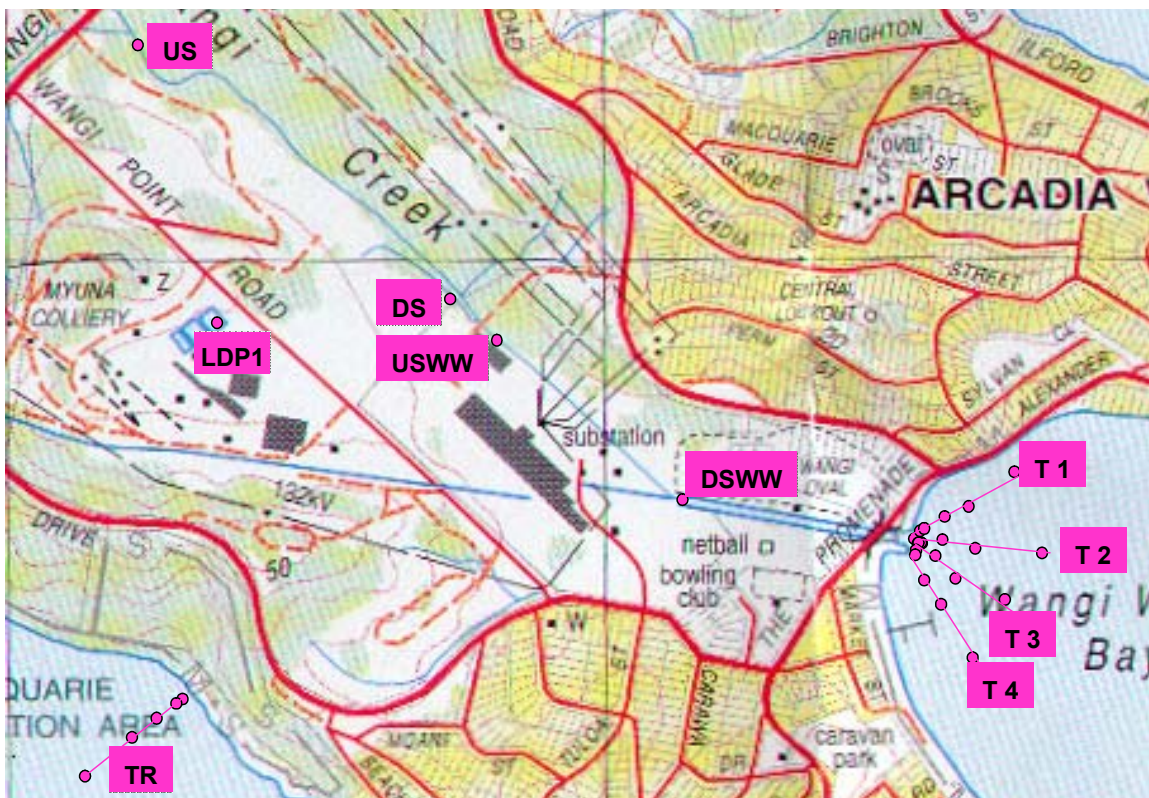


Figure 9: Location of the sampling sites

Reported on map IPI Swansea 9231-4N

3.2 Depth profiles

Depth profiles were taken at each site. Measurements of pH, temperature, electrical conductivity, dissolved oxygen, redox potential, salinity and turbidity were taken with a Yeo-Kal probe 611. The calibrated instrument was rented from Envirorent.



3.3 Manganese in water samples

All manganese analysis were carried out by the CSIRO Centre for Advanced Analytical Chemistry (Lucas Heights, NSW). The water samples were filtered upon arrival in the laboratory to avoid field contamination.

3.3.1 Dissolved manganese

On arrival at the CAAC centre, samples were filtered on 0.45 µm filters and analysed for manganese in the dissolved phase by ICP-AES. Samples were filtered by in-line syringe filtration (0.45 µm encapsulated filters cleaned with 2% (v/v) nitric acid and water, followed by a volume of the sample to be filtered). The filtrates were acidified with ultrapure nitric acid (0.2% v/v final concentration). Mn concentrations in the acidified samples were determined by ICP-AES (Spectro Analytical) using conditions recommended by the manufacturer. The instrument was calibrated using matrix matched standards prepared using clean seawater. The limit of detection for total dissolved manganese was 0.5 µg/L. The coefficient of variation at 100 µg/L (n=5) was typically 5%.

3.3.2 Colloidal manganese, microfiltration at 0.05 µm

Under the appropriate conditions, dissolved manganese (as Mn^{2+}) is readily oxidised into colloidal MnO_2 . Colloidal manganese has a low bioavailability, therefore, differentiating the proportion of manganese in true solution from the proportion of manganese in colloidal form was considered to be a valid approach in identifying the potential bioavailability of the effluent. Colloidal particles are usually considered to be between 1 nm and 1 µm in diameter (Hunter, 1987).

A 50 ml sample aliquot from each transect was ultrafiltered through Amicon PM 10 ultrafiltration membranes (10,000 molecular weight cut-off) housed in an Amicon ultrafiltration cell. All filtrations were conducted under positive nitrogen pressure (ca. 20 psi). The ultrafiltrates were acidified and analysed for Mn as described above.

3.3.3 Labile fraction

The toxicity of heavy metals is related to their physicochemical state; it is maximal when the metal is free, hydrated or present as very labile complexes. This fraction can be quantified by potentiometric techniques such as anodic stripping voltammetry. For manganese, the likely chemical species in the labile fraction will be inorganic manganese species such as $MnCl_2$ or $MnHCO_3^+$. The less labile fraction will include species for which manganese is complexed with organic acids such as fulvic and humic organic acids.



Electrochemical speciation analysis using an anodic square wave voltammetry (Metrohm VA 774 voltammetric analyser, hanging mercury drop with silver/silver chloride reference electrode) was conducted on three⁸ samples selected from Transect 2 (10, 50 and 100 m). The method used was the one described by Luther *et al.* (1994). The samples were analysed using standard additions (manganese added as Mn(II)). The results are expressed as concentration of labile manganese.

3.4 Manganese background in sediments

3.4.1 Sampling

Sediment samples were collected with a van Veen grab sampler at all transects sites in Myuna and Wangi Bay. For each site, three grab samples were collected, homogenised in a stainless steel bowl, collected in plastic bags and stored in eskies before being sent to the CSIRO Centre for Advanced Analytical Chemistry (CAAC, Lucas Heights, NSW) for analysis.

3.4.2 Particle size distribution

Following the recommendation of the NSW-EPA, the sediments were divided into three fractions: F1 < 63 µm; 63 µm < F2 < 2 mm and F3 > 2 mm. The quantification was done by the CSIRO CAAC.

3.4.3 Sediment analysis

The sediment samples were mineralised by a lithium tetraborate fusion followed by nitric acid dissolution. The recommended HF digestion was not applied due to interferences, but this approach produces equivalent results (Graeme Batley, e-mail 25 September 2003). Lithium tetraborate fusion is also the favourite option for commercial laboratories due to Health and Safety reasons and the possible damaging impact on the analytical apparatus (Andrew Bradbury, Advanced Analytical Australia Pty Ltd, pers. comm. and Michael Tobe, ALS enviro, pers. comm.). Manganese was quantified by ICP-MS analysis.

3.4.4 Manganese in porewater

Additional sediment samples were collected from transect 2 for porewater analysis. The porewater was collected by filtration on 0.45 µm membranes and analysed for manganese by ICP-AES.

⁸ The number of samples analysed for labile manganese was limited due to the cost of the analysis.



3.5 Analysis summary

The analyses carried out on each sample are detailed in Table 5.

Table 5: Analysis carried out for each site

Site Code	Depth profile	Dissolved			Porewater	Sediments
		Total	Colloidal	Labile	Total	Total
T1-5m	X	X	X			X
T1-10m	X	X				X
T1-50m	X	X				X
T1-100m	X	X				X
T1-200m	X	X				X
T2-5m	X	X	X		X	X
T2-10m	X	X		X	X	X
T2-50m	X	X		X	X	X
T2-100m	X	X		X	X	X
T2-200m	X	X			X	X
T3-5m	X	X	X			X
T3-10m	X	X				X
T3-50m	X	X				X
T3-100m	X	X				X
T3-200m	X	X				X
T4-5m	X	X	X			X
T4-10m	X	X				X
T4-50m	X	X				X
T4-100m	X	X				X
T4-200m	X	X				X
TR-5m	X	X	X			X
TR-10m	X	X				X
TR-50m	X	X				X
TR-100m	X	X				X
TR-200m	X	X				X
USWW		X				
DSWW	X	X				
US		X				
LDP1		X				
DS		X				



3.6 Toxicity testing procedures

3.6.1 Algae test procedure

Test: 72-h chronic algal growth inhibition test

Organism: marine alga *Nitzschia closterium*

Test procedure: Manganous chloride ($\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$) solid (18.011 g) was weighed out and dissolved in 100 ml Milli-Q water to form a nominal stock solution of 50 g/l. Aliquots of this stock were spiked into test vessels to form nominal test concentrations of 1-1000 mg/L. The top concentration was sub-sampled for manganese analysis on Day 0 and 3 of the test. Because losses were only 3%, concentrations for the algal test were then re-calculated using the Day 0 manganese value only. Concentrations of manganese were determined using ICP-AES.

Test method: This definitive test measures the decrease (inhibition) in algal growth rate (slope) of the temperate marine alga *Nitzschia closterium* after exposure to various concentrations of the sample for 72 h (initial cell density $2-4 \times 10^4$ cells/ml). The test protocol is based on the OECD Test Guideline 201(1984) and the protocol of Stauber *et al.* (1994). Cell counts were made at 24 h intervals for 72 h using a Coulter Multisizer II Particle Analyser with 70 μm aperture. The 72 h IC₅₀, LOEC and NOEC values were calculated using ToxCalc Version 5.0.23 (Tidepool Software).

3.6.2 Fish larvae test procedure

Organism: Two day old larvae of Australian bass, *Macquaria novemaculeata*.

Dilution water: Seawater was collected from Rose Bay, Sydney, stored in 15000 litre capacity epoxy lined concrete tanks and aerated. Prior to use in the toxicity test, the water was filtered through Aqua-Pure AP110 and AP124 filter cartridges of 5 and 50 μm pore size respectively followed by UV sterilisation. The salinity of this water is approximately 32 ‰ and pH is 8.0.

Test procedure: Nine concentrations of manganese and a seawater control were prepared. Four replicates for each concentration were prepared. 500 ml of appropriate concentrations of manganese, and the control solutions were placed in each 1 litre glass container. Five fish larvae were randomly selected and placed in each container. The fish were incubated over a 96-hour period and not fed over the test period. The solutions were gently aerated throughout the test to maintain the dissolved oxygen of the effluent above 60% saturation. Temperature, pH, salinity and dissolved oxygen of the test solutions were measured at the commencement and at the end of the test. The number of fish larvae displaying imbalance was noted at 24, 48, 72 and 96 hours.



The manganese concentration in the highest concentration was measured at the start and end of the test, and the geometric mean of these measurements was used in calculations of test endpoint concentrations. The other test concentrations were derived from the known dilutions of this highest concentration.

The data were analysed using a quasi-likelihood general linear model ANOVA and post hoc Dunnett's Multiple Comparison tests. Fit to the assumptions of the ANOVA model was assessed by graphical examination of residuals (residuals versus fit and residual normal quantile plots).

3.6.3 Rock oyster test procedure

Test: 48 hour larval development test using the rock oyster *Saccostrea commercialis*.

Dilution water: Seawater was collected from Rose Bay, Sydney, stored in 15000 litre capacity epoxy lined concrete tanks and aerated. Prior to use in the toxicity test, the water was filtered through Aqua-Pure AP110 and AP124 filter cartridges of 5 and 50 µm pore size respectively followed by UV sterilisation. The salinity of this water is approximately 32‰ and pH is 8.0.

Test procedure: Fertilised eggs from farm reared (Wallis Lake) *S. commercialis* were exposed to seven concentrations of manganese (as $MnCl_2$) and a seawater control and assessed for development to the D-veliger larval stage over 60 h. The manganese concentrations ranged from 0 to 28 mg/L. The top concentration was sub-sampled for manganese analysis at test commencement and after 60 h. Because losses were only 14%, concentrations for the oyster test were then re-calculated using the initial manganese value and theoretical dilutions. The test followed the Ecotox Services Australasia Pty Ltd protocol ESA SOP 106, which is based on APHA (1998). The test was extended to 60 h, rather than the standard 48 h, due to seasonal influences on larval development rates. In addition to the normal larval development sub-lethal endpoint, mortality was also recorded to obtain a simultaneous acute toxicity measure. The eggs are fertilised and introduced into each test vessel. At the end of the 60 h exposure period, the numbers of normally developed, abnormal and dead larvae were counted. Analysis of variance and Dunnett's multiple comparison tests and trimmed Spearman-Kärber statistical analyses were used to calculate the EC_{50} , LOEC and NOEC concentrations using ToxCalc Version 5.0.23 (Tidepool Software).

The test concentrations were determined by measuring the Mn concentration in the highest concentration at the start and end of the test. The concentration was found to have changed by less than 20% and the day 0 concentration was used in subsequent analyses. All other concentrations were based on the known dilution of the measured highest concentration.



3.6.4 Sea urchin test procedure

Test: 72 hour sea urchin larval development test using *Heliocidaris tuberculata*.

Dilution water: Seawater was collected from Rose Bay, Sydney, stored in 15000 litre capacity epoxy lined concrete tanks and aerated. Prior to use in the bioassay, the water was filtered through Aqua-Pure AP110 and AP124 filter cartridges of 5 and 50 µm pore size respectively followed by UV sterilisation. The salinity of this water is approximately 32 ‰ and pH is 8.0.

Test procedure: Fertilised eggs from wild caught (Lurline Bay) *H. tuberculata* were exposed to seven concentrations of manganese (as MnCl₂) and a seawater control and assessed for development to the pluteus stage after 72 h. The manganese concentrations ranged from 0 to 28 mg/L. The top concentration was sub-sampled for manganese analysis on Day 0 and Day 3 of the test. Because losses were only 4%, concentrations for the sea urchin test were then re-calculated using the Day 0 manganese value only. The test followed the Ecotox Services Australasia Pty Ltd protocol ESA SOP 105, which is based on APHA (1998) and Simon and Laginestra (1996). In addition to the normal larval development sub-lethal endpoint, mortality was also recorded to obtain a simultaneous acute toxicity measure. Gametes are obtained by injecting the body cavity of the sea urchins with potassium chloride. The eggs are fertilised and introduced into each test vessel. At the end of the 72 h exposure period, the numbers of normally developed, abnormal and dead larvae were counted. Analysis of variance and Dunnet's multiple comparison tests and trimmed Spearman-Kärber statistical analyses were used to calculate the EC₅₀, LOEC and NOEC concentrations using ToxCalc Version 5.0.23 (Tidepool Software).

The test concentrations were determined by measuring the manganese concentration in the highest concentration at the start and end of the test. The concentration was found to have changed by less than 20% and the day 0 concentration was used in subsequent analyses. All other concentrations were based on the known dilution of the measured highest concentration.

3.6.5 Tiger prawn test procedure

Test: 96 hour acute (survival) toxicity test using the tiger prawn *Penaeus monodon*.

Dilution water: Seawater was collected from Rose Bay, Sydney, stored in 15000 litre capacity epoxy lined concrete tanks and aerated. Prior to use in the bioassay, the water was filtered through Aqua-Pure AP110 and AP124 filter cartridges of five and fifty micron pore size respectively followed by UV sterilisation. The salinity of this water is approximately 32 ‰ and pH is 8.0.



Test procedure: Hatchery reared (Cairns) PL-15 juveniles of *P. monodon* were exposed to seven concentrations of manganese (as manganese chloride) and a seawater control and assessed for survival over a 96 h period. The manganese concentrations ranged from 0 to 27 mg/L. The top concentration was sub-sampled for manganese analysis on Day 0 and Day 4 of the test. Because losses were only 15%, concentrations for the prawn test were then re-calculated using the Day 0 Mn value only. The test followed the Ecotox Services Australasia Pty Ltd protocol ESA SOP 107, based on US-EPA (1994, 1996). To prevent cannibalism, the prawns were separated into glass tubes with screens at one end. The number of surviving prawns was counted daily. Analysis of variance and Dunnet's multiple comparison tests and trimmed Spearman-Kärber statistical analyses were used to calculate the LC₅₀, LOEC and NOEC concentrations using ToxCalc Version 5.0.23 (Tidepool Software).

The test concentrations were determined by measuring the Mn concentration in the highest concentration at the start and end of the test. The concentration was found to have changed by less than 20% and the day 0 concentration was used in subsequent analyses. All other concentrations were based on the known dilution of the measured highest concentration.

4. FIELD OBSERVATIONS

4.1 Sampling campaign

The sampling campaign was carried out on the 21st and 22nd of August 2003. The time of sampling for each transect is given in Table 6, the tidal timetable is given in Table 7. The time of sampling is of importance due to the tides and their possible influence on the measurements taken.

Table 6: Time of sampling for each transect

	Date	Start	End
Transect 1	21/08/03	11.33	12.34
Transect 2		7.10	10.58
Transect 3		14.16	15.25
Transect 4		15.43	16.46
Reference Transect	22/08/03	7.35	9.09

Table 7: Tidal timetable

21 st August		22 nd August	
Time	Height (m)	Time	Height (m)
02.27	1.1	03.47	1.1
6.16	0.7	09.20	0.7
15.09	1.4	15.11	1.5
22.06	0.7	23.14	0.6



Transects 1, 2 and 3 were sampled during an outgoing tide, with the boat drifting towards the bay, whereas transect 4 was sampled during an incoming tide and the boat was drifting towards the entrance of the outlet. The water samples were collected facing the flow as recommended by the guidelines.

4.2 Sampling Sites

In a radius of 50 m from the outlet of the canal (Plate 1), the bay averages 0.7-1 m depth, before increasing to 5.7 m for the deepest point studied (T3-200 m). The bottom of the shallow area is covered by seagrass, probably *Zostera* sp. (Plate 2). The sediments collected had a silty texture and a dark grey colour (Plate 2). As can be seen in Figure 9, transect 1 and transect 4 are located on each side of the bay. Transect 1 was shallow with a deepest point of 1.1 m. Transect 4 was deeper, but was directed towards the marina, and some samples had to be collected amongst boats.

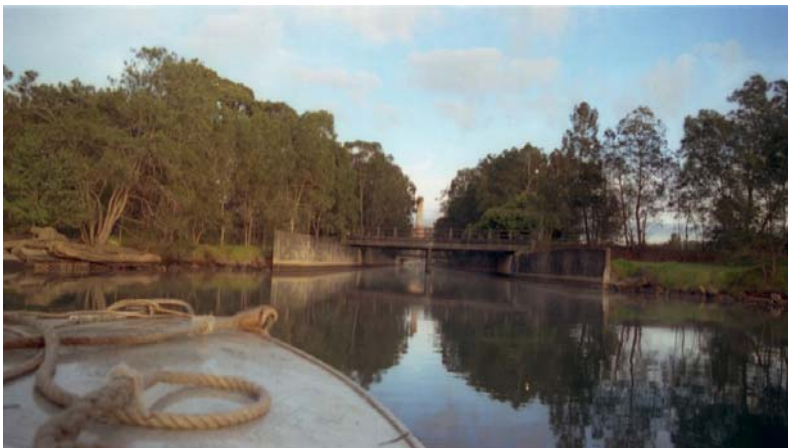


Plate 1: Entrance of the outlet canal at Wangi Bay

The reference site was located on the other side of Wangi Point, in Myuna Bay. This site presents several substantial differences from Wangi Bay. The most important one concerns the concrete that has been deposited at the edge of the water. The sediments close to the edge cannot be considered representative of the site, as they are sandy and contain high amounts of gravels, probably derived from the decomposed concrete (Plate 3). Another characteristic difference is the lack of seagrass and the presence of brown algae (Plate 3).



Plate 2: Grab sample collected next to the outlet



Plate 3: Reference transect site



Plate 4 : Sampling sediments



5. CHEMISTRY RESULTS

5.1 Wangi Creek water quality

Water quality data for Wangi Creek and the LDP1 (License Discharge Point) are provided in Table 8. The manganese concentration decreased by over 50 % from the discharge point (LDP1) to the point downstream of the Weir Wall (DSWW) located 300 m upstream of the creek's outlet in the bay. Simultaneously, pH and salinity increased to approach those characteristic of seawater, indicating the influence of the tides and the reflux of the water from the bay into the canal.

Table 8: Manganese, salinity and pH values for on-land sites (22/08/2003)

	Mn (µg/L)	Salinity (‰)	pH
US	36.2	0.2	6.2
LDP1	823	24.6	7.5
DS	784	23.9	7.7
USWW	764	23.7	7.6
DSWW	394	29.6	8.0

5.2 Wangi Bay water quality

5.2.1 Depth profiles

5.2.1.1 Salinity depth profile

The salinity-depth profiles are shown in Figure 10. The surface layer salinity values for the closest sites (5, 10 and 50 m) varied between 4 and 10 ‰ of the salinity at the more distant sites. This was the only evidence of lower salinity water originating from Wangi Creek. Table 9, provides the average salinity for each transect. Transect 1, the shallowest transect and also the closest to the shore, had the lowest salinity. The salinity at the reference site was slightly higher than at the other transects. The effluent pumped from the mine ponds into the creek was 25 ‰ less saline than the water at the reference site.

Table 9: Average salinity and pH values for each transect and on-land site

	Salinity (‰)	pH
T1	32.8	8.5
T2	33.2	8.6
T3	33.2	8.5
T4	33.3	8.5
TR	33.6	8.4
LDP1	25	7.5
US	0.2	6.2
DS	23.9	7.7
USWW	23.7	7.6
DSWW	29.6	8.0



5.2.1.2 pH depth profile

The pH depth profiles are shown in Figure 11. The values were not as homogeneous as the salinity values. The measured pH values fluctuated less as the distance from the outlet and from the shore increased. The values for the reference transect decreased as the distance from the shore increased.

5.2.2 Water chemistry

5.2.2.1 Dissolved phase

The dissolved (<0.45 µm) manganese concentrations measured for Wangi Bay and Myuna Bay are presented in Table 10.

Table 10: Manganese concentration in Wangi Bay and Myuna Bay

Distance	Filtration	Mn (µg/L)				Reference Transect
		Transect 1	Transect 2	Transect 3	Transect 4	
5 m	0.45µm	30.7	281	45.1	80.0	1.3
10 m		204	339	70.3	328	1.1
50 m		221	227	13.6	24.4	1.1
100 m		29.0	180	10.3	11.0	0.9
200 m		37.0	5.3	5.0	6.1	0.9

The detection limit is 0.4 µg/L

Generally, as the distance from the outlet increased, the manganese concentration decreased due to dilution. The highest concentrations were measured at the 10 m mark with a peak value of 339 µg/L for transect 2 (site T2-10m). The lowest concentrations were reported at the 200 m mark, with values lower than the values measured in Wangi Creek upstream of the mine (36.2 µg/L; Table 8). Transect 2 had the highest manganese concentrations. Manganese concentrations also varied between transects at similar distances indicating incomplete lateral mixing (Figure 12). The concentrations measured during this study were generally higher than those measured in November 2002.

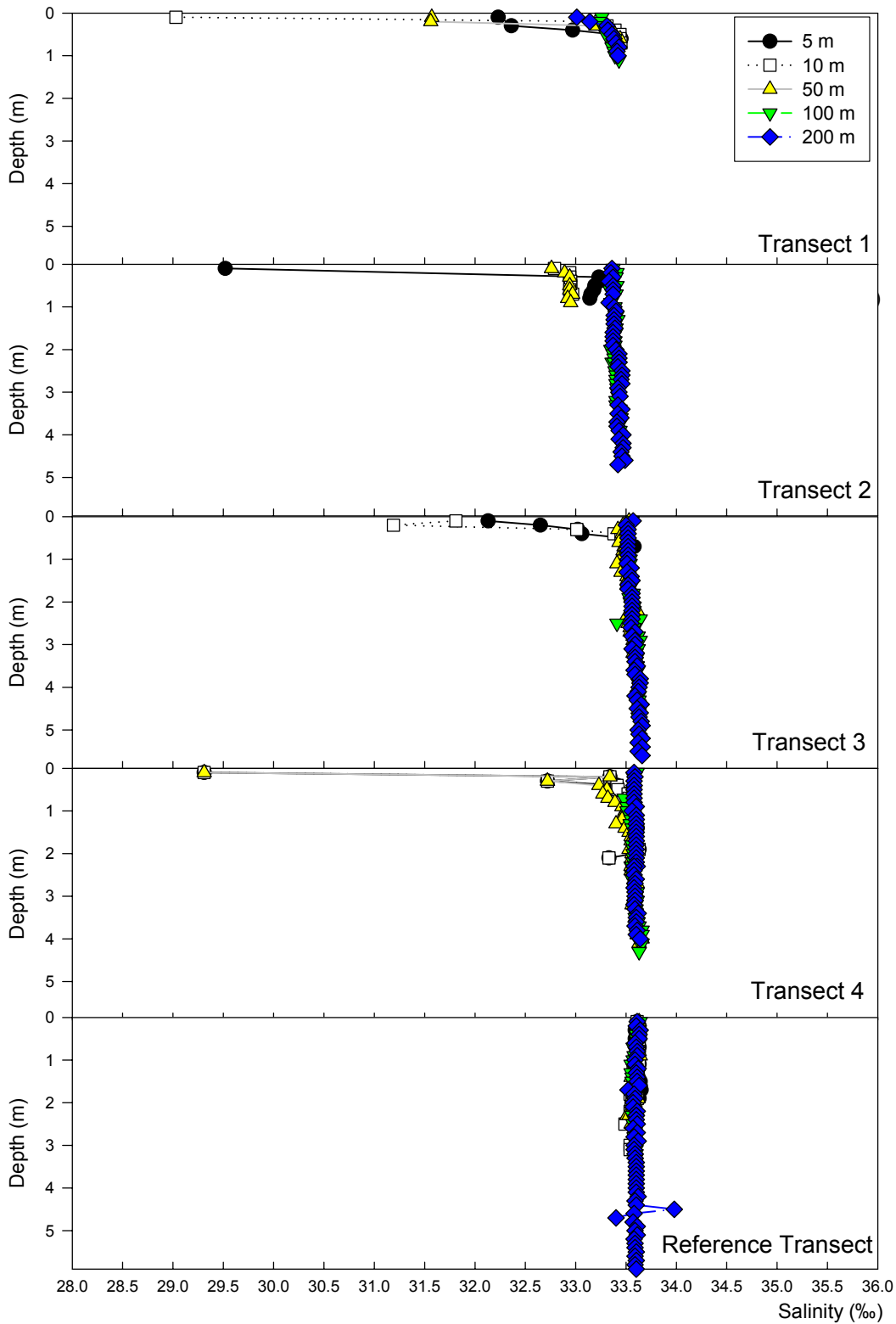


Figure 10 a, b, c, d, e: Depth profiles for salinity

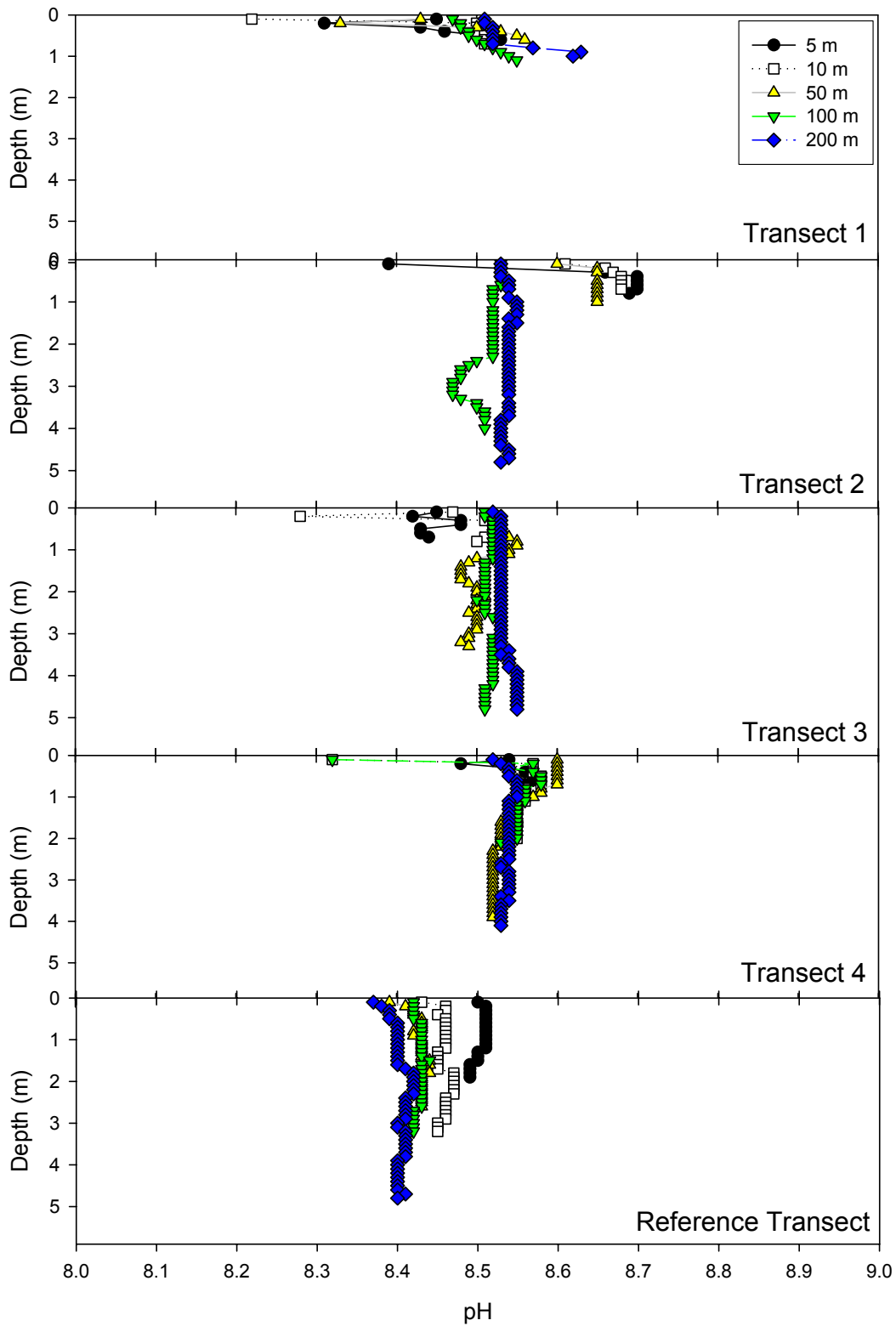


Figure 11 a, b, c, d, e: Depth profiles for pH



5.2.2.2 Colloidal manganese

Table 11 presents the manganese concentration values after filtration at 0.45 μm and after filtration at 0.05 μm , for the samples closest to the outlet of the canal. The difference between the two fractions represents the colloidal fraction. Negative values obtained for transect 1 and transect 4 are due to the lack of analytical precision often encountered on a single analysis of samples at low levels. There was negligible colloidal manganese in Wangi Bay, suggesting that the compound is essentially present as truly dissolved manganese.

Table 11: Manganese partitioning between colloidal and dissolved forms

Distance	Filtration	Mn ($\mu\text{g/L}$)				
		Transect 1	Transect 2	Transect 3	Transect 4	Reference Transect
5 m	UF 0.05 μm	33.9	278	45.1	80.5	
5 m	0.45 μm	30.7	281	45.1	80.0	1.3
5 m	Colloidal fraction	-3.2	2.9	0	-0.5	



Figure 12: Geographic variation of dissolved manganese

Low concentration sampling points are identified by small yellow dots.



5.2.2.3 Labile fraction

The labile manganese fraction was analysed for the three samples having the highest manganese concentration selected from Transect 2. The values obtained are presented in Table 12.

Table 12: Electrochemical speciation of manganese

Sample	Distance (m)	Dissolved manganese ($\mu\text{g/L}$)	Labile manganese ($\mu\text{g/L}$)	% labile
T2 – 10 m	10	339	228	67
T2 – 50 m	50	227	195	86
T2 – 100 m	100	180	122	68

The labile fraction analysed by square wave voltammetry quantifies free manganese and the very labile manganese complexes. This fraction is the one representing the majority of the bioavailable metal. In the present case, the labile fraction represented 67-86 % of the total dissolved concentration for the samples collected at 10, 50 and 100 m. Two of these values (67 and 68 %) were comparable to those obtained for free manganese (Mn^{2+}) in the modelling of manganese in seawater using the geochemical software Minteq (Section 2.3). Thus around two thirds of the dissolved manganese in Wangi Bay was bioavailable.

5.2.3 Manganese in sediment porewater

The porewater contained in the sediments collected on transect 2 was analysed for manganese. The values are presented in Table 13. As expected, manganese concentrations in the porewater were elevated compared with those measured in the surface water samples. However, these values were similar to those reported by previous studies on porewater in Lake Macquarie. Doyle *et al.*, 2003 reported values of 2100 $\mu\text{g/L}$ at their reference site, Fennel Bay in the north east of the lake, and up to 5200 $\mu\text{g/L}$ at Warners Bay in the north section of the lake. Therefore the high level of manganese concentration in the porewater can not be attributed to the discharge.

Table 13: Porewater manganese content at transect 2

Sampling Sites	Mn ($\mu\text{g/L}$)
T2 5m	243
T2 10m	750
T2 50m	2100
T2 100m	1130
T2 200m	800

The manganese content in the porewater increased from the outlet but reached a peak at 50 m. Generally, this trend could not be related to the manganese content in the sediment (discussed in the next section, 5.3.1).



5.3 Wangi Bay sediments

5.3.1 Total manganese content in sediments

The total manganese content data for the sediments samples collected in Myuna Bay and Wangi Bay are provided in Table 14. The complete set of data including total manganese, total aluminium and total iron content of the sediments, and the Particle Size Distribution (PSD) analysis is provided in Appendix G.

Table 14: Manganese content in sediments collected in Wangi Bay and Myuna Bay

Distance	Mn (mg/kg)				
	Transect 1	Transect 2	Transect 3	Transect 4	Reference Transect
5 m	213	151	152	206	140
10 m	191	165	147	175	200
50 m	118	155	212	182	80
100 m	146	182	150	121	120
200 m	70	144	187	65	290

The total manganese content values recorded in the sediments originating from Wangi Bay were comparable to those collected at the reference site (Myuna Bay) with values ranging from 70 to 213 mg/kg and 80 to 290 mg/kg respectively. These values were also lower than the data recorded from previous studies carried out at Lake Macquarie:

- NSW-EPA, courtesy of Tony Roach for 24 monitoring sites of Lake Macquarie ranging from 38 to 420 mg/kg (Appendix H)
- Roy and Crawford (1984) ranging from 350-400 mg/kg

Roy and Crawford (1984) suggested that manganese distributions in Lake Macquarie were anomalous, showing a reverse trend increasing towards the south whereas other heavy metals (zinc, lead, copper and cadmium) were higher towards the north and the industrialised areas of the lake. No manganese variation could be identified through the whole core depth (60 cm) indicating that manganese concentration in the sediments had not changed substantially since the urbanisation and industrialisation of the lake catchment. They concluded by highlighting the need for a better understanding of the mineralogy of the sediments and surrounding country rocks to explain the manganese content in the lake's sediments.

The distribution of manganese through each transect can be visualised in Figure 13. The values recorded for transect 2 and transect 3 were consistent, whereas transects 1 and 4 showed a decrease in manganese content with distance from the outlet. Statistical comparison by analysis of covariance, with transect as the main factor and distance from shore as a covariate found no significant difference between



transects and no significant overall distance relationship, but a significant interaction term, relating to the declining manganese concentration with distance for transects 1 and 4.

However, the consistencies (i.e. size and type) of the sediments sampled for these two transects were more likely to be influenced by external parameters due to the closeness to the shore for transect 1 and the presence of boats for transect 4. Indeed, it has been identified that the concentration of manganese in the sediments of Lake Macquarie varies strongly with the grain size and that this factor should be considered when interpreting results for sediment quality. (NSW-EPA, Michael Warne, e-mail, 15 August 2003). Analysis of covariance of the sediment concentrations from this study and the NSW-EPA data, with percent <math><63 \mu\text{m}</math> as the covariate found no significant difference between sites, but a significant relationship overall with percent <math><63 \mu\text{m}</math>. In addition it is widely acknowledge that manganese will deposit at the surface of the sediment as colloidal MnO_2 , and redissolve in the sediment column where redox condition favours chemical reduction and the presence of anaerobic bacteria.

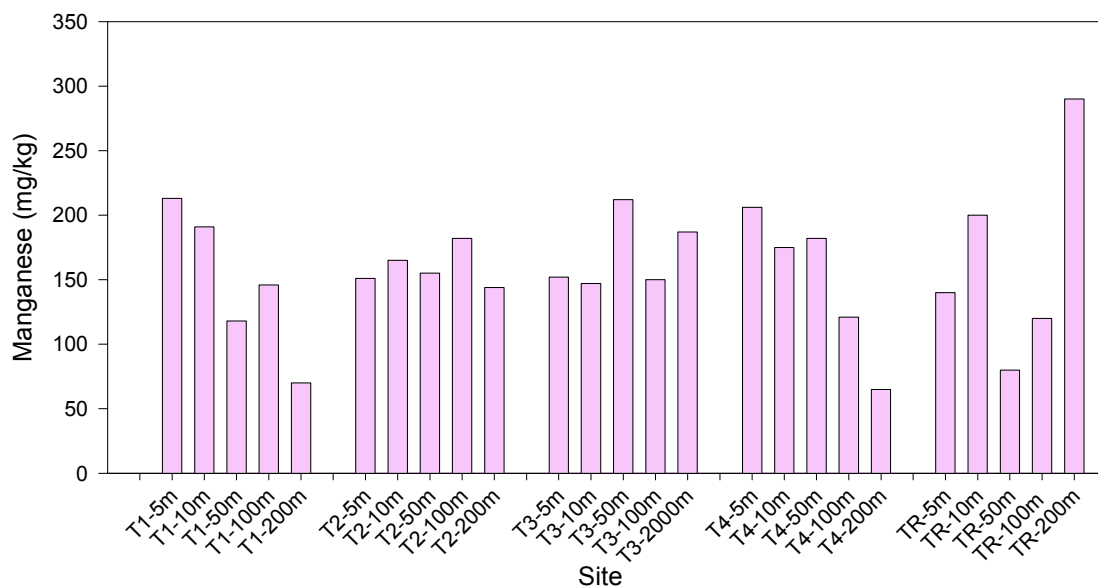


Figure 13: Manganese content of the sediments for each site

5.3.2 Particle size distribution

Figure 14 presents the particle size distribution at each of the sites. Three fractions were considered, $F1 > 2 \text{ mm}$, $63 \mu\text{m} < F2 < 2 \text{ mm}$ and $F3 < 63 \mu\text{m}$. This last fraction has also been referred to as mud by Tony Roach in his study (Appendix H).

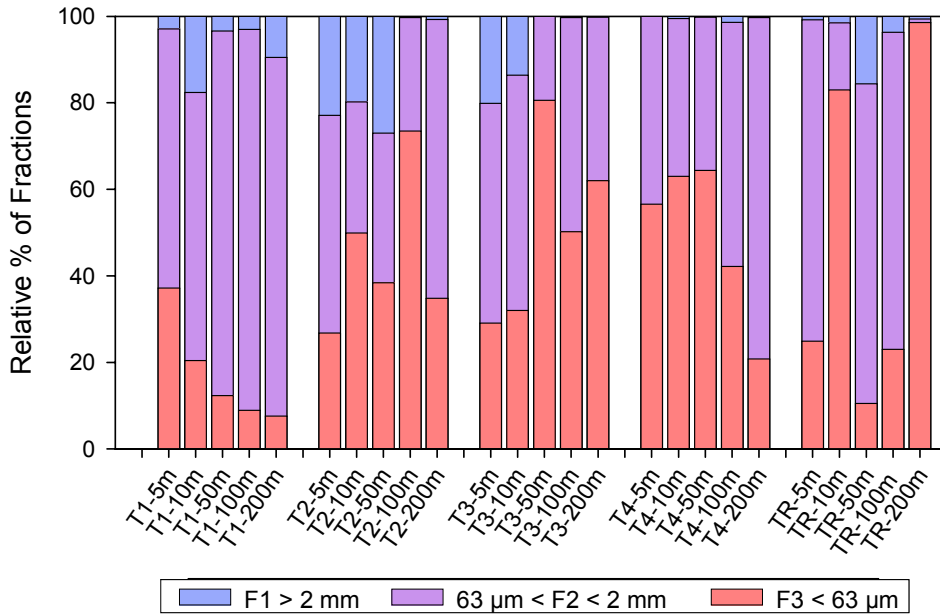


Figure 14: Particle size distribution for each sample

When plotting the percentage of each fraction against the manganese content (Figure 15), it appears that only the <63 µm fraction is proportional to the manganese content, the 63 µm<F2<2 mm is inversely proportional and the >2 mm fraction is randomly distributed (not presented). This confirms that manganese is essentially related to the amount of finer fraction.

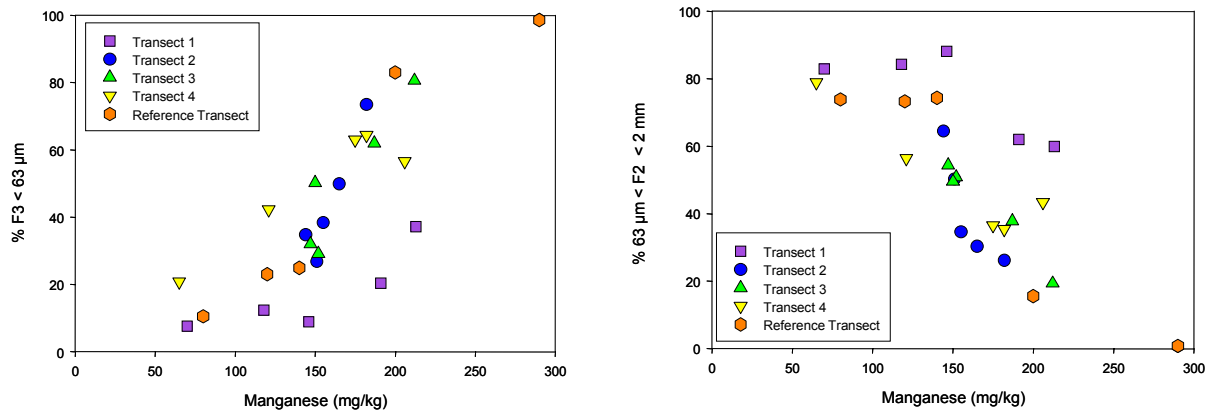


Figure 15a, b : Relationship between manganese content and fraction %

Figure 16 shows the concentration of manganese as a function of the percentage of the < 63 µm fraction, for the sediments sampled in this study and sediments sampled by the NSW-EPA at several of their Lake Macquarie monitoring sites (data courtesy of Tony Roach). The data collected at Wangi Bay and Myuna Bay are generally within the range of values provided by NSW-EPA.

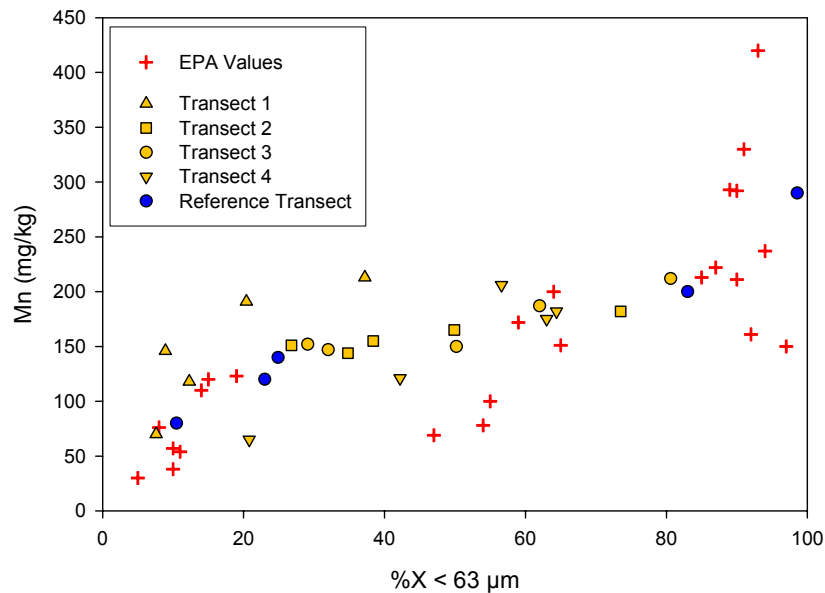


Figure 16: Manganese content vs %63 µm fraction

6. ECOTOXICOLOGY AND TRIGGER VALUE DERIVATION

As discussed in Section 2.4, ANZECC/ARMCANZ (2000) only presents a low reliability trigger value for manganese in marine waters. As this trigger value appears to be very conservative (Section 2.5), it was decided to investigate the possibility of deriving a higher reliability trigger value following the procedure of ANZECC/ARMCANZ (2000) Section 8.3.4.4 (illustrated in Figure 17). Two approaches were adopted. Firstly, to maximise the local relevance of the derived trigger value, and to ensure the inclusion of fish data as requested by the EPA, toxicity tests with Australian species were conducted to provide no observed effects concentrations (NOEC) for calculation of a trigger value. Secondly, a literature review was conducted of overseas and local toxicity testing results that could be used as input data for calculation of a trigger value. The two data sets were also combined.

6.1 Toxicity testing with locally relevant species

The toxicity tests with locally relevant species used were:

1. 60 h⁹ larval abnormality test (sublethal, chronic) using the rock oyster *Saccostrea commercialis* (based on APHA method 8610C, modified for use with *S. commercialis* by Krasso, 1996). Rock oysters occur naturally in Lake Macquarie. A second, lethal (acute) endpoint (larval mortality) was also measured for this test.

⁹ This test is nominally conducted over a 48 h period, but in this case was extended to 60 h due to seasonal effects on larval development rates for this species.



2. 72 h larval abnormality test (sublethal, chronic) using the sea urchin *Heliocidaris tuberculata* (based on APHA (1998) and Simon and Laginestra (1996)). *H. tuberculata* occurs naturally in coastal areas of central New South Wales. A second, lethal (acute) endpoint was also measured for this test. This species was also used by Doyle *et al.* (2003) to assess manganese toxicity in pore waters from Lake Macquarie sediments, although in that instance only nominal test concentrations were reported.
3. Algal growth rate inhibition (chronic) test using the marine diatom *Nitzschia closterium* (based on the protocol by Stauber *et al.*, 1994).
4. 96 h acute toxicity test using juvenile tiger prawn *Penaeus monodon* (based on US-EPA OPPTS 850.1045 and US-EPA (1993) for mysid shrimp).
5. 96 h acute imbalance testing using larvae of the Australian bass, *Macquaria novemaculeata*.

For all tests, manganese chloride solutions in filtered seawater were used as the test toxicants. Samples from the highest nominal test manganese concentration were taken at the start and end of the tests, and analysed for dissolved manganese concentration by the CAAC (CSIRO). The measured concentrations were used to proportionally adjust the nominal manganese concentrations for calculation of test statistics. The full test reports are provided in Appendix I. The results of the tests are summarised in Table 15. The rock oyster and sea urchin tests both had NOEC values of 1.0 mg/L for the chronic endpoint, and 3.1 mg/L for the acute endpoint, giving an acute to chronic ratio of 3.1. This is higher than the value of two that is typically applied for essential metals (ANZECC/ARMCANZ, 2000 page 8.3-29). Using this ratio to convert acute test results to chronic test equivalents, the most sensitive species were the oyster and urchin, while the least sensitive species was the alga, *Nitzschia*.

Table 15: Summary of the results of toxicity testing

Species/duration	Endpoint	Type	NOEC (mg/L)	EC ₅₀ /LC ₅₀ (mg/L)
Rock oyster 60 h	Larval survival	Acute	3.1	10.8
	Larval abnormality	Chronic	1.0	2.7
Urchin 72 h	Larval survival	Acute	3.1	14.3
	Larval abnormality	Chronic	1.0	4.2
Tiger prawn 96 h	Survival	Acute	9	26.1
Bass 96 h	Imbalance	Acute	49	97.5
<i>Nitzschia</i> 48 h	Growth	Chronic	18	87

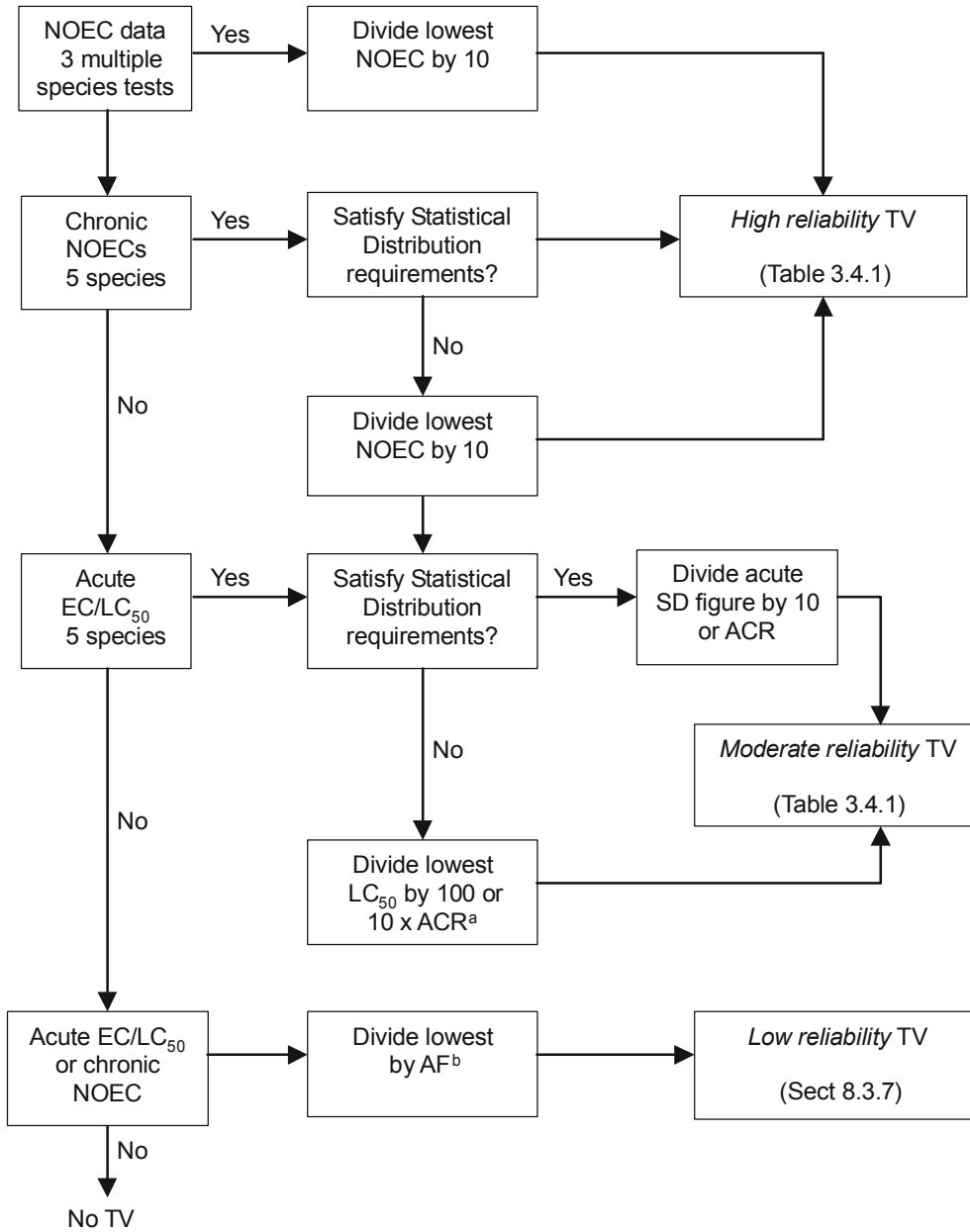


Figure 17: Schematic diagram of the procedures for deriving water quality guidelines from ANZECC/ARMCANZ (2000)



6.2 Toxicity data from the literature

The available literature-based toxicity data for manganese in marine waters is largely summarised in Section 2.5. Additional data were sourced from the draft WHO Concise Information Chemical Assessment Document for manganese (WHO, 2003 draft), and the toxicant database provided with ANZECC/ARMCANZ (2000). Table 16 summarises the toxicity data from WHO (2003 draft) and ANZECC/ARMCANZ (2000), which have been pre-screened for inclusion in calculation of water quality guidelines. Note that NOEC values were not reported for any of the tests included in Table 16.

The *Cancer anthonyi* test had an unusually low lowest observed effect concentration (LOEC), and as noted in Section 2.5, there was no concentration dependence to the response in that test over a concentration range of 0.01 to 10 mg/L manganese. This suggests that either manganese was not the substance principally responsible for the observed response, or that there was an uptake pathway other than via dissolved manganese in the test water. Because of this uncertainty, this test was not included in the calculation of the low-reliability trigger value of ANZECC/ARMCANZ (2000), and is not given further consideration in this report.

Table 16: Summary of toxicity testing results from the literature

Organism	Duration	Type	EC ₅₀ /LC ₅₀ (mg/L)	Source
<i>Ditylum brightwellii</i> (diatom)	120 h	Chronic	1.5	WHO (2003) ANZECC/ARMCANZ (2000)
<i>Nitzschia closterium</i> ¹⁰ (diatom)	96 h	Chronic	25.7	WHO (2003) ANZECC/ARMCANZ (2000)
<i>Astertorionella japonicum</i>	72 h	Chronic	4.9	WHO (2003)
<i>Nitocra spinipes</i> (copepod)	96 h	Acute	70	WHO (2003) ANZECC/ARMCANZ (2000)
<i>Crassostrea virginica</i> (oyster)	48 h	Acute	16	WHO (2003) ANZECC/ARMCANZ (2000)
<i>Heliocidaris tuberculata</i>	72 h	Chronic	5.2*	WHO (2003)
<i>Mytilus edulis</i> (mussel)	48 h	Acute	30	WHO (2003) ANZECC/ARMCANZ (2000)
<i>Cancer anthonyi</i> (crab)	168 h	Chronic	0.01 (LOEC)	ANZECC/ARMCANZ (2000)
<i>Mya arenia</i> (clam)	168 h	Acute ¹¹	300	WHO (2003)
<i>Artemia salina</i> (brine shrimp)	48 h	Acute	51.8	WHO (2003)

*NOEC 1.3 mg/L

¹⁰ Reported as *Phaeodactylum tricornutum* in ANZECC/ARMCANZ (2000)

¹¹ Defined as acute by WHO (2003 draft) but chronic under the ANZECC/ARMCANZ (2000) definitions.



6.3 Calculation of trigger values

The data from the testing undertaken for this study included both acute and chronic test results (Table 15). The acute to chronic ratio of 3.1 was used to convert the acute test NOEC values to chronic NOEC equivalents for inclusion into the dataset used to calculate a species sensitivity distribution (SSD). The BurrliOZ software (provided as part of the ANZECC/ARMCANZ, 2000 package) was used to calculate the SSD, which is presented in Figure 18. The 95% protection level with 50% confidence derived from the Burr Type III distribution fitted to the data was 660 µg/L. As this dataset includes NOEC data for a mix of acute and chronic tests, the resulting trigger value does not fall into either the High Reliability or the Moderate Reliability categories of ANZECC/ARMCANZ (2000), but could be regarded as a Moderate-High Reliability trigger value.

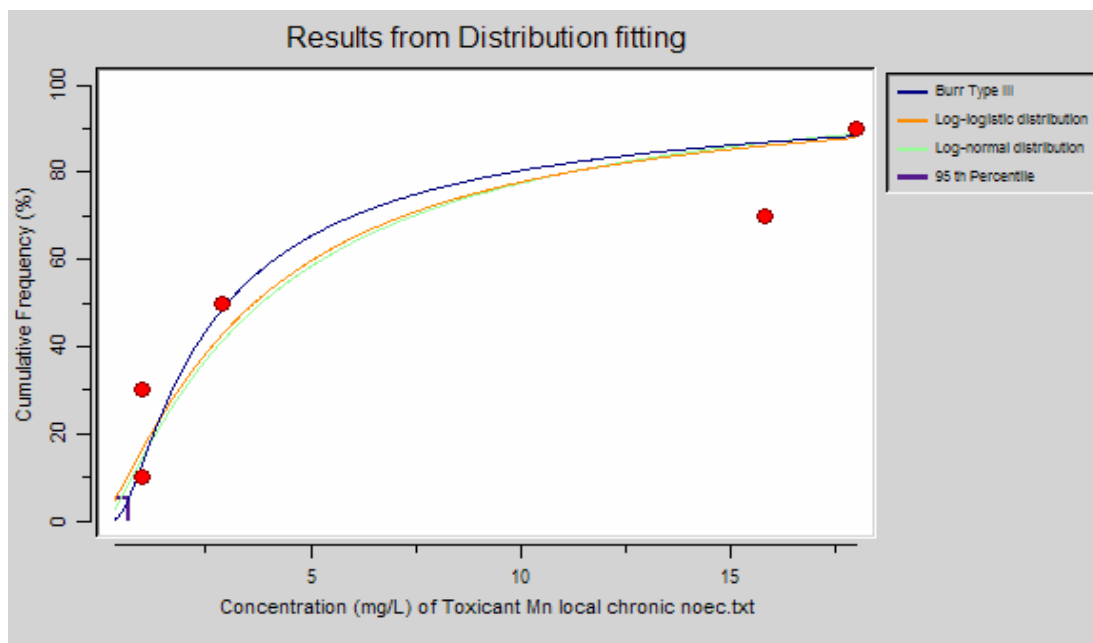


Figure 18: SSD derived from the toxicity tests undertaken for this study

The WHO (2003 draft) data (LC₅₀/EC₅₀ values) were used to calculate a SSD, similarly to the approach used for this study's toxicity tests. These data were used to generate a draft guideline in WHO (2003 draft) of 310 µg/L using an acute to chronic ratio of two, as a standard ratio for an essential metal and an EC₅₀ to NOEC conversion factor of 5. The resulting SSD is given in Figure 19. Note that this SSD did not include fish data, and the overall fit of the data to the Burr Type III, log-logistic and log-normal models was questionable. The data appear to be from more than one probability distribution, as evidenced by the two groups of derived NOEC values clustered above and below 5 mg/L Mn. The data significantly deviated from a log-normal distribution at the 10% level ($p = 0.08$, χ^2 goodness of fit test). The trigger value of 660 µg/L derived from the local data, which did include fish data, was equivalent to the 89% protection level of the WHO derived SSD.

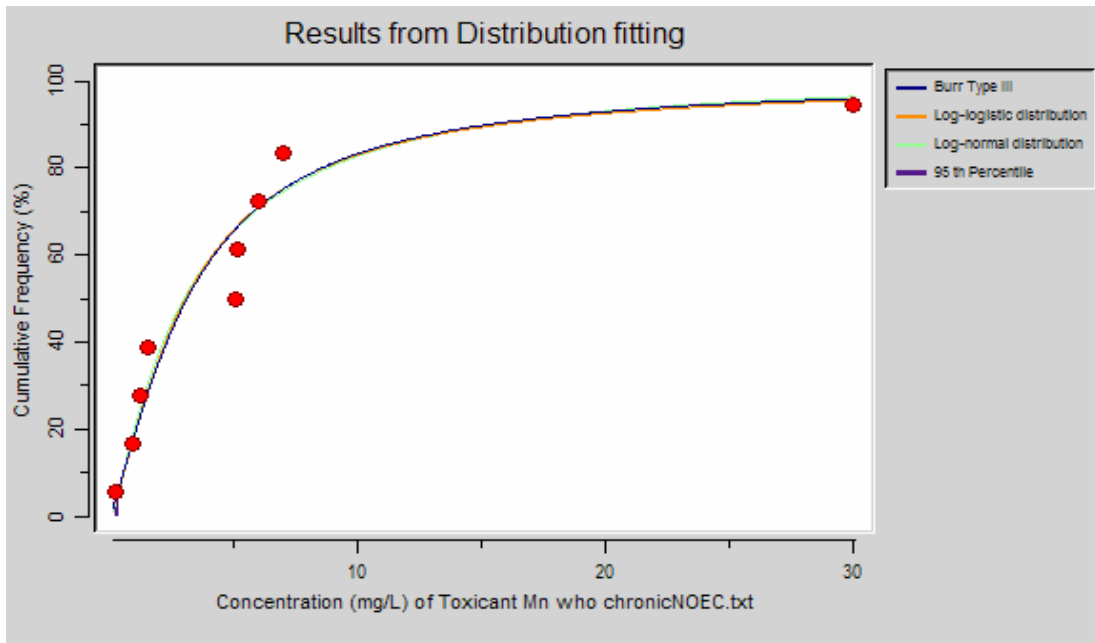


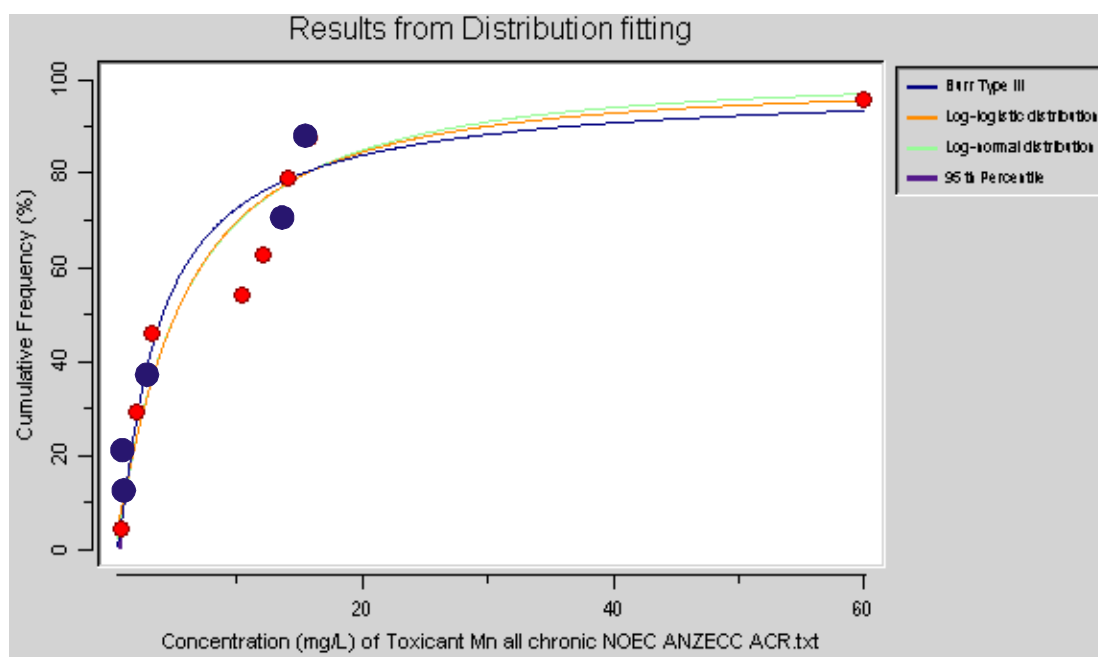
Figure 19: SSD derived by WHO (2003 draft)

Finally, in order to examine the comparability of the tests conducted for this study and the literature data, an SSD was derived for NOEC concentrations from this study's tests and the WHO (2003 draft)-ANZECC/ARMCANZ (2000). The chronic EC_{50} data were converted to NOEC equivalent results by division by 2.5 (M. Warne, NSW EPA, pers. comm., E-mail 11-01-2004). Acute LC_{50} data were either converted to NOEC equivalents by division by 5 (M. Warne, NSW EPA, pers. comm.), or by conversion to EC_{50} by division by the ACR developed from this study's results, and then division by 2.5. The data used are presented in Table 17. Note that the urchin larval NOEC value from this study was used in preference to the WHO (2003) value (from Doyle *et al.* 2003) as the latter value was based on nominal concentrations rather than measured values, and was little different from the result for this study. The resulting SSDs are illustrated in Figure 20 and Figure 21. In the figures, the data from this study are highlighted in blue. The tests from this study covered the majority of the range of sensitivities covered by the full dataset, from the second most sensitive species to the second most tolerant species, and conformed well to the overall SSD. The 95% protection level with 50% confidence derived from the Burr Type III distribution fitted to the combined data was 740 $\mu\text{g/L}$ for both types of conversion of acute data to NOEC values. This is little different from the 660 $\mu\text{g/L}$ derived from the tests performed for this study (the latter value was the 96.4% protection level for the combined SSD).

Therefore, the moderate-high reliability trigger value derived from this study's tests is based on data that are comparable to those used for the WHO (2003 draft) guideline, but was somewhat higher principally due to being based on measured NOEC values and an experimentally derived ACR, rather than an assumed essential metal ACR and conversion to NOEC-equivalent values via a very conservative application factor.

**Table 17: Combined toxicity data used to calculate an overall SSD**

Species	Source	NOEC	Calculation
Rock Oyster <i>S. commercialis</i>	This study	1	Unchanged
Urchin <i>H. tuberculata</i>	This study	1	Unchanged
Tiger Prawn <i>P. monodon</i>	This study	2.903	Acute NOEC/3.1
Bass <i>M. novemaculeata</i>	This study	15.806	Acute NOEC/3.1
Diatom <i>N. closterium</i>	This study WHO (2003), ANZECC/ARMCANZ (2000) value used	18 10.28 13.603	Unchanged EC ₅₀ /2.5 Geometric mean
<i>A. japonicum</i>	WHO (2003)	1.96	EC ₅₀ /2.5
Oyster <i>C. virginica</i>	WHO (2003), ANZECC/ARMCANZ (2000)	3.2 (2.06)	LC ₅₀ /5 (LC ₅₀ /3.1/2.5)
Clam <i>M. arenia</i>	WHO (2003)	60 (38.7)	LC ₅₀ /5 (LC ₅₀ /3.1/2.5)
Brine shrimp <i>A. salina</i>	WHO (2003)	10.36 (6.68)	LC ₅₀ /5 (LC ₅₀ /3.1/2.5)
Copepod <i>N. spinipes</i>	WHO (2003), ANZECC/ARMCANZ (2000)	14 (9.03)	LC ₅₀ /5 (LC ₅₀ /3.1/2.5)
Mussel <i>M. edulis</i>	WHO (2003), ANZECC/ARMCANZ (2000)	12	EC ₅₀ /2.5

**Figure 20: SSD derived from data from this study, ANZECC/ARMCANZ (2000) and WHO (2003 draft). Acute data converted by division by 5**

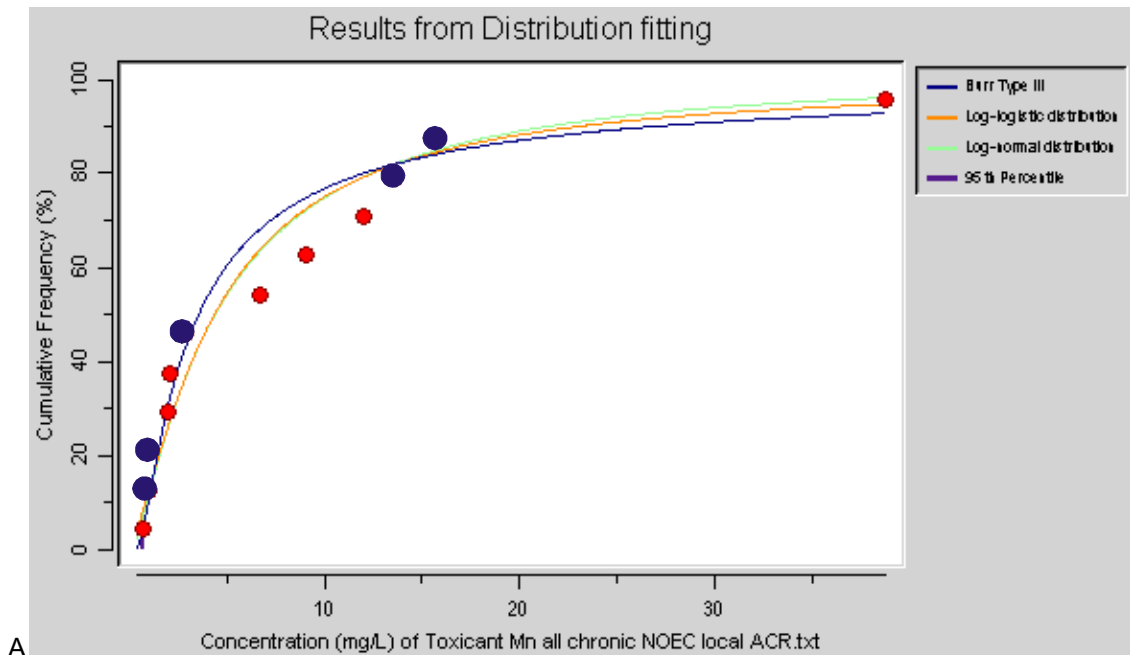


Figure 21: SSD derived from data from this study, ANZECC/ARMCANZ (2000) and WHO (2003 draft). Acute data converted by division by 3.1 and 2.5

All dissolved manganese concentrations recorded from Wangi Bay are lower than the trigger value derived from Australian species testing, indicating the dissolved manganese concentrations in the Bay are acceptable. The maximum recorded manganese concentration recorded in Wangi Bay in this study or the 2002 study of 339 µg/L was equivalent to the 99.6% protection level on the SSD calculated from the toxicity testing conducted for this study, and a comparable level of protection for the SSD derived from the combined literature values and this study's values. This is more than the level of protection required for slightly to moderately modified ecosystems or high conservation value ecosystems under the ANZECC/ARMCANZ (2000) classification.

Gale (2003) tested the toxicity of Wangi Bay sediments and dissolved manganese to two amphipod species. The species used for dissolved manganese testing was *Corophium cf. volutator*, and in a static test the NOEC was twenty times the maximum recorded Wangi Bay water column manganese concentration for that study, and three times the maximum recorded pore water concentration in that study. The species used for whole sediment toxicity testing was *Melita plumulosa*. Although the reference sediment used (Nords Wharf sediment with 25 % Bonnet Bay, Woronora River, sediment blended in) reduced growth and reproduction compared with the Bonnet Bay control sediment, the Wangi Bay sediments did not significantly affect growth and reproduction compared with the Nords Wharf reference sediment. While limited in extent, Gale's study provides some additional support for the conclusion of this study that the levels of dissolved manganese being discharged into Wangi Bay by Myuna Colliery are unlikely to be causing adverse ecological impacts.



7. CONCLUSION

Chemistry

The effect of the mine on Wangi Bay could only be detected through the measurement of manganese in the dissolved phase. Manganese levels recorded at the outlet decreased steadily as the distance from the outlet increased. It was found that the filterable manganese in the waters of Wangi Bay was essentially in truly dissolved form, with a negligible colloidal fraction and a high percentage of free/labile complexes. Finally, the sediment collected in Wangi Bay contained comparable amounts of manganese to those collected at the reference site and recorded at other EPA monitoring sites. This is in agreement with long time knowledge of naturally high levels on manganese in the area.

Ecotoxicology

Toxicity tests using locally relevant test species from five taxonomic groups, including a fish, were conducted. These tests included acute and chronic tests. An ACR derived from two of the test species was used to convert all the test results to chronic NOEC equivalent values, and a trigger value was derived using the methodology of ANZECC/ARMCANZ (2000) of 660 µg/L Mn. This was higher than a draft guideline value of 310 µg/L derived by WHO (2003 draft), but the latter was derived using an assumed essential metal ACR of 2 and conversion to NOEC-equivalent values via a very conservative application factor of 5, not measured NOEC values and a measured ACR. Furthermore, the draft WHO guideline was based on a data set that did not include fish test results. If the trigger value derived from the local species testing is used to assess the potential for environmental impacts, the measured Mn concentrations in Wangi bay would all be acceptable.



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Appendix A:

EPA Letter

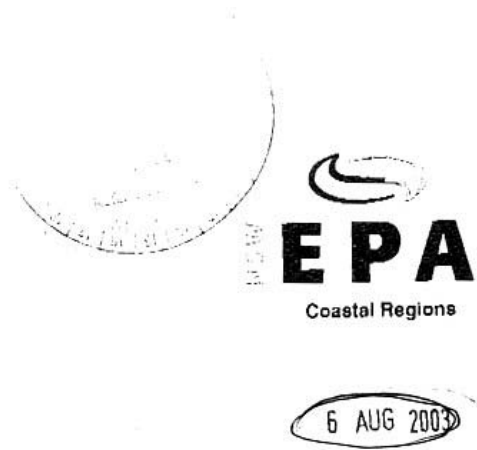
August 2003



Our reference : 270412A4
Contact : David Darvall (02)4908 6818

Centennial Myuna Pty Ltd
PO Box 1000
TORONTO NSW 2283

* Attn: Mr John Turner & Ms Donna Dryden



Dear Sir/Madam

Proposed Project Plan for Minewater Discharge – Myuna Colliery

I refer to the meeting between Centennial Myuna and the Environment Protection Authority (EPA) on 14 July 2003 to discuss Centennial Myuna's proposed project plan for assessing impacts of minewater discharge from Myuna colliery on receiving waters.

The EPA is of the opinion that the proposed study will provide an adequate understanding of the likely impacts of the proposed minewater discharges into Wangi Bay. However, some further detail is required as outlined below:

- Details of the methods that will be used for the chemical analyses of manganese should be submitted to the EPA, including instrumentation, detection limits, typical coefficients of variation at the sort of concentrations that are likely to be encountered, information on standards, controls and blanks and quality assurance/quality control procedures.
- The derivation of a new trigger value for Mn should be based on a comprehensive search of the literature. Details of databases, journals etc that will be searched to obtain the data should be submitted. The methodology that will be used to assess the quality of the data should be described. Data assessments and an explanation of any significant exclusions should form part of the final report.
- Describe what type of filters and what pore size filters apart from the 0.45um filter will be used. A description of the filtration process used and preparation of the filters should be submitted.
- The proposed study has three transects out from the mouth of Wangi Creek/canal. A fourth transect running towards the southern boundary of the lake should also be sampled. Sediment sampling should also be undertaken at all sites.
- Where salinity, turbidity and depth (CTD) profiles generated from surface samples are assumed to provide a three-dimensional snapshot of the mixing zone and therefore militate against analyses at depth, data should be submitted demonstrating the relationship between salinity, turbidity and the Mn concentrations. This data should be appropriately analysed showing the relationship.

Environment Protection Authority
PO Box 488G Newcastle NSW 2300 Australia Telephone 61 2 4908 6800 Facsimile 61 2 4908 6810 ABN 43 692 285 756
Ground Floor NSW Government Offices 117 Bull Street Newcastle West NSW 2302 www.epa.nsw.gov.au



- Details of the methods that will be used to compare toxicity data for Australasian species (tested for this study and previously published) to the distribution of overseas toxicity data to determine whether they are significantly different or not should be provided. This should include a discussion of the problem of the potential lack of power associated with testing a distribution based on five species.
- One fish species should be subjected to toxicity testing.
- Detailed methods for the toxicity tests should be provided, including QA/QC procedures, details of whether nominal or measured Mn concentrations will be used, reference toxicant tests, endpoints and measures of toxicity and how these will be calculated.

On a point of clarification the proposal states that "CORMIX is noted in ANZECC/ARMCANZ (2000) as being a suitable modeling package for development of mixing zones". However the guidelines simply state that there are a number of models and that the suitability of several of these including CORMIX have been assessed by Tsanis et al.

If you would like to discuss any aspects of the proposed study or these comments please contact me on (02) 4908 6818.

Yours sincerely

A handwritten signature in black ink, appearing to read 'D. Darvall'.

DAVID DARVALL
A/Head Regional Operations Unit



Appendix B:

ANZECC/ARMCANZ Guideline (2000) for manganese



Manganese is commonly used in steel alloys and dry cell batteries as well as in paints, inks, glass, ceramics, fireworks and fertilisers (CCREM 1987). It is a common constituent of discharges from mining and smelting activities (Stubblefield et al. 1997). It is widely distributed in the earth's crust, most commonly as MnO_2 . The current analytical practical quantitation limit (PQL) for manganese is 0.1 $\mu\text{g/L}$ in fresh water and 2 $\mu\text{g/L}$ in marine water (NSW EPA 2000).

Manganese is an essential trace element for microorganisms, plants and animals (CCREM 1987) and can be bioconcentrated up to 4 orders of magnitude, possibly to facilitate essential uses. It is present in natural waters in suspended form (similar to iron) although soluble forms may persist at low pH or low DO. Its toxicity is low compared to other trace metals and toxicity to brown trout *Salmo trutta* decreased significantly with increasing hardness (Stubblefield et al. 1997).

Freshwater guideline

Chronic data were available for manganese on only 3 taxonomic groups, so these data could only be used to derive an interim figure. More recent data (Stubblefield et al. 1997) determined an early life-stage IC_{25} to brown trout *Salmo trutta* of 4.67 mg/L at 30 mg/L hardness ($CaCO_3$) and 8.68 mg/L at 450 mg/L hardness. It was preferred to use the acute data to derive a *moderate reliability* trigger value. Freshwater data (mg/L) were as follows (pH range 6.75–8.4):

Fish: 3 spp, 48–96 h LC_{50} , 33.8–4540 mg/L (i.e. x 1000 $\mu\text{g/L}$); Chronic 28 d NOEC for additional species, *P. promelas*, 1270–9990 $\mu\text{g/L}$ (growth and mortality)

Amphibian: 1 sp, *Microhyla ornata*, 2–4 d LC_{50} , 14.3–16.6 mg/L

Crustaceans: 5 spp, 48–96 h LC_{50}/EC_{50} , 4.7 mg/L (*D. magna*) to 771 mg/L (*Asellus aquaticus*). An additional species, a harpacticoid copepod, had a 48-h LC_{50} of 54 $\mu\text{g/L}$ (0.054 mg/L), but this did not satisfy screening requirements.

Annelid: 1sp, *Tubifex tubifex*, 48–96 h LC_{50} , 171–208 mg/L

Algae: 1 sp, *Chlorella vulgaris*, NOEC, population growth, 4500 $\mu\text{g/L}$ (4.5 mg/L)

Macrophyte: 1 sp, *Lemna minor*, 96-h EC_{50} , growth, 32 mg/L

A freshwater moderate reliability trigger value of 1700 $\mu\text{g/L}$ was calculated for manganese using the statistical distribution method with 95% protection and an ACR of 9.1.

Marine guideline

Marine data were available for only 3 taxonomic groups, and this did not include fish:

Crustaceans: 2 spp, 10 $\mu\text{g/L}$ (crab, 7-d LOEC, mort.) to 70 000 $\mu\text{g/L}$. The low figure appears anomalous and needs to be checked.

Mollusc: 1 sp, 48-h LC_{50} , 16 000 $\mu\text{g/L}$

Algae: 2 spp, a figure of 1500 $\mu\text{g/L}$ for photosynthesis (EC_{50}) is not suitable for use, 96-h EC_{50} , growth, 25700 – 53800 $\mu\text{g/L}$

The marine dataset was more limited and there were some anomalies that may need to be checked. The outlying crab data and the photosynthesis EC_{50} for the alga were not used.

The marine dataset was more limited and there were some anomalies that may need to be checked. A marine low reliability trigger value at 80 $\mu\text{g/L}$ was derived for manganese from the mollusc figure using an AF of 200. This should only be used as an indicative interim working level.



Appendix C:

Toxicity of manganese to marine organisms



Appendix C: Toxicity of manganese to marine organisms

Phyla/ Division	Species	Life Stage	Duration of Exposure (h)	Manganese (mg/L)	Test Endpoint	Chemical Form	Test Media	Temp. (°C)	Salinity (‰)	pH	Reference
Bacillariophyta	Diatom (<i>Ditylum brightwellii</i>)		120	1.5	EC ₅₀ growth	Mn(II)	SiO ₂ Stosch-modified Schreiber medium				Canterford and Canterford, 1980
	Diatom (<i>Nitzschia closterium</i>)		72	>0.5	EC ₅₀	Mn(II)		21	32		Florence <i>et al.</i> , 1994
	Diatom (<i>Nitzschia closterium</i>)		96	26	EC ₅₀ growth	Mn(II)	Chelating and non- chelating Aquarium Systems Instant Ocean Sea Water	15.5		6.7-6.9 (chelating) 8.0-8.1 (non- chelating)	Rosko and Rachlin, 1975
	Diatom (<i>Asterionella japonica</i>)		24-72	4.9 (3.9-5.9)	EC ₅₀ growth	Mn(II)	Sterilised Bass Strait surface water (with f/2 nutrients, no EDTA, Cu or Zn)	23 ± 1			Fisher and Jones, 1981
	Diatom (<i>Entomoneis cf punctulata</i>)		24	>2.5	EC ₅₀ esterase inhibition	Mn(II)	Filtered seawater	21	34	8.1	Adams, 2000
	Diatom (<i>Chaetoceros calcitrans</i>)		96	19	EC ₅₀ growth (O.D. _{620nm})	Mn(II)	Artificial seawater + Walnes solution, vitamins silicate and nitrate. EDTA omitted. Solution sterilized.	28 ± 1	30 ± 2	8.0 ± 0.5	Ismael <i>et al.</i> , 2002
	Diatom (<i>Tetracelmis tetrahole</i>)		96	20	EC ₅₀ growth (O.D. _{620nm})	Mn(II)	Artificial seawater + Walnes solution, vitamins silicate and nitrate. EDTA omitted. Solution sterilized.	28 ± 1	30 ± 2	8.0 ± 0.5	Ismael <i>et al.</i> , 2002
	Diatom (<i>Tetracelmis sp.</i>)		96	21	EC ₅₀ growth (O.D. _{620nm})	Mn(II)	Artificial seawater + Walnes solution, vitamins silicate and nitrate. EDTA omitted. Solution sterilized.	28 ± 1	30 ± 2	8.0 ± 0.5	Ismael <i>et al.</i> , 2002



Phyla/ Division	Species	Life Stage	Duration of Exposure (h)	Manganese (mg/L)	Test Endpoint	Chemical Form	Test Media	Temp. (°C)	Salinity (‰)	pH	Reference
Chlorophyta	Green algae (<i>Chlorella stigmatophora</i>)		576	1000	LOEC growth	Mn(II)	Artificial seawater + SAAM levels of nitrogen, phosphorus, trace metals and EDTA		28		Christensen <i>et al.</i> , 1979
	Green algae (<i>Chlorella stigmatophora</i>)		240	64	LOEC growth	Mn(II)	Artificial seawater + SAAM levels of nitrogen, phosphorus, trace metals and EDTA		28		Christensen <i>et al.</i> , 1979
	Green algae (<i>Chlorella stigmatophora</i>)		504	50	EC ₅₀ (reduction in cell volume)	Mn(II)	Artificial seawater + SAAM levels of nitrogen, phosphorus, trace metals and EDTA		28		Christensen <i>et al.</i> , 1979
Chrysophyta	Golden algae (<i>Isochrysis galbana</i>)		96	7.2	EC ₅₀ growth (O.D. _{620nm})	Mn(II)	Artificial seawater + Walnes solution, vitamins silicate and nitrate. EDTA omitted. Solution sterilized.	28 ± 1	30 ± 2	8.0 ± 0.5	Ismael <i>et al.</i> , 2002
Arthropoda (Crustacea)	Hapacticoid copepod (<i>Nitocra spinipes</i>)	Adult	96	70 (52-94)	LC ₅₀	Mn(II)	Brackish water	20 ± 0.5	7	8	Bengtsson, 1978
	Brine shrimp (<i>Artemia salina</i>)		24	75	LC ₅₀	Mn(II)	Filtered seawater	28 ± 1	33-34	7.5-8.4	Gajbhiye and Hirota, 1990
	Brine shrimp (<i>Artemia salina</i>)		48	52	LC ₅₀ survival	Mn(II)	Filtered seawater	28 ± 1	33-34	7.5-8.4	Gajbhiye and Hirota, 1990
	Yellow rock crab (<i>Cancer anthonyi</i>)	Embryo	168	0.010	LOEC survival	Mn(II)	Filtered seawater	20	34	7.8	MacDonald <i>et al.</i> , 1988
	Yellow rock crab (<i>Cancer anthonyi</i>)	Embryo	168	0.010	LOEC embryo hatching	Mn(II)	Filtered seawater	20	34	7.8	MacDonald <i>et al.</i> , 1988
Mollusca (Bivalvia)	American oyster (<i>Crassostrea virginica</i>)	Embryo/ larvae	48	16 (14-19)	LC ₅₀	Mn(II)	Synthetic seawater	26	25	7.0-8.5	Calabrese <i>et al.</i> , 1973



Phyla/ Division	Species	Life Stage	Duration of Exposure (h)	Manganese (mg/L)	Test Endpoint	Chemical Form	Test Media	Temp. (°C)	Salinity (‰)	pH	Reference
Mollusca (Bivalvia) (continued)	American oyster (<i>Crassostrea virginica</i>)	Embryo/ larvae	48	5	NOEC	Mn(II)	Synthetic seawater	26	25	7.0-8.5	Calabrese <i>et al.</i> , 1973
	Common bay mussel, blue (<i>Mytilus adulis</i>)	Embryo/ larva	48	30	EC ₅₀ develop	Mn(II)		19	26	8.4	Morgan <i>et al.</i> , 1986
	Softshell clam (<i>Mya arenaria</i>)	Adult	48	300	LC ₀ (NOEC)	Mn(II)	Seawater	22 ± 0.5	30 ± 1	8.0 ± 0.1	Eisler, 1977
	Softshell clam (<i>Mya arenaria</i>)	Adult	48	>300	LC ₅₀	Mn(II)	Seawater	22 ± 0.5	30 ± 1	8.0 ± 0.1	Eisler, 1977
	Softshell clam (<i>Mya arenaria</i>)	Adult	48	>300	LC ₁₀₀	Mn(II)	Seawater	22 ± 0.5	30 ± 1	8.0 ± 0.1	Eisler, 1977
	Softshell clam (<i>Mya arenaria</i>)	Adult	96	300	LC ₀ (NOEC)	Mn(II)	Seawater	22 ± 0.5	30 ± 1	8.0 ± 0.1	Eisler, 1977
	Softshell clam (<i>Mya arenaria</i>)	Adult	96	>300	LC ₅₀	Mn(II)	Seawater	22 ± 0.5	30 ± 1	8.0 ± 0.1	Eisler, 1977
	Softshell clam (<i>Mya arenaria</i>)	Adult	96	>300	LC ₁₀₀	Mn(II)	Seawater	22 ± 0.5	30 ± 1	8.0 ± 0.1	Eisler, 1977
	Softshell clam (<i>Mya arenaria</i>)	Adult	168	30	LC ₀ (NOEC)	Mn(II)	Seawater	22 ± 0.5	30 ± 1	8.0 ± 0.1	Eisler, 1977
	Softshell clam (<i>Mya arenaria</i>)	Adult	168	300	LC ₅₀	Mn(II)	Seawater	22 ± 0.5	30 ± 1	8.0 ± 0.1	Eisler, 1977
	Softshell clam (<i>Mya arenaria</i>)	Adult	168	>300	LC ₁₀₀	Mn(II)	Seawater	22 ± 0.5	30 ± 1	8.0 ± 0.1	Eisler, 1977
Echinodermata	Sea urchin (<i>Helicidaris tuberculata</i>)	Sperm	1.33	>40	EC ₅₀ develop	Mn(II)	Filtered seawater	18 ± 2	34 ± 2	8.2 ± 2	Doyle, 2003
Echinodermata (continued)	Sea urchin (<i>Helicidaris tuberculata</i>)	Embryo/ larva	72	5.2	EC ₅₀	Mn(II)	Filtered seawater	18 ± 2	34 ± 2	8.2 ± 2	Doyle, 2003



Phyla/ Division	Species	Life Stage	Duration of Exposure (h)	Manganese (mg/L)	Test Endpoint	Chemical Form	Test Media	Temp. (°C)	Salinity (‰)	pH	Reference
	Sea urchin (<i>Heliocidaris tuberculata</i>)	Embryo/ larva	72	1.3	NOEC	Mn(II)	Filtered seawater	18 ± 2	34 ± 2	8.2 ± 2	Doyle, 2003
	Sea urchin (<i>Hemicentrotus pulcherrimus</i>)	Embryo/ larva	48	24 ^a	IC ₅₀ develop.	Mn(II)	Seawater	18			Kobayashi, 1990
	Sea urchin (<i>Arbacia punctulata</i>)	Sperm	0.5	0.14	NOEC (motility)	Mn(II)	Filtered seawater	22-23			Young and Nelson, 1974
	Starfish (<i>Asterias rubens</i>)		14	200 ^b	LT ₅₀	Mn(II)					Hansen and Bjerregaard, 1995
	Starfish (<i>Asterias rubens</i>)		18	100	LT ₅₀	Mn(II)					Hansen and Bjerregaard, 1995
	Starfish (<i>Asterias rubens</i>)		72	50	LT ₅₀	Mn(II)					Hansen and Bjerregaard, 1995

^aValues have been estimated by Stauber and Binet from data in original articles.

^bThese values represent the concentration at which an LT50 was determined (time at which 50% of the population was effected, when subject to one particular concentration of Mn). Therefore, the duration of the experiment is the significant value not the concentration.



Appendix D:

Data collected during the November 2002 sampling campaign



Appendix D: Data collected during the November 2002 sampling campaign

Results of Water Physico-Chemistry and Toxicants Relevant to Myuna Colliery

Water Sample Location	Rain in Previous 5 days	Date of Sample Collection				Ave	Variability	ANZECC Trigger Value	ANZECC Limit Triggered?
		26/06/02	03/07/02	10/07/02	17/07/02				
Upstream									
Manganese Filterable(mg/L)	No	0.04	0.04			0.04		1.9	No
Conductivity (ms/cm)	No	0.311	0.337			0.32	0.0003	-	n/a
Dissolved Oxygen (% saturation)	No	33	24			28.50		80-110	n/a
pH	No	5.96	5.8			5.88		5.0-9.0	n/a
Temperature (degrees)	No	8.9	9.4	10.2		9.50	0.4300	15-35	n/a
Turbidity (NTU)	No	4.1	4.5			4.30		0.5-10	n/a
LDP001									
Manganese Filterable(mg/L)	No	0.99	0.98			0.99		1.9	No
Conductivity (ms/cm)	No	39	39.8			39.40		-	n/a
Dissolved Oxygen (% saturation)	No	59	36			47.50		80-110	n/a
pH	No	7.4	7.6			7.50		5.0-9.0	n/a
Temperature (degrees)	No	19.7	20	19.4		19.70		15-35	n/a
Turbidity (NTU)	No	4.7	4.6			4.65		0.5-10	n/a
Downstream									
Manganese Filterable(mg/L)	No	0.82	1	0.84		0.91	0.0097	1.9	No
Conductivity (ms/cm)	No	35	39.4	41		38.47		-	n/a
Dissolved Oxygen (% saturation)	No	108	*	*		108.00		80-110	n/a
pH	No	7.6	7.7	7.8		7.70		5.0-9.0	n/a
Temperature (degrees)	No	19.4	19.3	18.7		19.13		15-35	n/a
Turbidity (NTU)	No	5.7	5	12		7.57		0.5-10	n/a
Weir Wall Upstream									
Manganese Filterable(mg/L)	No	0.94				0.94		1.9	No
Conductivity (ms/cm)	No	38.3				38.30		-	n/a
Dissolved Oxygen (% saturation)	No	76				76.00		80-110	n/a
pH	No	7.7				7.70		5.0-9.0	n/a
Temperature (degrees)	No	19.2				19.20		15-35	n/a



Appendix D

Turbidity (NTU)	No	5.3				5.30		0.5-10	n/a
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Water Sample Location	Rain in Previous 5 days	Date of Sample Collection				Ave	Variability	ANZECC Trigger Value	ANZECC Limit Triggered?
		26/06/02	03/07/02	10/07/02	17/07/02				
Weir Wall Downstream									
Manganese Filterable(mg/L)	No	0.15				0.15		1.9	No
Conductivity (ms/cm)	No	47.6				47.60		-	n/a
Dissolved Oxygen (% saturation)	No	77				77.00		80-110	n/a
pH	No	8				8.00		5.0-9.0	n/a
Temperature (degrees)	No	15.3				15.30		15-35	n/a
Turbidity (NTU)	No	2.2				2.20		0.5-10	n/a
Canal Outlet									
Manganese Filterable(mg/L)	No	0.07				0.07		1.9	No
Conductivity (ms/cm)	No	50.6				50.60		-	n/a
Dissolved Oxygen (% saturation)	No	81				81.00		80-110	n/a
pH	No	8.09				8.09		5.0-9.0	n/a
Temperature (degrees)	No	15.4				15.40		15-35	n/a
Turbidity (NTU)	No	1.9				1.90		0.5-10	n/a
10m from Canal Outlet									
Manganese Filterable(mg/L)	No	0.19	0.28	0		0.16	0.0204	1.9	No
Conductivity (ms/cm)	No	51.5	47.5	50		49.67	4.0833	-	n/a
Dissolved Oxygen (% saturation)	No	84	71	*		77.50		80-110	n/a
pH	No	8.1	8	8		8.03		5.0-9.0	n/a
Temperature (degrees)	No	14.9	14.3	13.8		14.33		15-35	n/a
Turbidity (NTU)	No	1.4	4.6	1.3		2.43		0.5-10	n/a
25m from Canal Outlet									
Manganese Filterable(mg/L)	No	0.04				0.04		1.9	No
Conductivity (ms/cm)	No	51.4				51.40		-	n/a
Dissolved Oxygen (% saturation)	No	85				85.00		80-110	n/a
pH	No	8.1				8.10		5.0-9.0	n/a
Temperature (degrees)	No	15.1				15.10		15-35	n/a
Turbidity (NTU)	No	1.6				1.60		0.5-10	n/a
50m from Canal Outlet									
Manganese Filterable(mg/L)	No	0.04				0.04		1.9	No



Appendix D

Conductivity (ms/cm)	No	50.4				50.40		-	n/a
Dissolved Oxygen (% saturation)	No	84				84.00		80-110	n/a
pH	No	8.1				8.10		5.0-9.0	n/a
Temperature (degrees)	No	14.9				14.90		15-35	n/a
Turbidity (NTU)	No	1.5				1.50		0.5-10	n/a
Water Sample Location	Rain in Previous 5 days	Date of Sample Collection				Ave	Variability	ANZECC Trigger Value	ANZECC Limit Triggered?
		26/06/02	03/07/02	10/07/02	17/07/02				
100m from Canal Outlet									
Manganese Filterable(mg/L)	No	0.02	0.15	0		0.06		1.9	No
Conductivity (ms/cm)	No	51.9	51.2	53		52.03		-	n/a
Dissolved Oxygen (% saturation)	No	84	66	*		75.00		80-110	n/a
pH	No	8.1	8.2	8.2		8.17		5.0-9.0	n/a
Temperature (degrees)	No	14.9	14.5	13.4		14.27		15-35	n/a
Turbidity (NTU)	No	0.8	0.8	1.5		1.03		0.5-10	n/a
200m from Canal Outlet									
Manganese Filterable(mg/L)	No	0.02				0.02		1.9	No
Conductivity (ms/cm)	No	52				52.00		-	n/a
Dissolved Oxygen (% saturation)	No	83				83.00		80-110	n/a
pH	No	8.2				8.20		5.0-9.0	n/a
Temperature (degrees)	No	14.8				14.80		15-35	n/a
Turbidity (NTU)	No	0.7				0.70		0.5-10	n/a
Myuna Bay Power Station CW Inlet									
Manganese Filterable(mg/L)	No	0.02	0	0.02	0.01	0.05		1.9	No
Conductivity (ms/cm)	No	51.7	51.8	52.3	52.1	51.98		-	n/a
Dissolved Oxygen (% saturation)	No	97	96	*	*	96.50		80-110	n/a
pH	No	8.1	8.1	8.1	8.2	8.13		5.0-9.0	n/a
Temperature (degrees)	No	18.1	14.4	15.3	15	15.70		15-35	n/a
Turbidity (NTU)	No	3.3	0.6	2.3	0.7	1.73		0.5-10	n/a
Pourmalong Creek									
Manganese Filterable(mg/L)	No	0.01	0	0	0.01	0.01		1.9	No
Conductivity (ms/cm)	No	47.9	48	49.5	49.4	48.70		-	n/a
Dissolved Oxygen (% saturation)	No	50	84	*	*	67.00		80-110	n/a
pH	No	8	7.8	8	7.9	7.93		5.0-9.0	n/a
Temperature (degrees)	No	14.4	12.8	13.1	11.9	13.05		15-35	n/a
Turbidity (NTU)	No	0.7	1.1	0.5	1.5	0.95		0.5-10	n/a





Results of Sediment Physico-Chemistry and Toxicants Relevant to Myuna Colliery

Sample Location	Date of Sample Collection	Rain in Previous 5 Days	Particle Fraction	Mass(%)	Total Mn (mg/kg)	Cumulative Mass (%)	Total Mn (mg/kg)	Average Total Mn (mg/kg)	ANZECC Trigger Value (mg/kg)	ANZECC Limit Triggered ?
10m from Canal Outlet	26/06/2002	No					143	146.5	460	No
	23/09/2002	No	>2mm	13.1	42	13.1	42			
			>630um-<2mm	9.2	117	22.3	73			
			<630um	77.7	172	100	35			
							150			
25m from Canal Outlet	23/09/2002	No	>2mm	14	48	14	48	175	460	No
			>630um-<2mm	14.4	135	28.4	92			
			<630um	71.6	208	100	35			
							175			
50m from Canal Outlet	23/09/2002	No	>2mm	6.7	43	6.7	43	161	460	No
			>630um-<2mm	7.4	164	14.1	107			
			<630um	85.9	170	100	10			
							161			
100m from Canal Outlet	26/06/2002	No					120	140	460	No
	23/09/2002	No	>2mm	1.8	51	1.8	51			
			>630um-<2mm	4.4	111	6.2	94			
			<630um	93.8	164	100	15			
						160				
Myuna Bay Cooling Water Inlet	26/06/2002	No					158	158	-	-
Pourmalong Creek	26/06/2002	No					4	4	-	-



Appendix E:

Sampling sites characteristics and coordinates



Characteristics and coordinates of the Sampling Sites

Site Code	Description	Zone	Easting	Northing
T0	Entrance of the Canal	56H	367515	6340517
T1-5m	Transect 1 – 5 m from the outlet	56H	367525	6340530
T1-10m	Transect 1 – 10 m from the outlet	56H	367532	6340534
T1-50m	Transect 1 – 50 m from the outlet	56H	367566	6340553
T1-100m	Transect 1 – 100 m from the outlet	56H	367607	6340569
T1-200m	Transect 1 – 200 m from the outlet	56H	367687	6340636
T2-5m	Transect 2 – 5 m from the outlet	56H	367528	6340510
T2-10m	Transect 2 – 10 m from the outlet	56H	367527	6340511
T2-50m	Transect 2 – 50 m from the outlet	56H	367562	6340516
T2-100m	Transect 2 – 100 m from the outlet	56H	367618	6340502
T2-200m	Transect 2 – 200 m from the outlet	56H	367731	6340495
T3-5m	Transect 3 – 5 m from the outlet	56H	367521	6340510
T3-10m	Transect 3 – 10 m from the outlet	56H	367522	6340511
T3-50m	Transect 3 – 50 m from the outlet	56H	367550	6340490
T3-100m	Transect 3 – 100 m from the outlet	56H	367585	6340454
T3-200m	Transect 3 – 200 m from the outlet	56H	367671	6340438
T4-5m	Transect 4 – 5 m from the outlet	56H	367518	6340499
T4-10m	Transect 4 – 10 m from the outlet	56H	367517	6340492
T4-50m	Transect 4 – 50 m from the outlet	56H	367532	6340451
T4-100m	Transect 4 – 100 m from the outlet	56H	367560	6340413
T4-200m	Transect 4 – 200 m from the outlet	56H	367614	6340327
TR-5m	Reference – 5 m from the outlet	56H	366291	6340272
TR-10m	Reference – 10 m from the outlet	56H	366281	6340265
TR-50m	Reference – 50 m from the outlet	56H	366247	6340242
TR-100m	Reference – 100 m from the outlet	56H	366205	6340211
TR-200m	Reference – 200 m from the outlet	56H	366126	6340149
USWW	Upstream of the Weir Wall	56H	366813	6340863
DSWW	Downstream of the Weir Wall	56H	367122	6340587
US	Upstream of the Colliery	56H	367121	6340578
LDP1	Licensed Discharge Point	56H	366360	6340899
DS	Downstream of the Colliery	56H	366732	6340928



Appendix F:

Depth profile data



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
Transect 1 – 5 m							
0.1	15.45	45.6	29.52	6.8	8.39	334	0.4
0.1	16.66	49.3	32.23	9.3	8.45	344	-1.4
0.2	14.96	0.7		11.3	8.31	341	-1.6
0.3	16.65	49.5	32.36	9.3	8.43	338	-0.7
0.4	16.41	50.3	32.97	9.5	8.46	338	-0.7
0.5	15.99	50.9	33.37	9.7	8.51	337	0.2
0.6	15.9	51	33.45	9.7	8.53	335	10.7
Transect 1 – 10 m							
0.1	17.41	44.9	29.03	7.8	8.22	330	-2.5
0.2	16.08	50.7	33.25	9.3	8.5	327	-1.8
0.3	16.01	50.8	33.31	9.3	8.5	327	-1.4
0.4	15.96	50.9	33.39	9.3	8.5	326	-1.6
0.5	15.96	51	33.44	9.2	8.51	326	-1.8
0.6	15.95	51	33.44	9.2	8.51	325	-1.6
0.7	15.94	51	33.45	9.3	8.51	325	45.1
Transect 1 - 50 m							
0.1	16.82	48.4	31.57	8.5	8.43	326	-3
0.2	16.89	48.4	31.56	8.5	8.33	325	-3.2
0.3	16.54	50.7	33.2	8.9	8.5	324	-3.4
0.4	16.48	50.8	33.34	9.3	8.53	323	-3.4
0.5	16.41	50.9	33.39	9.8	8.55	322	-3.2
0.6	16.41	51	33.44	10.1	8.56	322	154.9
Transect 1 - 100 m							
0.1	16.37	50.7	33.26	8.1	8.47	321	-2.1
0.2	16.34	50.7	33.24	8.7	8.48	320	-2
0.3	16.3	50.8	33.27	8.8	8.48	320	-2
0.4	16.26	50.8	33.31	8.9	8.49	320	-2.7
0.5	16.22	50.8	33.3	9	8.49	320	-2.9
0.6	16.17	50.9	33.39	9	8.5	319	-3.6
0.7	16.14	50.9	33.37	9.1	8.51	319	-3.4
0.8	16	50.9	33.36	9.2	8.52	319	-0.4
0.9	15.87	50.9	33.38	9.3	8.53	319	-3.6
1	15.82	50.9	33.39	9.5	8.54	319	-1.8
1.1	15.82	51	33.43	9.6	8.55	319	3.9
Transect 1 - 200 m							
0.1	16.42	50.4	33.01	9.4	8.51	319	-3.8
0.2	16.36	50.6	33.14	9	8.51	319	-3.9
0.3	16.21	50.8	33.31	9	8.52	319	-3.8
0.4	16.14	50.8	33.32	8.9	8.52	319	-3.9
0.5	16.05	50.9	33.36	8.9	8.52	319	-4.1
0.6	16.02	50.9	33.38	8.9	8.52	320	-3.9
0.7	16	50.9	33.4	8.8	8.52	320	-3.8
0.8	16.02	51	33.43	8.8	8.57	320	-3.4
0.9	16.04	50.9	33.41	9.7	8.63	319	-3.4
1	16.03	50.9	33.42	10.4	8.62	319	39.6
Transect 2 - 5 m							
0.1	15.45	45.6	29.52	6.8	8.39	334	0.4
0.2							
0.3	14.79	50.7	33.23	7.2	8.66	320	-0.2
0.4	14.8	50.7	33.23	7.9	8.7	318	1.4



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
0.5	14.79	50.6	33.19	7.9	8.7	317	0.7
0.6	14.8	50.6	33.18	7.9	8.7	316	0.4
0.7	14.79	50.6	33.15	7.9	8.7	316	61.8
0.8	14.8	50.6	33.14	7.9	8.69	315	13.2
Transect 2 - 10 m							
0.1	14.86	50.1	32.79	7.6	8.61	318	3.8
0.2	14.84	50.3	32.94	7.8	8.66	316	-0.4
0.3	14.84	50.3	32.94	7.9	8.67	315	-0.7
0.4	14.83	50.3	32.95	7.9	8.68	314	-1.4
0.5	14.83	50.3	32.95	8	8.68	314	-1.4
0.6	14.84	50.3	32.94	8	8.68	313	-1.4
0.7	14.85	50.3	32.97	8	8.68	312	-1.3
Transect 2 - 50 m							
0.1	14.94	50.1	32.76	7.8	8.6	314	-0.5
0.2	14.9	50.2	32.89	8	8.65	312	-0.7
0.3	14.89	50.3	32.94	8.1	8.65	311	-2
0.4							
0.5	14.89	50.3	32.94	8.1	8.65	311	-1.4
0.6	14.89	50.3	32.94	8.1	8.65	311	-1.8
0.7	14.9	50.3	32.97	8	8.65	311	-1.8
0.8	14.91	50.3	32.92	8.1	8.65	310	0.9
1	14.92	50.3	32.95	8.1	8.65	310	-1.3
Transect 2 - 100 m							
0.1	15.24	50.9	33.37	8.5	8.53	199	-2.3
0.2	15.24	50.9	33.41	8.6	8.53	207	-1.6
0.3	15.21	50.9	33.4	8.7	8.53	218	-2.7
0.4							
0.5	15.2	50.9	33.41	8.8	8.53	226	-2.7
0.6	15.12	50.8	33.34	8.8	8.53	230	-2.5
0.7	15.06	50.9	33.4	8.8	8.52	237	-2.3
0.8	15.04	50.9	33.37	8.7	8.52	241	-2.1
0.9	15.01	50.8	33.35	8.7	8.52	244	-2.5
1	14.97	50.9	33.39	8.7	8.52	248	-1.8
1.1	14.94	50.9	33.41	8.6	8.52	253	-2.3
1.2	14.93	50.9	33.42	8.6	8.52	254	3.4
1.3	14.92	50.9	33.39	8.6	8.52	256	-2.5
1.4	14.91	50.9	33.4	8.6	8.52	258	-2.1
1.5	14.9	50.9	33.4	8.6	8.52	260	-2.9
1.6	14.88	50.9	33.37	8.6	8.52	261	-2.5
1.7	14.86	50.9	33.39	8.7	8.52	262	-3
1.8	14.86	50.9	33.39	8.6	8.52	263	-3
1.9	14.85	50.9	33.35	8.6	8.52	264	-3
2	14.84	50.9	33.37	8.6	8.52	265	-3
2.1	14.82	50.9	33.38	8.6	8.52	266	-2.5
2.2	14.79	50.9	33.36	8.6	8.52	267	-2.3
2.3	14.78	50.9	33.38	8.5	8.5	269	-1.1
2.4	14.73	50.9	33.42	8.4	8.49	270	-1.3
2.5	14.71	50.9	33.39	8.1	8.48	272	1.1
2.6	14.71	50.9	33.4	8	8.48	273	-1.1
2.7	14.7	50.9	33.4	8	8.48	273	-1.1
2.8	14.7	50.9	33.4	7.8	8.47	275	11.5
2.9	14.69	50.9	33.41	7.8	8.47	276	-1.4



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
3	14.69	50.9	33.41	7.8	8.47	276	-0.2
3.1	14.68	50.9	33.42	7.8	8.47	277	-1.3
3.2	14.7	50.9	33.4	7.8	8.48	278	0
3.3	14.7	50.9	33.4	8.1	8.5	279	2.1
3.4	14.71	51	33.44	8.1	8.5	280	-0.5
3.5	14.7	51	33.45	8.2	8.51	281	-0.4
3.6	14.7	51	33.45	8.2	8.51	283	-0.7
3.7	14.7	51	33.45	8.2	8.51	283	-1.4
3.9	14.71	51	33.44	8.2	8.51	284	-0.4
Transect 2 - 200 m							
0.1	15	50.9	33.36	8.7	8.53	301	-3.6
0.2	15.06	50.8	33.35	8.6	8.53	300	-2.9
0.3	15.08	50.9	33.37	8.6	8.53	301	-3.8
0.4	15.04	50.8	33.33	8.7	8.53	301	-4.1
0.5	14.88	50.9	33.37	8.7	8.54	300	-3.8
0.6	14.88	50.9	33.37	8.7	8.54	300	-3.6
0.7	14.88	50.9	33.37	8.7	8.54	300	-3.9
0.8							
0.9	14.84	50.8	33.33	8.7	8.54	300	-4.1
1	14.78	50.9	33.38	8.7	8.55	300	-4.3
1.1	14.75	50.9	33.4	8.7	8.55	300	-3.9
1.2	14.72	50.9	33.38	8.7	8.55	300	-4.3
1.3	14.72	50.9	33.38	8.7	8.55	301	-2.3
1.4	14.72	50.9	33.38	8.7	8.54	301	-4.1
1.5	14.71	50.9	33.39	8.7	8.55	301	-3.9
1.6	14.69	50.9	33.37	8.7	8.54	302	-4.1
1.7	14.69	50.9	33.37	8.7	8.54	302	-3.8
1.8	14.69	50.9	33.37	8.7	8.54	302	-3.9
1.9	14.73	50.9	33.37	8.7	8.54	302	-3.4
2	14.75	50.9	33.4	8.7	8.54	302	-3.6
2.1	14.81	51	33.43	8.7	8.54	303	-4.1
2.2	14.82	51	33.43	8.6	8.54	303	-3.9
2.3	14.82	51	33.43	8.6	8.54	303	-3.2
2.4	14.81	51	33.43	8.6	8.54	303	-4.1
2.5	14.83	50.9	33.42	8.6	8.54	303	-3.8
2.6	14.83	51	33.46	8.6	8.54	304	-4.3
2.7	14.84	51	33.46	8.6	8.54	304	-4.1
2.8	14.85	51	33.45	8.6	8.54	305	-0.7
2.9	14.84	51	33.46	8.6	8.54	305	-3.8
3	14.83	50.9	33.42	8.6	8.54	305	-3.8
3.1	14.82	51	33.43	8.6	8.54	306	-2.9
3.2	14.8	51	33.44	8.6	8.54	306	-3
3.3							
3.4	14.78	50.9	33.42	8.6	8.54	307	-4.3
3.5	14.78	51	33.46	8.6	8.54	307	-4.3
3.6	14.78	50.9	33.42	8.6	8.54	307	-4.1
3.7	14.74	51	33.45	8.6	8.54	308	-4.3
3.8	14.74	50.9	33.41	8.6	8.53	308	-3
3.9	14.74	50.9	33.41	8.6	8.53	308	-4.1
4	14.71	51	33.43	8.4	8.53	310	-1.3
4.1	14.72	51	33.47	8.4	8.53	310	-2



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
4.2	14.71	51	33.43	8.4	8.53	310	2.5
4.3	14.72	51	33.47	8.4	8.53	310	0.7
4.4	14.72	51	33.47	8.4	8.53	310	-2.5
4.5	14.74	51	33.45	8.4	8.54	311	2.1
4.6	14.73	51	33.46	8.4	8.54	311	-1.3
4.7	14.75	51	33.49	8.4	8.54	311	77
4.8	14.73	50.9	33.42	8.4	8.53	311	79.5
Transect 3 – 5 m							
0.1	17.66	49.2	32.13	11.4	8.45	322	-3.6
0.2	17.56	49.9	32.65	11.1	8.42	322	-3.6
0.3	17.46	50.4	33.02	11.1	8.48	321	-3.6
0.4	17.41	50.5	33.06	11.3	8.48	321	-3.2
0.5	16.81	51	33.47	10.2	8.43	320	-2
0.6	16.8	51	33.48	10.1	8.43	319	-2.9
0.7	16.53	51.2	33.58	10.1	8.44	319	2.5
Transect 3 – 10 m							
0.1	17.29	48.8	31.81	10.2	8.47	321	7.9
0.2	17.26	47.9	31.19	9.1	8.28	322	2.1
0.3	17.27	50.4	33.01	9.2	8.51	321	-0.5
0.4	16.87	50.9	33.38	10.1	8.52	321	21.5
0.5	16.79	51	33.45	10.1	8.52	321	10.6
0.6	16.73	51.1	33.5	10.1	8.52	321	6.3
0.7	16.64	51	33.49	10.1	8.51	321	7.3
0.8	16.56	51.1	33.52	9.9	8.5	320	540.9
Transect 3 - 50 m							
0.1	16.59	51.1	33.53	8.8	8.52	322	-4.3
0.2	16.77	51	33.47	9.5	8.52	322	-4.3
0.3	16.77	50.9	33.42	9.7	8.53	322	-4.3
0.4	16.77	51	33.46	9.7	8.53	321	-3.9
0.5	16.77	51	33.46	9.8	8.53	321	-3.9
0.6	16.77	51	33.43	9.8	8.53	321	-4.5
0.7	16.8	51	33.48	9.8	8.54	321	-4.1
0.8	16.91	51	33.47	9.9	8.55	321	-3.6
0.9	16.91	51	33.47	10	8.55	321	-3.8
1	16.91	51.1	33.52	10	8.54	321	-4.1
1.1	16.84	50.9	33.41	10.1	8.54	321	-4.1
1.2	16.39	51	33.49	9.8	8.5	321	-4.7
1.3	16.29	51	33.45	9.6	8.49	321	-4.3
1.4	16.22	51.1	33.51	9.4	8.48	322	-4.1
1.5	16.17	51.1	33.51	9.2	8.48	322	-4.3
1.6	16.13	51.1	33.51	9.1	8.48	322	-4.1
1.7	16.07	51.1	33.55	9	8.48	322	-4.3
1.8	16.03	51.1	33.55	9	8.49	322	-3.8
1.9	16.02	51.1	33.55	9	8.5	322	-3
2	16	51.1	33.57	9.1	8.5	322	-3.8
2.1	15.99	51.2	33.58	9.1	8.51	322	-3.6
2.2	16	51.2	33.61	9.2	8.5	323	-3.4
2.3	15.99	51.1	33.54	9.2	8.5	323	-2.9
2.4	15.63	51.1	33.54	9.3	8.5	323	-3
2.5	15.55	51	33.49	9.3	8.49	323	-2.7
2.6	15.42	51.1	33.52	9.2	8.5	323	-2
2.7	15.34	51.1	33.54	9.1	8.5	323	-3.2



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
2.8	15.29	51.1	33.54	9	8.5	323	-3
2.9	15.26	51.1	33.57	9	8.5	323	-0.2
3	15.25	51.2	33.57	8.9	8.49	324	-1.3
3.1	15.24	51.2	33.58	8.8	8.49	324	-0.2
3.2	15.24	51.2	33.58	8.8	8.48	324	1.1
3.3	15.25	51.2	33.57	8.7	8.49	324	600
Transect 3 - 100 m							
0.1	16.2	51.1	33.56	7.8	8.51	365	-28.5
0.2	16.23	51.1	33.54	8.7	8.51	362	-28.5
0.3	16.27	51.1	33.51	8.8	8.52	361	-28.5
0.4	16.26	51.1	33.52	8.9	8.52	360	-28.5
0.5	16.31	51.1	33.52	8.9	8.52	357	-28.5
0.6	16.31	51.1	33.52	9	8.52	356	-28.5
0.7	16.29	51.1	33.53	9	8.52	356	-28.5
0.8	16.31	51.1	33.52	9	8.52	356	-28.5
0.9	16.28	51.1	33.5	9	8.52	355	-28.5
1	16.23	51.1	33.54	9	8.52	355	-28.5
1.1	16.19	51.1	33.54	9	8.52	355	-28.5
1.2	16.12	51.1	33.51	9	8.52	355	-28.5
1.3	16.04	51.1	33.54	9	8.51	354	-28.5
1.4	16	51.1	33.53	8.9	8.51	354	-28.5
1.5	15.99	51.1	33.54	8.9	8.51	354	-28.5
1.6	15.96	51.1	33.56	8.9	8.51	354	-28.5
1.7	15.95	51.1	33.53	8.8	8.51	353	-28.5
1.8	15.95	51.2	33.57	8.8	8.51	353	-28.5
1.9	15.95	51.1	33.53	8.8	8.51	353	-28.5
2	15.94	51.1	33.54	8.8	8.51	352	-28.5
2.1	15.94	51.2	33.58	8.8	8.51	352	-28.5
2.2	15.94	51.2	33.58	8.8	8.5	352	-28.5
2.3	15.92	51.1	33.55	8.8	8.51	352	-28.5
2.4	15.92	51.1	33.56	8.8	8.51	352	-28.5
2.5	15.72	51.2	33.64	8.8	8.51	351	-28.5
2.6	15.54	50.9	33.41	8.9	8.52	351	-28.5
2.7	15.34	51.2	33.58	9	8.53	351	-28.5
2.8	15.3	51.2	33.57	9	8.53	351	-28.5
2.9	15.25	51.2	33.62	9	8.53	351	-28.5
3	15.22	51.2	33.64	9	8.53	350	-28.5
3.1	15.21	51.2	33.6	9	8.52	350	-28.5
3.2	15.2	51.2	33.62	9	8.52	350	-28.5
3.3	15.17	51.2	33.6	9	8.52	350	-28.5
3.4	15.15	51.2	33.61	9	8.52	350	-28.5
3.5	15.12	51.2	33.6	9	8.52	350	-28.5
3.6	15.11	51.2	33.61	9	8.52	350	-28.5
3.7	15.1	51.2	33.62	8.9	8.52	350	-28.5
3.8	15.08	51.2	33.59	9	8.52	350	-28.5
3.9	15.06	51.2	33.6	9	8.52	349	-28.5
4	15.05	51.2	33.62	9	8.52	349	-28.5
4.1	15.04	51.2	33.63	9	8.52	349	-28.5
4.2	15.04	51.2	33.63	8.9	8.52	349	-28.5
4.2	15.03	51.2	33.63	8.9	8.51	349	-28.5
4.3	15.04	51.2	33.63	8.8	8.51	349	-28.5
4.4	15.04	51.2	33.63	8.8	8.51	349	-28.5



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
4.5	15.04	51.2	33.63	8.8	8.51	349	-28.5
4.6	15.04	51.2	33.63	8.8	8.51	349	-28.5
4.7	15.05	51.2	33.62	8.8	8.51	349	-28.5
Transect 3 - 200 m							
0.1	15.56	51.1	33.57	8.2	8.52	316	-5.9
0.2	15.63	51.1	33.5	8.7	8.53	316	-6.3
0.3	15.66	51.1	33.52	8.7	8.53	316	-5.9
0.4	15.66	51.1	33.52	8.7	8.53	316	-6.3
0.5	15.66	51.1	33.52	8.7	8.53	316	-6.4
0.6	15.66	51.1	33.52	8.7	8.53	316	-6.4
0.7	15.66	51.1	33.52	8.7	8.53	316	-6.1
0.8	15.66	51.1	33.52	8.7	8.53	317	-6.4
0.9	15.66	51.1	33.52	8.7	8.53	317	-6.4
1	15.66	51.1	33.52	8.7	8.53	317	-6.3
1.1	15.67	51.1	33.51	8.7	8.53	317	-6.3
1.2	15.68	51.1	33.55	8.7	8.53	317	-6.1
1.3	15.67	51.1	33.51	8.7	8.53	317	-6.3
1.4	15.68	51.1	33.55	8.7	8.53	317	-6.3
1.5	15.67	51.1	33.56	8.7	8.53	318	-5.6
1.6	15.66	51.1	33.52	8.7	8.53	318	-6.1
1.7	15.66	51.1	33.52	8.7	8.53	318	-6.3
1.8	15.66	51.1	33.56	8.7	8.53	318	-6.4
1.9	15.66	51.1	33.56	8.7	8.53	318	-6.3
2	15.67	51.1	33.56	8.7	8.53	318	-6.1
2.1	15.67	51.1	33.56	8.7	8.53	318	-5.9
2.2	15.67	51.1	33.56	8.7	8.53	318	-6.3
2.3	15.67	51.1	33.56	8.7	8.53	318	-6.1
2.4	15.67	51.1	33.56	8.7	8.53	319	-6.3
2.5	15.67	51.1	33.56	8.7	8.53	319	-6.1
2.6	15.68	51.1	33.55	8.7	8.53	319	-6.1
2.7	15.68	51.1	33.55	8.7	8.53	319	-6.1
2.8	15.68	51.2	33.59	8.7	8.53	319	-5.7
2.9	15.67	51.1	33.56	8.7	8.53	320	-6.3
3	15.68	51.2	33.59	8.7	8.53	320	-6.3
3.1	15.68	51.2	33.59	8.7	8.53	320	-6.3
3.2	15.67	51.1	33.56	8.7	8.53	320	-5.9
3.3	15.62	51.2	33.6	8.7	8.53	320	-5.7
3.4	15.57	51.2	33.59	8.8	8.54	320	-5.6
3.5	15.58	51.2	33.59	8.8	8.53	320	-5.7
3.6	15.56	51.2	33.61	8.8	8.54	320	-5.7
3.7	15.49	51.2	33.58	8.8	8.54	321	-4.8
3.8	15.33	51.2	33.59	8.8	8.54	321	-5.9
3.9	15.28	51.2	33.64	8.8	8.55	321	-5.6
4	15.27	51.3	33.64	8.8	8.55	321	-5.6
4.1	15.19	51.2	33.63	8.9	8.55	321	-6.1
4.2	15.14	51.2	33.62	8.9	8.55	321	-2.1
4.3	15.08	51.2	33.59	8.9	8.55	321	-5.7
4.4	15.06	51.2	33.61	8.9	8.55	321	-5.9
4.5	15.06	51.3	33.65	8.9	8.55	321	-4.8
4.6	15.06	51.2	33.61	8.9	8.55	321	-5.4
4.7	15.02	51.2	33.64	8.9	8.55	322	-5.6
4.8	15.03	51.2	33.63	8.9	8.55	322	-6.3



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
4.9	15.01	51.3	33.65	8.9	8.55	322	-5.6
5	14.99	51.3	33.66	8.9	8.54	322	-3.2
5.1	14.99	51.2	33.62	8.8	8.54	322	-3.9
5.2	14.99	51.2	33.63	8.8	8.54	322	-3.6
5.3	14.99	51.3	33.66	8.8	8.54	322	-1.3
5.4	14.99	51.2	33.62	8.8	8.54	323	-2
5.5	14.99	51.3	33.66	8.7	8.54	323	-2.5
5.6	14.99	51.2	33.62	8.7	8.54	323	-1.6
5.7	14.99	51.3	33.66	8.7	8.54	323	444.4
Transect 4 - 5 m							
0.1	16.7	48.7	31.79	8.5	8.54	334	-4.5
0.2	16.84	49.6	32.41	8.7	8.48	334	-3.4
0.3	16.77	50.5	33.06	8.9	8.54	333	-4.8
0.4	16.7	50.8	33.32	9.1	8.56	333	-5.2
0.5	16.32	51.2	33.59	9.3	8.57	333	-5.2
0.6	16.2	51.1	33.56	9.2	8.57	333	-5.9
0.7	16.17	51.1	33.55	9	8.56	333	-2
0.8	16.13	51.2	33.59	8.8	8.56	333	-5.4
0.9	16.13	51.2	33.58	8.8	8.56	333	-5.7
1	16.13	51.2	33.62	8.7	8.55	333	-5.7
1.1	16.13	51.2	33.62	8.7	8.55	333	-5.9
1.2	16.13	51.2	33.62	8.7	8.55	333	-3.8
1.3	16.15	51.2	33.61	8.7	8.55	333	-4.1
1.4	16.15	51.3	33.65	8.7	8.55	333	-4.3
1.5							
1.6	16.17	51.2	33.64	8.7	8.55	333	-1.8
1.7	16.17	51.2	33.64	8.7	8.55	332	600
Transect 4 - 10 m							
0.1	17.29	45.3	29.31	7.9	8.32	337	-3.2
0.2	16.87	50.8	33.34	8.7	8.57	335	-3.2
0.3	16.92	50	32.72	9.1	8.54	335	-4.1
0.4	16.54	50.9	33.41	9.3	8.57	335	-4.8
0.5	16.57	51	33.42	9.3	8.58	335	-4.3
0.6	16.56	51.1	33.52	9.3	8.58	335	-4.3
0.7	16.29	51.1	33.53	9.4	8.58	335	-5.6
0.8	16.16	51.1	33.56	9.2	8.56	335	-5.9
0.9	16.06	51.1	33.56	9	8.56	335	-5.7
1	16.04	51.2	33.58	8.9	8.56	335	-5.7
1.1	16.04	51.2	33.58	8.9	8.56	335	-5.7
1.2	16.03	51.2	33.59	8.8	8.55	335	-5.6
1.3	16.04	51.2	33.58	8.8	8.55	335	-4.3
1.4	16.05	51.2	33.61	8.7	8.55	335	-4.8
1.5	16.04	51.2	33.58	8.8	8.55	335	-5.2
1.6	16.03	51.2	33.59	8.7	8.55	335	-5.2
1.7	16.04	51.2	33.58	8.7	8.55	335	-5
1.8	16.03	51.2	33.59	8.7	8.55	335	-4.5
1.9	16.03	51.2	33.63	8.7	8.55	335	-4.5
2	16.04	51.2	33.58	8.7	8.55	335	-1.4
2.1	16.04	50.8	33.33	8.7	8.53	341	600
Transect 4 - 50 m							
0.1	16.85	50.7	33.23	8.5	8.6	335	-3.6
0.2	16.8	50.8	33.31	10.1	8.6	334	-3.8



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
0.3	16.8	50.7	33.27	10.1	8.6	334	-3.9
0.4	16.79	50.8	33.32	10.1	8.6	334	-3.8
0.5	16.76	50.9	33.39	10.1	8.6	334	-5
0.6	16.73	51	33.46	10	8.6	334	-4.7
0.7	16.69	51	33.49	10	8.6	334	-4.8
0.8	16.56	51	33.47	9.9	8.58	334	-5
0.9	16.57	51	33.46	9.8	8.58	334	-5
1	16.35	50.9	33.4	9.6	8.57	334	-5.6
1.1	16.05	51	33.49	9.3	8.54	334	-5.6
1.2	16.05	51.1	33.53	9.1	8.54	334	-5.7
1.3	15.92	51.1	33.55	8.9	8.54	335	-5.6
1.4	15.92	51.1	33.55	8.9	8.54	335	-5.6
1.5	15.92	51.1	33.56	8.9	8.54	335	-3.4
1.6	15.9	51.1	33.53	8.9	8.53	335	-4.5
1.7	15.86	51.1	33.56	8.8	8.53	335	-5.6
1.8	15.77	51.1	33.56	8.8	8.53	335	-5.6
1.9	15.76	51.1	33.57	8.8	8.53	335	-5.6
2	15.77	51.1	33.55	8.8	8.53	336	-5.7
2.1	15.77	51.1	33.55	8.8	8.53	336	-5.6
2.2	15.77	51.1	33.55	8.8	8.53	336	-5.7
2.3	15.79	51.2	33.58	8.8	8.52	336	-5.7
2.4	15.79	51.2	33.58	8.8	8.52	336	-5.6
2.5	15.8	51.2	33.61	8.8	8.52	336	-5.2
2.6	15.81	51.2	33.6	8.8	8.52	336	-5.4
2.7	15.81	51.2	33.6	8.8	8.52	336	-5.6
2.8	15.79	51.2	33.58	8.8	8.52	336	-5.7
2.9	15.8	51.2	33.57	8.8	8.52	336	-5.6
3	15.81	51.1	33.56	8.8	8.52	336	-5.7
3.1	15.82	51.2	33.6	8.7	8.52	336	-5.7
3.2	15.82	51.2	33.6	8.7	8.52	337	-5.6
3.3	15.83	51.2	33.59	8.7	8.52	336	-5.7
3.4	15.82	51.2	33.6	8.8	8.52	337	-5.9
3.5	15.91	51.2	33.61	8.7	8.52	337	-5.2
3.6	15.9	51.2	33.61	8.8	8.52	337	-4.1
3.7	15.85	51.2	33.61	8.8	8.52	337	-1.3
3.8	15.89	51.3	33.66	8.8	8.52	337	2
3.9	15.93	51.2	33.63	8.8	8.52	337	6.4
Transect 4 - 100 m							
0.1	16.35	51.2	33.61	7.7	8.53	343	-5.2
0.2	16.34	51.2	33.57	9.2	8.55	342	-5.6
0.3	16.33	51.2	33.59	9.2	8.56	341	-5.4
0.4	16.24	51.2	33.58	9.2	8.55	341	-5
0.5	16.18	51.2	33.59	9.2	8.56	341	-5.7
0.6	16.15	51.1	33.57	9.1	8.55	341	-5.4
0.7	16.2	51	33.48	9.1	8.56	340	-5.7
0.8	16.08	51.2	33.58	9.1	8.55	341	-5.7
0.9	16.02	51.1	33.51	9.1	8.55	341	-5.2
1	15.87	51.1	33.51	9.1	8.55	341	-5.6
1.1	15.84	51.2	33.58	9.1	8.55	341	-5.6
1.2	15.87	51.1	33.55	9	8.54	341	-5.4
1.3	15.84	51.1	33.54	8.9	8.55	341	-5.9
1.4	15.82	51.1	33.56	8.9	8.55	341	-5.6



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
1.5	15.79	51.2	33.58	8.9	8.54	341	-5
1.6	15.79	51.2	33.58	8.9	8.54	341	-5.6
1.7	15.78	51.2	33.59	8.9	8.54	341	-5.4
1.8	15.77	51.1	33.56	8.8	8.54	341	-5.6
1.9	15.76	51.1	33.57	8.8	8.54	341	-5.6
2	15.76	51.1	33.57	8.8	8.54	341	-5.7
2.1	15.75	51.2	33.57	8.8	8.54	341	-5.9
2.2	15.7	51.1	33.57	8.8	8.53	341	-5.6
2.3	15.68	51.1	33.55	8.8	8.53	341	-5.7
2.4	15.67	51.1	33.56	8.8	8.53	341	-5.6
2.5	15.67	51.2	33.6	8.8	8.53	341	-5.7
2.6	15.67	51.1	33.56	8.8	8.53	341	-5
2.7	15.67	51.1	33.56	8.8	8.53	341	-5.7
2.8	15.68	51.2	33.59	8.8	8.53	341	-5.4
2.9	15.7	51.2	33.58	8.7	8.53	341	-5.7
3	15.7	51.2	33.61	8.7	8.53	341	-5.7
3.1	15.71	51.2	33.6	8.7	8.53	341	-5.7
3.2	15.7	51.2	33.61	8.7	8.53	341	-4.7
3.3	15.71	51.2	33.6	8.7	8.53	341	-5.6
3.4	15.71	51.2	33.6	8.7	8.53	341	-5.7
3.5	15.71	51.2	33.6	8.7	8.53	341	-5.7
3.6	15.72	51.2	33.59	8.7	8.53	341	-5.7
3.7	15.74	51.2	33.62	8.7	8.53	342	-5.6
3.8	15.73	51.2	33.63	8.7	8.52	342	-5.4
3.9	15.74	51.3	33.66	8.7	8.52	342	-5.6
4	15.75	51.3	33.66	8.7	8.53	342	-5.6
4.1	15.76	51.2	33.61	8.7	8.53	342	-5.7
4.2	15.79	51.3	33.66	8.7	8.52	342	-27.2
4.4	15.78	51.2	33.63	8.7	8.52	342	-28.5
Transect 4 - 200 m							
0.1	15.64	51.2	33.58	8	8.52	323	-5.9
0.2	15.68	51.2	33.59	8.5	8.53	323	-5.9
0.3	15.7	51.2	33.58	8.6	8.54	323	-5.9
0.4	15.7	51.2	33.58	8.7	8.54	323	-5.9
0.5	15.7	51.2	33.58	8.7	8.54	323	-6.1
0.6	15.69	51.2	33.58	8.7	8.55	323	-6.1
0.7	15.7	51.2	33.58	8.7	8.55	323	-5.7
0.8	15.69	51.2	33.58	8.7	8.55	323	-5.9
0.9	15.66	51.2	33.6	8.7	8.55	324	-5.7
1	15.66	51.1	33.56	8.7	8.55	324	-5.7
1.1	15.67	51.2	33.6	8.7	8.54	325	-5.9
1.2	15.67	51.2	33.6	8.7	8.54	325	-5.4
1.3	15.67	51.2	33.6	8.7	8.54	325	-5.9
1.4	15.67	51.2	33.6	8.7	8.54	325	-5.9
1.5	15.67	51.2	33.6	8.7	8.54	325	-5.7
1.6	15.67	51.2	33.6	8.7	8.54	326	-4.8
1.7	15.67	51.2	33.6	8.7	8.54	326	-5.9
1.8	15.67	51.2	33.6	8.7	8.54	326	-5.7
1.9	15.66	51.2	33.6	8.7	8.54	326	-5.9
2	15.67	51.2	33.6	8.7	8.54	326	-5.9
2.1	15.67	51.2	33.6	8.7	8.54	326	-5.9



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
2.2	15.66	51.2	33.6	8.7	8.54	326	-5.7
2.3	15.65	51.2	33.61	8.7	8.54	326	-5.7
2.4	15.63	51.2	33.58	8.7	8.54	327	-5.9
2.5	15.59	51.2	33.58	8.7	8.54	327	-5.6
2.6	15.59	51.2	33.58	8.7	8.53	327	-5.9
2.7	15.56	51.2	33.6	8.7	8.53	327	-5
2.8	15.57	51.2	33.59	8.7	8.54	327	-5.9
2.9	15.59	51.2	33.58	8.7	8.54	327	-6.1
3	15.57	51.2	33.59	8.7	8.54	327	-6.1
3.1	15.57	51.2	33.59	8.7	8.54	327	-5.9
3.2	15.57	51.2	33.59	8.7	8.54	327	-6.1
3.3	15.54	51.2	33.58	8.7	8.54	327	-6.1
3.4	15.57	51.2	33.59	8.7	8.53	328	-5.9
3.5	15.55	51.2	33.62	8.7	8.54	328	-5.2
3.6	15.56	51.2	33.6	8.7	8.53	328	-5.7
3.7	15.56	51.2	33.6	8.7	8.53	328	-4.3
3.8	15.57	51.2	33.59	8.7	8.53	328	-3.6
3.9	15.56	51.2	33.61	8.7	8.53	328	-4.5
4	15.56	51.2	33.6	8.6	8.53	328	-4.3
4.1	15.57	51.2	33.64	8.6	8.53	329	-3.9
Reference Transect - 5 m							
0.1	18.07	51.2	33.61	7.9	8.5	403	-4.7
0.2	18.09	51.2	33.63	7.9	8.51	400	-4.7
0.3	18.09	51.2	33.59	7.9	8.51	398	-4.8
0.4	18.1	51.2	33.63	7.9	8.51	397	-4.3
0.5	18.09	51.2	33.59	8	8.51	396	-5
0.6	18.1	51.2	33.59	8	8.51	394	-4.8
0.7	18.1	51.2	33.63	8	8.51	393	-4.7
0.8	18.11	51.2	33.62	8	8.51	393	-4.5
0.9	18.1	51.2	33.59	8	8.51	392	-4.7
1	18.1	51.2	33.59	8	8.51	392	-4.7
1.1	18.1	51.2	33.63	8	8.51	391	-4.7
1.2	18.11	51.2	33.62	7.9	8.51	390	-4.5
1.3	18.12	51.2	33.61	8	8.5	389	-4.5
1.4	18.11	51.2	33.62	8	8.5	389	-4.7
1.5	18.08	51.2	33.64	8	8.5	389	-4.3
1.6	18.08	51.2	33.64	7.9	8.49	388	-4.5
1.7	18.07	51.3	33.65	7.9	8.49	388	-4.7
1.8	18.08	51.2	33.6	7.9	8.49	387	-4.1
1.9	18.09	51.2	33.63	7.9	8.49	387	13.8
Reference Transect - 10 m							
0.1	18.02	51.2	33.61	7.7	8.43	369	-4.5
0.2	18.07	51.2	33.61	8.1	8.46	367	-4.3
0.3	18.06	51.2	33.62	8.1	8.46	366	-4.7
0.4	18.08	51.2	33.64	8.1	8.45	366	-4.8
0.5	18.1	51.2	33.63	8.1	8.46	366	-4.8
0.6	18.09	51.2	33.63	8.1	8.46	366	-4.8
0.7	18.1	51.2	33.63	8.1	8.46	365	-4.8
0.8	18.1	51.2	33.63	8.1	8.46	365	-4.7
0.9	18.09	51.2	33.63	8.1	8.46	365	-4.8
1	18.09	51.2	33.63	8.1	8.46	365	-4.5
1.1	18.09	51.2	33.63	8.1	8.46	365	-4.7



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
1.2	18.07	51.1	33.57	8.1	8.46	365	-4.5
1.3	18.01	51.2	33.58	8.2	8.45	365	-3.9
1.4	17.94	51.2	33.6	8.2	8.45	365	-3.6
1.5	17.88	51.2	33.61	8.1	8.45	365	-3.9
1.6	17.81	51.2	33.58	8	8.45	365	-3.9
1.7	17.74	51.1	33.56	8	8.45	365	-4.1
1.8	17.41	51.1	33.54	8	8.47	365	-3.2
1.9	17.34	51.2	33.61	8	8.47	365	-2.3
2	17.3	51.1	33.56	8.1	8.47	365	-3
2.1	17.27	51.1	33.55	8.1	8.47	365	-3.2
2.2	17.22	51.1	33.54	8.1	8.47	365	-2.9
2.3	17.19	51.2	33.57	8.1	8.47	365	-3.2
2.4	17.19	51.2	33.57	8	8.46	365	-1.8
2.5	17.03	51.1	33.54	8	8.46	365	-2.5
2.6	16.98	51	33.49	8	8.46	365	-2.1
2.7	16.91	51.2	33.6	8	8.46	365	-2
2.8	16.93	51.2	33.58	7.9	8.46	365	-2
2.9	16.93	51.2	33.58	7.8	8.46	366	-1.8
3	16.93	51.2	33.58	7.8	8.45	366	-0.5
3.1	16.92	51.1	33.54	7.8	8.45	366	-0.9
3.2	16.78	51.1	33.54	7.7	8.45	366	0.5
Reference Transect - 50 m							
0.1	17.99	51.2	33.63	7.8	8.39	364	-4.1
0.2	18.01	51.2	33.62	8.3	8.41	363	-4.1
0.3	18.01	51.2	33.62	8.4	8.42	362	-3.8
0.4	18.01	51.2	33.62	8.4	8.42	362	-3.9
0.5	18.02	51.2	33.61	8.4	8.43	362	-4.5
0.6	18.02	51.2	33.61	8.4	8.43	362	-4.3
0.7	18.01	51.2	33.62	8.4	8.43	362	-4.1
0.8	17.99	51.2	33.63	8.4	8.42	362	-4.5
0.9	17.98	51.2	33.64	8.4	8.42	362	-3.6
1	17.97	51.2	33.57	8.4	8.43	362	-4.3
1.1	17.98	51.2	33.61	8.4	8.43	362	-4.3
1.2	17.93	51.2	33.6	8.4	8.43	362	-3.2
1.3	17.89	51.2	33.6	8.4	8.43	362	-3.8
1.4	17.76	51.1	33.55	8.4	8.43	362	-3.9
1.5	17.65	51.2	33.59	8.4	8.44	362	-2.7
1.6	17.63	51.1	33.57	8.4	8.44	362	-3
1.7	17.61	51.2	33.59	8.4	8.43	362	-3.8
1.8	17.57	51.2	33.58	8.4	8.44	362	-3.6
1.9	17.57	51.2	33.62	8.4	8.43	362	-3.4
2	17.55	51.2	33.59	8.4	8.43	362	-3.2
2.1	17.49	51.1	33.56	8.4	8.43	362	-3.6
2.2	17.42	51.2	33.58	8.4	8.43	362	-3.6
2.3	17.35	51.1	33.51	8.4	8.43	362	-2.7
2.4	17.28	51.1	33.53	8.4	8.43	362	-3.8
2.5	17.18	51.2	33.58	8.4	8.43	362	-3
2.6	17.16	51.1	33.55	8.3	8.43	362	-3.4
Reference Transect - 100 m							
0.1	17.84	51.2	33.64	8.5	8.42	254	-28.5
0.2	17.86	51.2	33.62	8.7	8.42	266	-28.6
0.3	17.89	51.2	33.6	8.7	8.42	271	-28.6



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
0.4	17.89	51.2	33.6	8.7	8.42	275	-28.6
0.5	17.89	51.2	33.6	8.7	8.42	277	-28.6
0.6	17.81	51.2	33.62	8.7	8.43	280	-28.6
0.7	17.77	51.2	33.57	8.8	8.43	281	-28.6
0.8	17.75	51.2	33.59	8.8	8.43	283	-28.6
0.9	17.72	51.2	33.58	8.8	8.43	284	-28.6
1	17.68	51.2	33.57	8.9	8.43	286	-28.6
1.1	17.65	51.1	33.55	8.9	8.43	287	-28.6
1.2	17.57	51.2	33.58	8.9	8.43	288	-28.5
1.3	17.55	51.1	33.55	8.9	8.43	289	-28.5
1.4	17.49	51.1	33.56	8.9	8.43	290	-28.5
1.5	17.44	51.1	33.56	8.8	8.44	291	155.8
1.6	17.42	51.2	33.58	8.8	8.43	292	9
1.7	17.37	51.2	33.58	8.8	8.43	293	-3
1.8	17.34	51.1	33.56	8.8	8.43	295	-2
1.9	17.34	51.1	33.56	8.8	8.43	296	-2.7
2	17.33	51.2	33.58	8.8	8.43	297	-0.7
2.1	17.32	51.2	33.58	8.8	8.43	298	-2.9
2.2	17.3	51.1	33.56	8.8	8.43	298	-3.4
2.3	17.27	51.2	33.59	8.8	8.43	299	-3.9
2.4	17.25	51.1	33.56	8.8	8.43	300	-3.4
2.5	17.22	51.2	33.58	8.7	8.43	301	-1.3
2.6	17.23	51.2	33.57	8.7	8.43	302	-2.5
2.7	17.21	51.2	33.59	8.7	8.42	302	-2.3
2.8	17.22	51.2	33.58	8.6	8.42	304	-2.1
2.9	17.22	51.2	33.58	8.6	8.42	304	-2.3
3	17.21	51.2	33.59	8.6	8.42	305	-2.1
3.1	17.2	51.2	33.6	8.6	8.42	305	-1.3
3.2	17.2	51.2	33.6	8.5	8.42	306	-2.5
3.3	17.2	51.2	33.6	8.5	8.41	307	-2.1
3.4	17.2	51.2	33.6	8.5	8.41	307	-1.4
3.5	17.2	51.2	33.6	8.5	8.41	308	-2
3.6	17.2	51.2	33.6	8.5	8.41	309	-0.2
3.7	17.2	51.2	33.6	8.5	8.41	310	339.5
Reference Transect - 200 m							
0.1	17.87	51.2	33.61	8	8.37	328	-4.3
0.2	17.89	51.2	33.6	8.7	8.38	327	-4.3
0.3	17.89	51.2	33.64	8.8	8.39	327	-4.3
0.4	17.9	51.2	33.63	8.8	8.39	327	-4.5
0.5	17.9	51.2	33.63	8.8	8.39	327	-3.8
0.6	17.9	51.2	33.59	8.8	8.4	327	-4.5
0.7	17.89	51.2	33.6	8.8	8.4	327	-4.5
0.8	17.88	51.2	33.61	8.8	8.4	327	-4.7
0.9	17.88	51.2	33.61	8.9	8.4	327	-4.5
1	17.85	51.2	33.59	8.9	8.4	327	-4.7
1.1	17.85	51.2	33.59	8.9	8.4	327	-4.5
1.2	17.82	51.2	33.62	8.9	8.4	327	-4.5
1.3	17.79	51.2	33.6	8.9	8.4	327	-4.5
1.4	17.78	51.2	33.61	8.9	8.4	327	-4.1
1.5	17.68	51.2	33.61	8.9	8.4	328	-4.5
1.6	17.65	51.2	33.63	8.9	8.4	328	-4.3
1.7	17.44	51.1	33.52	9	8.41	328	-4.3



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
1.8	17.12	51.2	33.58	9	8.42	328	-4.3
1.9	17.12	51.2	33.59	9	8.42	328	-4.1
2	17.09	51.1	33.57	8.9	8.42	328	-4.7
2.1	17.09	51.1	33.57	8.9	8.42	328	-4.1
2.2	17.09	51.2	33.61	8.9	8.42	329	-4.5
2.3	17.1	51.2	33.6	8.8	8.42	329	-4.3
2.3	17.1	51.2	33.6	8.8	8.41	329	-2.1
2.4	17.1	51.2	33.6	8.8	8.41	329	-4.1
2.5	17.09	51.2	33.61	8.8	8.41	329	-4.7
2.6	17.09	51.1	33.57	8.8	8.41	330	-4.5
2.7	17.09	51.2	33.61	8.8	8.41	330	-3.9
2.8	17.08	51.2	33.58	8.8	8.41	330	-3.9
2.9	17.08	51.2	33.62	8.8	8.4	330	-4.3
3	17.07	51.2	33.58	8.8	8.4	330	-4.5
3.1	17.07	51.2	33.58	8.8	8.41	330	-4.8
3.2	17.06	51.2	33.59	8.8	8.41	330	-4.7
3.3	17.06	51.2	33.59	8.8	8.41	331	-4.5
3.4	17.05	51.2	33.6	8.8	8.41	331	-4.1
3.5	17.05	51.2	33.6	8.8	8.41	331	-4.3
3.6	17.05	51.2	33.6	8.8	8.41	331	-4.5
3.7	17.05	51.2	33.6	8.8	8.41	331	-4.7
3.8	17.05	51.2	33.6	8.8	8.4	332	-4.5
3.9	17.05	51.2	33.6	8.8	8.4	332	-3.9
4	17.05	51.2	33.6	8.8	8.4	332	-4.7
4.1	17.05	51.2	33.6	8.8	8.4	332	-4.5
4.2	17.03	51.2	33.62	8.8	8.4	332	-4.3
4.3	17.01	51.2	33.59	8.8	8.4	332	-4.7
4.4	17	51.2	33.6	8.8	8.4	332	-2.9
4.5	16.45	51.7	33.98	8.5	8.4	333	-3.9
4.6	16.39	51.2	33.58	8.4	8.41	333	-3.4
4.7	16.2	50.9	33.4	8.4	8.4	333	-3.4
4.8	15.8	51.2	33.57	8	8.41	333	-3.2
4.9	15.76	51.2	33.61	8	8.41	334	-1.1
5	15.72	51.2	33.59	7.8	8.41	334	-2.9
5.1	15.7	51.2	33.61	7.8	8.42	334	-2.3
5.2	15.7	51.2	33.58	7.8	8.42	334	-2.1
5.3	15.68	51.2	33.59	7.8	8.42	334	-1.8
5.4	15.68	51.2	33.59	7.8	8.42	334	-1.4
5.5	15.67	51.2	33.6	7.8	8.42	334	-1.6
5.6	15.68	51.2	33.59	7.8	8.41	334	-1.1
5.7	15.67	51.2	33.6	7.8	8.42	334	-1.6
5.8	15.68	51.2	33.59	7.8	8.41	335	75.9
5.9	15.67	51.2	33.6	7.8	8.41	335	600
Upstream of Colliery							
0.3	11.8	0.4	0.18	8.1	6.05	380	24.3
0.3	11.85	0.4	0.18	8.4	6.05	383	26
LDP1							
0.1	20.47	38.8	24.64	6.7	7.49	388	-0.4
0.1	20.51	38.8	24.66	6.3	7.55	384	-0.4
Downstream of Colliery							
0	19.92	37.8	23.93	7.4	7.69	349	-1.4
0	19.94	37.7	23.92	7.3	7.69	340	-1.3



Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (‰)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mv)	Turbidity (NTU)
Upstream of Power station							
0	19.44	37.5	23.72	6.8	7.62	377	0.4
Downstream of Power station and weir							
0.1	19.13	42.8	27.53	7.9	7.97	367	1.1
0.2	19.16	42.8	27.51	8	7.97	367	-1.3
0.3	19.17	43.1	27.7	8.1	7.97	367	-1.4
0.4	19.11	43.4	27.97	8.1	7.97	367	1.1
0.5	19	44.1	28.46	8.1	7.98	367	1.6
0.6	18.47	46.4	30.12	8.2	8.05	367	2.3
0.7	18.17	47.7	31.06	8.3	8.08	368	4.8
0.8	17.46	50.2	32.86	8.5	8.15	368	107.6
0.9	17.29	50.6	33.16	8.3	8.2	368	-28.5



Appendix G:

Sediment analysis, particle size distribution



	Mn (mg/kg)	Mn/Fe	Mn/Al	> 2mm	63 µm <x< 2 mm	<63 µm
Transect 1						
5m	213	0.0123	0.0050	2.8	59.9	37.2
10 m	191	0.0149	0.0060	17.6	62.0	20.4
50 m	118	0.0136	0.0051	3.5	84.3	12.3
100 m	146	0.0197	0.0064	3.0	88.1	8.9
200 m	70	0.0125	0.0044	9.5	82.9	7.6
Transect 2						
5m	151	0.0123	0.0047	22.9	50.3	26.8
10 m	165	0.0127	0.0048	19.8	30.3	49.9
50 m	155	0.0121	0.0044	27.0	34.6	38.4
100 m	182	0.0087	0.0033	0.3	26.2	73.5
200 m	144	0.0084	0.0035	0.7	64.5	34.8
Transect 3						
5m	152	0.0126	0.0046	20	50.8	29.1
10 m	147	0.0103	0.0040	13.6	54.4	32.0
50 m	212	0.0078	0.0032	0.1	19.3	80.6
100 m	150	0.0074	0.0031	0.3	49.5	50.2
200 m	187	0.0075	0.0031	0.2	37.8	62.0
Transect 4						
5m	206	0.0094	0.0040	0.0	43.4	56.6
10 m	175	0.0080	0.0034	0.5	36.5	63.0
50 m	182	0.0083	0.0033	0.2	35.4	64.4
100 m	121	0.0077	0.0030	1.4	56.4	42.2
200 m	65	0.0076	0.0029	0.3	78.9	20.8
Reference Transect						
5m	140	0.0086	0.0044	0.8	74.3	24.9
10 m	200	0.0070	0.0033	1.5	15.5	83.0
50 m	80	0.0080	0.0038	15.6	73.9	10.5
100 m	120	0.0065	0.0043	3.7	73.3	23.0
200 m	290	0.0076	0.0036	0.5	0.8	98.6



Appendix H:

Sediment manganese content for 24 monitoring sites



Sediment manganese content for 24 monitoring sites, data provided by NSW-EPA, courtesy of Tony Roach.

Sediments are sampled via piston cores or gravity core depths vary but analysis indicate that the concentrations of metals background (eg lead zinc copper show strong linear relationship with grainsize and metals such as cd and hg on or near the limit of detection 0.1 mg kg⁻¹ dw). Metals have been extracted using HF acid – analysis by CSIRO Advanced analytical chemistry.

%mud	Al (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Fe/Al
0.19	22100	24600	123	0.402715
0.1	17500	8900	57	1.245714
0.54	42000	21800	78	0.97619
0.91	76000	41000	330	0.377632
0.97	87000	28700	150	0.494253
0.89	79000	43000	293	0.25443
0.08	20600	20100	76	1.281553
0.65	67000	26400	151	0.447761
0.87	67000	30000	222	0.083582
0.1	19500	5600	38	1.179487
0.59	46000	23000	172	0.717391
0.9	74000	33000	292	0.27027
0.15	22700	20000	120	0.30837
0.11	16600	7000	54	1.512048
0.47	43000	25100	69	0.883721
0.94	79000	38000	237	0.363291
0.92	86000	28700	161	0.430233
0.85	66000	37000	213	0.190909
0.14	22000	12600	110	1.027273
0.55	51000	22600	100	0.607843
0.9	69000	31000	211	0.058986
0.05	17100	4070	30	1.409357
0.64	51000	24100	200	0.666667
0.93	81000	34000	420	0



Appendix I:

Toxicity testing, laboratory reports



Centre for Advanced Analytical Chemistry

1. Lucas Heights Science and Technology Centre
2. New Illawarra Road, Lucas Heights, NSW
3. Private Mail Bag 7, Bangor, NSW, 2234, Australia
- 1) Telephone 61 2 9710 6808 Fax 61 2 9710 6837

Chronic Algal Growth Test Report 03244

Client: Hydrobiology
Project: Manganese Test
Tests Performed: 72-h chronic algal growth inhibition test using the marine alga *Nitzschia closterium*, metal analyses.

Samples Collected:	N/A	Test Initiated:	30/9/03
Samples Received:	N/A	Sample Description	
CSIRO Sample No.	Sample Name		
WQE03244	Algae T = 0		Time 0 h sub-sample for Mn analysis
WQE03245	Algae T = 72		Time 72 h sub-sample for Mn analysis

Sample Chemistry and Preparation: Manganous chloride ($MnCl_2 \cdot 4H_2O$) solid (18.011 g) was weighed out and dissolved in 100 mL Milli-Q water to form a nominal stock solution of 50 g Mn/L. Aliquots of this stock were spiked into test vessels to form nominal test concentrations of 1-1000 mg Mn/L. The top concentration was sub-sampled for Mn analysis on Day 0 and 3 of the test. Concentrations for the algal test were then re-calculated using the Day 0 Mn value. Concentrations of Mn were determined using Inductively Coupled Plasma - Atomic Emission Spectrometry (ICP-AES).

Sample ID	Sample Name	Manganese (mg/L)
WQE03244	Algae T = 0	920
WQE03245	Algae T = 72	890

Test Method: This definitive test measures the decrease (inhibition) in algal growth rate (slope) of the temperate marine alga *Nitzschia closterium* after exposure to various concentrations of the sample for 72 h (initial cell density $2-4 \times 10^4$ cells/mL). The test protocol is based on the OECD Test Guideline 201(1984) and the protocol of Stauber et al. (1994). Cell counts were made at 24-h intervals for 72 h using a Coulter Multisizer II Particle Analyser with 70 μm aperture. The 72-h IC50, LOEC and NOEC values were calculated using ToxCalc Version 5.0.23 (Tidepool Software).

Results:			
Mn concentration (mg/L) ^a	Growth Rate (doublings/day)	% Control	% Inhibition
Control (0)	1.61	100	0
0.9	1.59	99	1
1.8	1.58	98	2
4.6	1.50	93	7
18	1.40	87	13
46	1.14	71 ^b	29
92	0.77	48 ^b	52
460	0	0 ^b	100
920	0	0 ^b	100

^a Concentrations are based on known dilutions of the measured highest concentration (920 mg/L).
^b Significantly less than control

72 h IC50: 87 (74-110) mg Mn/L	LOEC 46 mg Mn/L	NOEC: 18 mg Mn/L
---------------------------------------	------------------------	-------------------------



Toxicity Test Report: TR0104/1

(page 1 of 1)

Client:	Hydrobiology PO Box 2050 Milton QLD 4064	ESA Job #:	PR0104
Attention:	Ross Smith	Date Sampled:	n/a
Order #:		Date Received:	n/a
		Sampled By:	n/a
		Quote #:	PL0104_q01

Lab ID No.:	Sample Name:	Sample Description:
n/a	Manganese chloride	AR grade reagent

Test Performed:	48-hour larval development test using the rock oyster <i>Saccostrea commercialis</i>
Test Protocol:	ESA SOP 106, based on APHA (1998)
Deviations from Protocol:	Test duration extended to 60 hrs
Source of Test Organisms:	Farm reared, Wallis Lake NSW
Test Initiated:	10 September 2003 at 2015 hrs

Concentration ¹ (mg/L)	% Survival (mean ± sd)	Concentration ¹ (mg/L)	% Normal larvae (mean ± sd)	Concentration ¹ (mg/L)	% Normal / Survival (mean ± sd)
0 (control)	89.8 ± 4.4	0 (control)	87.9 ± 5.3	0 (control)	78.9 ± 4.2
0.04	91.0 ± 5.8	0.04	84.1 ± 7.1	0.04	76.5 ± 7.5
0.1	89.8 ± 4.4	0.1	87.2 ± 2.5	0.1	78.3 ± 4.6
0.3	86.8 ± 4.1	0.3	90.9 ± 4.4	0.3	78.9 ± 5.8
1.0	91.0 ± 5.8	1.0	83.4 ± 6.1	1.0	75.8 ± 6.4
3.1	86.2 ± 6.4	3.1	36.8 ± 12.5**	3.1	31.6 ± 9.9***
9.3	64.9 ± 9.4*	9.3	0 ± 0	9.3	0 ± 0
28	0 ± 0	28	0 ± 0	28	0 ± 0
1) 60 hr EC50=10.8 (9.8-11.8) mg/L (TSK trim value=0.0%) NOEC=3.1 mg/L LOEC=9.3 mg/L		60 hr EC50=2.7 (2.4-3.0) mg/L (TSK trim value=0.5%) NOEC=1.0 mg/L LOEC=3.1 mg/L		Article I. 60 hr EC50=2.7 (2.4-2.9) mg/L (TSK trim value=1.3%) NOEC=1.0 LOEC=3.1	

1. ¹The reported concentration of manganese at the highest concentration represents a measured value for t=0 h. All other concentrations are nominal based on a serial dilution of the highest concentration. At t=60 h, the measured value in the highest concentration was 24 mg/L.

2. * Significantly reduced survival compared with the control treatment (Dunnett's test, 1 tailed, P<0.05, df=6,21).

** Significantly reduced number of normally developed larvae compared with the control treatment (Dunnett's Test, 1 tailed, P<0.05, df=5,18).

*** Significantly reduced number of normal surviving larvae compared with the control treatment (Dunnett's test, 1 tailed, P<0.05, df=4,15).

QA/QC Parameter	Criterion	This Test	Criterion met?
Control minimum % survival at 60 hr	>70%	89.8%	Yes
Control minimum % normal larvae at 60 hr	>70%	87.9%	Yes
Test Temperature limits	25.0 ± 1°C	24.5	Yes
Reference Toxicant within cusum chart limits	12.4-27.1 µg/L	22.4 µg/L	Yes

Test Report Authorised by:

Dr Rick Krassoi, Director on 23 October 2003



Toxicity Test Report: TR0104/2

(page 1 of 1)

Client:	Hydrobiology PO Box 2050 Milton QLD 4064	ESA Job #:	PR0104
Attention:	Ross Smith	Date Sampled:	n/a
Contract #:		Date Received:	n/a
		Sampled By:	n/a
		Quote #:	PL0104_q01

Lab ID No.:	Sample Name:	Sample Description:
n/a	Manganese chloride	AR grade reagent

Test Performed:	72-hr Sea urchin larval development test using <i>Heliocidaris tuberculata</i>
Test Protocol:	ESA SOP 105, based on APHA (1998) and Simon and Laginestra (1996)
Deviations from Protocol:	None
Source of Test Organisms:	Field collected on 10 September from Lurline Bay, NSW
Test Initiated:	10 September 2003 at 1800 hrs

Concentration (mg/L)	% Survival (mean ± sd)	Concentration (mg/L)	% Normal larvae (mean ± sd)	Concentration (mg/L)	% Normal/Survival (mean ± sd)
0 (control)	88.4 ± 3.7	0 (control)	91.5 ± 1.3	0 (control)	81.0 ± 4.4
0.04	86.1 ± 3.8	0.04	92.5 ± 1.9	0.04	79.6 ± 4.4
0.1	86.9 ± 3.8	0.1	93.0 ± 1.4	0.1	80.7 ± 2.7
0.3	83.3 ± 5.8	0.3	92.8 ± 2.5	0.3	77.3 ± 6.8
1.0	88.6 ± 4.6	1.0	93.0 ± 1.4	1.0	82.3 ± 4.5
3.1	86.6 ± 6.8	3.1	64.8 ± 4.8**	3.1	55.9 ± 4.3***
9.3	79.1 ± 5.5*	9.3	7.5 ± 5.9**	9.3	6.3 ± 5.2***
28	0 ± 0	28	0 ± 0	28	0 ± 0
72 hr EC50=14.3 (13.8-18.8) mg/L		72 hr EC50=4.2 (4.0-4.4) mg/L		72 hr EC50=4.1 (3.9-4.3) mg/L	
(TSK Trim value=2.2%) NOEC=3.1 mg/L LOEC=9.3 mg/L		(TSK Trim value=8.3%) NOEC=1.0 mg/L LOEC=3.1 mg/L		(TSK Trim value=1.1%) NOEC=1.0 mg/L LOEC=3.1 mg/L	

¹The reported concentration of manganese at the highest concentration represents a measured value for t=0 h. All other concentrations are nominal based on a serial dilution of the highest concentration. At t=72 h, the measured value in the highest concentration was 27 mg/L.

* Significantly reduced survival compared with the control treatment (Dunnett's Test, 1 tailed, P=0.05, df=6,21).

** Significantly lower % normally developed larvae compared with the control treatment (Dunnett's Test, 1 tailed, P=0.05, df=6,21).

*** Significantly reduced number of normal surviving larvae compared with the control treatment (Dunnett's Test, 1 tailed, P=0.05, df=6,21)

QA/QC Parameter	Criterion	This Test	Criterion met?
Control minimum % survival	>70%	88.4%	Yes
Control minimum % normal larvae	>70%	91.5%	Yes
Test Temperature limits	20.0 ± 1°C	19.0°C	Yes
Reference Toxicant within cusum chart limits	4.8-10.0 µg/L	7.5 µg/L	Yes

Test Report Authorised by:

Dr Rick Krassoi, Director on 23 October 2003

Results are based on the samples in the condition as received by ESA



Toxicity Test Report: TR0104/3

(page 1 of 1)

Client:	Hydrobiology PO Box 2050 Milton QLD 4064	ESA Job #:	PR0104
Attention:	Ross Smith	Date Sampled:	n/a
Order #:		Date Received:	n/a
		Sampled By:	n/a
		Quote #:	PL0104_q01

Lab ID No.:	Sample Name:	Sample Description:
n/a	Manganese chloride	AR grade reagent

Test Performed:	96-hr acute (survival) toxicity test using the tiger prawn <i>Penaeus monodon</i>
Test Protocol:	ESA SOP 107, based on USEPA (1994, 1996)
Deviations from Protocol:	None
Source of Test Organisms:	Hatchery-reared, Cairns Qld
Test Initiated:	12 September 2003 at 2130 h

Concentration ¹ (mg/L)	% Survival (at 96 hr)	Vacant
0 (control)	90.0 ± 11.5	
0.04	95.0 ± 10.0	
0.1	90.0 ± 11.5	
0.3	95.0 ± 10.0	
1	85.0 ± 10.0	
3	100.0 ± 0.0	
9	85.0 ± 19.1	
27	45.0 ± 10.0*	
96 hr EC50=26.1 (15.1-45.2) mg/L (TSK Trim value=48.6%) NOEC=9 mg/L LOEC=27 mg/L		

- ¹The reported concentration of manganese at the highest concentration represents a measured value for t=0 h. All other concentrations are nominal based on a serial dilution of the highest concentration. At t=96 h, the measured value in the highest concentration was 23 mg/L.
- * Significantly reduced survival compared with the control treatment (Dunnett's Test, 1 tailed, P=0.05, df=7,24).

QA/QC Parameter	Criterion	This Test	Criterion met?
Control % survival	≥90%	90%	Yes
Test Temperature limits	25.0 ± 1°C	24.5	Yes
Reference Toxicant within cusum chart limits	9.8-18.0 mg SDS/L	13.8 mg SDS/L	Yes

Test Report Authorised by:

Dr Rick Krassoi, Director on 23 October 2003



**TOXICITY OF MANGANESE TO THE
LARVAE OF THE AUSTRALIAN BASS,
*Macquaria novemaculeata***

A REPORT PREPARED

FOR

**ECOTOX SERVICES AUSTRALASIA PTY. LTD.
215 EUSTON RD.
ALEXANDRA
NSW**

BY

**RICHARD P. LIM
ECOTOXICOLOGY UNIT
DEPARTMENT OF ENVIRONMENTAL SCIENCES
UNIVERSITY OF TECHNOLOGY, SYDNEY
P.P. BOX 123
BROADWAY
NSW 2007**

28TH OCTOBER 2003



SUMMARY

A sublethal toxicity test (fish imbalance test) was conducted on manganese, to the larvae of the Australian bass, *Macquaria novemaculeata* for Ecotox Services Australasia Pty. Ltd. Manganese was not toxic to the fish larvae in the range of concentrations tested.

INTRODUCTION

A request was made by Ecotox Services Australasia Pty. Ltd, NSW to the Ecotoxicology Unit, Department of Environmental Sciences, University of Technology, Sydney to determine the 96 hour sublethal toxicity (fish imbalance test) of manganese to the larvae of the Australian bass, *Macquaria novemaculeata*. Manganese chloride was used for preparing the test solutions.

MATERIALS AND METHODS

Test organism

Two day old larvae of Australian bass, *Macquaria novemaculeata*, purchased from a fish farm were acclimated in a 40 litre tank for 24 hours before being used for the tests.

Dilution Water

Seawater was collected from Rose Bay, Sydney, stored in 15000 litre capacity epoxy lined concrete tanks and aerated. Prior to use in the bioassay, the water was filtered through Aqua-Pure AP110 and AP124 filter cartridges of five and fifty micron pore size respectively followed by UV sterilisation. The salinity of this water is approximately 32‰ and pH is 8.0.

Solution Preparation

All glassware and test containers used in the tests were initially washed in detergent, rinsed with acetone and finally rinsed in water purified by reverse osmosis. A manganese stock solution was prepared which was used to prepare appropriate concentrations by diluting aliquots of the solution with filtered and UV treated seawater.

Test Procedures

Nine concentrations of Mn (0.03, 0.1, 0.3, 1, 3, 30, 50, and 100mg/L) and a seawater control were prepared. Four replicates for each concentration were prepared. Five hundred mL of appropriate concentrations of Mn, and the control solutions were placed in each 1-litre glass container. Five fish larvae were randomly selected and placed in each container. The fish were incubated over a 96-hour period. They were not fed over the test period. The solutions were gently aerated (approximately 60 bubbles/min) throughout the test to maintain the dissolved oxygen of the effluent above 60% saturation. Temperature, pH, salinity and



dissolved oxygen of the test solutions were measured at the commencement and at the end of the test. The number of fish larvae displaying imbalance was noted at 24, 48, 72 and 96 hours.

A water sample from the highest concentration (100mg/L Mn) was taken at the beginning and at the end of the test and sent to a laboratory for analysis.

The data were analysed using the Kruskal-Wallis ANOVA and post hoc Dunn's Multiple Comparison tests.

RESULTS AND DISCUSSION

The physico-chemical measurements of the test solutions are given in Table 1. Temperature ranged between 19.4 to 20.2°C. Salinity ranged between 34.0 and 34.6‰. Overall, the pH values for all test solutions remained quite consistent at around 8 throughout the test. The percentage saturation of dissolved oxygen was well above 90% for all test solutions which meets the requirements recommended for fish toxicity tests (OECD 1987).

Measured Mn values in the 100mg/L treatment were 97 and 98 mg/L for the 0 and 96 hour samples respectively. If the test concentration is assumed to be the geometric mean of the two concentrations, this give a mean measured concentration of 97.5 mg/L in the 100mg/L treatment. Equivalent concentrations in the other treatments are given in Table 2.

Over the 96-hour test period larval imbalance of 50% was observed in the 98 mg/L measured concentration. Larval imbalance in the seawater control was 5%. The remaining concentrations had larval imbalances ranging from 0 to 25% (Table 2). Larval imbalances in the range of concentrations tested were not significantly different ($p>0.05$) from that of the control. Thus no LOEC or NOEC could be determined. However, the 98 mg/L treatment was significantly different ($p<0.05$) from those of the 0.029 and 0.01 mg/L treatments. Based on this comparison the larval imbalance LOEC and NOEC values are 98mg/L and 49 mg/L, respectively.

CONCLUSION

Manganese was not toxic to the larvae of Australian bass, *Macquaria novemaculeata* over the range tested. LOEC and NOEC values could not be determined based on comparisons of larval imbalances the treatments with that the sea water control.

REFERENCE

OECD 1987. OECD Guidelines for Testing of Chemicals. Organisation for Economic Co-operation and Development. Paris Guideline No. 202.



Table 1 . Salinity (‰), temperature (°C), pH and dissolved oxygen saturation (%) of the test solutions recorded at the beginning and end of the 96-hour test period.

Time (hrs)	Conc (%)	Salinity (‰)	Temp. (°C)	pH	D.O.(% sat.)
0	S.W. cont	34.0±0.0	19.4±0.0	8.18±0.00	103.9±0.0
	0.03	34.1±0.0	19.5±0.1	8.19±0.00	104.2±0.6
	0.1	34.0±0.0	19.9±0.1	8.18±0.00	103.3±0.2
	0.3	34.1±0.1	19.6±0.1	8.19±0.00	103.1±0.1
	0.1	34.0±0.0	19.9±0.0	8.18±0.00	103.5±0.5
	3	34.1±0.1	19.7±0.0	8.18±0.00	103.7±0.5
	29	34.1±0.0	19.4±0.0	8.17±0.01	103.4±0.2
	49	34.2±0.1	20.0±0.2	8.16±0.02	103.0±0.6
	98	34.1±0.1	20.0±0.1	8.12±0.01	103.0±0.4
96	S.W. cont	34.3±0.0	19.8±0.2	8.23±0.01	96.7±0.8
	0.03	34.3±0.1	20.2±0.6	8.24±0.00	97.2±0.0
	0.1	34.2±0.1	19.7±0.2	8.25±0.00	96.8±0.1
	0.3	34.3±0.0	19.6±0.0	8.25±0.00	96.8±0.1
	0.1	34.6±0.1	19.7±0.1	8.26±0.01	97.1±0.2
	3	34.4±0.2	19.7±0.3	8.22±0.02	97.1±0.2
	29	34.3±0.1	19.5±0.1	8.19±0.01	96.9±0.6
	49	34.3±0.1	19.6±0.2	8.17±0.01	97.0±0.3
	98	34.5±0.1	19.7±0.2	8.16±0.01	97.0±0.4

Table 2 Nominal and measured concentrations of Mn (mg/L)

Nominal	Measured	Measured rounded values
0.03	0.029	0.03
0.1	0.098	0.01
0.3	0.293	0.29
0.1	0.975	0.98
3	2.925	2.9
29	29.25	29
49	48.75	49
98	97.5	98

Table 3. Percentage of fish imbalanced on exposure to Mn test solutions in the 96-hour toxicity test

Concentration (%)	Fish imbalanced (%)
Sea water control	5
0.03	0
0.1	0
0.3	15
0.1	5
3	0
29	10
49	25
98	50

Appendix G – Water Activity Licence - WAL41560

NEW SOUTH WALES LAND REGISTRY SERVICES - TITLE SEARCH
-----FOLIO: WAL41560

SEARCH DATE	TIME	EDITION NO	DATE
-----	----	-----	----
11/1/2018	3:44 PM	-	-

CERTIFICATE OF TITLE HAS NOT ISSUED

WARNING NOTE: INFORMATION ON THIS REGISTER IS NOT GUARANTEED

TENURE TYPE: CONTINUING

HOLDER(S)

LICENCE HOLDER (DW AM811928)

ENCUMBRANCES (2 ENCUMBRANCES)

- 1 SECURITY INTERESTS IN THE WATER ENTITLEMENT REPLACED BY THIS ACCESS LICENCE THAT WERE REGISTERED OR CAPABLE OF BEING REGISTERED WITH LPI OR ASIC BEFORE THE COMMENCEMENT DATE OF THIS LICENCE 1/7/2016 MAY BE RECORDED ON THIS LICENCE WITHIN THREE YEARS FROM THE COMMENCEMENT DATE. SEE NOTES.
- 2 TERM TRANSFER: NIL

NOTATIONS

LICENCE CERTIFICATE NOT ISSUED. DEALINGS MAY NOT BE REGISTERED. SEE NOTES.

UNREGISTERED DEALINGS: NIL

ACCESS LICENCE DETAILS

CATEGORY: AQUIFER

SHARE COMPONENT:

SHARE - 4380 UNITS
WATER SOURCE - SYDNEY BASIN-NORTH COAST GROUNDWATER SOURCE
WATER SHARING PLAN - NORTH COAST FRACTURED AND POROUS ROCK
GROUNDWATER SOURCES 2016

EXTRACTION COMPONENT:

TIMES/RATES/CIRCUMSTANCES - SUBJECT TO THE CONDITIONS OF THE
WATER ACCESS LICENCE
EXTRACTION FROM - AQUIFER
EXTRACTION ZONE - WHOLE WATER SOURCE

NOMINATED WORKS:

END OF PAGE 1 - CONTINUED OVER

FOLIO: WAL41560

PAGE 2

ACCESS LICENCE DETAILS (CONTINUED)

WORK APPROVAL NUMBER(S) - NIL
INTERSTATE TAGGING ZONE - NIL

CONDITIONS

LICENCE CONDITIONS FORM A PART OF THIS LICENCE AND AFFECT THE SHARE AND EXTRACTION COMPONENTS. CONDITION STATEMENTS ARE AVAILABLE FROM THE NSW OFFICE OF WATER (NOW).

NOTES

A WATER LICENCE INFORMATION SHEET IS AVAILABLE FROM THE NSW OFFICE OF WATER (NOW) AND SHOULD BE REFERRED TO IN INTERPRETING THIS LICENCE. NOW WEBSITE WWW.WATER.NSW.GOV.AU, PHONE 1800 353 104, EMAIL INFORMATION@WATER.NSW.GOV.AU
NOW REFERENCE NUMBER: 20AL219022
PREVIOUS WATER ACT LICENCE NUMBER(S): 20PT911754.

*** END OF SEARCH ***



015 005236DLX/21

Centennial Fassifern Pty Limited
Level 20 1 Market Street
SYDNEY NSW 2000

Our ref: OUT22/20896

Date: 02/03/2023

Customer Reference Number: 423169

Subject: Changes to water access licence and water supply work approval conditions in the North Coast Fractured and Porous Rock Groundwater Sources

Dear Licence/Approval holder,

On 1 July 2016, the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* began.

This water sharing plan incorporated an area previously covered by the *Water Act 1912*, as well as the following groundwater sources from three existing water sharing plans:

- Alstonville Plateau Groundwater Sources, and
- Dorrigo Basalt Groundwater Source
- Kulnura Mangrove Mountain Groundwater Source.

As your water access licence and/or water supply work approval has a groundwater source which is subject to this water sharing plan, we have updated your licence and/ or approval to include the conditions from the Plan.


We have included details on what has changed, what you need to do, and the key conditions in the enclosed fact sheets.

For questions about the water sharing plan, contact the department on 1300 081 047.

For questions about your conditions, contact WaterNSW on 1300 662 077. Please ensure you have your work approval number ready when you call.

If you need an interpreter, please call the Translating and Interpreting Service on 131 450 between 9am and 4.30pm and ask them to telephone WaterNSW on 1300 662 077.

Yours sincerely,



Allan Raine

Director, Water Planning Implementation



Statement of Conditions
as at Wednesday, 1 March 2023
issued under Water Management Act 2000



21 - 36

WAL number 41560
Reference number 20AL219022

Contact for service of documents

Name CENTENNIAL FASSIFERN PTY LIMITED
Address Level 20
1 Market Street
Sydney NSW 2000

All holders

Name(s) CENTENNIAL FASSIFERN PTY LIMITED

Licence details

Water source SYDNEY BASIN-NORTH COAST GROUNDWATER SOURCE
Water sharing plan NORTH COAST FRACTURED AND POROUS ROCK GROUNDWATER SOURCES
2016
Management zone
Category AQUIFER
Share component 4380 units
Nominated work(s) 20MW065029
Tenure type Continuing

Conditions

The water access licence with Reference No 20AL219022 is subject to the following conditions:

Plan conditions

Water sharing plan

North Coast Fractured and Porous Rock Groundwater Sources 2016

Take of water

MW6629-00001

The maximum water allocation that can be carried over from one water year to the next water year in the water allocation account for this access licence is equal to:

- A. 100 % of the access licence share component for access licences with share components expressed as ML/year, or
- B. 1 ML/unit share of the access licence share component for access licences with share components expressed as a number of unit shares.

MW8237-00001

The volume of water taken under this access licence in any water year must not exceed:

- A. the sum of water allocations accrued to the water allocation account of this access licence from available water determinations in that water year, plus
- B. the water allocations carried over in the water allocation account of this access licence from the previous water year, plus
- C. the net amount of water allocations assigned to or from the water allocation account of this access licence under a water allocation assignment in that water year, plus
- D. any water allocations re-credited by the Minister to the water allocation account of this access licence in that water year.

Monitoring and recording

MW8295-00001

- A. The access licence holder must record the following information in a logbook for each period of time that water is taken:
 - i. date, start and end time when water was taken, volume of water taken, and
 - ii. the water supply work approval number under which the water was taken, and
 - iii. the purposes for which water was taken.
- B. The access licence holder must record the following information in the logbook at the end of each water year:
 - i. the volume of water taken in the water year, and
 - ii. the maximum volume of water permitted to be taken in that water year.
- C. This condition ceases to apply to this access licence on the day on which the relevant mandatory metering equipment condition applies as specified in clause 230(1) in the Water Management (General) Regulation 2018.
- D. This condition does not apply to this access licence if the licence nominates only water supply works that have:
 - i. a meter that complies with Australian Standard AS 4747 - Meters for non-urban water supply, and
 - ii. a data logger.

MW6612-00001

A logbook used to record water take information must be retained for five (5) years from the last date recorded in the logbook.

MW8241-00001

A. The water access licence holder must produce the Logbook to the Minister for inspection when requested.
 B. This condition does not apply to this access licence if the licence only nominates water supply works that have:

- i. a meter that complies with Australian Standard AS 4747
- Meters for non-urban water supply, and
- ii. a data logger.

Reporting**MW6983-00024**

A. Once the water access licence holder becomes aware of a breach of any condition on this water access licence, the water access licence holder must notify the Minister as soon as practicable.
 B. If the initial notification was not in writing, written notice must be provided within seven days of becoming aware of the breach by:

- i. email: nrar.enquiries@nrar.nsw.gov.au, or
- ii. mail:
 - DPE Water, PO Box 2213, Dangar NSW 2309, or
 - DPE Water, Locked Bag 10, Grafton NSW 2460.

Other conditions

No other conditions applicable

Glossary

logbook - A logbook is a document, electronic or hard copy, that records specific required information.

share component - The share component is the specified shares in the available water within a particular water management area.

water allocation assignment - A water allocation assignment is where licence holders assign water allocations from one licence to another licence; the water allocation account of one licence is debited by a volume and the water allocation account of the receiving licence is credited by that volume.

water year - A water year starts on 1 July and ends on 30 June in the following year.

General Notes

All conditions on a water access licence require compliance. An appeal to the Land and Environment Court against a decision to impose certain conditions on an approval can be made within 28 days after the date the decision is made. Conditions identified with the first letter "D" are those that can be appealed during the appeal period.

Certain dealings and other matters relating to this water access licence or a holding in this water access licence must be registered in the Access Register in accordance with section 71A of the *Water Management Act 2000*.



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Appendix H – Environmental Protection Licence 366 (EPL 366)