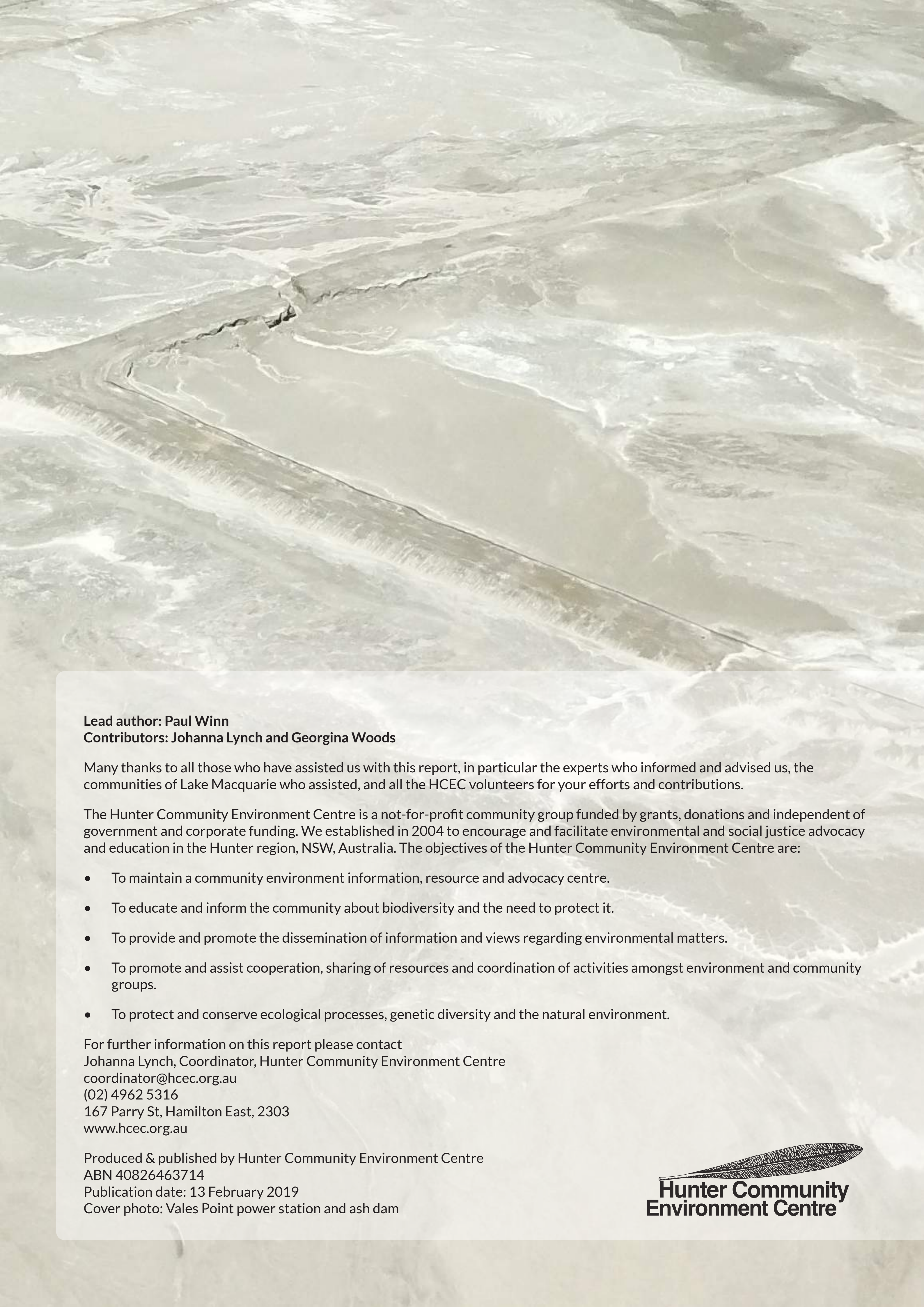
Hunter Community Environment Centre

OUT OF THE ASHES

Water pollution and Lake Macquarie's aging coal-fired power stations



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Many thanks to all those who have assisted us with this report, in particular the experts who informed and advised us, the communities of Lake Macquarie who assisted, and all the HCEC volunteers for your efforts and contributions.

The Hunter Community Environment Centre is a not-for-profit community group funded by grants, donations and independent of government and corporate funding. We established in 2004 to encourage and facilitate environmental and social justice advocacy and education in the Hunter region, NSW, Australia. The objectives of the Hunter Community Environment Centre are:

- To maintain a community environment information, resource and advocacy centre.
- To educate and inform the community about biodiversity and the need to protect it.
- To provide and promote the dissemination of information and views regarding environmental matters.
- To promote and assist cooperation, sharing of resources and coordination of activities amongst environment and community groups.
- To protect and conserve ecological processes, genetic diversity and the natural environment.

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Hunter Community
Environment Centre

Executive Summary

This report uses new environmental investigations and research and a review of existing research to examine heavy metal concentrations in the water, sediments and seafood of Lake Macquarie to understand how the two coal fired power stations in the southern portion of the Lake are contributing to this problem.

Construction of the coal ash dams of Eraring and Vales Point power stations pre-dates NSW's environmental pollution law, the *Protection of the Environment Operations Act 1997* (POEO Act). Both of these ash dams are unlined and both benefit from specific regulations created in Australia and New South Wales to exempt coal ash from regulation of hazardous waste and landfill.

Over 60 million tonnes of coal ash is stored in these two ash dams, about 26 million tonnes at Vales Point Ash Dam and 35 million tonnes at Eraring. An additional 1.9 million tonnes is produced each year - 0.55Mt by Vales Point and 1.34Mt by Eraring, 90 percent of which is fly ash – captured in the power station smoke stack filters.

The ash dams of both power station are at or near their capacity. Origin Energy is applying for an expansion of the capacity of its ash dam. The power stations themselves are both near to the end of their designed lives. Origin Energy is committed to decommission Eraring in 2032, but the expansion of ash dam capacity will only provide room for ash storage to 2024 at the current ash production and re-use rates. Delta Electricity has indicated a desire to maintain Vales Point for a further 30 years beyond its 2021 decommissioning date.

Coal ash is the residue left behind after coal is burnt for electricity. As a result, it concentrates the trace elements in coal once the carbon is burnt, particularly heavy metals. Despite this, fly ash from Australian coal-fired power stations is specifically excluded from the hazardous waste classification under the Commonwealth Controlled Waste National Environmental Protection Measure. In NSW, consumers of coal ash are specifically exempted from licensing requirements under s48, and licensed waste facility contributions under s88 of the *POEO Act*, and from obligations for tracking and transportation of waste, waste facility reporting and notification, and restrictions on the application of waste to land used for growing plants. Unlike most landfill sites, coal fired power stations are not required to provide a financial security for the rehabilitation of coal ash dumps, leaving tax-payers exposed to the cost of clean-up.

These exemptions were in part created to encourage the re-use of coal ash from power stations, but Australia has very low rates of coal ash reuse compared to other countries. Only 25 percent of ash generated each year by Vales Point and Eraring is reused, with Eraring faring slightly better than Vales Point, despite producing more than twice the volume of the smaller power station.

The discharge of metals from ash dumps has been linked to a number of lethal and sub-lethal effects on fish species, including reduced growth and reproductive success. Given the risk these ash dams pose and the damage they have inflicted in other countries, HCEC set out to understand whether the ash dams of Vales Point and Eraring were contributing ongoing heavy metal pollution to Lake Macquarie.

Methodology

To prepare this report, the Hunter Community Environment Centre:

- Reviewed the original and subsequent Environmental Impact Statements for the ash dams and previous studies of heavy metals in water, fish and sediments in Lake Macquarie, particularly the southern half of the Lake;
- Used freedom of information law to obtain the Office of Environment and Heritage's most recent (2018) study of metals in fish and crabs in the Lake, and undertook our own analysis of the data behind that report;
- Obtained samples of coal supplied to Eraring and Vales Point power stations from contracted coal mines and analyses of constituent elements of that coal to derive a mass balance showing the volume of metals generated by the power stations.
- Reviewed coal ash literature from around Australia and the world and current regulation pertaining to coal ash in NSW to identify deficiencies, barriers to coal ash re-use and potential environmental harms from the unlined and poorly-regulated ash dams on the shores of Lake Macquarie;
- Obtained and analysed 15 surface water samples and two sediment samples near the power stations and their ash dams.
- Identified new safe coal-ash reuse options that might provide a means for ridding the Lake of its coal ash problem while providing jobs for displaced worker.

Heavy metals in seafood caught in Lake Macquarie

The findings of the OEH 2018 study of heavy metals in 12 species of fish and crustacea in four zones of Lake Macquarie reveals ongoing heavy metal presence in the Lake. Of these zones, two are in the southern portion of the lake, near the power stations - Zone 3 near Eraring and Zone 4 near Vales Point.

The study found that any consumption of Mud Crab and Blue Swimmer Crab from Lake Macquarie could result in exposure to cadmium, and that consumption of finfish above certain quantities can result in exposure to selenium, particularly among children.

The Australian food standard does not set a maximum for cadmium in fish or crustaceans, but 20 samples of Mud Crab and Blue Swimmer Crab caught from all four zones in Lake Macquarie exceeded the EU's maximum concentration for cadmium.

The OEH study identified elevated concentrations of zinc, copper and arsenic in seafood samples, though the latter was in the form of organic arsenic, which is not generally considered toxic.

The OEH risk assessment did not present an analysis of metal concentrations in seafood in different zones, other than for selenium and cadmium, but HCEC has analysed the data to show the geographic distribution of results for all species and metals. Fish caught in the northern area of the Lake generally show higher concentrations of heavy metals, particularly lead and mercury, but this was not the case for selenium. Selenium in all species was higher in samples caught in the southern areas, as was arsenic in Mud Crabs, Sand Whiting, and Yellowfin Bream; copper in Silver Trevally, and zinc in Sea Mullet.

Water sampling and monitoring results

The results of HCEC's own water sampling show concentrations of a number of heavy metals in excess of ANZECC (2000) trigger values for "slightly to moderately disturbed" ecosystems (95% species protection) applied in NSW. Water samples from the Lake taken closest to the Vales Point power station cooling water outflow and ash dam overflow, in Mannering Bay and southern Wyee Bay, were found to be contaminated with copper, nickel and zinc at concentrations that exceeded ANZECC (2000) trigger values for marine waters.

Six of the seven water samples taken near to Vales Point power station were found to contain concentrations of copper above the 95% protection level. All the water samples taken near to the Vales Point power station were found to contain concentrations of aluminium, iron, and manganese above ANZECC aquaculture protection guidelines of 10 parts per billion (ppb), which indicates they are likely be harmful to edible fish, molluscs and crustaceans. The highest concentrations were found in the sample (Sample 8) collected in a small creek draining from the ash dam, with concentrations of arsenic of 24ppb, nickel of 30ppb, and zinc of 98ppb. All water samples were found to contain concentrations of aluminium, iron, and/or manganese above ANZECC (2000) trigger values for water used for recreation, with sample 8 found to have 175 times the trigger value for aluminium and 48 times the trigger value for manganese. Sample 3, taken at the cooling water outflow after heavy rain, was also found to contain concentrations of cadmium, lead, and zinc above those recommended by the ANZECC saltwater aquaculture protection guidelines.

All of the five samples taken near Eraring power station were found to be contaminated with copper, lead, nickel and/or zinc at concentrations that exceed the ANZECC trigger values for marine waters. Four of the five water samples taken near to the Eraring power station were found to contain concentrations of aluminium, iron and/or manganese above ANZECC aquaculture protection guidelines, and therefore likely be harmful to edible fish, molluscs and crustaceans. A sediment sample taken from the same site as one Eraring water sample shows the sediment contained concentrations of arsenic eight times the ANZECC sediment quality guidelines trigger values, and chromium, nickel, and zinc also exceed the sediment trigger value.

Selenium is not listed in the trigger values of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, but our review of water quality monitoring undertaken by Vales Point power station for its Environment Protection Licence shows concentrations of selenium in the water discharged into Lake Macquarie are increasing. Sediment in the creek receiving the Eraring ash dam overflow was found to have a selenium concentration of 110 parts per million, over 55 times the level recommended to protect sensitive fish and birds, and suggests a history of high selenium concentrations in the ash dam overflow, which flows into Lake Macquarie.

HCEC water quality monitoring of the Vales Point power station has revealed selenium concentrations of 5 parts per billion at the cooling water outlet into Lake Macquarie. This is 2.5 times the concentration limit imposed on the Eraring Power Station.

The impact of this pollution on the ecology of the Lake is of primary concern. One study has recommend that waterborne selenium concentrations of 2 parts per billion or greater be considered highly hazardous to the health and long-term survival of sensitive fish and aquatic birds due to food- chain bioaccumulation and resultant dietary exposure and reproductive effects. HCEC water quality analyses reveals that selenium concentrations near Vales Point Power Station are above this level. These levels must be reduced and to do so, discharge of selenium into the Lake must be reduced considerably.

While the concentrations of metals in water sampled by HCEC are likely considered by the NSW EPA and power station operators as "manageable," the volumes of the water discharged are very high. With Eraring licenced to discharge 11,000ML a day from cooling water outfall, even the maximum 2ppb selenium limit represents almost 22 kilograms discharged into the Lake a day.

The 5 ppb selenium concentration found by HCEC in Vales Point cooling water outfall, licenced to discharge 6,500ML a day, but with no limit on the concentration of selenium it discharges, represents almost 33kg of selenium a year. .

These are very high loads into a Lake with a one percent tidal exchange, and the area around Vales Point power station is only flushed by tides every 500 days. Very high loads indeed, when one considers that just 5mg of selenium is considered toxic to humans and water with just 2ppb selenium hazardous to sensitive aquatic life.

Groundwater monitoring results reported by the operator of Vales Point power station reveals elevated concentrations of arsenic, copper, chromium, and lead in the groundwater below the Vales Point ash dam. Similarly groundwater monitoring reported by the Eraring power station operator reveals elevated concentrations of arsenic, copper, nickel, and zinc. Many of these metals were also found in water samples collected from Lake Macquarie near to Vales Point power station. It seems likely that contaminated groundwater seepage is also entering the Lake.

Currently, the Environment Protection Licences for Vales Point and Eraring only require limited monitoring of heavy metals in discharge and they impose no concentration limits for metals, other than for copper, iron, selenium at one of the two discharge points from Eraring power station.

Barriers and failures in coal ash management and re-use

The coal ash stored and causing pollution at Eraring and Vales Point is indicative of a broader problem at coal fired power stations across the country. As the phased closure of coal-fired power stations occurs, how we manage the massive volumes of coal ash left in ash dams will be of particular concern to communities and to the construction and manufacturing industries for whom coal-ash re-use presents new business and job opportunities. Simply capping unlined coal ash dams does not prevent leachate and contamination and is a waste of a substance that, despite its hazardous characteristics, can actually help reduce greenhouse gas emissions. Safe coal ash utilisation is vital to reduce the massive volumes of coal ash generated and stockpiled, prevent ongoing heavy metal pollution and reduce greenhouse pollution.

Many of the current uses of coal ash such as mine site rehabilitation and mine void backfilling, agricultural soil amendments, fertilisers and potting mixes are high risk, but fly ash can safely be used to replace cement in concrete mix. To do so improves the workability of plastic concrete, and the strength and durability of hardened concrete. The use of fly ash to replace cement also has major greenhouse gas savings. Globally, the manufacture of cement produces more greenhouse gas emissions than any other single product – about 3 billion tonnes per year, or 8 percent of the world total. In Australia, production of Portland cement is responsible for 7.4 million tonnes of emissions, about 1.3 percent of national emissions.

While rates of economically-beneficial coal ash utilisation in Australia have been rising, it still remains at about 20 percent of the volume of ash generated each year. In other parts of the world, coal ash reuse is perused more vigorously. Between 1995 and 2011 Japan increase its utilisation of coal ash from 67 percent to 97 percent, during a period when coal ash generation almost doubled. Of the 97 percent utilisation by Japan in 2011, 67.3 percent was used for cement and concrete. It is estimated that about 12.3 Mt of coal ash was generated in Australia in 2016, of which 9.4 Mt was dumped in on-site ash dams. Only 1.8 Mt was used in high value-added applications such as cement and concrete. Meanwhile, more than 400 Mt of coal ash is sitting in largely unlined ash dumps around Australia. These aging poorly-designed and run hazardous waste containment facilities are aging, increasing the risk of off-site contamination.

The barriers to reuse are partly regulatory and partly commercial. Currently, power stations charge a royalty fee for coal ash. Shifting this cost-burden onto the power stations that actually create this hazardous waste is a key first step to ensuring it is reused. In order to qualify for the exemption to relevant waste control regulations in NSW, the EPA's *Coal Ash Order 2014* imposes contaminant concentration limits that must be met by suppliers of coal ash.. In January 2019, AGL suspended sales of coal ash and ash by-products from its Bayswater and Liddell power stations after testing of coal ash showed elevated levels of heavy metals, including chromium, cadmium and copper, which exceeded limits set by the *Coal Ash Order 2014*.

The primary commercial barriers to fly ash reuse are a result of the vertically integrated structure of the cement industry in Australia. For a variety of reasons, including the ownership structure of the cement industry and over-capacity of production, the actual value of coal ash is less than the cost of cement production. Ironically, this limits the motivation of vertically integrated cement and concrete industries to reduce cement consumption and replace it with coal ash. Concrete companies only use as much fly ash as their fully-owned cement producers want them to.

This situation has led to cement manufacturers being prosecuted by the Australian Competition and Consumer Commission (ACCC) for breaching the Trade Practices Act in Queensland by entering into contracts with power stations to prevent them selling their coal ash to other buyers.

HCEC believes the cement industry is behaving in a similar way in NSW. Flyash Australia (FAA), a joint venture equally owned by Boral and Cement Australia has a contract for exclusive rights to raw fly ash from Eraring power station's fabric filters - concrete grade fly ash that needs little processing. FAA only purchases half of the cement-grade shake ash produced by Eraring, and denies competitors access to the remainder. Flyash Australia also has exclusive contracts to buy or use fly ash at Mount Piper and Bayswater power stations in NSW and Collie power station in WA.

Another coal ash use that encapsulates the ash and prevents leaching of heavy metals is a light weight aggregate called Lytag, suitable for on-site manufacture using Eraring and Vales Point coal ash. HCEC believes about 500,000 tonnes of Lytag (from the same amount of Lake Macquarie coal ash) could be sold into the high value lightweight concrete markets of Sydney, Newcastle, and Wollongong each year. With rail loops already in place at both Earring and Vales Point, transport costs and truck movement could be significantly minimised.

> *With appropriate regulation and government incentives, we believe that coal ash re-use can be undertaken in an environmentally responsible way, removing a key source of heavy metal contamination from the shores of Lake Macquarie, reducing a key source of greenhouse pollution and providing for new enterprises on the sites of decommissioning coal fired power stations, and potentially provide new jobs for a redeployed workforce.*

Recommendations

Recommendation 1: The NSW EPA undertake an investigation into coal ash generated in NSW and ensure appropriate waste classification and licensing.

Recommendation 2: The Commonwealth *Controlled Waste NEPM* (National Environmental Protection Measure) hazardous waste classification be amended to delete the exclusion of "*fly ash generated from Australian coal fired power stations*".

Recommendation 3: NSW power station operators must obtain a 'Waste storage - hazardous, restricted solid, liquid, waste licence' and a 'Hazardous waste recovery licence'.

Recommendation 4: The NSW EPA must require all coal fired power station operators to provide financial assurance to secure or guarantee funding during the operation of the facility and during the post-closure period and until the EPA is satisfied that the site is stable and not polluting.

Recommendation 5: To reduce the amount of coal ash dumped in ash dams in NSW, the EPA impose a load-based licence fee of at least $20 a tonne on all coal ash disposed of in ash dams, landfills, and mine voids.

Recommendation 6: The EPA ensure that all water monitoring data undertaken by Sunset Industries International for its Vales Point power station be uploaded to its website as soon as practicable after the monitoring is undertaken.

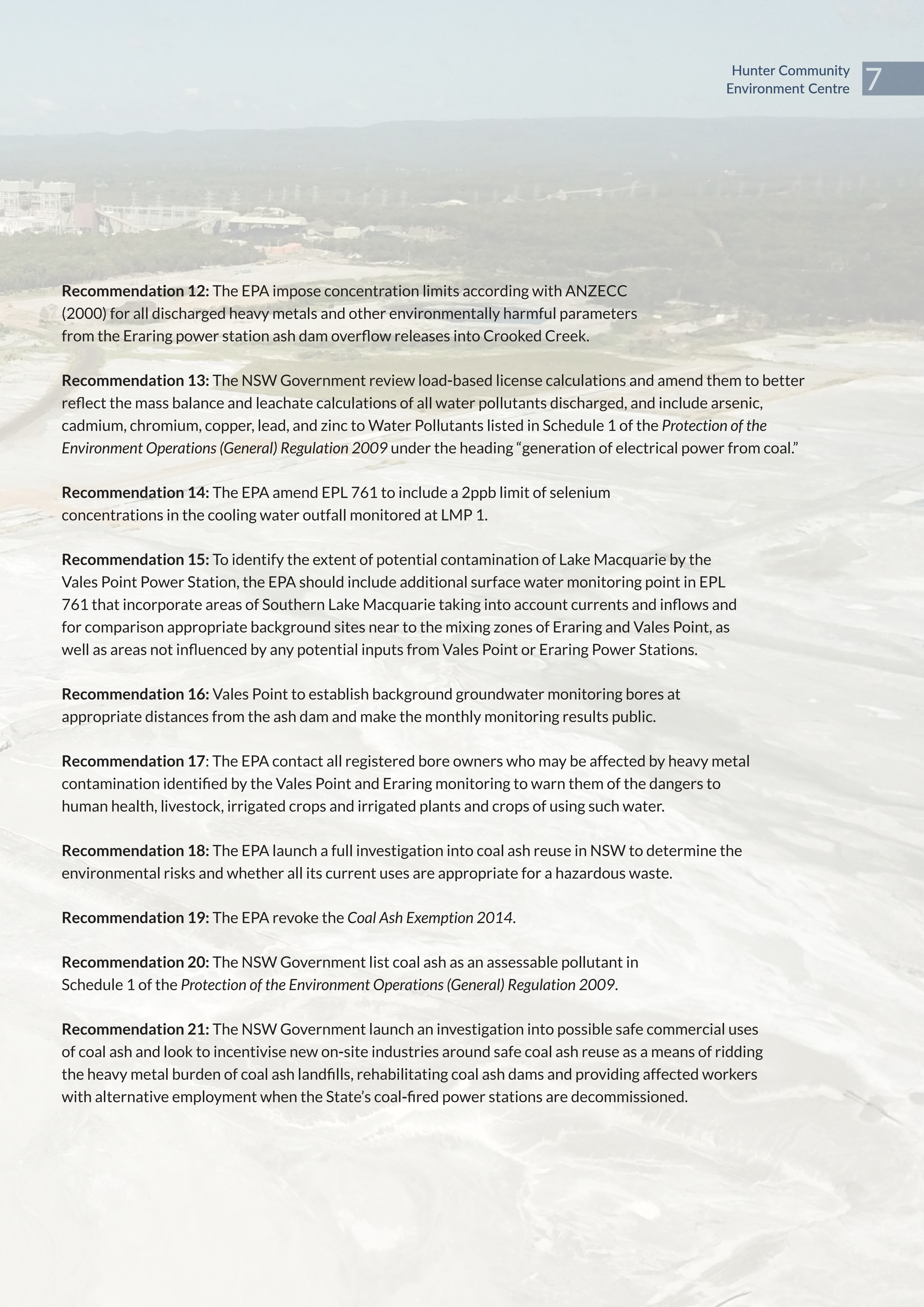
Recommendation 7: The EPA ensure that additional monthly monitoring for aluminium, arsenic (iii, and v), cadmium, chromium (iii, and vi), copper, iron, lead, manganese, nickel, selenium, vanadium, and zinc be added to the Vales Point power station EPL to be undertaken at Mannering Bay, Wyee Creek, and Wyee Bay.

Recommendation 8: The EPA ensure that all surface water EPL monitoring sites include monthly monitoring for aluminium, arsenic (iii, and v), cadmium, chromium (iii, and vi), copper, iron, lead, manganese, nickel, selenium, vanadium, and zinc with results published on the operator's website.

Recommendation 9: The EPA impose concentration limits according with ANZECC (2000) trigger values for heavy metals and other environmentally-harmful parameters for all discharge from the ash dam including overflow releases into Mannering Bay and Wyee Creek.

Recommendation 10: The EPA require additional monthly monitoring for aluminium, arsenic (iii, and v), cadmium, chromium (iii, and vi), copper, iron, lead, manganese, nickel, selenium, vanadium, and zinc, be added to the Eraring power station EPL to be undertaken at Muddy Lake and Crooked Creek.

Recommendation 11: The EPA ensure that all Eraring power station surface water EPL monitoring sites include monthly monitoring of aluminium, arsenic (iii, and v), cadmium, chromium (iii, and vi), copper, iron, lead, manganese, nickel, selenium, vanadium, and zinc and these made public on the operator's website.



Recommendation 12: The EPA impose concentration limits according with ANZECC (2000) for all discharged heavy metals and other environmentally harmful parameters from the Eraring power station ash dam overflow releases into Crooked Creek.

Recommendation 13: The NSW Government review load-based license calculations and amend them to better reflect the mass balance and leachate calculations of all water pollutants discharged, and include arsenic, cadmium, chromium, copper, lead, and zinc to Water Pollutants listed in Schedule 1 of the *Protection of the Environment Operations (General) Regulation 2009* under the heading "generation of electrical power from coal."

Recommendation 14: The EPA amend EPL 761 to include a 2ppb limit of selenium concentrations in the cooling water outfall monitored at LMP 1.

Recommendation 15: To identify the extent of potential contamination of Lake Macquarie by the Vales Point Power Station, the EPA should include additional surface water monitoring point in EPL 761 that incorporate areas of Southern Lake Macquarie taking into account currents and inflows and for comparison appropriate background sites near to the mixing zones of Eraring and Vales Point, as well as areas not influenced by any potential inputs from Vales Point or Eraring Power Stations.

Recommendation 16: Vales Point to establish background groundwater monitoring bores at appropriate distances from the ash dam and make the monthly monitoring results public.

Recommendation 17: The EPA contact all registered bore owners who may be affected by heavy metal contamination identified by the Vales Point and Eraring monitoring to warn them of the dangers to human health, livestock, irrigated crops and irrigated plants and crops of using such water.

Recommendation 18: The EPA launch a full investigation into coal ash reuse in NSW to determine the environmental risks and whether all its current uses are appropriate for a hazardous waste.

Recommendation 19: The EPA revoke the *Coal Ash Exemption 2014*.

Recommendation 20: The NSW Government list coal ash as an assessable pollutant in Schedule 1 of the *Protection of the Environment Operations (General) Regulation 2009*.

Recommendation 21: The NSW Government launch an investigation into possible safe commercial uses of coal ash and look to incentivise new on-site industries around safe coal ash reuse as a means of ridding the heavy metal burden of coal ash landfills, rehabilitating coal ash dams and providing affected workers with alternative employment when the State's coal-fired power stations are decommissioned.

Contents

Executive Summary. 1

Methodology 2

Heavy metals in seafood caught in Lake Macquarie 2
Water sampling and monitoring results 3
Barriers and failures in coal ash management and re-use 4

Recommendations. 6

Introduction 11

Lake Macquarie 11
Coal ash 15
  Coal ash in Australia 18

Part 1: Lake Macquarie ash dams and water pollution 23

Sources of Lake Macquarie heavy metal pollution 25
  Eraring ash dump 26
  Vales Point ash dump 28

Heavy metal contamination of Lake Macquarie 29
  Heavy metals in Lake Macquarie seafood 31
  Water and sediment quality guidelines and objectives 37
  HCEC assessment of Lake Macquarie water and sediment 37

Environmental Protection Licences 45
Vales Point EPL 761 46
Eraring EPL 1429 48
National Pollution Inventory and Load Based Licences 50
Selenium pollution 52
Groundwater contamination 56

Part 2 - Coal ash utilisation and rehabilitation of ash dams 63

Coal ash regulation 64
Cement and concrete 66
Blockages to coal ash reuse by the cement and concrete industries. 67
LYTAG – lightweight aggregate 69

Conclusions. 71

References 72

Appendix 1. Analytical reports - HCEC water and sediment samples. 81

Appendix 2.- Analytical report - Coal samples. 118

Introduction

This report sets out the results of a southern Lake Macquarie water and sediment testing program undertaken by the Hunter Community Environment Centre (HCEC) between July 2018 and February 2019.

We compare the results with previous studies of heavy metals in the Lake, and recommend new pollution licence conditions and other regulatory changes aimed at reducing heavy metal loads from the two remaining coal-fired power stations, Origin Energy's Eraring and Delta Electricity's (Sunset Power International P/L) Vales Point power stations.

We examine the two large unlined coal ash dams associated with the power stations on the shores of Lake Macquarie, and put forward proposals for their management, regulation and rehabilitation utilising the hazardous waste as a transition industry for power station workers facing retrenchment as a result of the power stations eventual closure.

We then consider the regulatory and commercial barriers to environmentally-responsible coal ash re-use and make recommendations for removing those barriers.

Lake Macquarie

Lake Macquarie, a wave-dominated barrier lagoon lying between Sydney and Newcastle, is the largest coastal estuary in eastern Australia covering an area of about 110km^2 and 15 per cent of the City of Lake Macquarie.

With the exception of the entrance at the Swansea Channel, tidal currents are non-existent in most of the Lake, with winds producing larger changes in water levels than tides.[1] Despite the poor tidal exchange, the Lake has a marine character due to minimal inflows from the two main freshwater creeks of Dora Creek in the south of the Lake and Cockle Creek in the north.[2]

Bordered by residential, industrial, and rural land, the Lake is an important tourism area with a number of camping and caravan reserves providing holiday and semi-permanent accommodation for visitors. Before the end of commercial fishing in 2002, it produced 430 tonnes of commercial fish a year, the second highest estuary catch in NSW and it was an important source of crustacea and molluscs.

Much of the Lake's shoreline is undeveloped and the Lake itself is of significant ecological value with a rich diversity of aquatic marine life supported by important habitats including the third largest area

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[1] Schneider, 2014.
[2] ibid

of seagrass in NSW (13.4 km^2).[3] Monitoring over the past 10 years has shown that light penetration has improved by over a metre, allowing a measurable expansion of seagrass re-colonising deeper areas.[4]

In general, the water quality of Lake Macquarie has improved since the 1980s following expanded reticulated sewerage, stormwater management, foreshore stabilisation and sediment control measures which have limited the discharge of excess nutrient loads and have seen improvements to the ecological function of the Lake.[2] In addition, bush regeneration and the stabilisation of potentially erodible surfaces have assisted in improving water clarity.[5] However, heavy metal contaminated sediments from industrial discharges persist.[6]

Lake Macquarie was a poor choice for receiving contaminated discharge. Only about 1% of the Lake's volume exchanges with ocean waters during an average tidal cycle and averaged e-folding time (a measurement of tidal flushing[7]) is estimated at 277 days.[8] However, tidal flushing of the Lake is highly variable. The southern end of the Lake, where Vales Point power station discharges, the e-folding time is as long as 500 days (See Figure 1).

The Lake is effectively divided in two by Wangi Wangi Point ('the big spit'). In the northern area of the Lake, industrial discharge has been significantly reduced since the Pasminco zinc and lead smelter, built in 1896, closed in 2003 and the site since rehabilitated. In the southern area of the Lake, three coal-fired power stations were built in the second half of the last century.

> *While historically the greatest heavy metal contaminations has been found is in the northern area, the result of discharge from the now decommissioned Pasminco smelter,[9] the highest concentrations of selenium has been found at sites adjacent to the power stations in the south.*[10]

A 1994 study of contaminants in various fish in a number of 'hot-spot' areas in the Lake near coal ash dams and power stations revealed concentrations of selenium in the edible muscle of fish were high, posing potential risks to human health.[11]
A 2003, a health risk assessment that warned recreational fishers to limit the consumption of fish caught in Lake Macquarie remains in place.[12]

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[3] NSWDPI, 2007.
[4] Lake Macquarie Council, 2017.
[5] Umwelt, 2014.
[6] ibid
[7] Tidal flushing of Lake Macquarie refers to the replacement of water within the lake with water from outside the lake as the tidal fluctuations bring seawater through the channel on the flood tide and carries out lake water on the ebb tide.
[8] Worley Parsons, 2010a.
[9] Umwelt, 2014.
[10] Roach, 2005.
[11] Roberts, 1994.
[12] Dalton and Phillip, 2003.

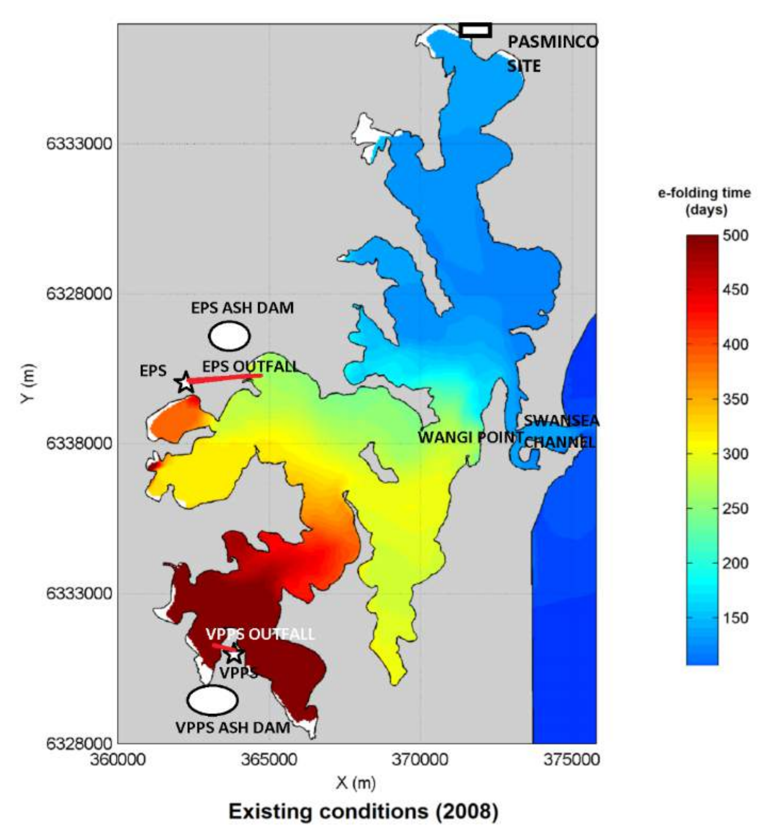

Figure 1: E-folding times in Lake Macquarie.[13]

Power station cooling water discharge also has an impact on hydrodynamic processes of the southern area of the Lake.[14] Eraring power station's cooling water system drives water circulation in the central section of the lake, at a daily inflow rate equivalent to a 1 in 40 year ARI rainfall event.[15]

Cooling water discharges from the two power stations also increase the temperature of waters in the Lake embayments surrounding the power stations by between 2°C and 5°C above ambient lake temperature.[16] When first built, Eraring power station increased the temperature of 0.5km^2 of the Lake surface area in summer and 1.7km^2 in winter by 5°C and an area of Lake surface of 5km^2 in summer and 9.1km^2 in winter by 2°C.[17] The areas of thermal effect was effectively doubled when units 3 and 4 were built in 1978.[18]

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[13] From Worley Parsons, 2010b.
[14] Umwelt, 2014.
[15] ibid.
[16] ibid.
[17] ELCOM NSW, 1975.
[18] ELCOM NSW, 1977.

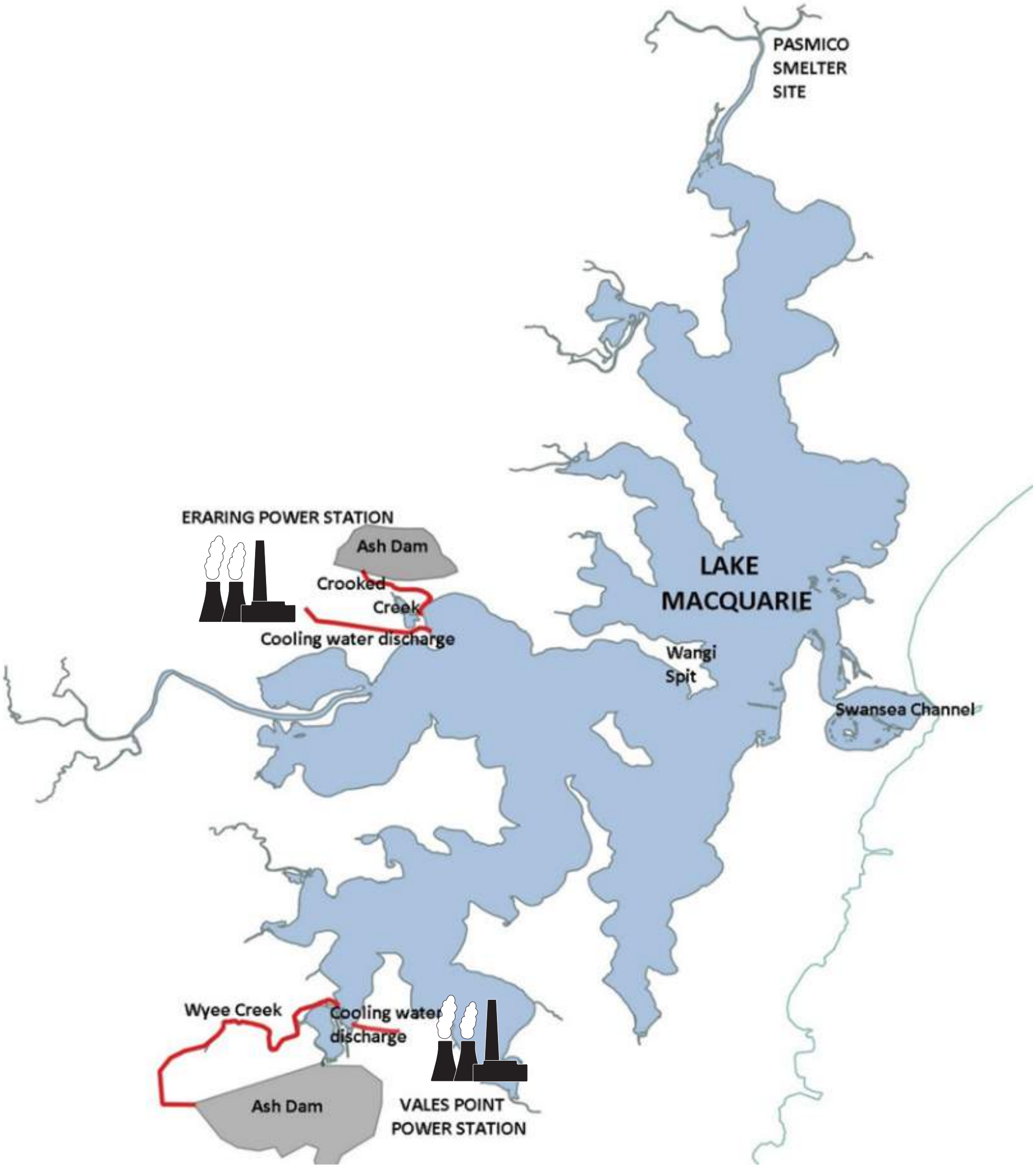

Figure 2: Major industrial discharge into Lake Macquarie.

Since the first power station was built, the population of Lake Macquarie has more than doubled[19] to over 200,000,[20] with a projected increase of some 60,000 people expected by 2031.[21] One power station, Wangi, has now closed and the remaining two, Vales Point and Eraring, reconfigured and updated a number of times, are nearing the end of their designed lives, provide an opportunity for Lake Macquarie to finally rid itself of industrial discharge and begin the process of natural cleansing of its industrial legacies. The end of heavy metal discharge into Lake Macquarie will not end, however, until the power station ash dams are satisfactorily rehabilitated.

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[19] ABS, 2014.
[20] ibid.
[21] Umwelt, 2014.

Coal ash

Coal-fired power plants produce an enormous amount of coal ash residue from the combustion of coal in boilers to produce steam for turbines. In 2010, the World Wide Coal Combustion Production Network estimated global coal ash generation was about 780 Million tonnes (Mt).[22]

Fly ash represents the major component of coal ash, followed by flue gas desulfurisation material, bottom ash, and boiler slag.[23] Fly ash remains in the furnace gases and is transported by the combustion gases through the power station boilers and captured, usually, in an electrostatic precipitator or bag filters, at the boiler outlet.[24] The remaining coal ash produced in the boiler falls to the bottom of the furnace where it is removed as bottom ash.[25]

After coal combustion, coal ash is usually stored in large coal ash dams, either in dry or wet state, and some is disposed of in cement or building products, road base and landfills. Storage of wet coal ash usually protects from wind spreading, but increases the leaching of various elements including heavy metals.[26] This leaching can be destructive to life forms, as shown in Lake Velenje in Slovenia, where stored coal ash caused the death of most life forms.[27] Coal ash can also jeopardise water resources and cause radioactive contamination.[28]

Coal ash is mostly silicon, aluminum and iron oxides consisting of glassy spheres, crystalline matter and unburnt carbon.[29]

> *As coal is itself a concentrated source of many trace elements, its combustion produces residual ash with further concentrated non-volatile trace elements known to stress aquatic ecosystems by generating anoxic conditions through limited photosynthesis, enhanced microbial activity, and metal toxicity.*[30]

It has been suggested that the major contributor to the toxic marine conditions of the late Permian mass extinction event was the global dispersal of fly ash from the combustion of Siberian coal caused by volcanic eruptions in the Siberian Tunguska Basin.[31]

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[22] Heidrichl et al, 2013.
[23] Kalyoncu, 2001.
[24] Heidrichl et al, 2013.
[25] ibid
[26] Iturbe et al, 1996
[27] Tamse, 1995.
[28] Vukovic et al, 1996
[29] Heidrichl et al, 2013.
[30] Rowe et al, 2002.
[31] Grasby, 2011.

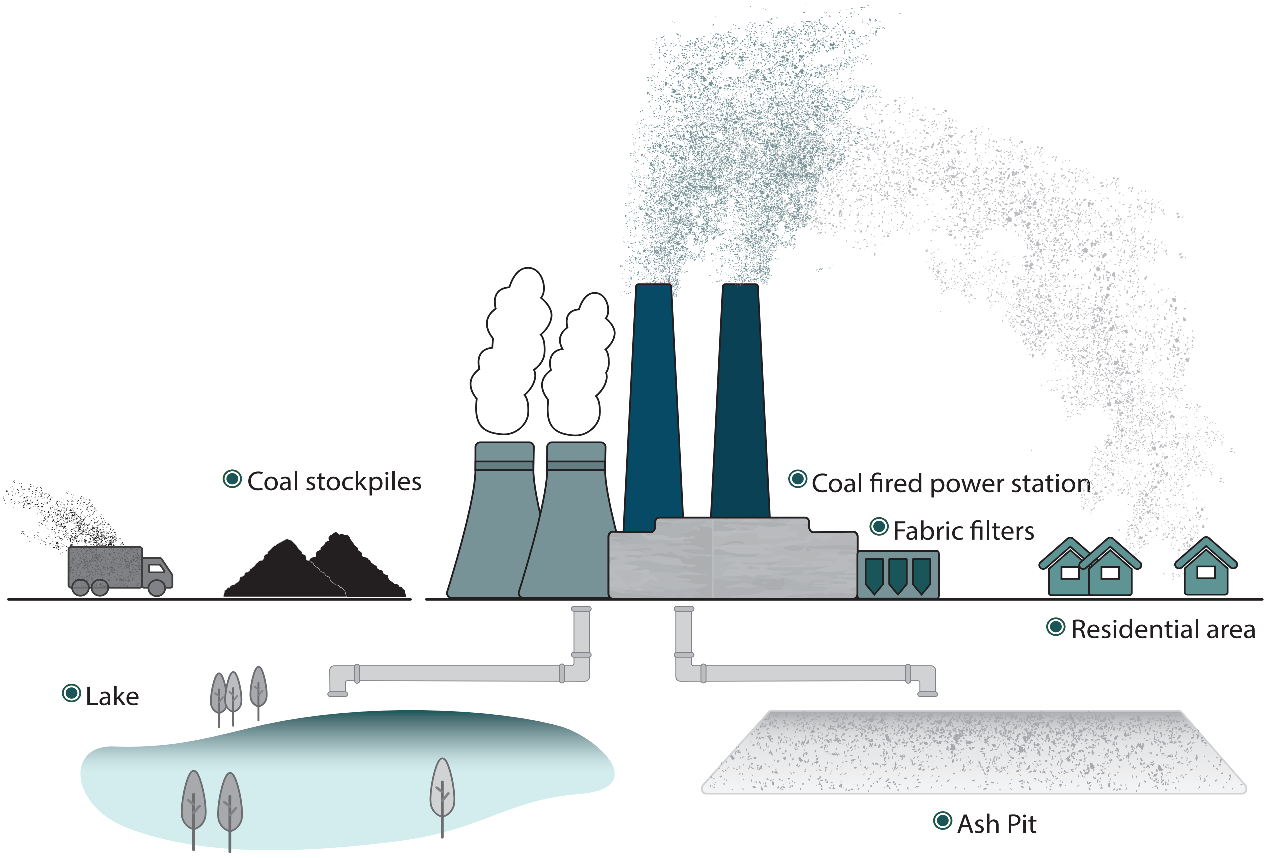

Figure 3: coal-fired power stations and their coal ash waste streams

Coal is a heterogeneous product with a wide variety of ranks, types and classifications, including ash content, which ranges between about 6 and 30 percent.[32] Depending on where the coal was mined, coal ash contains a number of trace elements, with varying concentrations, including arsenic, lead, mercury, cadmium, chromium, selenium, thallium,[33] and radioelements including uranium, thorium, radium and radon.[34] In the presence of water, these elements can move into the environment in the form of leachates and be consumed or absorbed by people and organisms, where they can bio-accumulate and cause severe toxicological effects.[35]

The amount of heavy metals released from coal ash dumps depends largely on acidity, bonding between the element and the ash, its chemical form, and physicochemical properties of water.[36] If eaten, drunk or inhaled in sufficient quantities, these metals can cause cancer and nervous system impacts such as cognitive deficits, developmental delays and behavioral problems, heart damage, lung disease, respiratory distress, kidney disease, reproductive problems, gastrointestinal illness, birth defects, and impaired bone growth in children.[37]

The US Environmental Protection Agency (US EPA) has found that people living near an unlined wet ash dam that drink water from a well, may have as much as a 1 in 50 chance of getting cancer from arsenic-contaminated water,[38] and the risk for young children increased by about 25 percent compared to adults.[39] The US EPA found that the concentrations of arsenic in ground water beneath some unlined

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[32] See for example S&P Global Plats, 2018.
[33] US EPA, 2010; Wadge and Hutton, 1987; Querol et al, 1996.
[34] USGC, 1997.
[35] Bryan & Langston, 1992.
[36] Fulekar & Dave 1991; Pandey, 2014.
[37] U.S. EPA, 2007.
[38] ibid
[39] US EPA, 1999.

wet ash dams in the USA would not return to safe drinking levels for more than 500 years.[40]

Living near coal ash dumps was found to be significantly associated with increased adverse health outcomes and sleep problems for children.

Attention-deficit hyperactivity disorder, gastrointestinal problems, difficulty falling asleep, frequent night awakenings, sleep talking, and complaint of leg cramps were greater in children living near coal ash dumps.[41]

Coal ash dams on waterways pose significant toxicological risks. A failure of an ash dam containment structure either through flooding, storm surge or engineering or design flaws, will result in contamination by heavy metals threatening human health and aquatic ecosystems.[42]

The presence of heavy metals in the aquatic environment is of major concern because of their toxicity and tendency to bio-accumulate in animals and plants. There is a large amount of data demonstrating that plants and animals inhabiting coal ash contaminated sites or chronically exposed to coal ash in laboratory or field based experiments accumulate trace elements, sometimes to very high concentrations.[43] Fishes are on the top of the aquatic food chain and accumulate large amounts of metals from water and sediment.[44]

Bioaccumulation of metals in marine sediments can have a severe impact on fisheries and cause human health impacts.[45] Marine life can have considerable capability for bioaccumulation and biosorption[46] of radionuclides and heavy metals from their surroundings.[47]

The discharge of metals from ash dumps has been linked to a number of lethal and sub-lethal effects on fish species. Populations of fish have decreased in lakes,[48] and growth, condition factor, and lipid storage decreased in fish exposed to coal ash contaminated sediments.[49] A number of coal ash trace elements have been found to result in lethal and sub-lethal impacts including decreased growth and condition factors,[50] population density, reproductive success, and adult biomass, [51] fish abnormalities,[52] and the reduction in fitness through increased susceptibility to disease, predation, and decreased reproductive capacity. [53]

In December 2014, the US EPA released a rule, or set of standards, covering coal ash dumps.[54] The US rule was initiated after a devastating coal ash spill in 2008 at a power plant in Kingstone, Tennessee. The spill flooded land destroying houses and releasing coal ash into waterways. Surveys in the immediate aftermath of the coal ash spill found very high arsenic and mercury concentration in sediments up to about 5km from the ash dam.[55] The death toll among cleanup workers is reported to now be 30, mostly from cancer, and sickened workers now number at least 200.[56]

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[40] ibid
[41] Sears & Zierold, 2017.
[42] Islam and Tanaka, 2004; Igwe and Abia, 2006.
[43] Rowe et al, 2002.
[44] Lakshmanasenthil et al, 2013.
[45] ibid
[46] Biosorption is a property of certain types of inactive, dead, microbial biomass to bind and concentrate heavy metals from even very dilute aqueous solutions. It is particularly the cell wall structure of certain algae, fungi and bacteria which was found responsible for this phenomenon. Marine animal has tendency to burrow down in the bottom sea sediments and rocks, filtering on organic particles and algae along with tiny fishes and planktons, which may lead to increase the uptake of radioactive and heavy metals.
[47] Khandaker et al, 2015.
[48] See for example Cumbie and VanHorn, 1978; Olmsted et al, 1986; Lemly, 1997.
[49] Rowe, 2003.
[50] Hopkins, 2001.
[51] Garrett and Inman, 1984.
[52] Sorensen EMB, 1988.
[53] Hatcher et al, 1992; Rowe et al, 2002.
[54] US EPA, 2015.
[55] Ruhl et al, 2009.
[56] Jamie Satterfield, 2018.

Coal ash in Australia

In Australia, coal-fired power stations are one of the main sources of metal contaminants to estuarine lakes as a result of coal ash residues[57] leaching and overflowing from ash dams and from stack emissions.[58] Coal ash from NSW bitumous coal contains a number of trace elements that are potentially toxic, particularly heavy metals (See Table 1).

Trace element	**Min ppm**	**Max ppm**
Arsenic	2.2	18
Boron	30	250
Barium	<250	300
Cadmium	0.3	0.4
Chromium	40	100
Copper	25	100
Mercury	0.001	0.34
Manganese	40	2000
Nickel	6	150
Lead	20	150
Selenium	0.8	11
Thorium	12	40
Thalium	<1	4
Uranium	6	14
Zinc	20	1000

Table 1: Trace elements found in fly ash from NSW bituminous coal[59]

The *Waste Classification Guidelines 2014 (NSW)*[60] classifies waste and the means of disposal or reuse of it that can legally be undertaken in NSW.

Despite the risks posed by coal ash to waterways, under these Guidelines, NSW coal ash is classified as General Solid Waste. The result is that few restrictions exists for its disposal, transport, and reporting.

Given the volumes of coal ash generated and its potential for pollution, far greater focus must be applied by the EPA to its classification.

> *All fly ash and 20 percent of bottom ash sampled by AADA could therefore be classified as hazardous waste under NSW legislation.*

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[57] Scheider, 2014.
[58] Davies &, Linkson, 1991.
[59] Swain & Goodarizi, 1995.
[60] EPA, 2014a.

Eraring ash dump

Recommendation 1: The NSW EPA undertake an investigation into coal ash classification and ensure appropriate waste classification and licensing of coal ash disposal in NSW to remove the current risks to the environment.

Despite the heavy metal content, and its listing on Annex 1 of the United Nations Basel Convention on the control of transboundary movements of hazardous wastes and their disposal,[61] fly ash from Australian coal-fired power stations is specifically excluded from the relevant Commonwealth Controlled waste NEPM (National Environmental Protection Measure) by hazardous waste classification *N150 fly ash, excluding fly ash generated from Australian coal fired power stations.*[62]

Recommendation 2: The Commonwealth Controlled waste NEPM (National Environmental Protection Measure) hazardous waste classification be amended to delete the exclusion of "fly ash generated from Australian coal fired power stations".

In 2016, Australian coal-fired power stations produced 12.35 million tonnes (Mt) of coal ash,[63] representing almost 20 percent of all the waste produced in Australia.[64]

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[61] United Nations Treaty Series, 1992.
[62] Latimer, 2017.
[63] ADAA, 2016.
[64] Pickin et al, 2018.

The Ash Development Association of Australia (ADAA) states that of the coal ash generated in 2016, 75 percent (9.36 Mt) went into onsite ash dumps. This volume is 50 percent greater than all other hazardous waste generated in Australia.[65]

The NSW Environmental Guidelines Solid waste landfills 2016[66] sets out 'Minimum Standards' for the environmental management of landfills in NSW. Broadly, landfills must not pollute waters and the guidelines restrict landfills from being built near to sensitive sites such as residences and schools, permanent water bodies, drinking water catchments, drinking water aquifers, or conservation areas, as well as setting out standards for design, construction and operation of landfills. Under the guideline, liquid and untreated hazardous wastes are not permitted to be landfilled in NSW. Despite such strict oversight of the disposal of other waste, 400 million tonnes of coal ash sits in unlicensed on-site ash dumps in Australia.[67]

No NSW power station ash dam complies with the required standards set out in the NSW Environmental Guidelines Solid waste landfills 2016 as they do not incorporate a leachate barrier system to contain leachate and prevent the contamination of surface water and groundwater. Many, including the Eraring and Vales Point ash dams, are situated in areas that would be deemed too sensitive for landfill.

Most landfill licences in NSW contain a condition under Part 9.4 of the *Protection of the Environment Operations Act 1997* that licensees provide and maintain a financial assurance to secure or guarantee funding for works required under a licence. The financial assurance must be maintained during the operation of the facility and during the post-closure period until the EPA is satisfied that the site is stable and not polluting.

No NSW power station operator is required to provide a financial security, which would alleviate the potential costs of ash dam rehabilitation should any become financially insolvent. Indeed, no NSW power station ash dam is licenced as a solid waste landfill.

Recommendation 3: NSW power station operators must be required to obtain a 'Waste storage - hazardous, restricted solid, liquid, waste licence' and a 'Hazardous waste recovery licence'.

Recommendation 4: The NSW EPA must require all coal fired power station operators to provide financial assurance to secure or guarantee funding for during the operation of the facility and during the post-closure period and until the EPA is satisfied that the site is stable and not polluting.

The many regulatory exemptions provided to coal ash (see Part 2 for further exemptions), such as the exemption from listing coal ash as a hazardous waste and its exclusion from landfill requirements, are in place to enable coal ash re-use, which is thought to alleviate the burden of disposal in landfills. As coal ash has a number of commercial and beneficial uses, a global industry has been established around its use. Current uses for coal ash range from agricultural soil amendments, to potting mixes, mine void fill and high-tech aggregates, While many of the current uses of coal ash present significant toxicological risks, regulative exemptions to encourage coal ash re-use should have meant very little coal ash remains dumped in on-site coal ash dams at power stations. Of the coal ash produced in 2016, however, only 20% was beneficially used, with a similar amount utilised from existing ash dumps.[68]

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[65] In 2014-15 Australia produced around 5.6 million tonnes of hazardous waste, which is about 9% of all waste generated (64 million tonnes) in this period.
[66] EPA, 2016.
[67] Heidrich & Heeley, 2014.
[68] ADAA, 2016.

Due to a range of factors including limitations in market need, unsustainable economics, restrictive levels of contaminants,[69] or resistance by Australian Cement industry,[70] most coal ash generated in Australia is dumped in on-site ash dams[71] with no plans other than capping them with clean fill.

Based on figures published by the ADAA it has been estimated that since 1975 about 225Mt of fly ash from coal fired power stations has been stored in legacy ash dumps in Australia.[72] ADAA estimates that the total amount of coal combustion residue (fly ash, bottom ash, gypsum etc) stored in homogenous ash dumps across Australia is more than 400 Mt.[73]

Recommendation 5: To reduce the amount of coal ash dumped in ash dams in NSW, the EPA impose a load-based licence fee of at least $20 a tonne on all coal ash generated disposed of in ash dams, landfills, and mine voids.

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[69] Latimer, 2017.
[70] ACCC, 2017..
[71] Latimer, 2017.
[72] *ibid*
[73] Heidrich & Heeley, 2014.

Part 1: Lake Macquarie ash dams and water pollution

The coal ash produced by Vales Point and Eraring power stations is disposed of in two dams constructed over wetlands on the shores of Lake Macquarie. At Vales Point power station, part of Mannering Bay (The Hole) was dammed off from the main body of the Lake and has been progressively filled by ash-slurry.[1] At Eraring power station, both a freshwater and a brackish wetland was used.[2]

> *Over 60 million tonnes of coal ash is stored in these two ash dams, about 26 Mt at the Vales Point Ash Dam and about 35 million tonnes at Eraring.*

An additional 1.9Mt is produced each year - 0.55 Mt by Vales Point and 1.34 Mt by Eraring. Only 25 percent or about 500,000t of ash generated each year is reused, comprising 402,000 t (30%) of the ash produced at Eraring and 95,000t from Vales Point (17%).[3]

About 90 percent of the ash generated by these power stations is fly ash and the remaining is furnace or bottom ash.[4]

HCEC collected samples of coal from Newstan and Chain Valley mines and had it analysed by Bureau Veritas Minerals Laboratories in Cardiff (see Appendix 2 for full laboratory report). Newstan colliery sells coal to Eraring power station and the Chain Valley mine supplies coal to Vales Point power station.

With the results of this analysis, a mass balance of trace elements can be performed to estimate the volumes of heavy metals produced by each power station.

Table 3 sets out the mass balance calculations for each power station based on 2013/14 coal consumption and the coal samples from Newstan and Chain Valley collieries.

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[1] WMB, 1996.
[2] ibid
[3] van Koeverden et al, 2012.
[4] ELCOM NSW, 1980.

Element		Units	DL	VPPS - coal consuption ~2.6mtpa		EPS - coal consuption ~4.99mtpa	
				Chain Valley mine (ppm)	Mass balance (kg)	Newstan mine (ppm)	Mass balance (kg)
Arsenic	As	mg/kg db	0.2	1.9	4,940	0.6	2,994
Boron	B	mg/kg db	5	46	119,600	30	149,700
Antimony	Sb	mg/kg db	0.2	0.3	780	0.3	1,497
Selenium	Se	mg/kg db	0.2	0.7	1,820	0.6	2,994
Mercury	Hg	mg/kg db	0.01	0.02	52	0.04	200
Cobalt	Co	mg/kg db	2	2	5,200	3	14,970
Chromium	Cr	mg/kg db	1	9	23,400	12	59,880
Copper	Cu	mg/kg db	2	16	41,600	10	49,900
Manganese	Mn	mg/kg db	1	40	104,000	40	199,600
Molibdenum	Mo	mg/kg db	2	<2	<5200	<2	<9980
Nickel	Ni	mg/kg db	1	6	15,600	4	19,960
Zinc	Zn	mg/kg db	1	21	54,600	10	49,900
Silver	Ag*	mg/kg db	0.1	0.11	286	0.11	549
Cadmium	Cd	mg/kg db	0.01	0.04	104	0.04	200
Lead	Pb	mg/kg db	0.1	9	23,400	9.2	45,908
Tin	Sn*	mg/kg db	2	<2	<5200	<2	<9980
Thallium	Tl*	mg/kg db	1	<1	<2600	<1	<4990
Uranium	U*	mg/kg db	0.1	1.3	3,380	1.6	7,984
Sub Total					398,762		606,235
Aluminium	Al*	%	0.005	1.7	44,200,000	2.8	139,720,000
Iron	Fe*	%	0.005	0.28	7,280,000	0.26	12,974,000
Total					51,878,762		153,300,235

Table 3: Annual mass balance calculations for a number of metals based on laboratory analyses of the coal bunt by Eraring power station (EPS) and vales Point power station (VPPS).

For the metals analysed, and based on the coal samples collected, we estimate that the two Lake Macquarie power stations generate over 200,000 tonnes of metals a year, mostly aluminium and iron. The mass balance calculations suggest the two power station collectively generate over 1,000 tonnes of highly toxic heavy metals each year, most of which (~99% for most metals) is collected by the smoke stack bag filters and dumped on site as part of the coal ash waste stream.

While only a small proportion will escape as leachate into waterways, the leaching of these metals will continue for many decades after the ash dams are 'rehabilitated'.

Sources of Lake Macquarie heavy metal pollution

Despite sediment quality data indicating a reduction in surface metal concentrations throughout Lake Macquarie over the past 20 years or more,[5] in some areas of the Lake sediment concentration of many metals remain above ANZECC (2000) Guidelines.[6] In the southern area of the Lake, much of this sediment is a legacy of 40 years of poor pollutions control mechanisms employed by power station operators and the ash dams continue to pollute the Lake with heavy metals.

A 1996 Lake Macquarie Estuary Management Study[7] identified the only acceptable long-term strategy to reduce the environment effects of the ash dams was to "maximise ash sales thus minimising placement of fly ash and furnace ash into the dams".[8] At that time, closing the power stations and removing the ash was never seriously contemplated. In the twenty years since, ash sales have not increased substantially and the Lake has continued to be polluted with heavy metals from dumped ash, substantially adding the pollution loads in the Lake.

The ash dams of both power station are at or near their capacity. Origin Energy is applying for an expansion of the capacity of its ash dam and coal ash 'sales' remain less than 30 percent of the ash generated.

The power stations themselves are both near to the end of their designed lives. Origin Energy is committed to decommission Eraring in 2032. Before privatisation, Vales Point was expected to close in 2021. Delta Electricity has now indicated a desire to maintain Vales Point for 20 years beyond the Australian Energy Market Operator's expected closure date of 2029..[9]

> *Rehabilitation measures currently consist of merely capping the dams to prevent rainwater ingress. As such, rehabilitation will not prevent coal ash leachate from within the dumped ash migrating into groundwater and then into Lake Macquarie.*

The only ecologically sustainable rehabilitation option is to remove the ash from the ash dams and either dispose of it in sealed appropriately engineered containment facilities, or incentivise and appropriately regulate environmentally-safe commercial use of it.

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[5] Umwelt, 2014.
[6] ibid
[7] WBM, 1996.
[8] ibid
[9] Joanne McCarthy, 2018.

Eraring ash dump

Originally built in 1958 to accommodate coal ash generated by the Wangi power station, the unlined ash dam at Eraring was expanded to 250ha in 1976 to accommodate 20 million m^3 of ash expected to be generated by the newly built Eraring power station. The expansion raised the ash level from 10m above sea level to 25m above sea level with ash decant discharged into a return water reservoir used for further ash transport. However, runoff from the ash dam in excess of ash transport requirements discharges over a control weir into Crooked Creek, which flows into Whitehead's Lagoon and Myuna Bay.[10]

The 1975 Environmental Impact Statement (EIS) for Eraring admitted that the geology of the site was not ideal. Alluvial material under the ash dam overlies a number of coal seams[11] that have since been mined.

From 1981 to 1999, Eraring utilised a wet fly ash disposal system which allowed fly ash slurry to be pumped to the ash dam. In 1999, the power station installed a system to convey dry fly ash to silos which fed a system that mixed fly ash with water into a lean phase paste and used recycled ash dam decant to transport the ash to the dam. Leachates were reduced 30 percent and more material could be held in the dam.

In 2007, approval was granted for the first expansion of the Eraring ash dam and a goal introduced to reuse 80 percent of all produced ash (both fly ash and bottom ash) by 31 December 2015.[12] By 2015 the power station was only achieving 55 percent reuse.[13]

In 2018, Origin Energy again proposed to expand the Eraring ash dam as the generation of coal ash waste

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[10] ELCOM NSW, 1975.
[11] ELCOM NSW, 1980.
[12] Eraring Energy, 2007.
[13] ibid

exceeds storage capacity.[14] Origin Energy's preferred option is to raise the ash dam wall by 14 metres which would increase ash holding capacity by 5 million m^3 and extend its operational life to approximately 2024. No mention is made in the EIS of what disposal or use is proposed for the ash generated by the power station after that time. If the current modification is granted, Eraring will still have only five more years of ash storage capacity without significantly expanding coal ash reuse.

There are abandoned coal mine shafts just 20m below the ash dump. There is likely to be cracking between the surface and the coal mine shafts that would allow coal ash leachate to migrate into groundwater and into tributaries of Lake Macquarie.

There is also potential for subsidence in the form of either pillar collapse or roof failures leading to sink-hole formation on the ash dam and the western embankment.

The need for additional ash storage capacity is due to Origin Energy's failure to meet the target set by the Department of Planning for beneficial reuse of the coal ash generated by Eraring power station. The deadline for reaching the 80 percent reuse target has been pushed back to 2021, just two years away, but only 30 percent of the ash generated is currently reused.[15]

Unless Origin is forced to aggressively pursue an environmentally-safe coal ash reuse strategy, the target of 80 percent reuse is unlikely to be achieved. In this circumstance, if Eraring were to continue operating beyond 2024 to its nominal 2032 closure date, there would need to be another expansion of the ash dam and a further growing pile of hazardous waste thoughtlessly heaped on Lake Macquarie's shore.

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[14] Origin Energy, 2018.

[15] ibid

Vales Point ash dump

Originally built in 1962 with a capacity of 18.5 million m^3, the unlined Vales Point ash dam was expanded in 1982 to increase its capacity to 30 million m^3. At the time, this was thought sufficient volume to host ash from both Munmorah and Vales Point power stations until about 2000.[16] Water decanting from the ash (leachate) as well as runoff discharged into Lake Macquarie through Mannering Lagoon Creek into Mannering Lagoon.[17]

The 1982 augmentation included the construction of the unlined Wyee channel to divert the flow of Mannering Creek to Wyee Creek and the Wyee Dam. The Dam was built to ameliorate flooding of Wyee caused by the raising of the 13m ash dam earth wall to between 18.5 and 21.5m using natural clay fill and coal washery refuse.[18]

The 15 page EIS for the 1982 expansion, which pre-dates NSW pollution control law by 15 years, blithely concluded that the expansion of the Mannering Park ash dam would not introduce any significant environmental problems.[19]

In 1995 the ash dam capacity was again increased[20] and recycling of ash dam waters introduced.[21] Before this time, coal ash was mixed with lake water and pumped to the ash dam, which drained directly into Wyee Bay via Mannering Bay. Since 1995, water has been removed from the ash dam and recycled back to the power station, where it is mixed with cooling water before being discharged into Wyee Bay. The new procedures were expected to raise selenium concentrations within the ash dam but reduce the amount of suspended and dissolved trace metals reaching the lake.[22]

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[16] ELCOM NSW, 1980.
[17] ibid
[18] ibid
[19] ibid
[20] Marsh & Hausmann, 1996.
[21] Kirby et al, 2001.
[22] Peters, 1999.

Heavy metal contamination of Lake Macquarie

Heavy metals are major environmental pollutants and their toxicity is a problem of increasing significance for human health and the environment. Because of their high solubility in water, heavy metals can be absorbed by living organisms. Once they enter the food chain, concentrations of heavy metals can magnify as they accumulate in organisms and ecosystems. If the metals are ingested beyond recommended maximum concentration, they can cause serious health disorders and significant environmental harm.

While elevated concentrations of cadmium, lead, mercury, selenium, silver and zinc were found in sediment throughout the Lake system in 2004, concentrations of cadmium, lead and zinc had declined Lake-wide since 1990. The largest declines occurred at sites in the northern part of the Lake, in line with reduced loads of metals following the closure of the Pasminco lead and zinc smelter and the introduction of unleaded petrol.[23]

However, the results of extensive core dating of sediments in southern Lake Macquarie taken in 2010 clearly showed that power stations are the main contributors of metals, as most metal contamination there has occurred since the 1960s and the commissioning of the two remaining power stations.[24] Indeed, numerous studies have found power station ash dams have been the main contributor of the high metal concentrations in southern Lake Macquarie.

A study in 1976 found between 20-40 percent of sediments in Wyee Bay was composed of fly ash from the Vales Point ash dam.[25]

A 1990 study for the Electricity Commission of NSW[26] found increased selenium, arsenic and manganese in sediments attributable to the ash dam outfalls. The study found the ash dam outfall at Eraring Power Station had caused selenium contamination of the drains and all the surface sediment of Whiteheads Lagoon to a depth of 20 cm by as much as 25 times natural levels (52 ppm).[27]

Despite its status as an essential trace element, waterborne selenium concentrations of 2 ppb or greater are considered highly hazardous to the health and long-term survival of sensitive fish and aquatic birds.[28] The threat is due to dietary exposure and reproductive effects due to food-chain bioaccumulation, not direct waterborne toxicity. Some species will be relatively unaffected at the 2 ppb level, but sensitive species, many of which are the most important in terms of ecological integrity and public recreational value, can be seriously affected.

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[23] Roach, 2005.
[24] Schneider, 2014.
[25] Crawford et al, 1976.
[26] Pollution Research Pty. Ltd and Electricity Commission of New South Wales, 1990.
[27] ibid
[28] Lemly, 2002.

Under certain environmental conditions, waterborne selenium concentrations of 1 ppb or less have the potential to bioaccumulate to levels in the food chain that are toxic to predatory species.[29]About 5 mg selenium per day is considered toxic in the human diet, making it the third most toxic trace element after mercury and lead.[30]

Significant bioaccumulation can occur in aquatic food chains at water concentrations as low as 1 ppb.[31] International criteria indicated in 1990 that remediation should be carried out at sediment selenium concentrations of 1-3 ppm.

In 1990, fish and shellfish analysed from Whitehead's Lagoon and outside the lagoon had selenium levels significantly above the National Health and Medical Research Council (NHMRC)'s then-allowable level of 1 ppm. The maximum level found was 9 ppm. It was recommended that fish from Whitehead's Lagoon should not be eaten. However, the study found fish caught four kilometres away from Whitehead's Lagoon also had selenium levels of up to 2.5 ppm. [32]

The 1990 report identified three remediation options including doing nothing, covering the contaminated sediment with clean material, or removing the sediment and disposing of it into the ash dam. However, the report noted that in the absence of further input, surface levels would be expected to show a gradual decline due to mixing by biological processes and sediment Input. Further heavy metal inputs into Lake Macquarie from the power stations did not, however, stop.

A 1993 study[33] found mullet (*Mulgil cephalus*) and silverbiddy (*Gerres ovatus*) from a number of 'hot-spot' areas near the ash dams had average muscle tissue selenium concentrations of 10 and 8.2 ppm and a maximum concentration of 64 ppm (dry basis), twelve times the NHMRC limit.[34]

A 1996 Estuary Management Study of ambient water monitoring by the EPA found localised concentrations of selenium persisted in many streams and lagoons where discharges from the ash dams entered the Lake.[35]

A 1997 study for the Hunter Public Health Unit[36] found heavy metal contamination in Bream, Flathead, Whiting and Blue Swimmer Crabs. Flathead, Bream and Whiting are predators feeding not only on small fish but sediment dwelling crustaceans, worms and molluscs.[37] There was a significant relationship between the mean concentration of selenium in the muscle tissue of the commercial fish sampled and the concentration of selenium in sediment samples nearest to where the fish were captured, suggesting significant bioaccumulation.[38]

Bioaccumulation of metals can cause significant impacts on the reproductive success of fish populations and possibly the viability of their populations.[39] Metals accumulated by adult females can be transferred to the ovaries and thereby transferred to the offspring in the egg yolk. Larvae are then exposed to the metals as they use the egg yolk during development.

Such exposure can be directly toxic to eggs and larvae or cause physical deformities in larvae, which increase the rates of mortality.[40]

While a 1998 study[41] found selenium concentrations in mullet had decreased from 10 ppm in 1993 to 5.9 ppm in 1997, metal concentrations were still greater than that reported for fish sampled from relatively uncontaminated environments.[42] Copper and zinc concentrations had decreased in mullet muscle tissue, from 21 ppm in 1993 to 3.6 ppm in 1997, and zinc from

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[29] ibid
[30] Alloway & Ayres, 1993.
[31] Peterson & Nebeker, 1992.
[32] Pollution Research Pty. Ltd and Electricity Commission of New South Wales, 1990.
[33] Roberts, 1994.
[34] ibid
[35] WMB, 1996.
[36] Wlodarczkyk & Beath, 1997.
[37] ibid
[38] Wlodarczkyk & Beath, 1997.
[39] Kingsford, 1996.
[40] Kingsford, 1996; Lemly, 1993.
[41] Kirby et al, 2001.
[42] ibid

27 ppm in 1993 to 14 ppm in 1997. However, zinc concentrations measured in mullet muscle tissues in 1998 were higher at 26 ppm and zinc concentrations in mullet stomach, kidney and heart tissues and cadmium concentrations in mullet livers had significantly increased from 2.3 ppm in 1993 to 6 ppm in 1998.[43]

A 1999 study found sediments in Mannering Bay, near the Vales Point power station, contained an average of 12 times more selenium than background and a maximum selenium concentration 17.2 ppm or 69 time background levels.[44] Pore water concentrations in sediments from Mannering Bay were also high, up to 5 ppb compared to a background level of 0.2 ppb. Selenium concentrations in polychaete worms and molluscs of Mannering Bay were up to 58 times higher than background.[45]

At the polluted sites, the age profile indicated that major contamination had occurred since the mid-1960s, and therefore had come from the Vales Point ash dam.[46]

A 2005 study found two sites in southern Lake Macquarie where copper concentrations had increased in sediments compared to those taken at the same sites in 1987.[47] A 2008 study confirmed that cadmium, lead, selenium and zinc had significantly bioaccumulated in fish in Lake Macquarie.[48]

> *For most of the species analysed the highest selenium concentrations in muscle tissue and ovaries were found in fish caught near to the power station ash dams in Wyee Bay and Whitehead's Lagoon.*[49]

The highest muscle selenium concentration of 15.8 ppm and the highest ovary concentration of 13ppm was found in a southern log finned goby (*Favonigobious lateralis*) from Wyee Bay. Gobys are thought to be resident and live much of their adult life and spawn in the same area and thus had bio accumulated significantly more selenium than fish commonly consumed.[50]

Heavy metals in Lake Macquarie seafood

A 1996 NSW health study found mean selenium concentration of the muscle of Lake Macquarie finfish was 1.2 ppm (dry weight).[51] Dalton and Bird (2003) conducted a risk assessment for consumption of fish species from Lake Macquarie based on sampling and analysis conducted in 1996.

Documents obtained by the HCEC from the NSW Office of Environment and Heritage (OEH) under freedom of information law suggest these concentrations have not changed markedly over the intervening 23 years.[52]

In 2017, twelve species of fish and crustaceans were caught in four zones of Lake Macquarie as part of a NSW government study into PFAS and heavy metals in seafood. The four zones where the marine organisms were caught correspond with major metals sources include coal mines and the former Pasminco smelter at the north end (Zone 1), a lower northern area above Wangi spit (Zone 2), Eraring power stations in the south west (Zone 3) and Vales Point power

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[43] ibid
[44] Peters et al, 1999.
[45] Peters et al, 1999
[46] ibid
[47] Roach, 2005.
[48] Roach et al, 2008.
[49] ibid
[50] SPCC, 1981.
[51] Dalton & Bird, 2003.
[52] OEH EPS Branch, 2019.

station in the southern end (Zone 4) of the Lake.

Samples were analysed as 122 composite samples from 820 individual animals caught in the different zones. Finfish muscle fillets with skin on, shelled prawns with heads removed, and claw muscle from crabs were analysed by the National Measurement Institute (NMI) for total recoverable trace elements for:

- Arsenic (As)
- Cadmium (Cd)
- Chromium (Cr)
- Copper (Cu)
- Lead (Pb)
- Mercury (Hg)
- Nickel (Ni)
- Selenium (Se)
- Zinc (Zn)

The dietary assessment by OEH, based on the laboratory analyses of the seafood, warns that consumption of Mud Crab and Blue Swimmer Crab from Lake Macquarie can result in exposure to cadmium, and the consumption of finfish can result in exposure to selenium, particularly among children

Based on calculations for exposure to selenium, the risk assessment warns that in one week children should not consume more than:

- *225 grams of Yellowfin Bream,*
- *375 grams of Estuary Perch,*
- *450 grams of Silver Trevally,*
- *300 grams of Sand Whiting, or*
- *300 grams of Giant Mud Crab.*

In 2003, Dalton and Bird reported that the allowable intake of fish based on selenium concentrations was 1.35 kg/week for an adult, which is consistent with the result of this risk assessment.

However, the most recent NSW government study also warns that for cadmium, in one week, adults and children should not consume any Mud Crab, children should not consume any Blue Swimmer Crab, and no more than 150 grams of Eastern King Prawns, and adults should consume no more than 750 grams of Eastern King Prawns or 150 grams of Blue Swimmer Crab caught from Lake Macquarie.

The risk assessment also found mean zinc concentrations above the 90th percentile of the Generally Expected Level (GEL)[53] for Luderick, Sand Whiting, and Tailor; concentrations of selenium and zinc exceeded the adopted criteria in Giant Mud Crab, and concentrations of copper in Eastern King Prawn were elevated.

Figures 4, 5, and 6 below, set out the mean heavy metal concentrations of the species analysed by OEH.

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[53] Food Authority 2010.

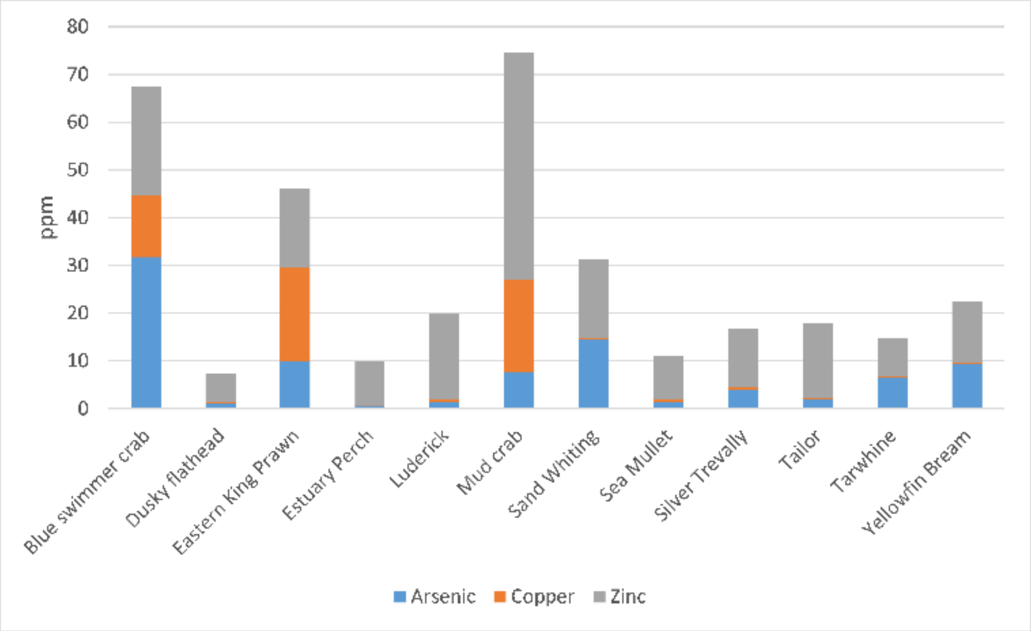

Figure 4: Average arsenic, copper, and zinc concentrations in Lake Macquarie seafood analysed by OEH

Blue Swimmer, Mud Crab, and Eastern King Prawns show the highest heavy metal loads with Mud Crabs, Blue Swimmer Crabs, Sand Whiting, Yellow Bream, Silver Trevally, and Tarwhine all showing significant concentrations of organic arsenic.

Four Blue Swimmer Crab samples from southern Lake Macquarie, two from the area affected by Vales Point and two from the area affected by Eraring power station, were found with organic arsenic concentration of between 50 and 70ppm.

The OEH risk assessment further analysed these species for inorganic arsenic, considered to be of concern for human health. No inorganic arsenic concentrations above the laboratory detection limit of 0.05ppm was found.

Concentrations of arsenic in open seawater are typically less than 0.002 ppm.[54] The risk associated with arsenic from seafood is based on the inorganic arsenic component with organic arsenic generally considered to be non-toxic. Concentrations of inorganic arsenic in marine fish are normally very low (<0.005 ppm), although shellfish and some seaweeds may contain higher levels.[55] While some seaweeds and bivalves have been identified as potential exposure risks for inorganic arsenic, data indicates that toxicity at high concentrations of some species of organic arsenic compounds in seafood may be occurring.[56]

Arsenobetaine (AB), the major organic arsenic species in most fish, is considered non-toxic and not metabolised. However, other more complex organic arsenic compounds in the form of arsenosugars and arsenolipids are also present at significant quantities in some types of seafood, and have been shown to be taken up and metabolised in humans.[57] Indeed, recent findings have shown that some forms of organic arsenic and their intermediate metabolites display cytotoxicity in cell cultures.[58]

The OEH study found copper concentrations in crustaceans caught from Lake Macquarie were up to 2.6 times the Generally Expected Levels (GEL), and up to three time in finfish.[59]

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[54] Ng JC, 2005.
[55] European Food Safety Authority (EFSA), 2009.
[56] Taylor et al, 2017.
[57] ibid
[58] Leffers et al, 2013; Meyer et al, 2014; Meyer et al, 2015.
[59] FSANZ, 2001.

Zinc concentrations in crustaceans were up to twice the GEL (25ppm) and finfish were up to five times the GEL (5ppm).[60] Indeed, 30 finfish samples were above the 90th percentile GEL (15ppm). All but one of the Mud Crab samples were above the 90th percentile GEL for crustaceans (40ppm). [61]

Mud Crabs and Luderick had the highest mean concentrations of lead, with a Mud Crab and a Luderick sample from the area affected by Eraring power station (Zone 3) showing the highest concentrations of 0.83 and 0.75ppm respectively. The Australian food safety standard set a maximum of 0.5 ppm for lead in fish, but does not include a maximum for crustaceans.[62] The European Union sets a 0.3ppm safe maximum lead concentration in fish at and 0.5ppm in crustaceans.[63]

Older organisms tend to contain the greatest body burdens of lead. In aquatic organisms, lead concentrations are usually highest in benthic organisms and algae, and lowest in uppertrophic level predators (e.g., carnivorous fish).[64]

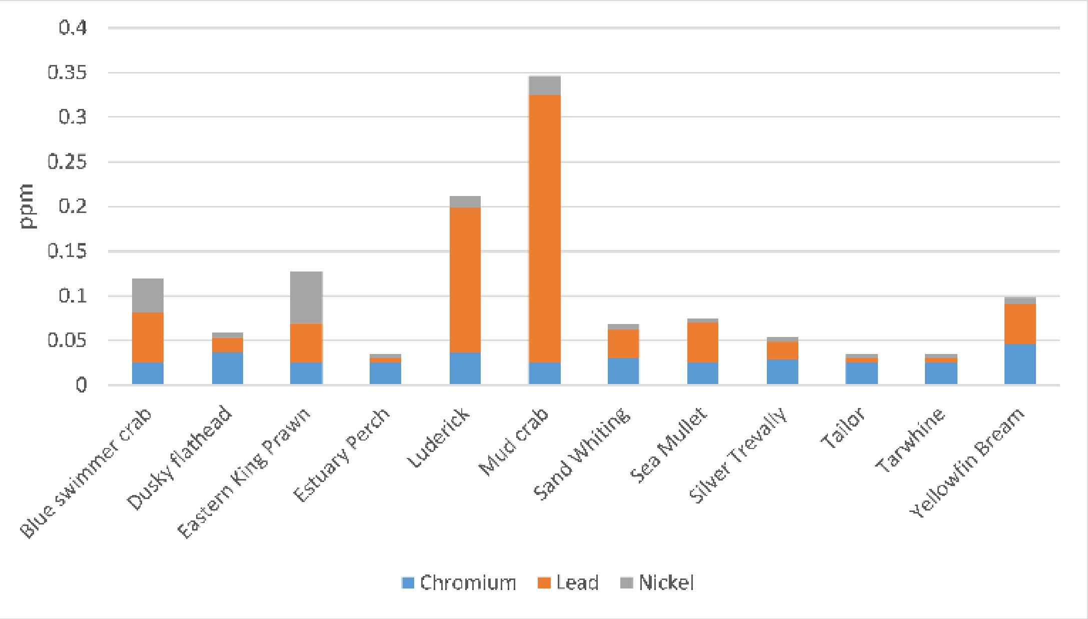

Figure 5: Average chromium, lead, and nickel concentrations in Lake Macquarie seafood analysed by OEH

The highest concentrations of nickel were found in Eastern King Prawns caught in Swansea Channel and Blue Swimmer Crabs from Zone 2 and 3 with between 0.05 and 0.08 ppm. The highest chromium concentrations were found in Yellowfin Bream and Luderick from Zone 3 with between 0.067 and 0.13 ppm.

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[60] FSANZ, 2001.
[61] ibid
[62] FSANZ 2018.
[63] European Commission Regulation (EC) No 1881/2006 .
[64] ATSDR, 2007.

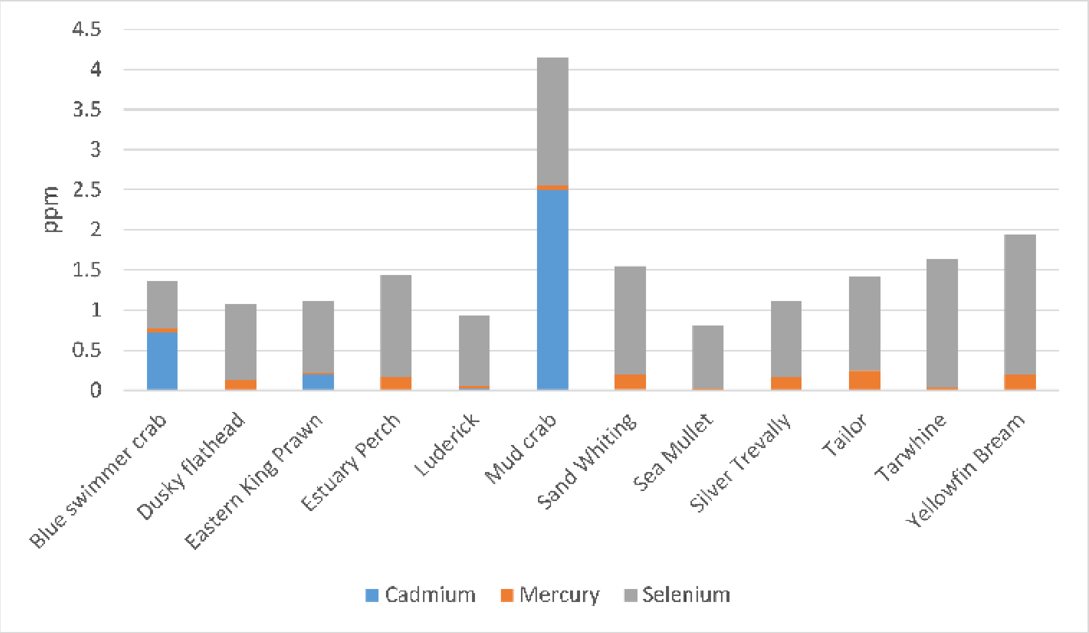

Figure 6: Average cadmium, mercury, and selenium concentrations in seafood analysed by OEH

Mud Crabs and Blue Swimmer Crabs had the highest averageconcentrations of cadmium. The Australian food standard does not set a maximum for cadmium in fish or crustaceans. The EU, however, sets a maximum of 0.05 to 1ppm for all fish other than ocean pelagic fish, and 0.5 for crustaceans. Twenty samples of Mud Crab and Blue Swimmer Crab exceeded the EU maximum limit for cadmium, caught from all four zones.

The highest cadmium concentrations were found in Mud Crabs from Zone 1 and Zone 3 with between 2.9 and 3.4ppm, roughly six times the EU maximum. No Mud Crabs were caught in Zones 2 and 4.

Selenium was high in all species sampled, with the highest found in 3 samples of Yellowfin Bream (2.4 to 3 ppm) from Zone 4 at the southern end of the Lake and a Sand whiting sample (2.8ppm) from the northern end (Zone 1). These selenium levels are comparable to those detected in finfish sampled in 1990.[65]

Elevated mercury was also found in all the predatory species reflecting its bioaccumulation in these higher trophic species. The highest concentrations of 0.45ppm mercury was found in a Yellowfin Bream caught in Zone 3. The Australian food standard sets a maximum of 0.5ppm mercury in fish, other than large ocean species.

The OEH risk assessment only presented an analysis of metal concentrations in seafood in different zones for selenium and cadmium, but HCEC has analysed the data to show the geographic distribution of results for all species and metals.

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[65] Pollution Research Pty. Ltd and Electricity Commission of New South Wales, 1990.

	Lake area	As	Cu	Z	Cd	Cr	Pb	Hg	Ni	Se
Silver Trevally	N	3.83	0.58	12.50	0.01	0.03	0.03	0.19	0.01	0.86
	S	3.88	0.79	11.95	0.01	0.03	0.01	0.14	0.01	1.05
Sea Mullet	N	1.68	0.50	9.50	0.01	0.03	0.06	0.01	0.01	0.73
	S	1.24	0.36	9.10	0.01	0.03	0.03	0.01	0.01	0.85
Sand Whiting	N	9.45	0.26	16.19	0.01	0.03	0.05	0.23	0.01	1.39
	S	13.90	0.25	16.25	0.01	0.04	0.02	0.15	0.01	1.38
Luderick	N	1.51	0.91	18.00	0.06	0.03	0.24	0.04	0.01	0.90
	S	1.49	0.26	18.60	0.01	0.04	0.07	0.02	0.01	1.03
Mud crab	N	7.10	21.75	51.50	2.83	0.03	0.44	0.07	0.02	1.53
	S	8.90	14.50	39.50	1.86	0.03	0.01	0.03	0.02	1.70
Dusky flathead	N	1.31	0.14	6.35	0.01	0.05	0.02	0.15	0.01	0.88
	S	0.85	0.10	6.05	0.01	0.03	0.01	w	0.01	1.05
Yellowfin Bream	N	9.28	0.24	14.38	0.01	0.04	0.06	0.24	0.01	1.58
	S	9.35	0.20	11.68	0.01	0.05	0.03	0.15	0.01	1.91
Blue Swimmer Crab	N	34.88	14.13	23.25	0.77	0.03	0.10	0.08	0.04	0.56
	S	28.60	12.01	21.88	0.68	0.03	0.02	0.03	0.03	0.63

Table 4: Mean concentrations of heavy metals in seafood samples taken from the northern and southern areas of Lake Macquarie

A rough analysis shows that, with the exception of selenium, fish caught in the northern area of the Lake generally show higher concentrations of heavy metals, particularly lead and mercury. Selenium in all species is higher in samples caught in the southern areas, as is arsenic in Mud Crabs, Sand Whiting, and Yellowfin Bream; copper in Silver Trevally, and zinc in Sea Mullet.

A 2005, NSW Fisheries undertook a study into recreational fishing in Lake Macquarie and estimated that between 472,174 and 615,148 individual fish, crabs and cephalopods were caught in a year totaling 178 and 224 tonnes.[66] The heavy metal concentrations found in seafood in Lake Macquarie is, therefore, a public health issue.

Heavy metal contamination in Lake Macquarie is often described as a legacy of past environmental contamination and the on-going high metal concentrations in fish as a result of burrowing and disturbance of sediment by benthic organisms. While heavy metal discharge into Lake Macquarie from the two power station ash dams has decreased from the days when environmental contamination was just another cost of doing business, significant loads of heavy metals are still discharged in the Lake Macquarie from the two power stations, so it is not accurate to describe the problem solely in terms of past practices. Metal concentrations can only be put right when pollution of Lake Macquarie ceases.

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[66] Steffe et al, 2005.

Water and sediment quality guidelines and objectives

The NSW Water Quality Objectives[67] are the agreed environmental values and long-term goals for NSW surface waters. The Marine Water Quality Objectives for NSW Ocean Waters of the Hunter and Central Coast,[68] which includes Lake Macquarie, are to maintain or improve the ecological condition of marine waters. These objectives use the ANZECC (2000) trigger values to describe the condition and quality of water in the Lake.

The ANZECC Guidelines (2000) set out values to assess if a water resource is fit for recreation, food production, and aquatic ecosystem health. If the 'trigger values' are reached, it may not be safe for that use and management action can be triggered to either more accurately determine whether the water is safe for that use, or to remedy the problem. The guidelines form the central technical reference of the National Water Quality Management Strategy[69], which the federal and all state and territory governments have adopted for managing water quality.

The ANZECC guidelines identify different levels of protection for different water bodies and specify levels of protection corresponding to high conservation value, slightly to moderately disturbed, or highly disturbed ecosystems. The level of protection applied to most waterways in NSW is that suggested for 'slightly to moderately disturbed' ecosystems.[70] While the ANZECC Guidelines suggest a preference for local biological effects data to derive guidelines for ecosystem protection, in the absence of such data, 95% protection levels is the default for slightly to moderately disturbed, with 99% recommended for chemicals that bioaccumulate or for which 95% provides inadequate protection for key test species.

For marine waters, the ANZECC Guidelines are conservative and do not incorporate scientific research on ecotoxicology that has not been confirmed multiple times. ANZECC therefore omits trigger values for a number of metals based on 'Insufficient Data' (ID). Of the 30 metals and metalloids provided with trigger values for freshwater, only 12 have values specified for marine waters. However, the ANZECC Guidelines provide information on 27 inorganic toxicants that have an impact on aquaculture. Of these, the ones identified in the Guidelines as of greatest concern to fisheries include aluminium, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel and zinc.

HCEC assessment of Lake Macquarie water and sediment

To determine whether coal ash contamination from the Lake Macquarie power stations was still occurring, the HCEC took 17 water and sediment samples from southern Lake Macquarie between July and December 2018 and had them analysed by EnviroLab, Sydney (See appendix 1).

The results show concentrations of a number of heavy metals in excess of ANZECC (2000) trigger values for 'slightly to moderately disturbed' ecosystems (95% species protection) applied in NSW (See Tables 5 and 6).

Some of these sample sites could be defined as "effluent discharge" and the waters managed at a higher pollution concentration in the 'mixing zone' than the broader body of water into which the effluent is received. ANZECC (2000b)[71] defines mixing zones as 'explicit area around an effluent

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[67] Available from: https://www.environment.nsw.gov.au/ieo/
[68] DEC, 2005.
[69] Department of Agriculture and Water Resources, 2018.
[70] DEC, 2006.
[71] ANZECC, 2000b.

discharge where the Management Goals of the ambient waters do not need to be achieved and hence the designated Environmental Values (EVs) may not be protected". However, the ANZECC Guidelines states that "The use of mixing zones is not appropriate for managing the discharge of nutrients, bio-accumulatory or particulate substances," which would include effluent from the ash dams, due to the bio-accumulatory nature of the metals it contains.

While the concentrations of metals in water sampled by HCEC are likely considered by the NSW EPA and power station operators as manageable, the volumes of the water discharged are very high. With Eraring licenced to discharge 11,000ML a day from its cooling water outfall, even the maximum 2ppb selenium limit represents almost 22 kilograms discharged into the Lake a day. The 5 ppb selenium concentration found by HCEC in Vales Point cooling water outfall, licenced to discharge 6,500ML a day, and with no limit set for selenium concentrations, represents almost 33 kg selenium a day.

These are very high loads into a Lake with a one percent tidal exchange (the area around Vales Point power station only flushed by tides every 500 days). Very high loads indeed, when one considers that just 5mg of selenium is considered toxic to humans and water with just 2ppb selenium harmful to sensitive aquatic life.

HCEC staff taking water sample.

Vales Point water and sediment samples

The waters of the Lake closest to the Vales Point Power station cooling water outflow and ash dam overflow, Mannering Bay and southern Wyee Bay, were found to be contaminated with copper, nickel and zinc at concentrations that exceeded ANZECC (2000) trigger values for marine waters.

Six of the seven water samples taken near to Vales Point power station were found to contain concentrations of copper above the 95% protection level (1.3ppb), with 2 samples, taken below the ash dam wall in Mannering Creek after heavy rain (samples 9 and 11), found to have copper concentrations above the 90% species protection value of 3ppb. The highest copper concentration of 6ppb was found in the sample taken from where the cooling water outflow enters the Lake in south Wyee Bay (sample 3).

Selenium is not listed in the trigger values of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, however, the highest selenium concentration of 5ppb was also found in sample 3 from cooling water outfall.

Figure 7: Water samples sites near to Vales Point Power Station

	Vales Point power station							**ANZECC Guidelines**						**NHRM**
Sample #	**1**	**11**	**3**	**7**	**8**	**9**	**10**	**Marine water trigger values**				**Saltwater aquaculture protection guidelines**	**Recreational purposes water guidelines**	**Drinking water guidelines**
Site	**Mannering Bay**	**Mannering creek**	**Cooling outflow**	**Cooling outflow**	**Ash dam drainage**	**Ash dam wall outflow**	**Ash dam sepage pump**	**99%**	**95%**	**90%**	**80%**			
pH	8.01	6.25	8.4	8.42	3.59	6.75	7.3							
Date	22-Sep	10-Oct	15-Sep	27-Sep	10-Oct	10-Oct	10-Oct							
Temp C	15.05	18.9	26	25.8	18.9	18	18							
EC (uS)	>4000	>4000	>4000	>4000	>4000	>4000	>4000							
Aluminium-Total (ppb)	**350**	**3300**	**290**	**240**	**35000**	**1100**	**130**					**10**	*200*	
Arsenic Total (ppb)	2	4	4	2	24		3					**30**	*50*	7
Boron Total (ppb)	*5100*	*1300*	*5200*	*5100*	100	*1300*	*6900*						*1000*	400
Cadmium-Total (ppb)	0.3		**0.6**	0.2	0.2		0.2	0.7	5.5	14	36	**0.5**	*5*	2
Chromium-Total (ppb)	2		6	1				7.7	27.4	48.6	90.6	**20**	*50*	50
Copper Total (ppb)	3	4	6	2	2	4		0.3	1.3	3	8	**5**	*1000*	200
Iron-Total (ppb)	***460***	***940***	***400***	***330***	***1000***	***920***	***1100***					**10**	*300*	
Lead-Total (ppb)		***2***	***2***		2			2.2	4.4	6.6	12	**1**	*50*	10
Manganese Total (ppb)	**13**	***760***	**29**	***22***	***4800***	***260***	***120***					**10**	*100*	500
Nickel Total (ppb)		4	3	1	30			7	70	200	560	**100**	*100*	20
Selenium Total (ppb)	2		5	1			2					**10**	*10*	10
Thallium (ppb)			2											
Vanadium (ppb)		4		2		2	11	50	100	160	280	**100**		
Zinc-Total (ppb)	9	20	9	10	98	10	2	7	15	23	43	**5**	*5000*	

Table 5: Laboratory results and water quality guidelines for water samples taken near to Vales Point power station (ANZECC (2000) suggests the 99% protection trigger values for cadmium, mercury and nickel should apply to "slightly modified ecosystems")

Six of the seven water samples taken near to Vales Point power station were found to contain concentrations of zinc in excess of ANZECC trigger values. Two samples, taken below the ash dam (samples 8 and 20) were found to contain zinc concentrations above the 95% species protection level set in NSW. The highest concentration of zinc (98ppb) was found in a sample taken from a small stream entering Mannering Creek (sample 8), which was 6.5 times the NSW recommended level for zinc (15ppb) in marine waters (95% protection trigger value).

Sample 8 also contained concentrations of nickel above the ANZECC (2000) suggested trigger value for slightly to moderately disturbed ecosystems. The stream had an electrical conductivity above 4000 µS/cm and a pH of 3.59; highly acidic, saline water, indicating that a high proportion of the stream's flow was coal ash leachate.

All the water samples taken near to the Vales Point power station were found to contain concentrations of aluminum, iron, and manganese above ANZECC aquaculture protection guidelines of 10ppb, and therefore likely be harmful to edible fish, molluscs and crustaceans. The highest concentrations were found in sample 8 with an aluminium concentration of 35,000ppb, an iron concentration of 1,000ppb, and a manganese concentration of 4,800ppb.

Sample 3, taken at the cooling water outflow after heavy rain, was also found to contain concentrations of cadmium, lead, and zinc above those recommended by the ANZECC saltwater aquaculture protection guidelines.

All water samples were found to also exceed the concentrations recommended for aluminum, iron, and/or manganese under the ANZECC water quality guidelines for recreational purposes.

Further, Samples 8 and 11 exceeded the NHMRC drinking water guidelines for manganese and sample 8 contained a concentration of arsenic of 24ppb, which is 3 times the 7ppb maximum recommended by the NHMRC drinking water guidelines.

Eraring water and sediment samples

Five samples were taken near to the Eraring power station. One from the cooling water outflow (5), one from Muddy Lake, north of Dora Creek (6), and three samples from Crooked Creek which flows from the ash dam decant return water lagoon, into Whitehead's Lagoon (12, 14, and 16).

All the samples taken were found to be contaminated with copper, lead, nickel and/or zinc at concentrations that exceeded ANZECC (2000) trigger values for marine waters.

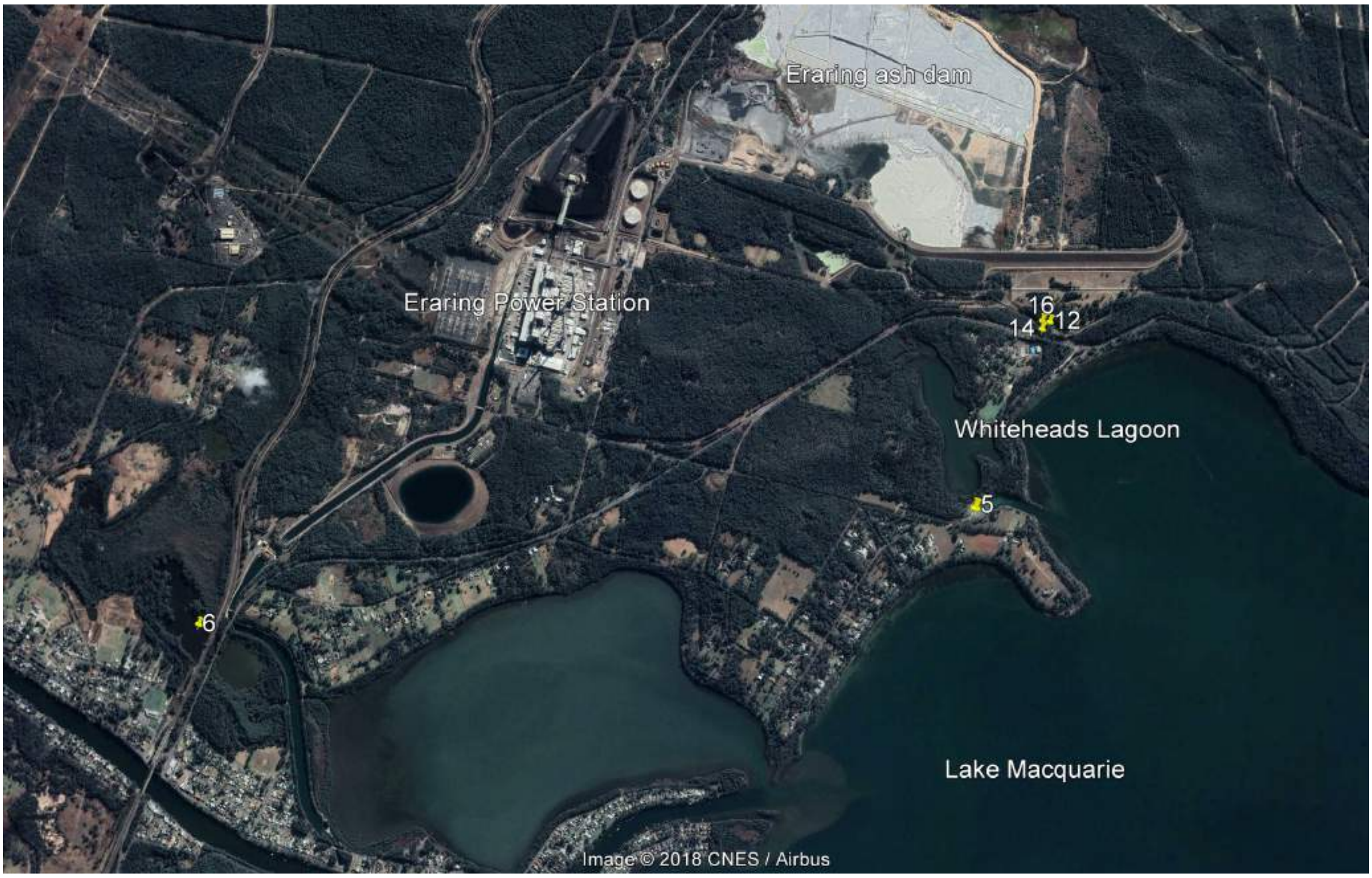

Figure 8: Water sample sites near to Erariung power station

Four of the five water samples taken near to Eraring power station were found to contain concentrations of copper above the 95% protection level (1.3ppb), with sample 14, taken after heavy rain below the ash dam wall in Crooked Creek, found to have copper concentrations above the 90% species protection value of 3ppb.

	Eraring Power Station					**ANZECC Guildeines**						**NHRM**
Sample #	**5**	**6**	**12**	**14**	**16**	**Marine water trigger values**				**Saltwater aquaculture protection guidelines**	**Recreational purposes water guidelines**	**Drinking water guidelines**
Site	**Cooling outflow**	**Muddy Lake**	**Crooked Creek**	**Crooked Creek**	**Crooked Creek**	**99%**	**95%**	**90%**	**80%**			
pH	8.3	8.8	5.55	5.89	4.48							
Date	27-Sep	27-Sep	28-Oct	28-Oct	28-Oct							
Temp ©	27.4	16	16.2	16.2	16.5							
EC (uS)	<4000	>4000	3450	3300	>4000							
Aluminium-Total (ppb)	**40**	10	***510***	***1000***	***4200***					**10**	*200*	
Arsenic Total (ppb)	1	1	1	3	4					**30**	*50*	7
Boron Total (ppb)	*5100*	200	*740*	*980*	*640*						*1000*	400
Cadmium Total (ppb)	0.2					0.7	5.5	14	36	**0.5**	*5*	2
Chromium Total (ppb)						7.7	27.4	48.6	90.6	**20**	*50*	50
Copper Total (ppb)	3		3	4	2	0.3	1.3	3	8	**5**	*1000*	200
Iron-Total (ppb)	***66***	***400***	***4400***	***12000***	***9600***					**10**	*300*	
Lead-Total (ppb)			3		2	2.2	4.4	6.6	12	**1**	*50*	10
Manganese-Total (ppb)		**86**	***940***	***960***	***2200***					**10**	*100*	500
Nickel-Total (ppb)		12	6	3	11	7	70	200	560	**100**	*100*	20
Selenium Total (ppb)					1					**10**	*10*	10
Thallium (ppb)												
Vanadium (ppb)	1			2	5	50	100	160	280	**100**		
Zinc-Total (ppb)	**7**	5	29	10	40	7	15	23	43	**5**	*5000*	

Table 6: Laboratory results and water quality guidelines for water samples taken near to Eraring power station concentrations of nickel above the ANZECC recommended trigger values for 'slightly to moderately disturbed ecosystems'.

Four of the five water samples taken near to Eraring power station were also found to contain concentrations of zinc in excess of ANZECC trigger values. Two samples from Crooked Creek (Samples 12 and 16), were found to contain zinc concentrations above the 90% species protection level. Sample 16 had an electrical conductivity above 4000 µS/cm and a pH of 4.48, which indicates highly acidic, saline water and probably a high proportion of the flow was ash dam leachate.

All the water samples taken near to the Eraring power station, with the exception of the cooling water outflow, were found to contain concentrations of aluminum, iron and/or manganese above ANZECC aquaculture protection guidelines, and therefore likely be harmful to edible fish, molluscs and crustaceans. The highest aluminium and manganese concentration of 4,200ppb and 2,200ppb respectively was found in Sample 16, with the highest iron concentration of 12,000ppb found in Sample 14.

All the water samples also exceeded the ANZECC water quality guidelines for recreational purposes for aluminum and iron, and all but sample 5, from the cooling water outflow, exceeded the ANZECC recreational water guideline for manganese. Samples 12, 14, and 16, from Crooked Creek, also exceeded the NHMRC drinking water guidelines for manganese.

The Mandalong coal mine operated by Centennial Coal discharges mine affected water into Muddy Lake, which would likely contribute to the concentrations of metals found in sample 16.

HCEC also took three sediment samples from the same locations in Crooked Creek. The laboratory results from Envirolab are set out in Table 7 and they reveal significantly elevated concentrations of a number of heavy metals.

Sample 17, which was taken from the same site as water Sample 16, contained concentrations of arsenic, chromium, nickel, and zinc that exceed the ANZECC (2000) sediment quality guidelines trigger values. The concentrations of zinc (240ppm) was found in excess of the trigger value (200ppm) and the concentrations of arsenic (160ppm) was eight times the trigger value and exceeded the high Interim Sediment Quality Guideline (ISQG) levels.

The ANZECC Guidelines do not set a trigger value for selenium in sediment. However, selenium concentrations found in the sediment of sample 17 (110ppm) was 55 times the maximum for the protection of sensitive aquatic species recomended by Lemly (2002).

Sample # (ppm)	**13**	**15**	**17**	**ANZECC (2000)**	
Date	28-Oct	28-Oct	28-Oct	ISQG - Low (trigger value)	ISQG - High
Silver	<1	<1	<1		
Aluminium-Total	2900	7300	65000		
Arsenic-Total	<4	7	160	20	70
Boron-Total	<3	10	77		
Cadmium-Total	<0.04	<0,04	0.9	1.5	10
Chromium-Total	4	7	87	80	370
Copper-Total	13	13	38	65	270
Iron-Total	7500	6800	100000		
Lead-Total	36	16	29	50	220
Mercury-Total	<0.1	<0.1	<0.1	0.15	1
Manganese-Total	100	56	720		
Nickel-Total	4	6	42	21	52
Selenium-Total	<2	6	110		
Thorium-Total					
Thallium -Total	<2	<2	<2		
Vanadium -Total	10	33	580		
Zinc-Total	110	18	240	200	410

Table 7: Laboratory results and interim sediment quality guidelines (ISQG) for sediment samples taken near to Eraring power station.

These heavy metal concentrations in sediments in Crooked Creek suggest a history of highly contaminated discharge from the ash dam. Discharges continue to this day when heavy rain forces Origin Energy to release water from the emergency ash dam overflow.

Environmental Protection Licences

Pollution in NSW is regulated under the *Protection of the Environment Operations Act* (1997) (*POEO Act*), the objects of which are to:

- to protect, restore and enhance the quality of the environment in New South Wales, having regard to the need to maintain ecologically sustainable development,
- to provide increased opportunities for public involvement and participation in environment protection,
- to ensure that the community has access to relevant and meaningful information about pollution,
- to reduce risks to human health and prevent the degradation of the environment by the use of mechanisms that promote the following:
- pollution prevention and cleaner production,
- the reduction to harmless levels of the discharge of substances likely to cause harm to the environment,
- the elimination of harmful wastes,
- the reduction in the use of materials and the re-use, recovery or recycling of materials,
- the making of progressive environmental improvements, including the reduction of pollution at source,
- the monitoring and reporting of environmental quality on a regular basis,
- to rationalise, simplify and strengthen the regulatory framework for environment protection,
- to improve the efficiency of administration of the environment protection legislation,
- to assist in the achievement of the objectives of the *Waste Avoidance and Resource Recovery Act 2001* .

HCEC believes the NSW Environment Protection Authority (EPA) has failed to fully meet these objects in relation to the contamination of Lake Macquarie by Eraring and Vales Point power stations, and a number of amendments to the Act and Regulations are required to enable the EPA to properly carry out its duty to protect the people and environment of NSW from pollution.

In NSW it is a Tier I offence under the POEO Act for any person to pollute water with penalties up to $1,000,000 or 7 years' imprisonment. If committed by a corporation, the offence attracts a maximum penalty of $5,000,000 with special executive liability for directors or managers. It is a defence against prosecution if the water pollution was regulated by an environment protection licence (EPL) and the conditions of that licence are not contravened.

In addition to the specific requirements of an EPL, there are general obligations for licensees set out in the *POEO Act* and Regulations, including to control the pollution of waters and to report incidents causing or threatening material environmental harm.

HCEC believes these obligations have not been fully met by the power station operators and a number of amendments and additions to their EPLs are also required to ensure water pollution is controlled and does not cause further material harm to the environment.

Specifically, the EPLs are not preventing pollution from the Vales Point and Eraring ash dams nor are they protecting Lake Macquarie from increasing loads of heavy metals.

Vales Point EPL 761

The Vales Point EPL specifies 13 Licence Monitoring Points (LMP), the monitoring data for which are on the Operator's website.[72] These monitoring points identify a number of pollutants discharged into Lake Macquarie and leached into groundwater, which will also find its way to Lake Macquarie. The monitoring points are depicted in Figure 9 and include:

1. Cooling water outlet at Wyee Bay (LMP 1 - VPOC).

2. Discharge from the ash water recycle system to the cooling water outlet canal (LMP2 – VPADB)

3. Pump at Retention Pond 2 that discharges treated effluent and stormwater runoff from the north-eastern corner of the ash dam to the Ash Dam Effluent Application Area, LMP 3 -Pond 2).

4. Seepage from ash dam rehabilitated area (LMP 4 –VPADS).

5. Ambient water quality monitoring point located in Crangan Bay, marked and shown as "LMB5

6. Ambient water quality monitoring point in Wyee Bay, marked and shown as "LMB7"

7. Ambient water quality monitoring point located in Chain Valley Bay, marked and shown as "LMB15" Overboarding of Ash Dam (LMP 18 – VPADD)

8. Groundwater bore (LMP 19 - VPGM/D3)

9. Groundwater bore (LMP 20 -VPGM/D5)

10. Groundwater bore (LMP 21 - VPGM/D6)

11. Groundwater bore (LMP 22 -VPGM/D8)

12. Groundwater bore (LMP 23 -VPGM/D10)

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[72] Delta Electricity, 2018.

Figure 9: Vales Point Power Striation EPL Monitoring Points. Groundwater monitoring points are in pink and surface water monitoring point in yellow

The only monitored licensed discharge points are from LMP 1 (Cooling water outlet at Wyee Bay) and LMP 2 (Discharge from the ash water recycle system to the cooling water outlet canal). However, monitoring data from LMP 1 is not available from the operator's website.

Recommendation 6: The EPA ensure that all water monitoring data undertaken by Sunset Industries International for its Vales Point operation be uploaded to its website as soon as practicable after the monitoring is undertaken.

Recommendation 7: Additional monthly monitoring for aluminium, arsenic (iii, and v), cadmium, chromium (iii, and vi), copper, iron, lead, manganese, nickel, selenium, vanadium, and zinc, be added to the Vales Point power station EPL to be undertaken at Mannering Bay, Wyee Creek, and Wyee Bay.

Recommendation 8: All surface water EPL monitoring sites include monthly monitoring for aluminium, arsenic (iii, and v), cadmium, chromium (iii, and vi), copper, iron, lead, manganese, nickel, selenium, vanadium, and zinc with results published on the operator's website.

Recommendation 9: Appropriate concentration limits be set for heavy metals and other environmentally harmful parameters for all discharge from the ash dam including overflow releases into Mannering Bay and Wyee Creek.

Other potential pollutants licenced to be disposed of from the Vales Point ash dam under EPL 761 include detergents, oil sheens, chemical spill residues, chemical cleaning solutions, oil and chemically impacted soil, treatment plant discharges, chlorine plant precipitates and water from coal mine dewatering. But not asbestos.

Eraring EPL 1429

The Eraring Licence monitoring points are far more extensive than those for Vales Point and include a number of ambient water quality sites in Lake Macquarie. The monitoring points are set out in Figure 10 and include:

- EPA 1 - Discharge of effluent, water quality and volume monitoring.
- EPA 2 - Discharge of effluent, water quality and volume monitoring. The emergency ash dam outlet at the culvert under Main Road 217.
- EPA 3 - 3 Discharge from the Final Pond in Pasveer Sewage System to the utilisation area adjacent to sewage treatment works.
- EPA 4 - Ambnient water quality monitoring of Lake Macquaire midway between cooling water inlet and Hungary Point.
- EPA 5 -Ambient water quality monitoring of Lake Macquaire located off the old Wangi Power Station inlet point in Myuna Bay.
- EPL 6- Ambient water quality monitoring of Lake Macquaire located at the Eraring/ Vales Point mixing zone off Fishery Point.
- EPL 7 - Ambient water quality monitoring of the northern waters of Lake Macquarie east of Lake Macquarie Yacht Club.
- EPA 8 - Ambient water quality monitoring of the inlet canal of the cooling water intake from Lake Macquarie.EPA 10 - Ambient water quality monitoring of ash dam discharge after the Siphon Pond Weir.
- EPA 17-Discharge of effluent and water quality monitoring of emergency discharge from the Toe Drain Collection Pond.
- EPA 20 - Discharge and water quality monitoring of water from Ash Dam discharge pipe to the Outlet Canal (Tunnel Spillway).
- EPA 21 – Groundwater monitoring bore.
- EPA 22 – Groundwater monitoring bore.
- EPA 23 – Groundwater monitoring bore.
- EPA 24 – Groundwater monitoring bore.

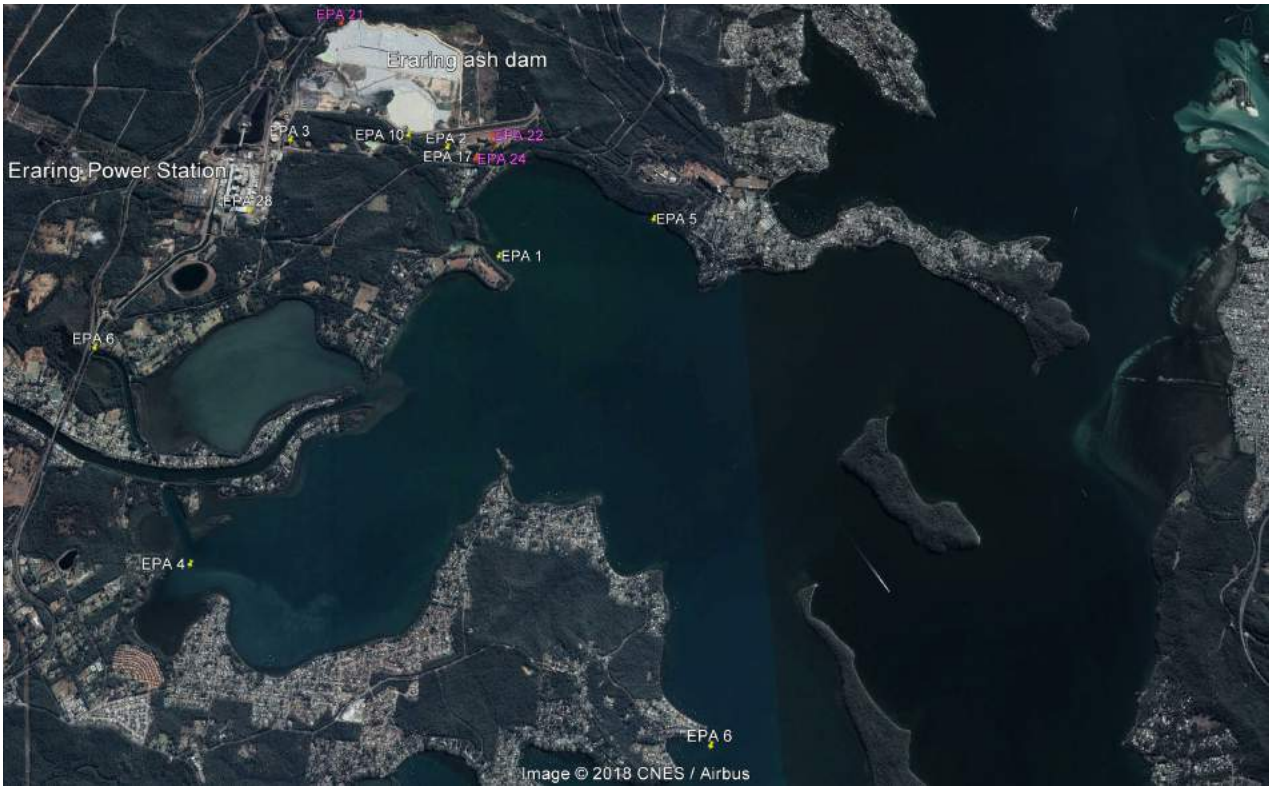

Figure 10: All Eraring power station EPL water monitoring points

Figure 11: Earring power station EPL surface water and groundwater monitoring points for which monthly data is made public

The monitoring points for which monthly and quarterly data are published on Origin Energy's website include surface water monitoring points 1, 6, 10, and 17, and groundwater monitoring points 21, 22,23, and 24 (in purple on Figure 11).

Origin Energy's Eraring EPL only sets discharge concentration limits for copper (5 ppb), iron (300ppb), selenium (2ppb), temperature, and pH, at the cooling water outlet (EPL 1). The siphon weir below the decant pond (EPA 10) is monitored for some heavy metals, but no limits are set. The overflow from the ash dam into Crooked Creek, which drains into Lake Macquarie and where high heavy metals were found by HCEC in water and sediment samples is not monitored for heavy metals. EPL 2 at the top of Crooked Creek pH and TSS are monitored, for which limits are set. However, this monitoring is not made public on Origin Energy's website.

Recommendation 10: Additional monthly monitoring for aluminium, arsenic (iii, and v), cadmium, chromium (iii, and vi), copper, iron, lead, manganese, nickel, selenium, vanadium, and zinc, be added to the Eraring power station EPL to be undertaken at Muddy Lake, Crooked Creek.

Recommendation 11: All surface water EPL sites include monthly monitoring of aluminium, arsenic (iii, and v), cadmium, chromium (iii, and vi), copper, iron, lead, manganese, nickel, selenium, vanadium, and zinc and these made public on the operator's website.

Recommendation 12: Appropriate limits be set for heavy metals and other environmentally harmful parameters for the discharge of ash dam overflow releases into Crooked Creek.

National Pollution Inventory and Load Based Licences

Schedule 1 of the *POEO Act* includes all the substances for which load based licence fees are charged to polluters that release or emit "assessable pollutants" listed in the *Protection of the Environment Operations (General) Regulation 2009*. The Regulation establishes the method of calculating licence fees, including load based licence fees, and environmental protection notice fees.

While the Lake's power station operators collectively report ten heavy metals discharged into Lake Macquarie to the National Pollution Inventory (NPI), the only assessable water pollutants listed in Schedule 1 of the *Protection of the Environment Operations (General) Regulation 2009* under the "generation of electrical power from coal" are salt, selenium and suspended solids.

Vales Point NPI Substances	Water (kg)	Total (kg)
Arsenic and compounds	36	39
Chromium (111) compounds	44	121
Copper and compounds	9.6	28
Lead and compounds	4.4	29
Nickel and compounds	17	117
Zinc and compounds	55	187

Eraring NPI Substances	Water (kg)	Total (kg)
Arsenic and compounds	29	43
Cadmium and compounds	0.07	11
Chromium (111) compounds	17	144
Cobalt and compounds	0.25	30
Copper and compounds	3	27
Lead and compounds	0.2	151
Manganese	54	658
Mercury	0.0001	1.3
Nickel and compounds	3	229
Zinc and compounds	6	229

Tables 8 and 9: Vales Point and Eraring power stations National Pollution Inventory calculations for 2017/18

The *Load Calculation Protocol (June 2009)* is used by holders of EPLs when calculating assessable pollutant loads.[73] The assessable load, and the licence fees calculated, for each pollutant is the lowest of the actual, weighted or agreed load and not necessarily the amount of pollutants discharged.

For example, Delta Electricity paid just $21,930 in 2017/18 for its Vales Point power station to discharge 328kg of selenium into the Lake and Origin Energy paid just $1,590 in 2017/18 for Eraring to discharge 32 kg of selenium into the Lake.

The 360kg combined volume of selenium pollution to water paid for by the power stations in 2017/18 differs from estimates of selenium pollution provided elsewhere for the two power stations. A 1995 study reported EPA estimated selenium inputs to the Lake from both power stations at that time was approximately 400kg/year.[74] While the Lake Macquarie power station operators suggested later that selenium pollution was reduced to less than 240kg/year for both power station after new ash handling procedures were introduced,[75] the input of selenium from the ash dams into Lake Macquarie from the two operating power stations was estimated in 2015 to be 1,135 kg a year.[76]

Recommendation 13: Load based license calculations be reviewed and amended to better reflect the mass balance and leachate calculations of all water pollutants discharged, and additional water pollutants including arsenic, cadmium, chromium, copper, lead, and zinc be added to Water Pollutants in Schedule 1 of the Protection of the Environment Operations (General) Regulation 2009 under the heading "generation of electrical power from coal"

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[73] EPA, 2009.
[74] AWACS, 1995.
[75] WMB, 1996.
[76] Ellwood et al, 2015.

Selenium pollution

The Vales Point monitoring data reveals a number of heavy metals being discharged into Lake Macquarie and leaching into groundwater and for some, particularly selenium, the concentrations are increasing.

Selenium discharge from the Vales Point ash dam to Lake Macquarie into the Vales Point cooling water canal (LMP 2) has been increasing from about 20ppb in 2013 to 30 to 60 ppb in 2018 (See Figure 12)

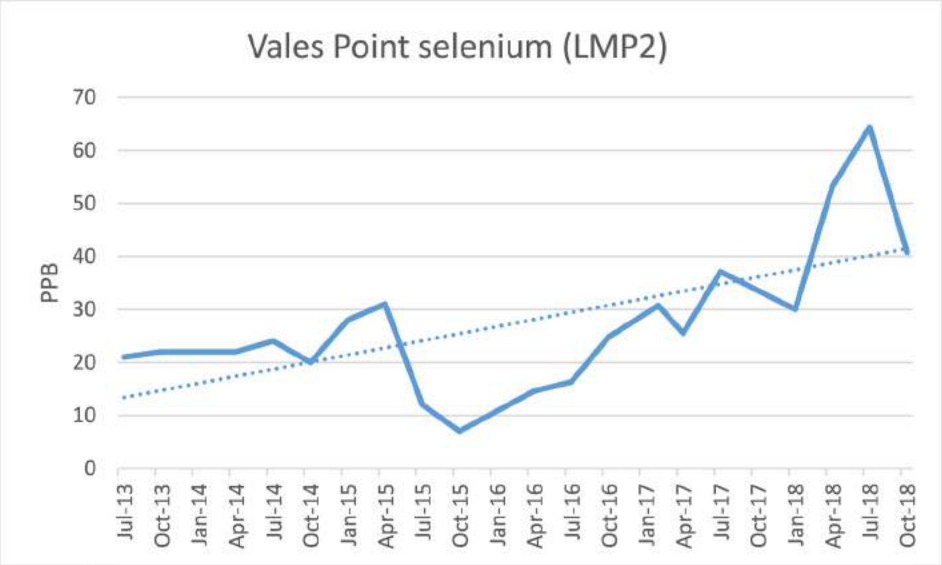

Figure 12: Selenium concentrations in water discharged by Sunset Power International from their Vales Point Power Station at LMP2 from June 2013 to October 2018

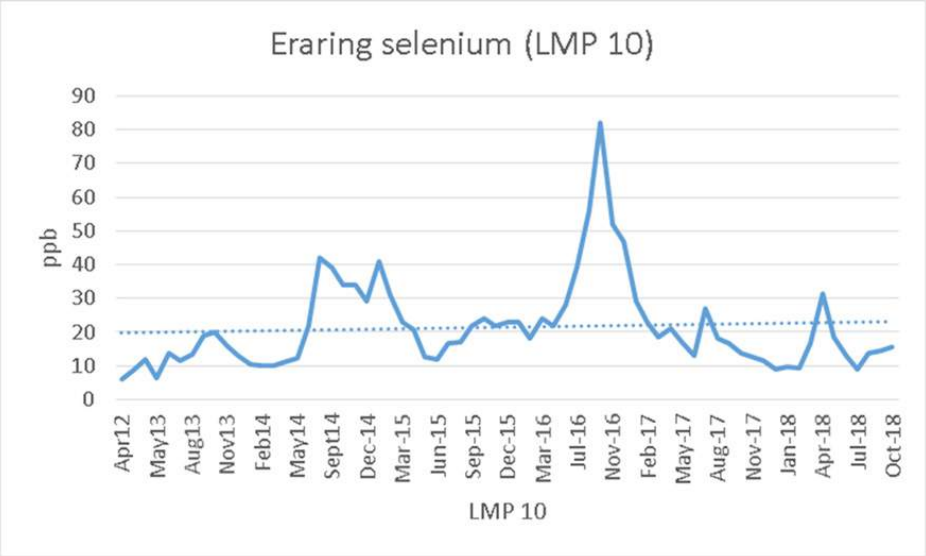

Figure 13: Selenium concentrations in Eraring ash dam discharged after the Siphon Pond Weir (LMP 10) by Origin Energy from June 2013 to October 2018

Selenium concentrations have also been showing a moderately increasing trend in the Eraring ash dam, though less so than for Vales Point (See Figure 13).

Selenium concentrations in Lake Macquarie have been a concern for a number of years with a risk assessment in 2003 finding significantly elevated selenium concentrations in fish from Lake Macquarie.[77] As discussed above, the recent human health risk assessment obtained by HCEC from the Office of Environment and Heritage under NSW freedom of information laws suggested selenium levels in fish from Lake Macquarie have not improved markedly since 1996.[78]

However, it is the impact on the ecology of the Lake that is of primary concern. Selenium is immobile in anoxic reduced sediments but becomes available to invertebrates and fish through biota modifying the redox status of sediments and bioaccumulation and transformation by macrobenthos and bacteria.[79] Lemly (2002) recommended that waterborne selenium concentrations of 2 ppb (0.002 ppm) or greater be considered highly hazardous to the health and long-term survival of sensitive fish and aquatic birds due to food- chain bioaccumulation and resultant dietary exposure and reproductive effects.

HCEC water quality analyses reveal that selenium concentrations near to Vales Point Power Station are above 2 ppb in Mannering Bay and 5 ppb at the cooling water outlet into Lake Macquarie (2.5 times the concentration limit imposed on the Eraring Power Station). Discharge of selenium into the Lake must be reduce considerably.

Recommendation 14: EPL 761 be amended to include a 2ppb limit of selenium concentrations in the cooling water outfall monitored at LMP 1.

Lake sediments are the final resting place for heavy metals and the concentrations of heavy metals in sediments of Lake Macquarie have been found to be high in a number, particularly selenium.

HCEC sediment analyses has confirmed pervious reports of sediment in Southern Lake Macquarie with one site near to Vales Point exceeding 10ppm. Lemly (2002) calculated a value of 2 ppm in sediment as the threshold beyond which selenium bioaccumulation exceeds the dietary toxic level for fish which is 3 ppb in benthos. At 4 ppb in sediment, concentrations in benthos can reach 10 ppb, and when sediments contain 5 ppb, concentrations in benthos may exceed 15 ppb. Lemy (2000), therefore, recommends that 2 ppb be used as the toxic threshold value for selenium in sediment.

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[77] Dalton and Bird, 2003.
[78] OEH EPS Branch, 2019.
[79] Peters et al, 1999.

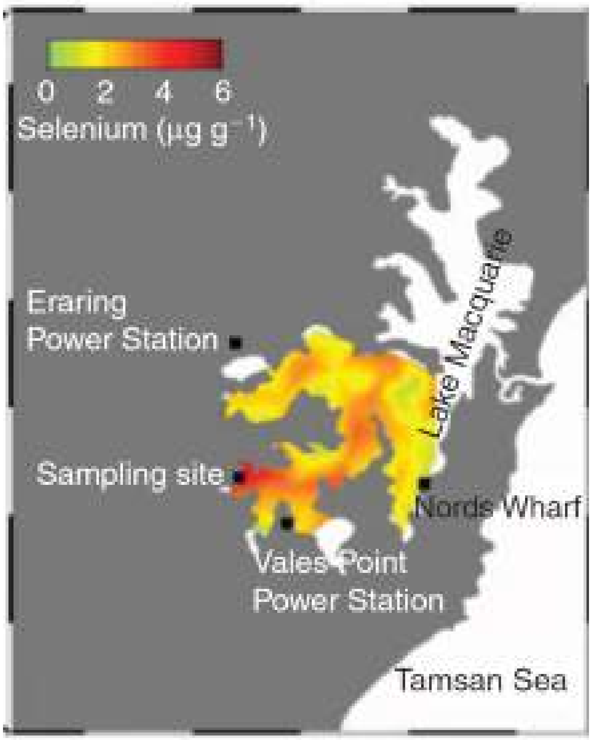

Figure 14: Location map for Lake Macquarie and selenium concentrations in surface sediments.[80]

Selenium discharge from each power station increases selenium in different areas of the Lake sediment. Figure 14 shows selenium concentration reported in 2015 in sediment across most southern Lake Macquarie is above 2ppm and highlights the closed nature of the system with areas to the west near to Morisset Hospital (sampling site shown on Figure 14) with the highest selenium sediment concentrations (6ppm) with a tongue of selenium affected sediment gradually reducing to the north.

Figure 15 shows the Lake currents generated by the inflows of Wyee Creek to the south likely to carrying Vales Point heavy metal discharge north and west to the area of highest selenium concentrations (near to "Sample site" on Figure 15).

As previously discussed, Eraring power station affects a much larger area of the central area of the Lake due to its cooling water outflow driving water circulation,[81] along with inflows from Dora Creek. This is likely to spread heavy metal discharge over a larger area, thus a lower selenium concentration in sediments in the northern area of southern Lake Macquarie.

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[80] Ellwood et al, 2015.
[81] Umwelt, 2014.

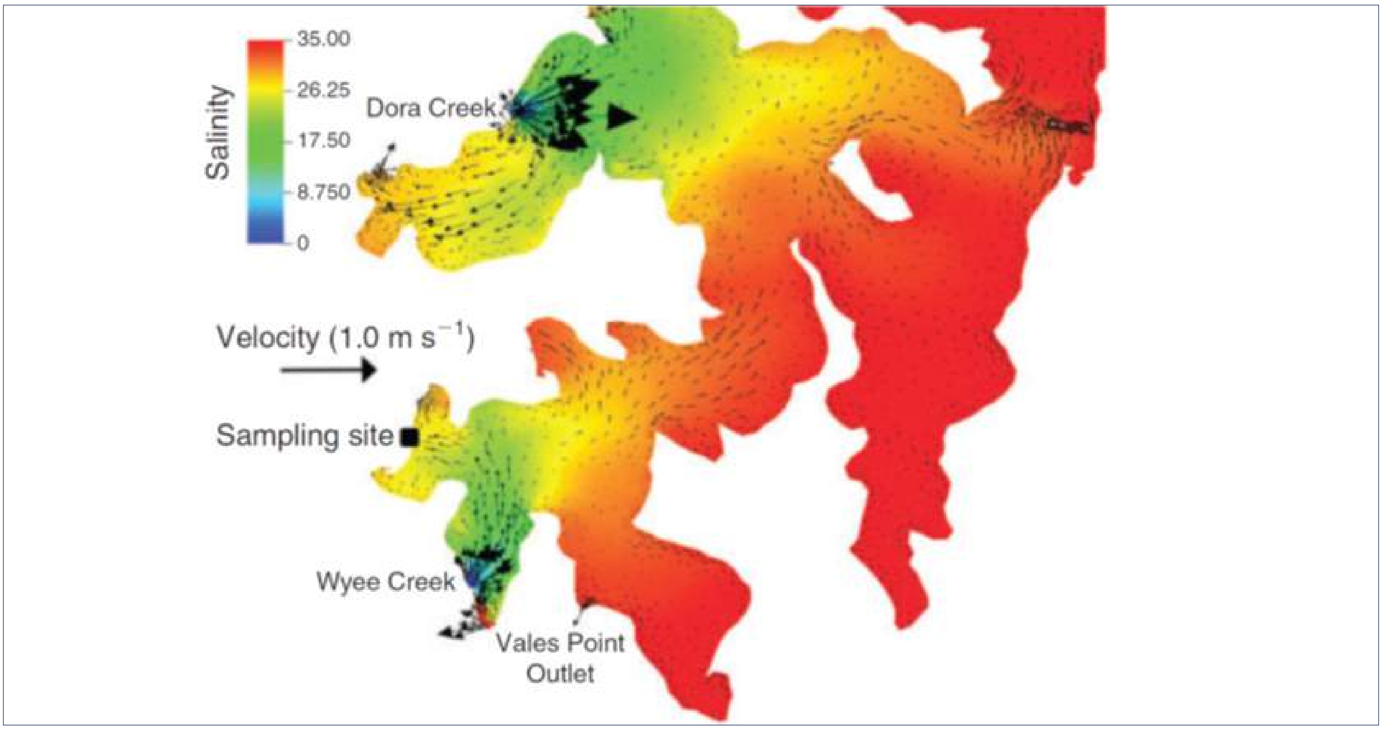

Figure 15: Hydrological model of Lake Macquarie[82] - water flow patterns determined by salinity, lake inflows and wind speed and direction. Arrows indicate the direction of the water flow in the lake after applying the model, where the longer the arrow, the greater the flow.

Recommendation 15: To identify the extent of potential contamination of Lake Macquarie by the Vales Point Power Station additional surface water monitoring point be included in EPL 761 that incorporate areas of Southern Lake Macquarie taking into account currents and inflows and for comparison appropriate background sites near to the mixing zones of Eraring and Vales Point, as well as areas not influenced by any potential inputs from Vales Point or Eraring Power Stations.

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[82] Ellwood, et al, 2015.

Groundwater contamination

The geology and soil of the ash dam beds is described in the various environmental assessments produced for Vales Point and Eraring suggest it consists of Munmorah conglomerate outcropped with Narrabeen Sandstone of about 150m consisting of conglomerate interbedded with sandstone and siltstone bands.

The soil overlying this is alluvial up to a maximum of 3m of silt and silty sand.[83] Such rock strata is very porous and therefore likely to hold a large volume of groundwater. These basal units below the unlined ash dams are therefore at significant risk of contamination by heavy metals from the unlined ash dams.

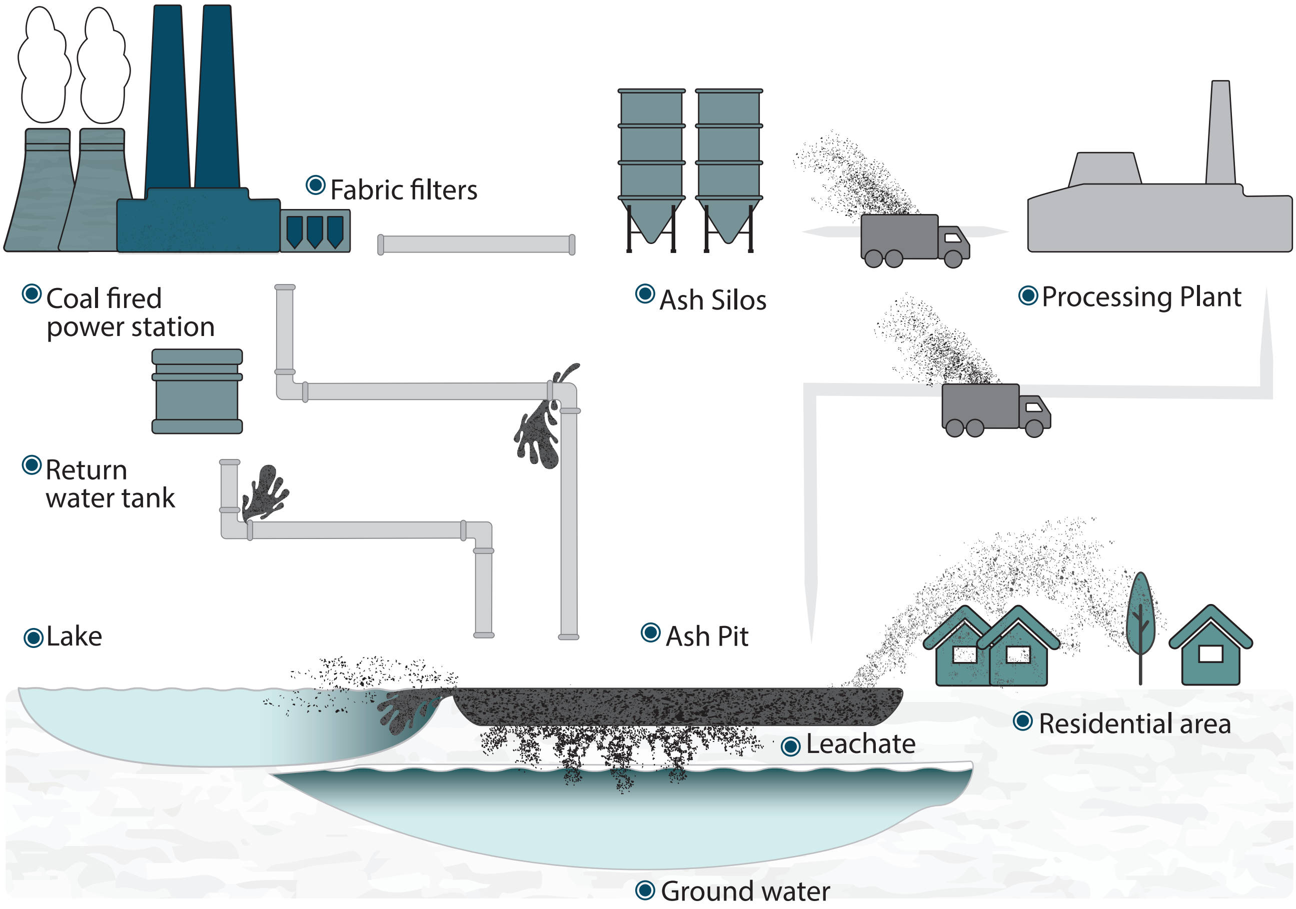

Figure 16: Coal fired power stations ash dams and the relationship to groundwater.

In 2016 Sunset Power International (Delta Electricity) issued a media statement saying "There is no evidence of leaching from the Vales Point Ash Dam into the groundwater table." However, Sunset's own monitoring data reveals significantly elevated heavy metal concentrations at the groundwater LMPs.

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[83] ELCOM NSW, 1980.

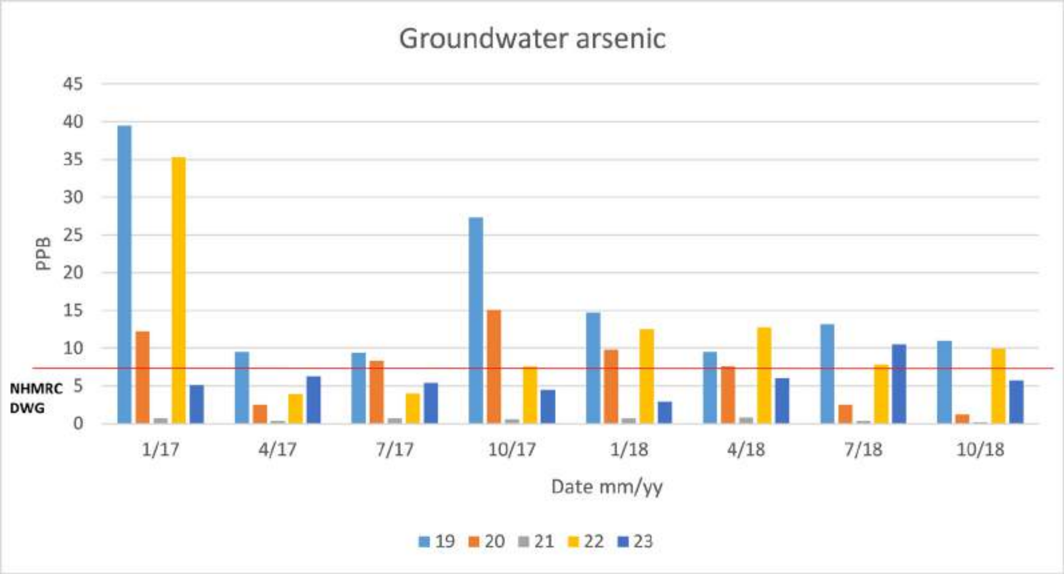

Figure 17: Arsenic found in Vales Point groundwater monitoring points from January 2017 to October 2018.

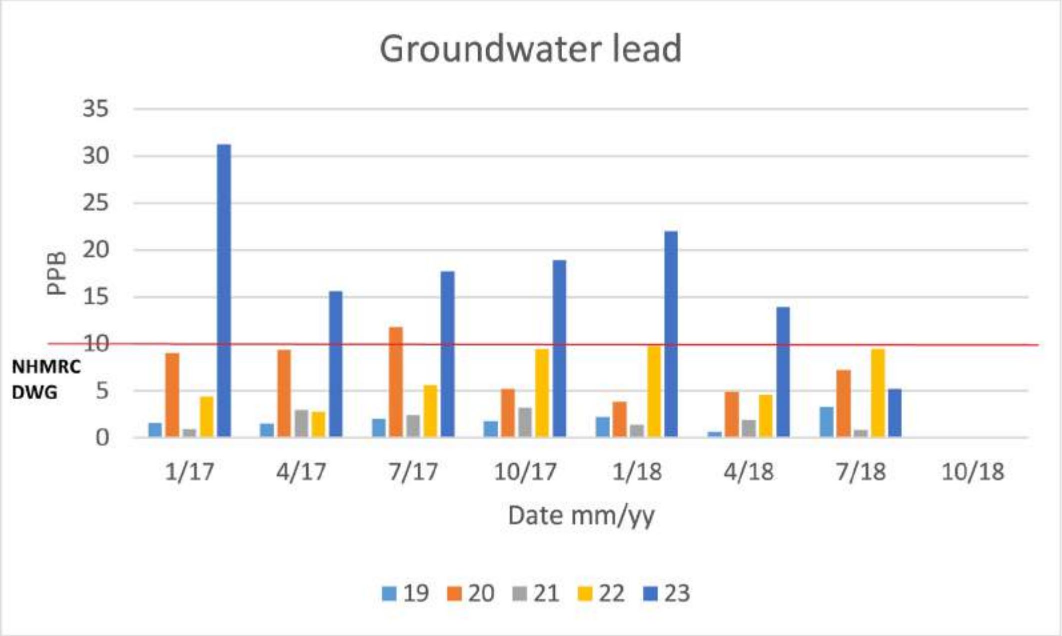

Figure 18: Lead concentrations found in Vales Point groundwater monitoring points from January 2017 to October 2018.

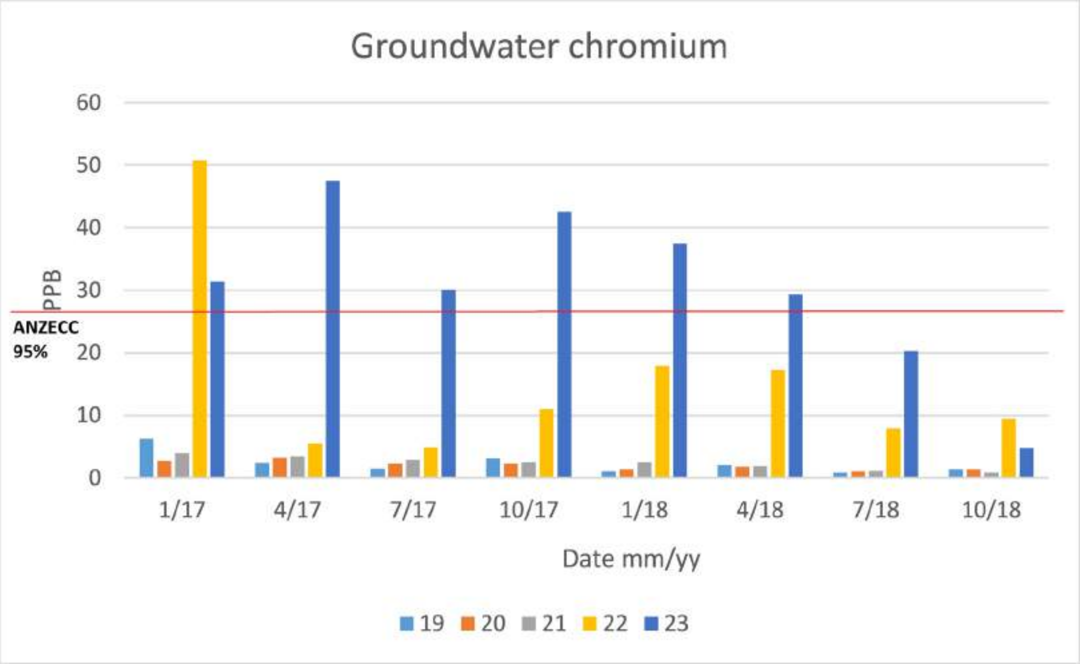

Figure 19: Chromium, and lead concentrations found in Vales Point groundwater monitoring points from January 2017 to October 2018.

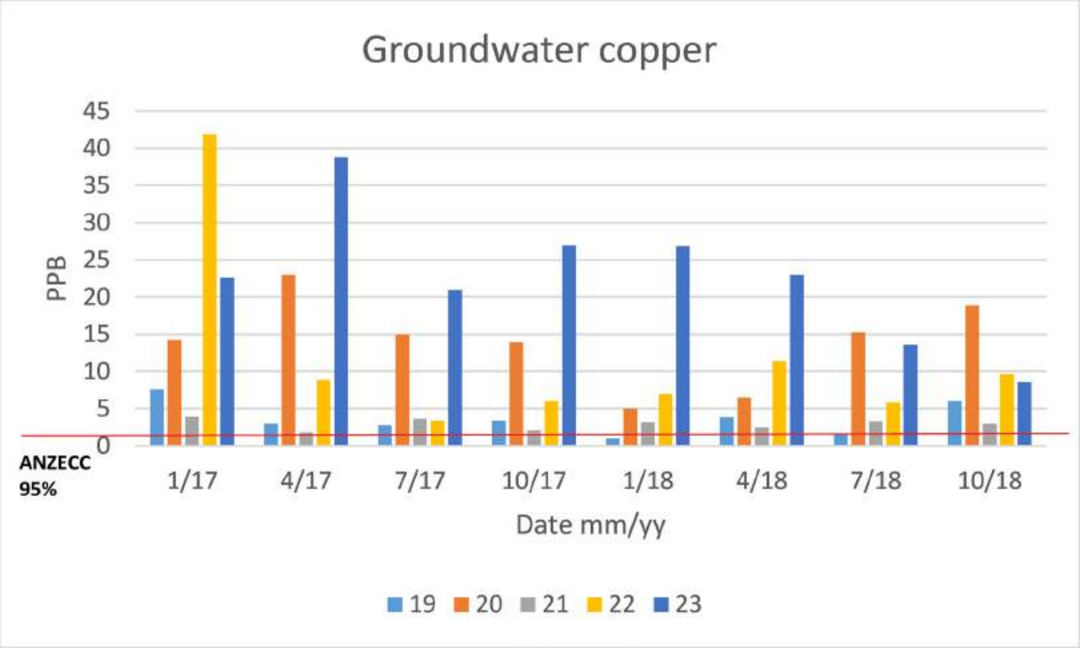

Figure 20: Copper found in Vales Point groundwater monitoring points from January 2017 to October 2018.

The groundwater monitoring reveals elevated concentrations of arsenic, copper, chromium and lead in the groundwater below the Vales Point ash dam. Many of these metals were found in water samples collected from Lake Macquarie near to Vales Point power station. It is therefore likely that contaminated groundwater seepage is entering the Lake.

Recommendation 16: Background groundwater monitoring bored be established at appropriate distances from the ash dam and the monthly monitoring results be made public.

ANZECC (2000) should apply to the quality both of surface water and of groundwater since the environmental values which they protect relate to above-ground uses: "Hence groundwater should be managed in such a way that when it comes to the surface, whether from natural seepages or from bores, it will not cause the established water quality objectives for these waters to be exceeded, nor compromise their designated environmental values."[84]

Heavy metal contamination of groundwater below the Eraring ash dam is also suggested in the EPL monitoring data. Origin Energy's EIS Ash Dam Modification 2018 suggested that, "Historical groundwater monitoring results indicate that there are a number of trace metals in groundwater beneath the ash dam which have, on occasion, been recorded in concentrations in excess of the ANZECC 2000 criteria. It is unclear whether the concentrations can be attributed to background or naturally elevated conditions". It would be quite inconceivable that groundwater below an unlined coal ash dam built on alluvial material over sandstone and conglomerate bed rock would not be contaminated with heavy metals.

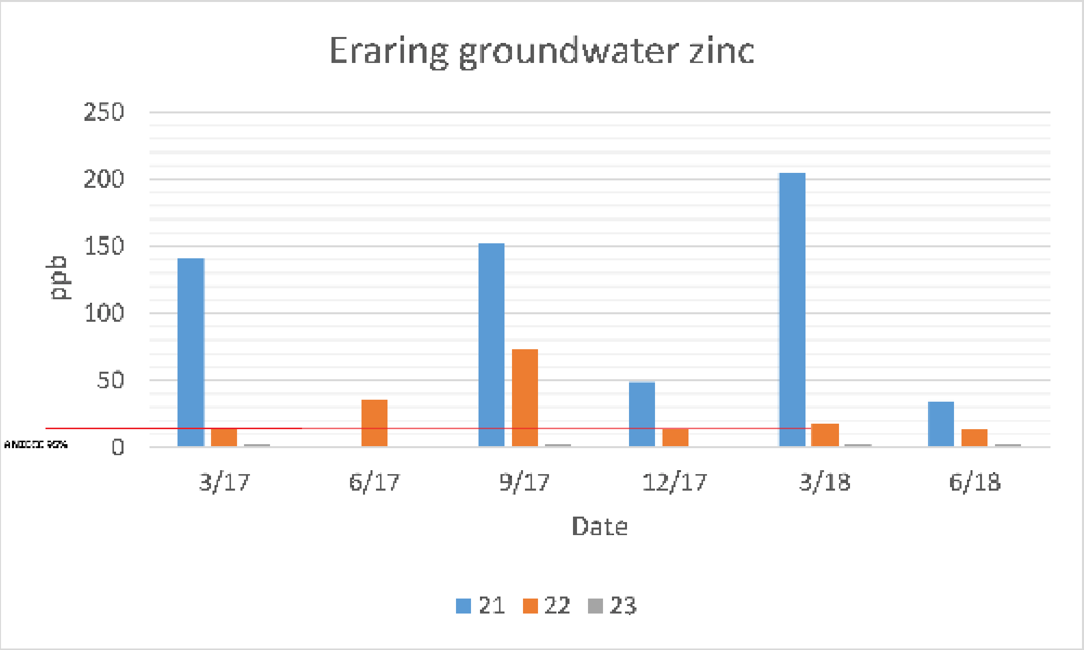

Figure 21: Zinc found in Eraring groundwater monitoring points from March 2017 to 2018.

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[84] ANZECC (2000).

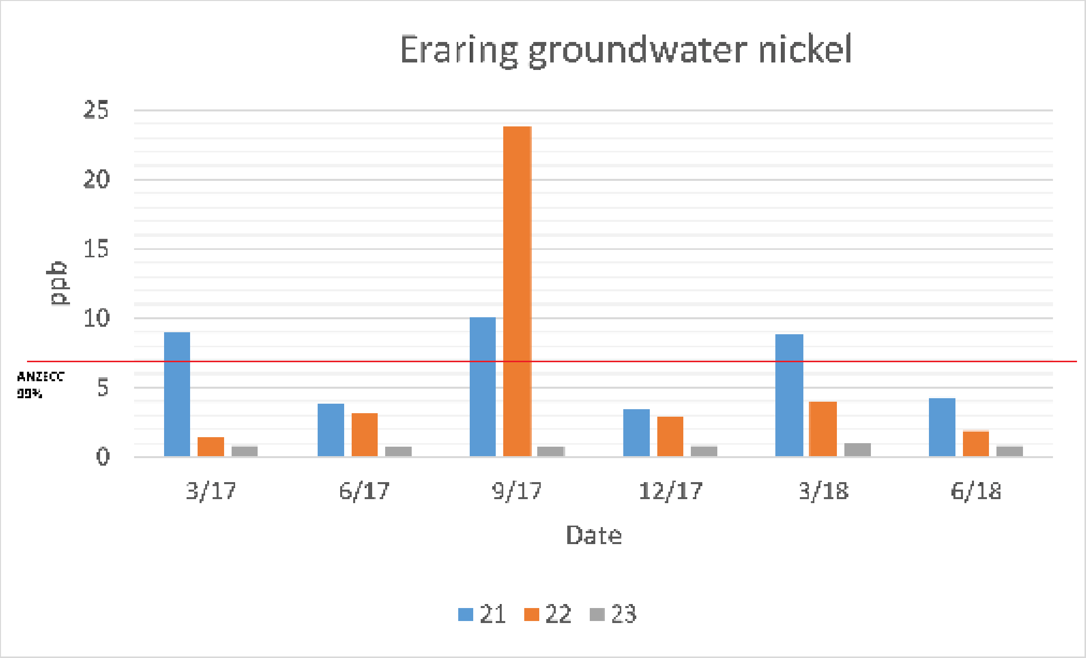

Figure 22: Nickel concentrations found in Eraring groundwater monitoring points from March 2017 to 2018.

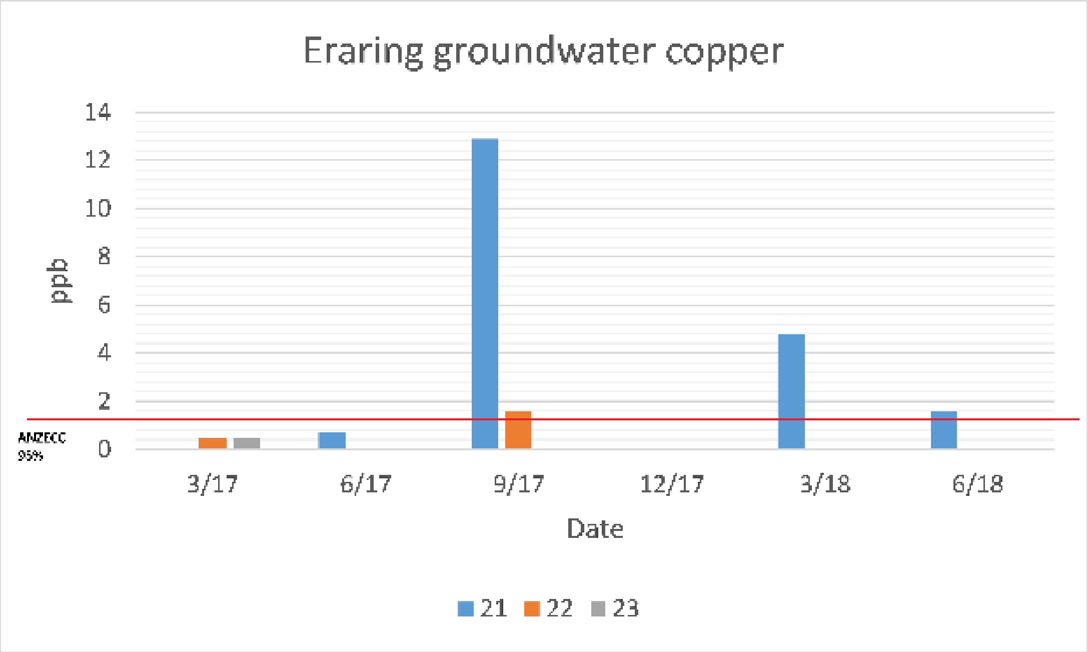

Figure 23: Copper found in Eraring groundwater monitoring points from March 2017 to 2018.

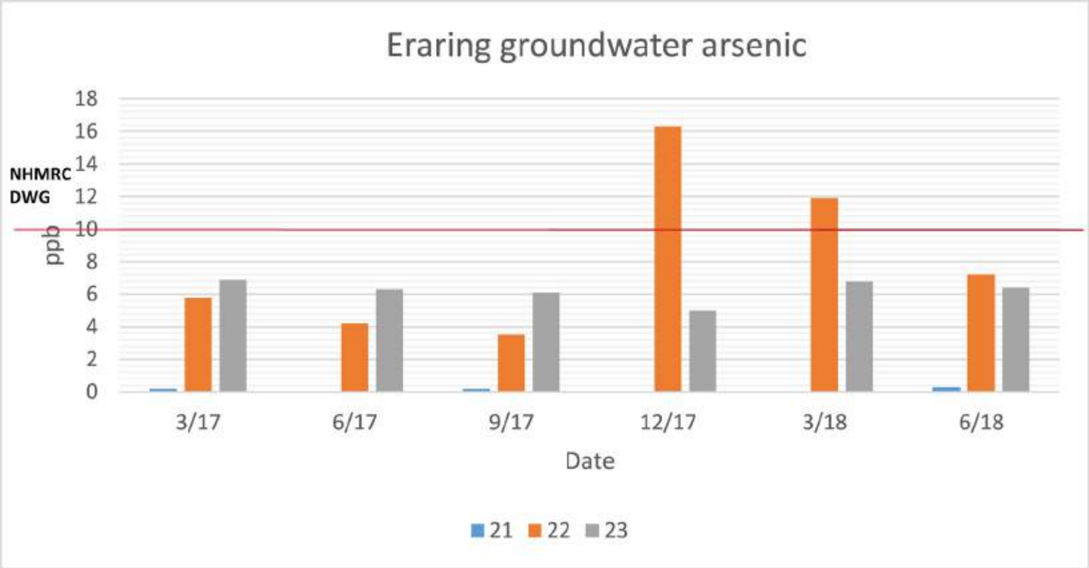

Figure 24: Arsenic found in Eraring groundwater monitoring points from March 2017 to 2018.

We have assumed groundwater contamination will eventually migrate to Lake Macquarie and therefore have used ANZECC marine water trigger values, however, groundwater users in the area may also be affected. While we have used the ANZECC trigger values for marine waters to identify groundwater contamination levels, freshwater trigger values are more comprehensive and in all cases are set at lower concentrations. Zinc, copper, and nickel concentrations found in groundwater below the Eraring ash dam, and chromium and copper concentrations in groundwater below the Vales Point ash dam are significantly above ANZECC trigger values for “slightly to moderately disturbed” ecosystems.

Despite the short time period these groundwater samples results represent, concentrations do show a decreasing trend. It is therefore, perhaps too soon to tell if any mitigation effort by the power station operators put in place will see continued improvement.

A search of the registered bores in the area reveal a number of registered bores that may be using heavy metal contaminated bore water. If they have not been warned of the dangers of using such water for irrigation or domestic use, the EPA, Sunset Power International, and Origin Energy are negligent in their duty of care.

Recommendation 17: The EPA should contact all registered bore owners who may be affected by heavy metal contamination identified by the Vales Point and Eraring monitoring to warn them of the dangers to human health, livestock, irrigated crops and irrigated plants and crops of using such water.

Part 2 - Coal ash utilisation and rehabilitation of ash dams

As the phased closure of coal-fired power stations rolls out across the country, how we manage the massive volumes of coal ash left in ash dams will be of particular concern to communities, due to human and ecological health factors, as well as to the construction and manufacturing industries for whom coal-ash re-use presents new business and job opportunities.[1]

Coal ash utilisation is necessary to reduce the massive volumes of coal ash generated and stockpiled. Australia is a dismal failure in coal ash reuse. While rates of economically-beneficial coal ash utilisation in Australia have been rising, it still remains at about 20 percent of what is generated.[2]

In other parts of the world, coal ash reuse is perused more vigorously. For example between 1995 and 2011 Japan increase its utilisation of coal ash from 67 percent to 97 percent, a period when coal ash generation almost doubled. Of the 97 percent utilisation by Japan in 2011, 67.3 percent was for cement/concrete, 14.3 percent for ground material and 3.2 percent for architectural material.[3]

It is estimated that about 12.3 Mt of coal ash was generated in Australia in 2016, of which 9.4 Mt was dumped in on-site ash dams.[4] Only 1.8 Mt was used in high value-added applications such as cement and concrete. A further 0.48 Mt was used as as flowable fills, structural fills, road bases, aggregates and mine site remediation and 2.3 Mt was used as low value land fill, mine backfilling and local haul roads which generated little or no economic return.[5] Indeed, many of these low value uses also present significant human health and environmental risk.

More than 400 Mt of coal ash is sitting in unlined ash dumps around Australia.[6] These poorly-designed- and -run unlicenced hazardous waste containment facilities are aging, increasing the risk of off-site contamination. Indeed, it is likely that all are causing some level of pollution. With the right incentives and appropriate regulation and oversight, this massive volume of hazardous waste could be beneficially re-used, alleviating pollution, assisting with ash dam rehabilitation, and providing transition opportunities for affected power station employees when they eventually close.[7]

While fly ash and bottom ash from Australian power stations have similar chemical compositions, their uses are quite different. Fly ash, a grey powder similar to cement, is used in a range of cement-based products. Bottom ash, which is coarser, is used as a sand replacement, aggregate for lightweight concrete blocks, a road-base component, for agricultural drainage mediums and as engineered bulk fill.

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[1] Matthew Stevens, 2018.
[2] ADAA, 2015.
[3] Kenichi et al, 2015.
[4] ADAA, 2016.
[5] ibid
[6] Heidrich & Heeley P., 2014.
[7] Beyond Zero Emissions, 2017.

Due to its finer consistency and greater surface area, fly ash generally has higher concentrations of heavy metals than bottom ash. However, all proposed coal ash applications should be thoroughly investigated by the EPA for their potential to cause environmental harm. Currently, responsibility for testing for heavy metals and other toxic material in coal ash that is sold for reuse is left to the ash generator. There is no requirement for the EPA to conduct monitoring or even to provide the EPA with testing results of the concentration of metals and other contaminants in the coal ash. Improved regulation and EPA oversight is essential to minimise the risks.

Incentivising safe coal ash reuse also requires government intervention to alleviate some of the blockages currently being experienced. For example, power stations charge a royalty fee for coal ash. We understand from industry insiders that no power station in Australia directly subsidises the cost of providing ash to third parties to increase its rate of external use. Some operators are prepared to waive their royalty rights to encourage particular projects, but this is normally done on an ad hoc basis. Royalties are normally paid by an ash marketing company to a power station operator to protect the market, and prevent an operator providing ash to any other party. These arrangements perpetuate the situation that only the highest value applications are pursued, in order to achieve a commercial return to the ash marketer in selling a product with a high enough return to cover all of its costs, primarily transport and processing costs.[8]

Coal ash regulation

Regulatory exemptions for coal ash reuse have clearly failed to increase coal ash utilisation rates. These exemptions have risked human health and environmental harm for no perceptible benefit. HCEC argues that it is, therefore, no longer in the public's interests to continue with these exemptions.

Under the Waste Regulation (*Protection of the Environment Operations (Waste) Regulation 2014*) it is an offence in NSW to pollute land with certain types of waste, but unlicensed landfills operators who maintain certain minimum operational standards are given a defense against prosecution. The Waste Regulation also clarifies obligations and responsibilities of generators, processors and consumers of waste materials.

Specific resource recovery orders and exemptions apply to coal ash under the Waste Regulation to encourage and facilitate the reuse of coal ash. *The Coal Ash Exemption 2014* exempts consumers of coal ash from

- licensing requirements under s48, and licenced waste facility contributions under s88 of the *POEO Act*, and

- obligations for tracking and transportation of waste under Part 4, the waste facility reporting and notification requirements under clauses 109 and 110, and restrictions to the application of waste to land used for growing vegetation under clause 114 of the *Waste Act*. [9]

Complimentary to the *Coal Ash Exemption*, the *Coal Ash Order 2014* imposes requirements that must be met by suppliers of coal ash and blended coal ash to which the *Coal Ash Exemption* applies.

Primarily, a coal ash generator must not supply coal ash for reuse if the concentration of heavy metals are greater than those listed in Table 1 of *The Coal Ash Order 2014*. The receipt of coal ash, however, remains subject to other relevant environmental regulations in the *POEO Act* and Waste Regulation.

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[8] Pacific Power International, 2003.
[9] EPA, 2014.

In 2007, the ADAA undertook laboratory testing of 28 samples of coal ash generated and utilised by its members.[10] These members included:

- CS Energy (QLD)
- Blue Circle Ash (NSW)
- Flinders Power (SA)
- Flyash Australia (NSW, SA)
- Verve Energy (WA)
- Pozzolanic Enterprises (QLD)
- Delta Electricity (NSW) – The operators of Vales Point power station
- Tarong Energy (QLD)
- Eraring Energy (NSW)
- LaTrobe Valley Generators (VIC)
- Macquarie Generation (NSW) – AGL bought Mac Gen and now operates Bayswater and Liddell power stations, but is not a member of the ADAA.

The results of laboratory analyses undertaken on the black coal fly ash and bottom ash are summarized in Table 10 below, together with the concentration limits of *the Coal Ash Order 2014*.

		Fly ash				**Bottom ash**				***The Coal Ash Order 2014***		
ppm	**EQL**	**No.**	**Min**	**Max**	**Mean**	**No.**	**Min**	**Max**	**Mean**	**Colunmn 2**	**Column 3**	**Column 4**
Antimony	**1**	28	0.5	2	0.8	20	<1	<1	<1			
Arsenic	**1**	28	2	14	6.9	20	0.5	1	0.5	10		**20**
Barium	**5**	28	5	2570	343.5	20	10	482	115.1			
Beryllium	**1**	28	0.5	10	1.8	20	0.5	1	0.6			
Boron	**5**	28	5	508	98.2	20	2.5	37	8.2	75		**150#/60***
Cadmium	**0.1**	28	0.05	2	0.2	20	<0.1	<0.1	<0.1	0.5	0.5	**1**
Chromium	**1**	28	2	31	11.9	20	1	25	8.1	25	25	**50**
Cobalt	**1**	28	0.5	39	6.1	20	0.5	12	1.9			
Copper	**2**	28	3	78	19.6	20	1	18	4.8	20		**40**
Lead	**2**	28	1	42	11.8	20	1	4	1.2	25	25	**50**
Manganese	**5**	28	2.5	640	192.0	20	2.5	1120	215.7			
Moybdenum	**1**	28	2	26	6.5	20	0.5	4	1.2	10		**20**
Nickel	**1**	28	0.5	59	10.4	20	0.5	17	4.4	25	25	**50**
Selenium	**2**	26	1	4	2.0	20	<2	<2	<2	10	10	**20**
Silver	**0.1**	28	0.05	0.2	0.1	20	<0.1	<0.1	<0.1			
Tin	**1**	28	0.5	7	2.4	20	0.5	2	0.6			
Thallium	**1**	28	0.05	6	0.3	20	<1	<1	<1			
Zinc	**5**	28	5	141	31.8	20	2.5	49	10.1	35	35	**70**
Mercury	**0.05**	28	0.025	0.37	0.1	20	<0.1	<0.1	<0.1	0.5		**1**

Table 10: Laboratory analysis of Australian black coal fly and bottom ash with The Coal Ash Order 2014 ash concentration limits.

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[10] ADAA, 2007.

The ADAA ash analyses was undertaken on one-off ash samples. The *Coal Ash Order 2014* stipulates the coal ash must be sampled by taking 3 composite samples analysed per year and the average of these must not exceed Column 2 and any sample analysed must not exceed Column 4. It could not be established whether the ADAA coal ash samples were composites analyses. However, 19 of the 28 fly ash samples and 1 of the 20 bottom ash samples exceeded the average concentration limits for heavy metals set under column 2 of table 1 of the *Coal Ash Order 2014*. Nine samples exceeded the column 4 absolute concentration limit for engineering uses, and a further four exceeded the absolute concentration limit for use as a soil amendment (Boron).

In January 2019, AGL suspended sales of coal ash and ash by-products from its Bayswater and Liddell power stations after testing of coal ash showed elevated levels of heavy metals including chromium, cadmium and copper which exceeded limits set by the *Coal Ash Order 2014*.[11]

The EPA has launched an investigation and has demanded AGL submit its coal ash testing records along with those records showing where and how much coal ash has been distributed. The HCEC believes the EPA must broaden its investigation into all coal ash generated by the five coal-fired power stations in NSW.

Recommendation 18: The EPA launch a full investigation into coal ash reuse in NSW to determine the environmental risks and whether all its current uses are appropriate for a hazardous waste.

Many of the current uses of coal ash such as mine site rehabilitation and mine void backfilling, agricultural soil amendments, fertilizers and potting mixes are high risk.

Given its properties, coal ash should be categorised as hazardous waste and the regulation for its use should be significantly strengthened. The HCEC believes that the resource recovery exemptions are not appropriate and an alternate regulatory regime is required that places the EPA in the position of oversight and final arbitrator for all coal ash uses contemplated.

Licencing of coal ash landfills is also required, as well as improved regulations to ensure coal ash reuse is carried out in a manner that protects the environment and public health from this hazardous waste.

NSW power station operators must therefore be provided with a 'Waste storage - hazardous, restricted solid, liquid, clinical and related waste' licence and a 'Hazardous waste recovery licence'.

***Recommendation 19: The EPA must revoke the Coal Ash Exemption 2014*.**

The use of coal ash in fertilisers, potting mixes and agricultural soils, for example, must cease altogether due to the possibility for contamination and leachate pollution, and trace element uptake into plants and animals.[12] Mine backfilling, and mine site rehabilitation uses similarly should cease, due to the possibility of groundwater contamination. For cementitious applications, a large body of evidence suggests that the potential for leaching of trace elements from a bound matrix is very low. As such cementitious applications in general considered to be safe.[13]

Cement and concrete

It is theoretically possible to replace 100 percent of Portland cement with fly ash, but above 80 percent generally requires a chemical activator. The *Australian Standard 3600 - Concrete Structures* permits the replacement of up to 40 percent of the cement in a normal concrete mix with fly ash. However, studies have found that the optimum replacement level is around 30 percent.[14]

Fly ash can improve certain properties of concrete. Because it generates less heat of hydration, it is particularly well suited for mass concrete applications. Fly ash use in concrete improves the workability of plastic concrete, and the strength

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[11] AGL, 2019.
[12] Pacific Power, 2003.
[13] ibid
[14] Duhita & Doye, 2017.

and durability of hardened concrete. Generally, fly ash benefits concrete by reducing the mixing water requirement and improving flow behaviour.[15]

The use of fly ash to replace cement also has major greenhouse gas savings. Globally, the manufacture of cement produces more greenhouse gas emissions than any other single product – about 3 billion tonnes per year, or 8 percent of the world total. In Australia, production of Portland cement is responsible for 7.4 million tonnes of emissions, about 1.3 percent of national emissions. [16]

Rather than being left in unregulated landfill to indefinitely pollute and affect community health,[17] coal-ash can be intelligently re-deployed as a high-quality substitute for limestone and other minerals in cement production.

According to a recent report on coal ash reuse in cement manufacture, there are sufficient stockpiles of suitable fly ash to supply an estimated 20 years or more of domestic cement production.[18] More than 1 million tonnes of coal ash a year is already used in Australia as a supplement in Portland cement.[19] Based on the conservative assumption that 25 percent of stockpiled fly ash will be suitable after processing, there is likely to be at least 100 million tonnes available in Australia. [20]

The most commonly quoted impediment to greater utilisation of coal ash is transport costs and logistics. Governments need to provide incentives for environmentally-benign coal ash applications that result in large volumes of ash being removed from ash dams. To incentivise its reuse, it is critical to reduce the impact of transport costs by finding uses that have the high value to the end user and by ensuring that the power stations that generate coal ash pay for the pollution it causes.

In 2003, to improve the incentive to reuse coal ash a proposal was made to impose an $18 to $20 per tonne levy on coal ash generated and placed in an ash dams.[21] This could be achieved through the imposition of an EPA regulated Load Based Licence levy. However, much tighter regulation of coal ash storage, use, tracking, and transportation is required to ensure that re-using this hazardous waste does not cause more environmental harm than it alleviates.

Recommendation 20: Coal ash be listed as an assessable pollutant in Schedule 1 of the Protection of the Environment Operations (General) Regulation 2009.

Currently the major blockage to increasing coal ash reuse in cement and concrete is the cement industry itself.

Blockages to coal ash reuse by the cement and concrete industries.

In 2014-15 Australia's three cement manufacturers (Adelaide Brighton, Boral and Cement Australia) produced 9.1 million tonnes of cement for domestic consumption.[22] This was supplemented with 2.76 million tonnes of imported clinker and cement, mostly from Japan and China.[23] The industry had a turnover of $2.4 billion and employed over 1,500 people.[24]

In Australia, there are just five integrated cement plants (combining clinker manufacture and cement grinding) and five stand-alone cement mills.[25] These plants are major investments, costing hundreds of millions of

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[15] Duhita & Doye, 2017.
[16] BZE, 2017.
[17] Angelique Donnellan, 2018.
[18] Beyond Zero Emissions, 2017.
[19] ibid
[20] ibid.
[21] Pacific Power, 2003.
[22] Cement Industry Federation, 2016.
[23] ABS, 2016.
[24] Cement Industry Federation, 2016.
[25] BZE, 2017.

dollars to set up and tens of millions more to maintain and upgrade. These high costs mean cement-making tends to be a highly integrated, centralised industry.[26]

For a variety of reasons including the ownership structure of the cement industry, and over-capacity of production, the actual value of coal ash is less than the cost of cement production. This challenge was identified as far back as 1992 when The Bureau of Industry Economics stated in its benchmark report *BRE 45*, *Cement Extenders in Australia* that, "the structure of the cement industry, and particularly the vertical integration of quarries, cement manufacturers and concrete suppliers' are factors which limit the use of fly ash and in concrete… Transport costs, the lumpiness of capital equipment and its longevity, and slow growing and highly inelastic demand all seem to mitigate against vigorous price competition". These factors not only limit price competition, but also limit the motivation of cement and concrete industries to reduce their cement consumption and replace it with coal ash.[27] In other words, if your capital equipment will be under-utilised by reducing the amount of cement produced, then unit production costs of cement will increase for a given decrease in production.[28]Vertical integration of ownership ensures that concrete companies only use as much fly ash as their fully-owned cement producers want them to.[29]

This situation has led to cement manufacturers being prosecuted by the Australian Competition and Consumer Commission (ACCC) for breaching the Trade Practices Act in Queensland for entering into contracts with four power stations to prevent them selling their coal ash to other buyers. The proceedings related to contracts that were entered into between 2002 and 2006 with the operators of the Millmerran, Tarong, Tarong North and Swanbank power stations in South East Queensland to acquire flyash. Penalties totaling $20.6 million were imposed on Cement Australia and two subsidiaries.[30]

HCEC believes the cement industry is behaving in a similar way in NSW. In 1985, a tender for exclusive rights to market Eraring power station fly ash given was let by then operator Pacific Power to Flyash NSW, later becoming Flyash Australia (FAA), a joint venture equally owned by Boral and Cement Australia. Boral is a major cement producer in Australia and while the company is pursuing reuse of coal ash as a business opportunity in America, it does not appear to be doing so here.[31] It our understanding that the contract has since been renewed several times without going to tender.

The contract provides FAA with exclusive rights to the finer fractions of fly ash from Eraring's fabric filters - concrete grade fly ash that needs little processing. Eraring produces 1.3 million tonnes of fly ash per year, but of the 700,000 tonnes of cement-grade shake ash produced, FAA only purchases half. FAA refuses to allow Daracon, which has access to coal ash in the ash dam that requires processing, to use the other 350K tonnes pa of cement grade fly ash that FAA does not use. Flyash Australia also has contracts to buy or use fly ash at Mount Piper and Bayswater power stations in NSW and Collie power station in WA.

Currently, power station operators have little to no incentive to increase ash reuse or to ensure that coal ash contracts are let to users and marketers with the most capacity and incentive to reuse coal ash. A levy on coal ash disposed of in landfills and ash dams payable by the power station operator would provide a powerful motivation to change that position.

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[26] ibid
[27] Ilyushechkin et al, 2012.
[28] Pacific Power, 2003.
[29] *ibid*
[30] ACCC- 2017.
[31] Matthew Stevens, 2018.

LYTAG – lightweight aggregate

Another coal ash use that encapsulates the ash and prevents leachate from escaping is a light weight aggregate called Lytag.

Sintered pulverised fuel ash lightweight aggregate, more commonly known as Lytag® is made by pelletising fly ash.[32] Lytag aggregates can be manufactured to a variety of grades from sand to course aggregates. Lytag is primarily used in structural lightweight concrete which reduces the quantities of construction material, reduces vehicle movements and leads to significant overall cost savings. Lytag is also suitable for use in precast concrete products, fill, screed and drainage application.

By adding a controlled amount of water to coal ash in specially designed dish pelletising pans, rounded pellets are formed. The pellets are then heated on a sinter strand to a temperature of 1100°C. In such a way the heavy metals are encapsulated and cannot leach out. The result is a hard, honeycombed structure of interconnecting voids within the aggregate. The particles formed are rounded in shape and generally range in size from 14mm down to fines; these are processed to the required grading, depending on the final use.

Lytag aggregate can be expected to sell at a price two to three times that of normal aggregates and is suited to Australian fly ashes with a Loss of Ignition (LOI – a test for unburnt carbon content) of fly ash of approx 6% needed for fusion. Vales Point coal ash has an LOI above this. For lower LOI ashes, such as for Eraring's ash, waste coal washery fines can be added to compensate.

Lytag structural concrete has a compressive strengths in excess of 60 MPa with an effective reduction in dead load of approximately 25% over normal weight concrete. The reductions in concrete density allows reduced foundation sizes, additional floors to be constructed, and thinner section beams and columns used. Lightweight aggregate can be used in precast units with an associated reduction in handling and transportation costs. As well as weight reductions, Lytag® also imparts improved durability benefits to concrete, improves thermal insulation, and reduces the quantity of cement required in construction.

Widely used as a structural fill to raise existing surfaces to achieve new falls or to construct ramps, provide a deep screed within which services may be buried, infill between items such as bridge beams to provide a level surface for the structural deck, formation of architectural features, infill for raised access flooring and permeable back fill for retaining walls, bridge abutments etc. Lytag is also used in filter media, vehicle arrestor beds, horticultural, sports areas, floor and roof screeds

In the 1990s Pacific Power and Fly Ash Australia carried out a major investigation into the Lytag process with a small lab scale manufacturing plant set up at Eraring. Eraring fly ash was used and mixed with coal washery waste to achieve a LOI of 6%. A full design and costing of the plant was carried out for a 500,000 tonne pa plant. Fly ash aggregates were also made at the CSIRO facility at North Ryde with satisfactory test concretes made with the finished material. Unfortunately, with the privatisation and split up of the NSW power stations work did not proceed.

Had the proposal gone ahead, together with the existing concrete market, most generated Eraring fly ash would have been utilised, alleviating the need to expand the ash dam, and the heavy metal burden this additional ash is causing.

HCEC believes about 500,000 tonnes of Lytag (from the same amount of Lake Macquarie coal ash) could be sold into the high value lightweight concrete markets of Sydney, Newcastle, and Wollongong each year. With rail loups already in place at both Earring and Vales Point transport costs and truck movement could be significantly minimised.

Recommendation 21: The NSW Government launch an investigation into possible safe commercial uses of coal ash and look to incentivise new on-site industries around safe coal ash reuse as a means of ridding the burden of coal ash landfills, rehabilitating coal ash dams and providing affected workers with alternative employment when the State's coal-fired power stations are decommissioned.

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[32] Lytag, 2017.

Conclusions

Heavy metal concentrations in Lake Macquarie, including worrying concentrations in fish and crustaceans caught throughout the lake, is often described as a legacy of poor environmental management practices of the past. But discharge and leaching of heavy metals into the southern portion of Lake Macquarie is still occurring. This report reveals a clear link between high heavy metal concentrations in seafood caught in the Lake and current pollution from the coal ash dams of the power stations on the Lake's perimeter.

HCEC believes the NSW EPA has not fully met the objects of the Protection of the Environment Operations Act 1997 in relation to the contamination of Lake Macquarie by Eraring and Vales Point power stations and recommends amendments to the POEO Regulations to enable the EPA to properly carry out its duty to protect the people and environment of NSW from pollution.

Furthermore, under NSW law holders of Environment Protection Licences are required to control water pollution and report incidents causing or threatening material environmental harm. From the evidence we have collected, the Environment Protection Licences held by Vales Point and Eraring power stations are not preventing water pollution or material environmental harm from the ash dams of either facility, nor are they protecting Lake Macquarie from increasing loads of some heavy metals.

Our investigation reveals significant limitations and gaps in the monitoring and control of heavy metals discharged and leaching from both Eraring and Vales Point power stations. The Environment Protection Licences for these facilities do not set limits for heavy metals at three of the four discharge points where our water sampling found elevated concentrations of metals. Indeed, neither power station is required to monitor or limit the concentrations of all the heavy metals we found being discharged.

Coal ash is exempt from a number of hazardous waste and pollution laws to encourage its reuse in the construction industry. However, despite these concessions coal ash reuse remains less than 20 percent of what is generated. Coal ash is shipped around the country without having to comply with the proper hazardous waste tracking, reporting and landfill obligations. No government agency knows where the ash is being sent or what it's being used for with many of its uses, such as fill in mine voids and agricultural soil amendments, highly dangerous due to the metal concentrations identified in Australian coal ash leachate.

Given its properties, coal ash should be categorised as a hazardous waste and the regulation for its use significantly strengthened. There are millions of tonnes of this hazardous material accumulating in piles not just on the shores of Lake Macquarie, but around Australia. HCEC believes that resource recovery exemptions are not appropriate and an alternate regulatory regime is required that places the EPA in the position of oversight and final arbitrator for all coal ash uses contemplated.

Coal ash regulation needs urgent reform. This reform needs to consider the whole life cycle of coal burning, ash production, handling, storage, transport, and reuse. Regulatory amendments are required that put the financial burden for safe disposal of coal ash back onto the power station operators. In addition, incentives are required that encourage environmentally-responsible coal ash reuse to remove a key source of heavy metal contamination from the shores of Lake Macquarie, reduce a key source of greenhouse gas pollution, and encourage new on-site enterprises that will provide new jobs for displaced workers when these aging facilities are decommissioned.

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Appendix 1. Analytical reports - HCEC water and sediment samples

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CERTIFICATE OF ANALYSIS 199267

Client Details

Client	Hunter Comminity Enviroment Centre
Attention	Paul Winn
Address	167 Perry St, Hamilton East, NSW, 2303

Sample Details

Your Reference	**Lake Macquarie**
Number of Samples	1 Water, 1 Sediment
Date samples received	27/08/2018
Date completed instructions received	27/08/2018

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date results requested by	03/09/2018
Date of Issue	06/09/2018

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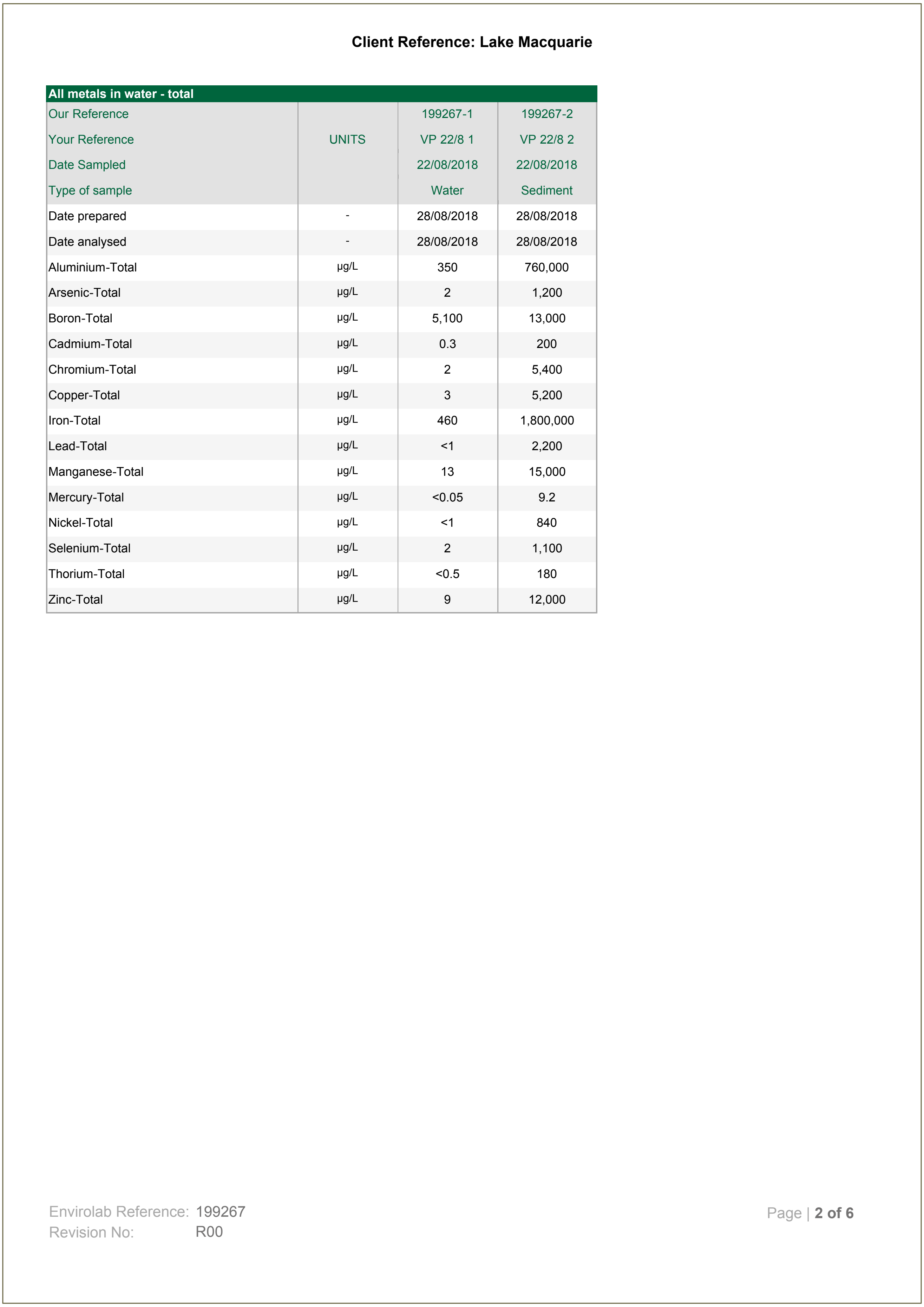
Results Approved By
Long Pham, Team Leader, Metals

Authorised By
Jacinta Hurst, Laboratory Manager



Client Reference: Lake Macquarie

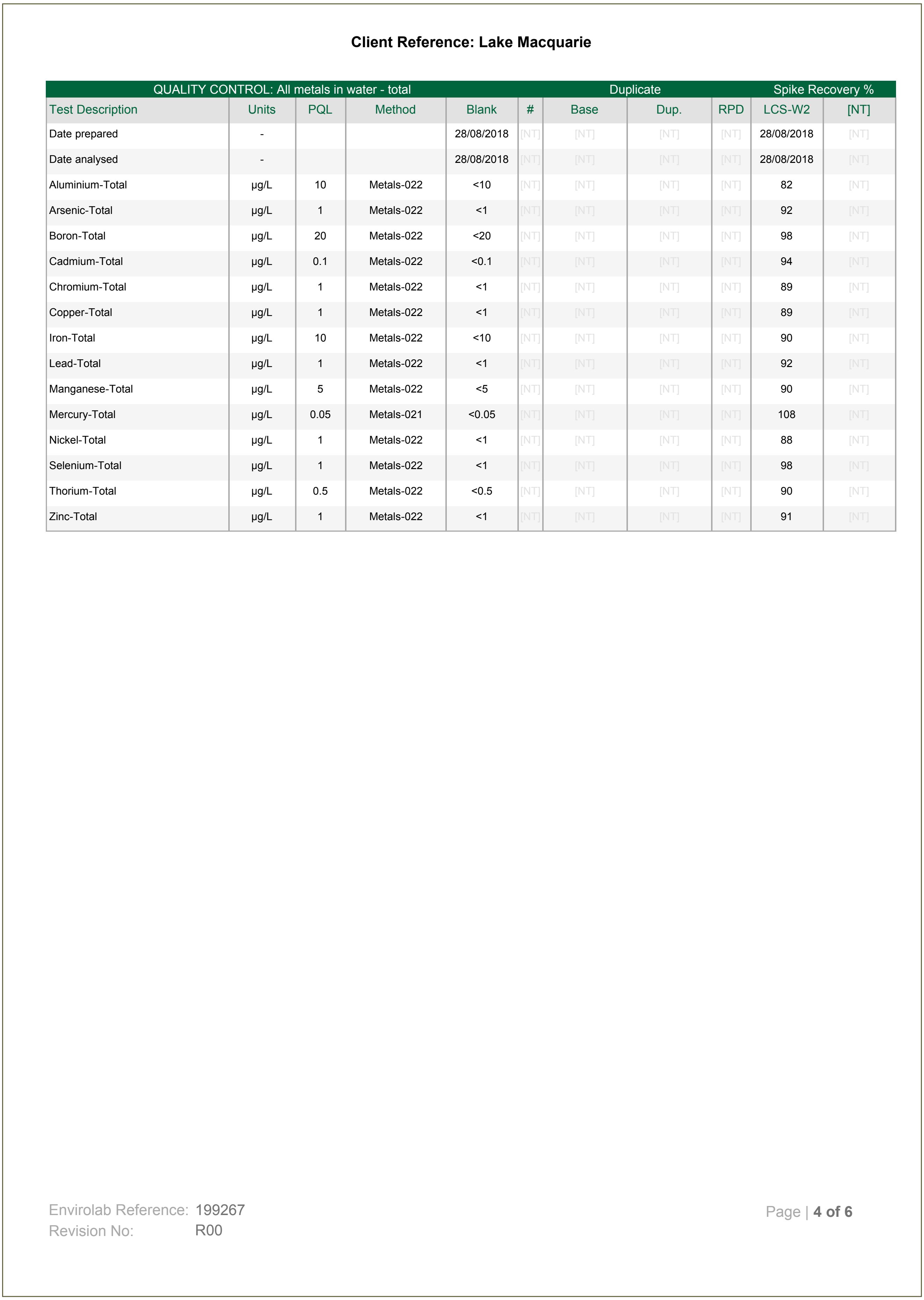
All metals in water - total			
Our Reference		199267-1	199267-2
Your Reference	UNITS	VP 22/8 1	VP 22/8 2
Date Sampled		22/08/2018	22/08/2018
Type of sample		Water	Sediment
Date prepared	-	28/08/2018	28/08/2018
Date analysed	-	28/08/2018	28/08/2018
Aluminium-Total	μg/L	350	760,000
Arsenic-Total	μg/L	2	1,200
Boron-Total	μg/L	5,100	13,000
Cadmium-Total	μg/L	0.3	200
Chromium-Total	μg/L	2	5,400
Copper-Total	μg/L	3	5,200
Iron-Total	μg/L	460	1,800,000
Lead-Total	μg/L	<1	2,200
Manganese-Total	μg/L	13	15,000
Mercury-Total	μg/L	<0.05	9.2
Nickel-Total	μg/L	<1	840
Selenium-Total	μg/L	2	1,100
Thorium-Total	μg/L	<0.5	180
Zinc-Total	μg/L	9	12,000

Envirolab Reference: 199267
Revision No: R00

Page | **2 of 6**

Client Reference: Lake Macquarie

Method ID	Methodology Summary
Metals-021	Determination of Mercury by Cold Vapour AAS.
Metals-022	Determination of various metals by ICP-MS.



Client Reference: Lake Macquarie

QUALITY CONTROL: All metals in water - total					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W2	[NT]
Date prepared	-			28/08/2018	[NT]	[NT]	[NT]	[NT]	28/08/2018	[NT]
Date analysed	-			28/08/2018	[NT]	[NT]	[NT]	[NT]	28/08/2018	[NT]
Aluminium-Total	µg/L	10	Metals-022	<10	[NT]	[NT]	[NT]	[NT]	82	[NT]
Arsenic-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	92	[NT]
Boron-Total	µg/L	20	Metals-022	<20	[NT]	[NT]	[NT]	[NT]	98	[NT]
Cadmium-Total	µg/L	0.1	Metals-022	<0.1	[NT]	[NT]	[NT]	[NT]	94	[NT]
Chromium-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	89	[NT]
Copper-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	89	[NT]
Iron-Total	µg/L	10	Metals-022	<10	[NT]	[NT]	[NT]	[NT]	90	[NT]
Lead-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	92	[NT]
Manganese-Total	µg/L	5	Metals-022	<5	[NT]	[NT]	[NT]	[NT]	90	[NT]
Mercury-Total	µg/L	0.05	Metals-021	<0.05	[NT]	[NT]	[NT]	[NT]	108	[NT]
Nickel-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	88	[NT]
Selenium-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	98	[NT]
Thorium-Total	µg/L	0.5	Metals-022	<0.5	[NT]	[NT]	[NT]	[NT]	90	[NT]
Zinc-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	91	[NT]

Client Reference: Lake Macquarie

Result Definitions	
NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Quality Control Definitions	
Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.

Client Reference: Lake Macquarie

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

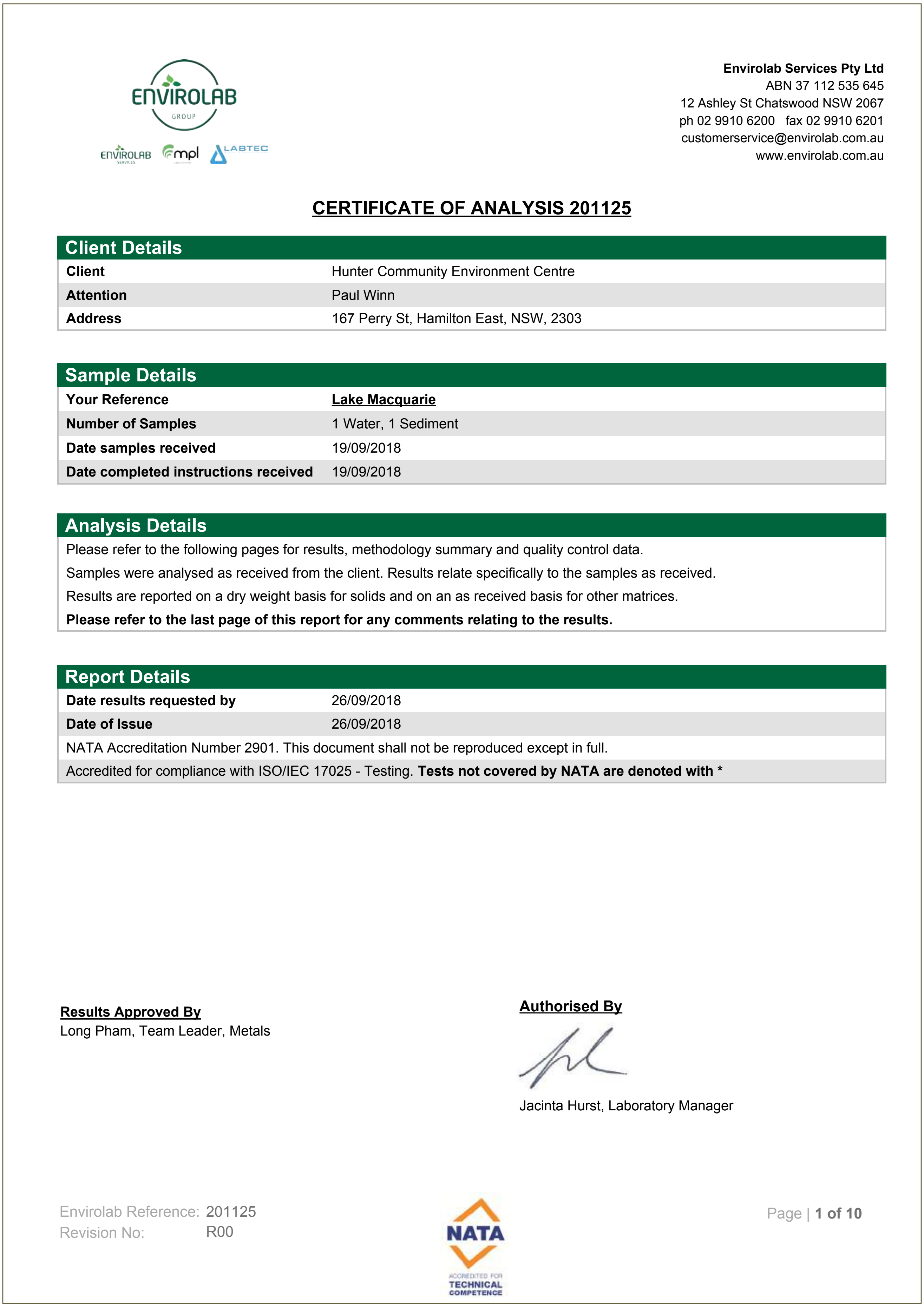
Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.



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CERTIFICATE OF ANALYSIS 201125

Client Details

Client	Hunter Community Environment Centre
Attention	Paul Winn
Address	167 Perry St, Hamilton East, NSW, 2303

Sample Details

Your Reference	Lake Macquarie
Number of Samples	1 Water, 1 Sediment
Date samples received	19/09/2018
Date completed instructions received	19/09/2018

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Please refer to the last page of this report for any comments relating to the results.

Report Details

Date results requested by	26/09/2018
Date of Issue	26/09/2018

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Results Approved By
Long Pham, Team Leader, Metals

Authorised By

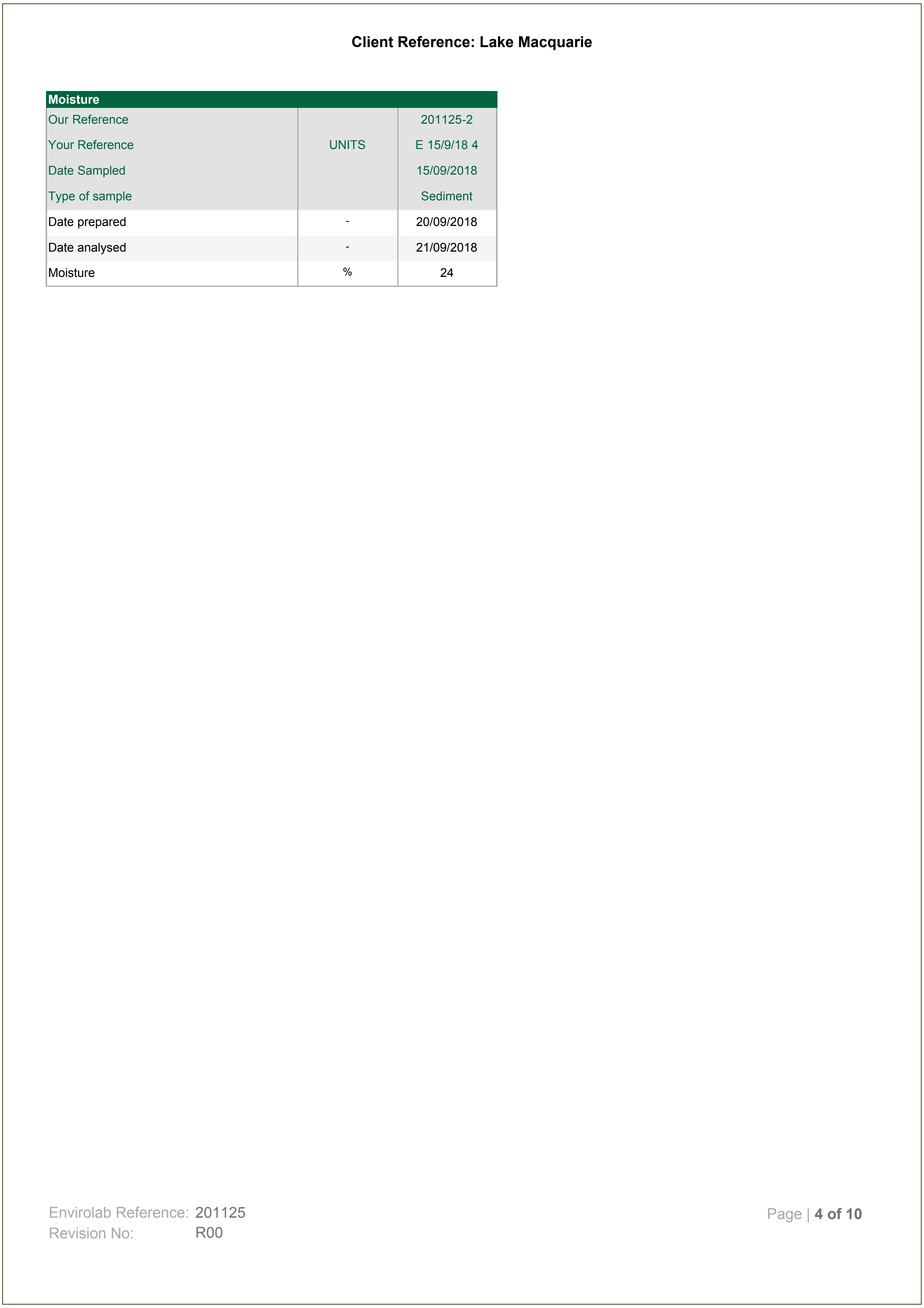
Jacinta Hurst, Laboratory Manager

Client Reference: Lake Macquarie

All metals in water - total		
Our Reference		201125-1
Your Reference	UNITS	VP 15/9/18 3
Date Sampled		15/09/2018
Type of sample		Water
Date prepared	-	20/09/2018
Date analysed	-	20/09/2018
Aluminium-Total	µg/L	290
Arsenic-Total	µg/L	4
Boron-Total	µg/L	5,200
Cadmium-Total	µg/L	0.6
Chromium-Total	µg/L	6
Copper-Total	µg/L	6
Iron-Total	µg/L	400
Lead-Total	µg/L	2
Manganese-Total	µg/L	29
Mercury-Total	µg/L	<0.05
Nickel-Total	µg/L	3
Selenium-Total	µg/L	5
Thallium-Total	µg/L	2
Zinc-Total	µg/L	9

Client Reference: Lake Macquarie

Total Metals in solid material		
Our Reference		201125-2
Your Reference	UNITS	E 15/9/18 4
Date Sampled		15/09/2018
Type of sample		Sediment
Date prepared	-	20/09/2018
Date analysed	-	20/09/2018
Aluminium	mg/kg	900
Arsenic	mg/kg	<4
Boron	mg/kg	20
Cadmium	mg/kg	<0.4
Chromium	mg/kg	1
Copper	mg/kg	5
Iron	mg/kg	1,900
Lead	mg/kg	2
Manganese	mg/kg	11
Mercury	mg/kg	<0.1
Nickel	mg/kg	1
Selenium	mg/kg	<2
Thallium	mg/kg	<2
Zinc	mg/kg	12

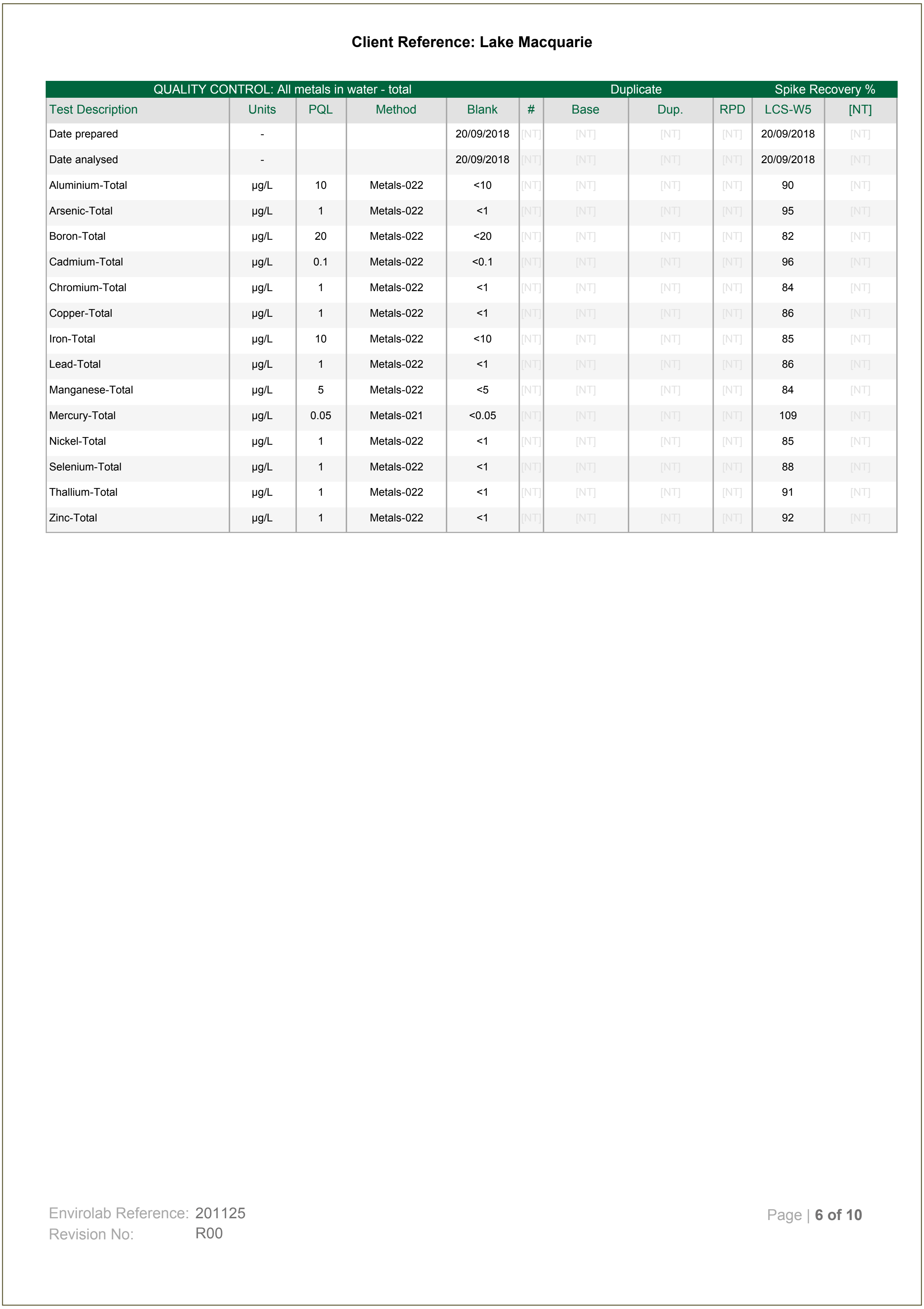


Client Reference: Lake Macquarie

Moisture		
Our Reference		201125-2
Your Reference	UNITS	E 15/9/18 4
Date Sampled		15/09/2018
Type of sample		Sediment
Date prepared	-	20/09/2018
Date analysed	-	21/09/2018
Moisture	%	24

Client Reference: Lake Macquarie

Method ID	Methodology Summary
Inorg-008	Moisture content determined by heating at 105+/-5 °C for a minimum of 12 hours.
Metals-020	Determination of various metals by ICP-AES.
Metals-021	Determination of Mercury by Cold Vapour AAS.
Metals-022	Determination of various metals by ICP-MS.

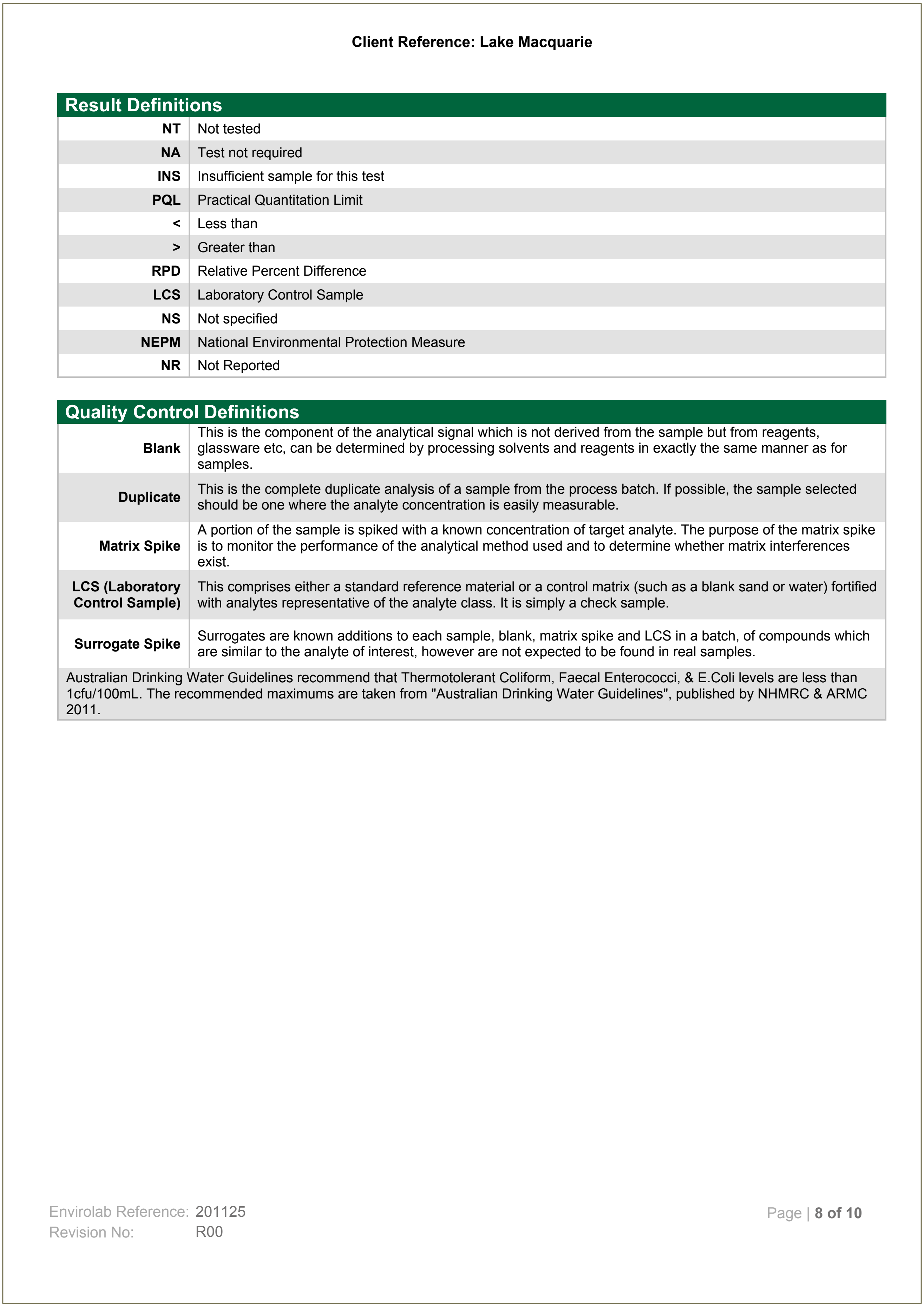


Client Reference: Lake Macquarie

QUALITY CONTROL: All metals in water - total					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W5	[NT]
Date prepared	-			20/09/2018	[NT]	[NT]	[NT]	[NT]	20/09/2018	[NT]
Date analysed	-			20/09/2018	[NT]	[NT]	[NT]	[NT]	20/09/2018	[NT]
Aluminium-Total	µg/L	10	Metals-022	<10	[NT]	[NT]	[NT]	[NT]	90	[NT]
Arsenic-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	95	[NT]
Boron-Total	µg/L	20	Metals-022	<20	[NT]	[NT]	[NT]	[NT]	82	[NT]
Cadmium-Total	µg/L	0.1	Metals-022	<0.1	[NT]	[NT]	[NT]	[NT]	96	[NT]
Chromium-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	84	[NT]
Copper-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	86	[NT]
Iron-Total	µg/L	10	Metals-022	<10	[NT]	[NT]	[NT]	[NT]	85	[NT]
Lead-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	86	[NT]
Manganese-Total	µg/L	5	Metals-022	<5	[NT]	[NT]	[NT]	[NT]	84	[NT]
Mercury-Total	µg/L	0.05	Metals-021	<0.05	[NT]	[NT]	[NT]	[NT]	109	[NT]
Nickel-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	85	[NT]
Selenium-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	88	[NT]
Thallium-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	91	[NT]
Zinc-Total	µg/L	1	Metals-022	<1	[NT]	[NT]	[NT]	[NT]	92	[NT]

Client Reference: Lake Macquarie

QUALITY CONTROL: Total Metals in solid material					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-4	[NT]
Date prepared	-			20/09/2018	[NT]	[NT]	[NT]	[NT]	20/09/2018	[NT]
Date analysed	-			20/09/2018	[NT]	[NT]	[NT]	[NT]	20/09/2018	[NT]
Aluminium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	113	[NT]
Arsenic	mg/kg	4	Metals-020	<4	[NT]	[NT]	[NT]	[NT]	114	[NT]
Boron	mg/kg	3	Metals-020	<3	[NT]	[NT]	[NT]	[NT]	116	[NT]
Cadmium	mg/kg	0.4	Metals-020	<0.4	[NT]	[NT]	[NT]	[NT]	106	[NT]
Chromium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	112	[NT]
Copper	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	119	[NT]
Iron	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	117	[NT]
Lead	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	110	[NT]
Manganese	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	109	[NT]
Mercury	mg/kg	0.1	Metals-021	<0.1	[NT]	[NT]	[NT]	[NT]	93	[NT]
Nickel	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	110	[NT]
Selenium	mg/kg	2	Metals-020	<2	[NT]	[NT]	[NT]	[NT]	106	[NT]
Thallium	mg/kg	2	Metals-020	<2	[NT]	[NT]	[NT]	[NT]	106	[NT]
Zinc	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	106	[NT]



Client Reference: Lake Macquarie

Result Definitions

NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.
Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.	

Envirolab Reference: 201125
Revision No: R00

Page | **8 of 10**

Client Reference: Lake Macquarie

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

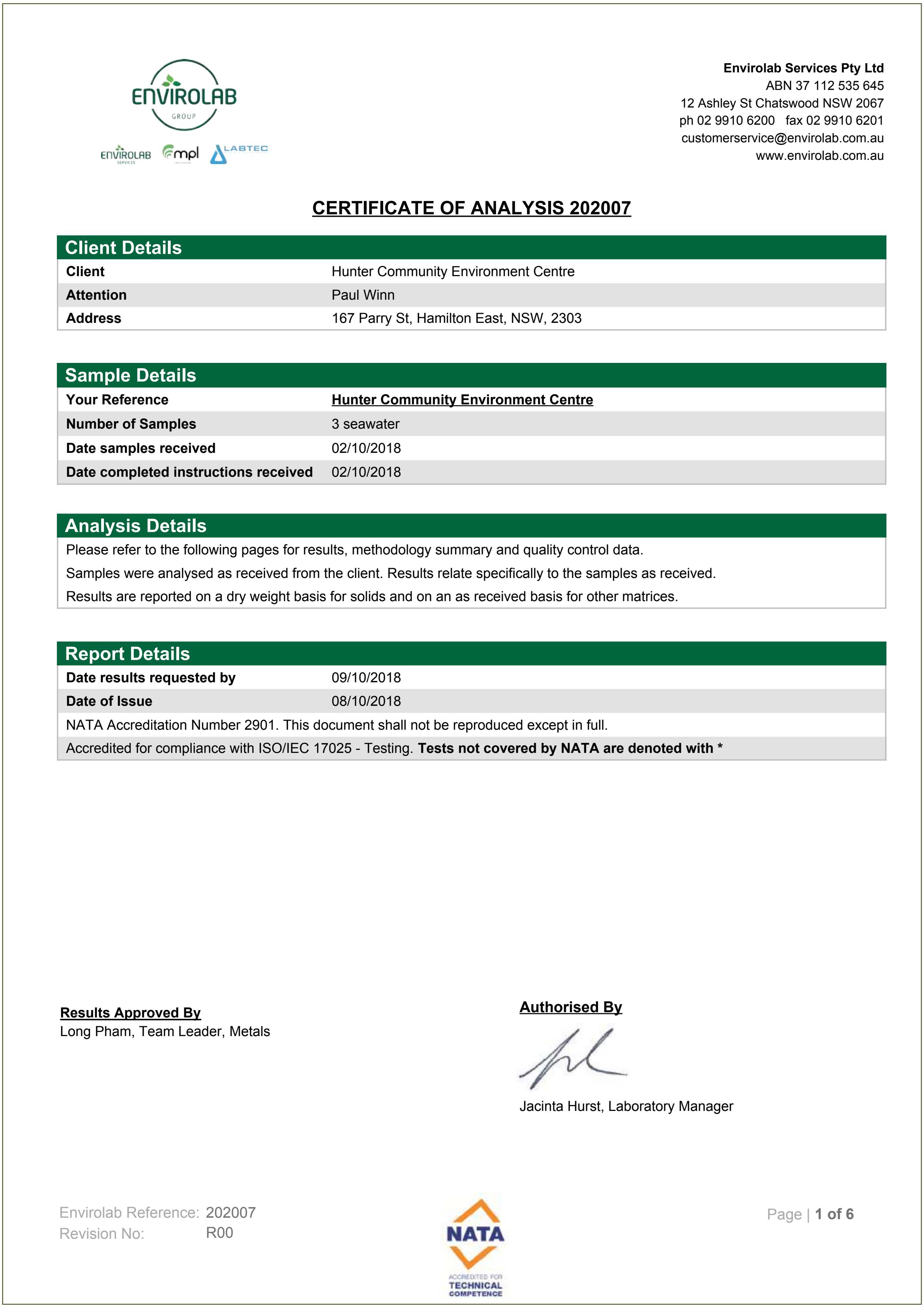
Measurement Uncertainty estimates are available for most tests upon request.

Client Reference: Lake Macquarie

Report Comments

Total metals: no preserved sample was received, therefore analysis was conducted from the unpreserved sample bottle.

Note: there is a possibility some elements may be underestimated.



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CERTIFICATE OF ANALYSIS 202007

Client Details

Client	Hunter Community Environment Centre
Attention	Paul Winn
Address	167 Parry St, Hamilton East, NSW, 2303

Sample Details

Your Reference	**Hunter Community Environment Centre**
Number of Samples	3 seawater
Date samples received	02/10/2018
Date completed instructions received	02/10/2018

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date results requested by	09/10/2018
Date of Issue	08/10/2018

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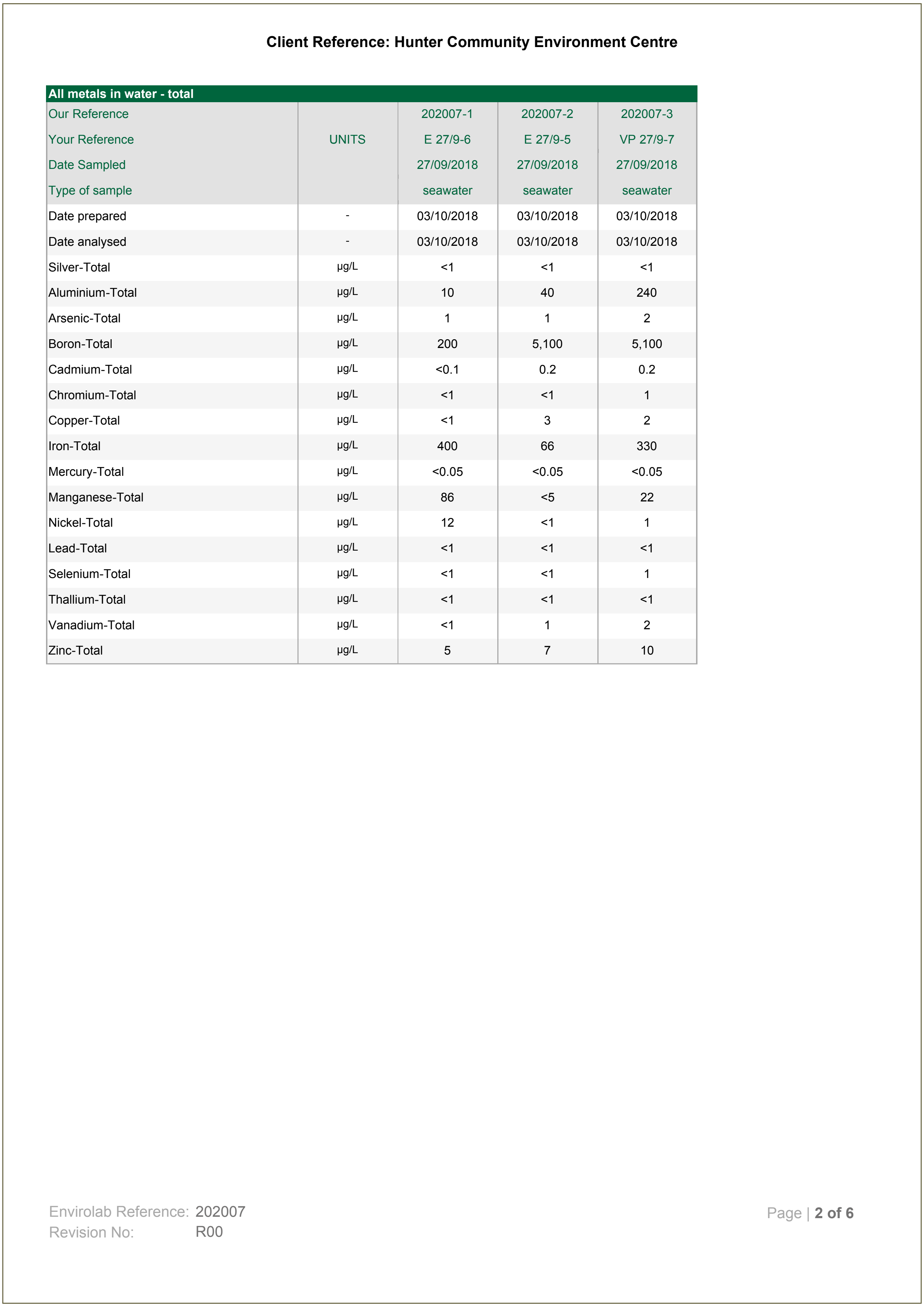
Results Approved By
Long Pham, Team Leader, Metals

Authorised By

Jacinta Hurst, Laboratory Manager

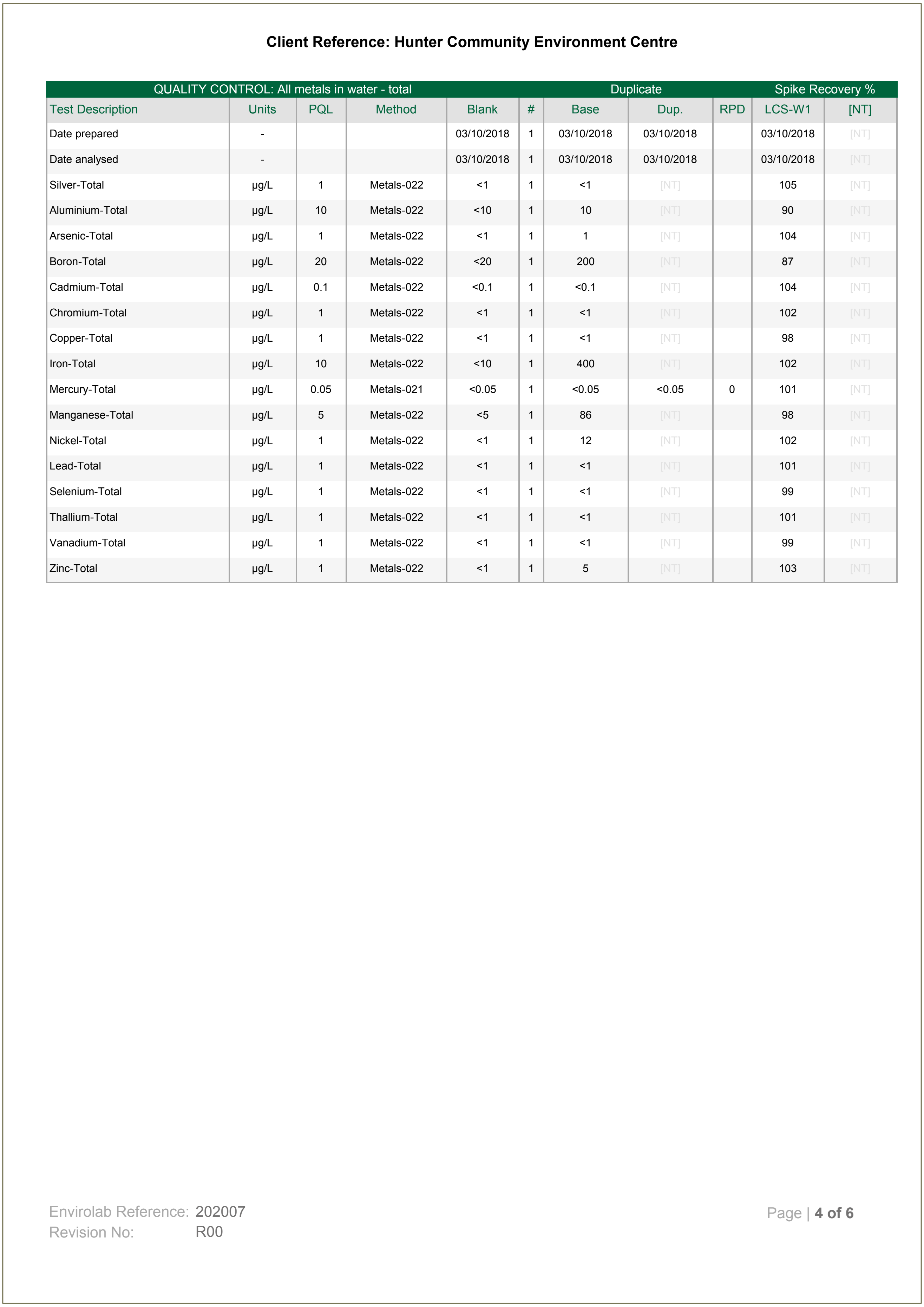


Client Reference: Hunter Community Environment Centre

All metals in water - total				
Our Reference		202007-1	202007-2	202007-3
Your Reference	UNITS	E 27/9-6	E 27/9-5	VP 27/9-7
Date Sampled		27/09/2018	27/09/2018	27/09/2018
Type of sample		seawater	seawater	seawater
Date prepared	-	03/10/2018	03/10/2018	03/10/2018
Date analysed	-	03/10/2018	03/10/2018	03/10/2018
Silver-Total	µg/L	<1	<1	<1
Aluminium-Total	µg/L	10	40	240
Arsenic-Total	µg/L	1	1	2
Boron-Total	µg/L	200	5,100	5,100
Cadmium-Total	µg/L	<0.1	0.2	0.2
Chromium-Total	µg/L	<1	<1	1
Copper-Total	µg/L	<1	3	2
Iron-Total	µg/L	400	66	330
Mercury-Total	µg/L	<0.05	<0.05	<0.05
Manganese-Total	µg/L	86	<5	22
Nickel-Total	µg/L	12	<1	1
Lead-Total	µg/L	<1	<1	<1
Selenium-Total	µg/L	<1	<1	1
Thallium-Total	µg/L	<1	<1	<1
Vanadium-Total	µg/L	<1	1	2
Zinc-Total	µg/L	5	7	10

Client Reference: Hunter Community Environment Centre

Method ID	Methodology Summary
Metals-021	Determination of Mercury by Cold Vapour AAS.
Metals-022	Determination of various metals by ICP-MS.



Client Reference: Hunter Community Environment Centre

QUALITY CONTROL: All metals in water - total					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W1	[NT]
Date prepared	-			03/10/2018	1	03/10/2018	03/10/2018		03/10/2018	[NT]
Date analysed	-			03/10/2018	1	03/10/2018	03/10/2018		03/10/2018	[NT]
Silver-Total	µg/L	1	Metals-022	<1	1	<1	[NT]		105	[NT]
Aluminium-Total	µg/L	10	Metals-022	<10	1	10	[NT]		90	[NT]
Arsenic-Total	µg/L	1	Metals-022	<1	1	1	[NT]		104	[NT]
Boron-Total	µg/L	20	Metals-022	<20	1	200	[NT]		87	[NT]
Cadmium-Total	µg/L	0.1	Metals-022	<0.1	1	<0.1	[NT]		104	[NT]
Chromium-Total	µg/L	1	Metals-022	<1	1	<1	[NT]		102	[NT]
Copper-Total	µg/L	1	Metals-022	<1	1	<1	[NT]		98	[NT]
Iron-Total	µg/L	10	Metals-022	<10	1	400	[NT]		102	[NT]
Mercury-Total	µg/L	0.05	Metals-021	<0.05	1	<0.05	<0.05	0	101	[NT]
Manganese-Total	µg/L	5	Metals-022	<5	1	86	[NT]		98	[NT]
Nickel-Total	µg/L	1	Metals-022	<1	1	12	[NT]		102	[NT]
Lead-Total	µg/L	1	Metals-022	<1	1	<1	[NT]		101	[NT]
Selenium-Total	µg/L	1	Metals-022	<1	1	<1	[NT]		99	[NT]
Thallium-Total	µg/L	1	Metals-022	<1	1	<1	[NT]		101	[NT]
Vanadium-Total	µg/L	1	Metals-022	<1	1	<1	[NT]		99	[NT]
Zinc-Total	µg/L	1	Metals-022	<1	1	5	[NT]		103	[NT]

Client Reference: Hunter Community Environment Centre

Result Definitions

NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
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Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.

Client Reference: Hunter Community Environment Centre

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

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Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

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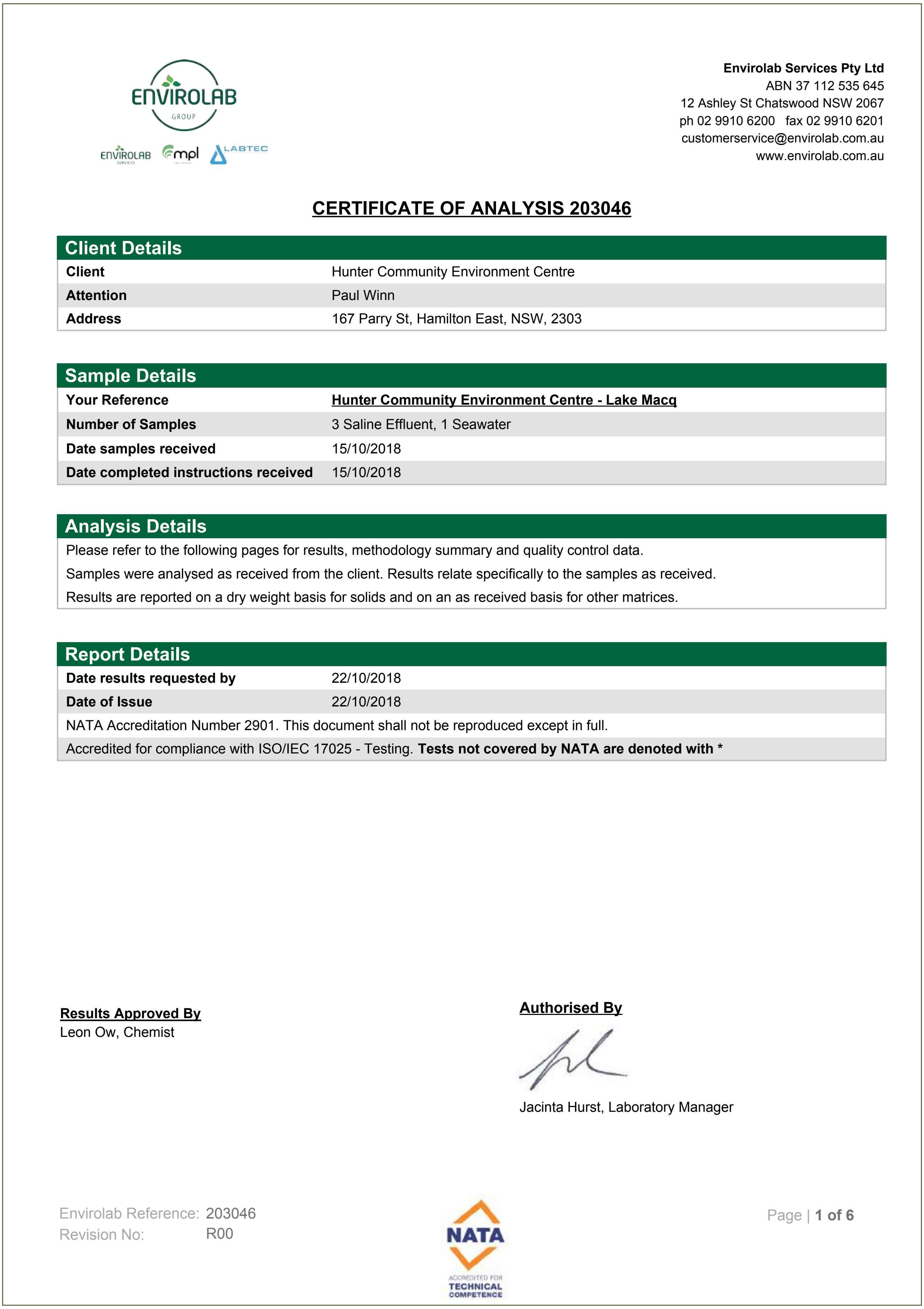

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CERTIFICATE OF ANALYSIS 203046

Client Details

Client	Hunter Community Environment Centre
Attention	Paul Winn
Address	167 Parry St, Hamilton East, NSW, 2303

Sample Details

Your Reference	**Hunter Community Environment Centre - Lake Macq**
Number of Samples	3 Saline Effluent, 1 Seawater
Date samples received	15/10/2018
Date completed instructions received	15/10/2018

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date results requested by	22/10/2018
Date of Issue	22/10/2018

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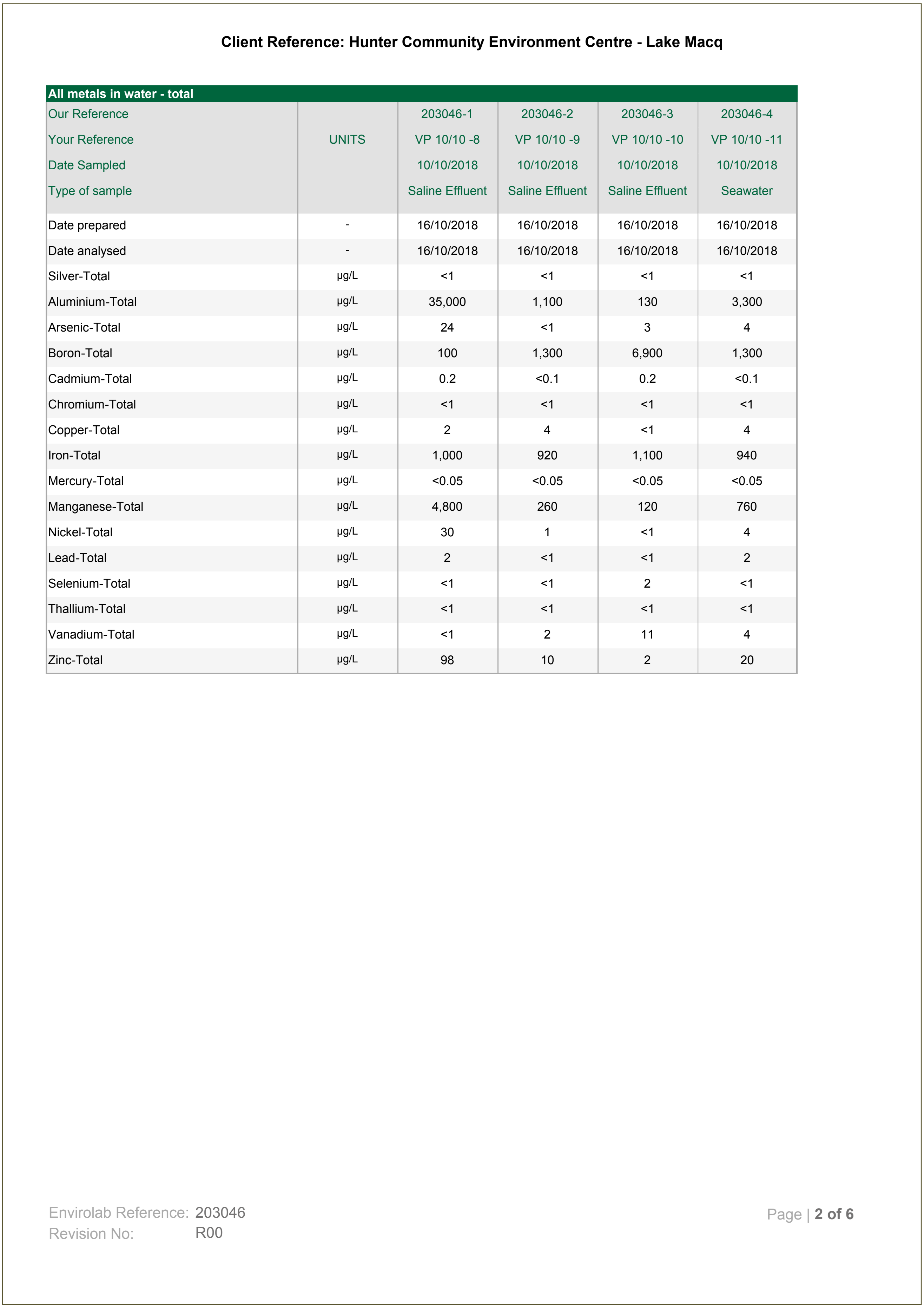
Results Approved By
Leon Ow, Chemist

Authorised By

Jacinta Hurst, Laboratory Manager



Client Reference: Hunter Community Environment Centre - Lake Macq

All metals in water - total					
Our Reference		203046-1	203046-2	203046-3	203046-4
Your Reference	UNITS	VP 10/10 -8	VP 10/10 -9	VP 10/10 -10	VP 10/10 -11
Date Sampled		10/10/2018	10/10/2018	10/10/2018	10/10/2018
Type of sample		Saline Effluent	Saline Effluent	Saline Effluent	Seawater
Date prepared	-	16/10/2018	16/10/2018	16/10/2018	16/10/2018
Date analysed	-	16/10/2018	16/10/2018	16/10/2018	16/10/2018
Silver-Total	µg/L	<1	<1	<1	<1
Aluminium-Total	µg/L	35,000	1,100	130	3,300
Arsenic-Total	µg/L	24	<1	3	4
Boron-Total	µg/L	100	1,300	6,900	1,300
Cadmium-Total	µg/L	0.2	<0.1	0.2	<0.1
Chromium-Total	µg/L	<1	<1	<1	<1
Copper-Total	µg/L	2	4	<1	4
Iron-Total	µg/L	1,000	920	1,100	940
Mercury-Total	µg/L	<0.05	<0.05	<0.05	<0.05
Manganese-Total	µg/L	4,800	260	120	760
Nickel-Total	µg/L	30	1	<1	4
Lead-Total	µg/L	2	<1	<1	2
Selenium-Total	µg/L	<1	<1	2	<1
Thallium-Total	µg/L	<1	<1	<1	<1
Vanadium-Total	µg/L	<1	2	11	4
Zinc-Total	µg/L	98	10	2	20

Client Reference: Hunter Community Environment Centre - Lake Macq

Method ID	Methodology Summary
Metals-021	Determination of Mercury by Cold Vapour AAS.
Metals-022	Determination of various metals by ICP-MS.

Client Reference: Hunter Community Environment Centre - Lake Macq

QUALITY CONTROL: All metals in water - total						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W3	[NT]
Date prepared	-			16/10/2018	1	16/10/2018	16/10/2018		16/10/2018	[NT]
Date analysed	-			16/10/2018	1	16/10/2018	16/10/2018		16/10/2018	[NT]
Silver-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	96	[NT]
Aluminium-Total	µg/L	10	Metals-022	<10	1	35000	34000	3	107	[NT]
Arsenic-Total	µg/L	1	Metals-022	<1	1	24	24	0	100	[NT]
Boron-Total	µg/L	20	Metals-022	<20	1	100	100	0	83	[NT]
Cadmium-Total	µg/L	0.1	Metals-022	<0.1	1	0.2	0.2	0	96	[NT]
Chromium-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	96	[NT]
Copper-Total	µg/L	1	Metals-022	<1	1	2	2	0	93	[NT]
Iron-Total	µg/L	10	Metals-022	<10	1	1000	990	1	101	[NT]
Mercury-Total	µg/L	0.05	Metals-021	<0.05	1	<0.05	[NT]		101	[NT]
Manganese-Total	µg/L	5	Metals-022	<5	1	4800	4800	0	98	[NT]
Nickel-Total	µg/L	1	Metals-022	<1	1	30	30	0	100	[NT]
Lead-Total	µg/L	1	Metals-022	<1	1	2	2	0	100	[NT]
Selenium-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	94	[NT]
Thallium-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	97	[NT]
Vanadium-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	101	[NT]
Zinc-Total	µg/L	1	Metals-022	<1	1	98	94	4	95	[NT]

QUALITY CONTROL: All metals in water - total						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	[NT]	[NT]
Date prepared	-			[NT]	2	16/10/2018	16/10/2018		[NT]	[NT]
Date analysed	-			[NT]	2	16/10/2018	16/10/2018		[NT]	[NT]
Silver-Total	µg/L	1	Metals-022	[NT]	2	<1	[NT]		[NT]	[NT]
Aluminium-Total	µg/L	10	Metals-022	[NT]	2	1100	[NT]		[NT]	[NT]
Arsenic-Total	µg/L	1	Metals-022	[NT]	2	<1	[NT]		[NT]	[NT]
Boron-Total	µg/L	20	Metals-022	[NT]	2	1300	[NT]		[NT]	[NT]
Cadmium-Total	µg/L	0.1	Metals-022	[NT]	2	<0.1	[NT]		[NT]	[NT]
Chromium-Total	µg/L	1	Metals-022	[NT]	2	<1	[NT]		[NT]	[NT]
Copper-Total	µg/L	1	Metals-022	[NT]	2	4	[NT]		[NT]	[NT]
Iron-Total	µg/L	10	Metals-022	[NT]	2	920	[NT]		[NT]	[NT]
Mercury-Total	µg/L	0.05	Metals-021	[NT]	2	<0.05	<0.05	0	[NT]	[NT]
Manganese-Total	µg/L	5	Metals-022	[NT]	2	260	[NT]		[NT]	[NT]
Nickel-Total	µg/L	1	Metals-022	[NT]	2	1	[NT]		[NT]	[NT]
Lead-Total	µg/L	1	Metals-022	[NT]	2	<1	[NT]		[NT]	[NT]
Selenium-Total	µg/L	1	Metals-022	[NT]	2	<1	[NT]		[NT]	[NT]
Thallium-Total	µg/L	1	Metals-022	[NT]	2	<1	[NT]		[NT]	[NT]
Vanadium-Total	µg/L	1	Metals-022	[NT]	2	2	[NT]		[NT]	[NT]
Zinc-Total	µg/L	1	Metals-022	[NT]	2	10	[NT]		[NT]	[NT]

Client Reference: Hunter Community Environment Centre - Lake Macq

Result Definitions

NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
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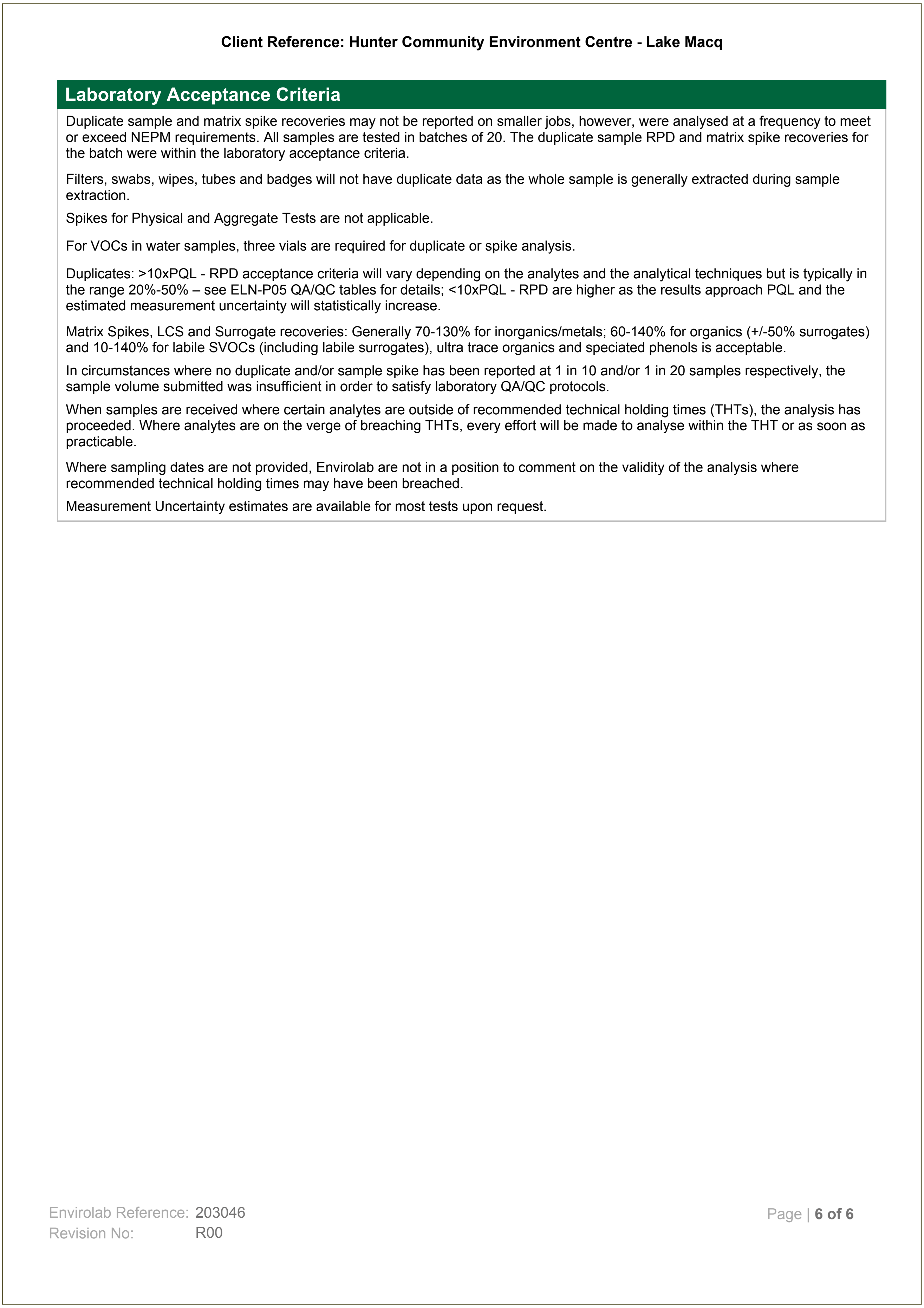
Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.



Client Reference: Hunter Community Environment Centre - Lake Macq

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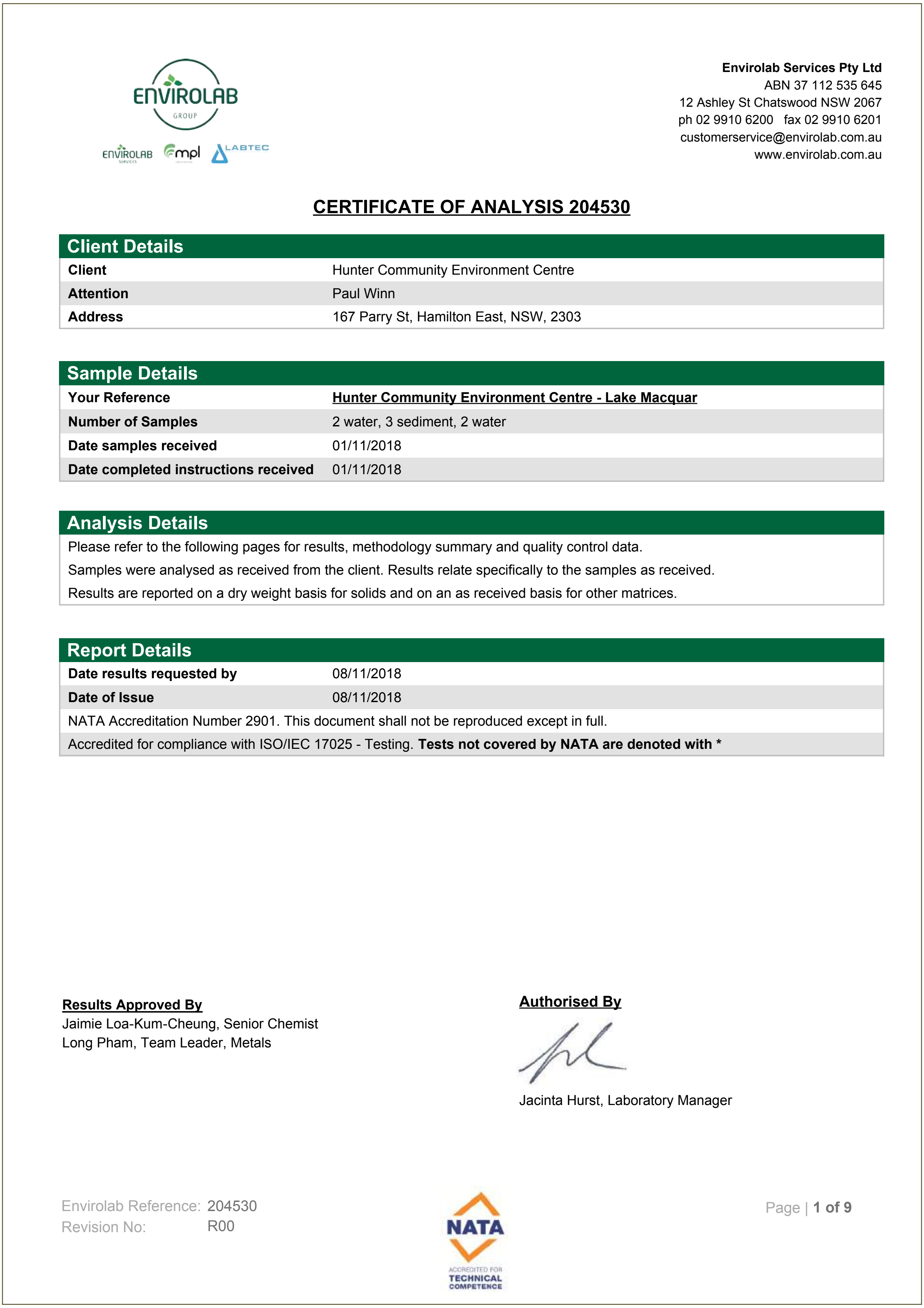
Measurement Uncertainty estimates are available for most tests upon request.



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customerservice@envirolab.com.au
www.envirolab.com.au

CERTIFICATE OF ANALYSIS 204530

Client Details

Client	Hunter Community Environment Centre
Attention	Paul Winn
Address	167 Parry St, Hamilton East, NSW, 2303

Sample Details

Your Reference	**Hunter Community Environment Centre - Lake Macquar**
Number of Samples	2 water, 3 sediment, 2 water
Date samples received	01/11/2018
Date completed instructions received	01/11/2018

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date results requested by	08/11/2018
Date of Issue	08/11/2018

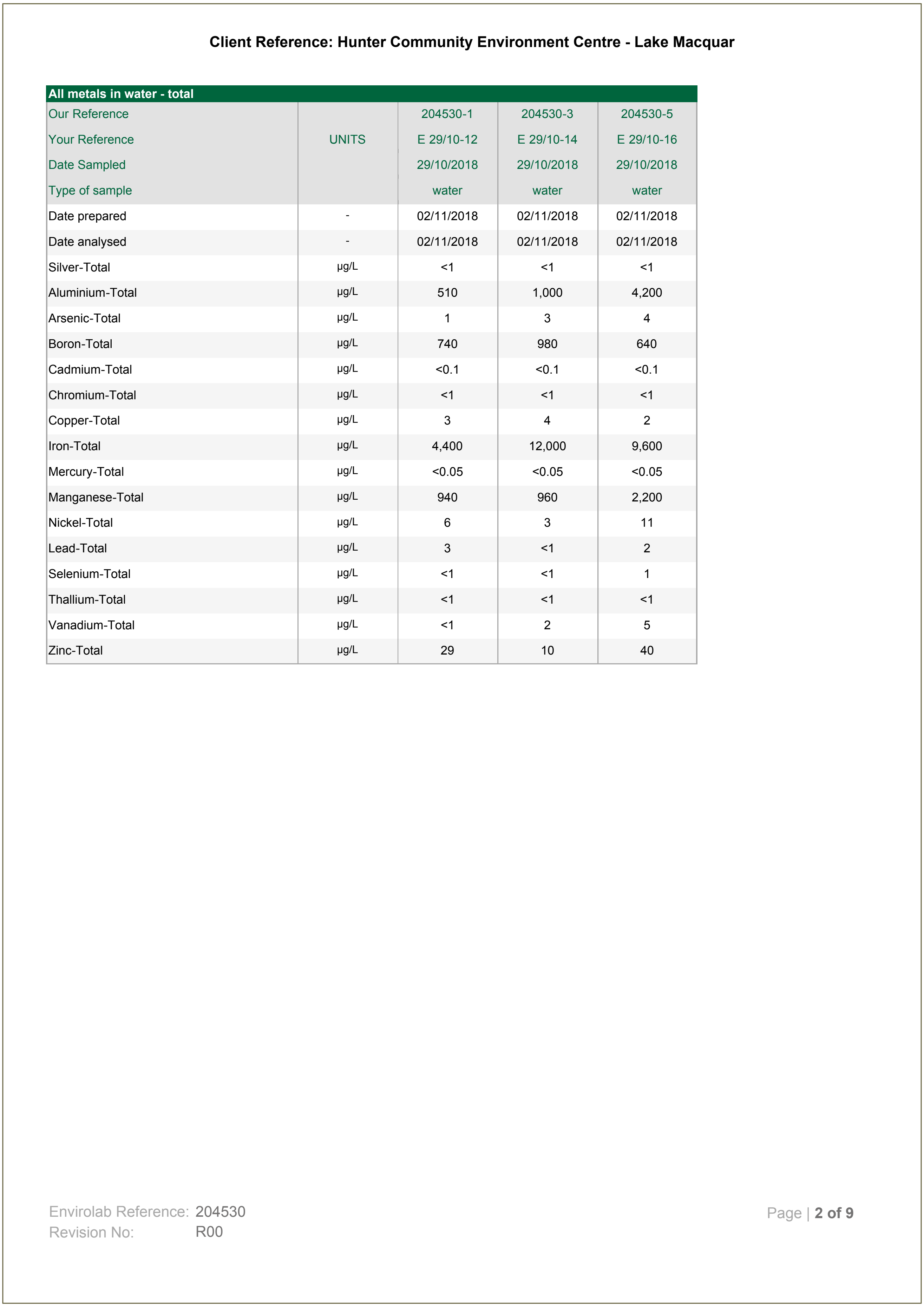
NATA Accreditation Number 2901. This document shall not be reproduced except in full.

Accredited for compliance with ISO/IEC 17025 - Testing. **Tests not covered by NATA are denoted with ***

Results Approved By
Jaimie Loa-Kum-Cheung, Senior Chemist
Long Pham, Team Leader, Metals

Authorised By

Jacinta Hurst, Laboratory Manager



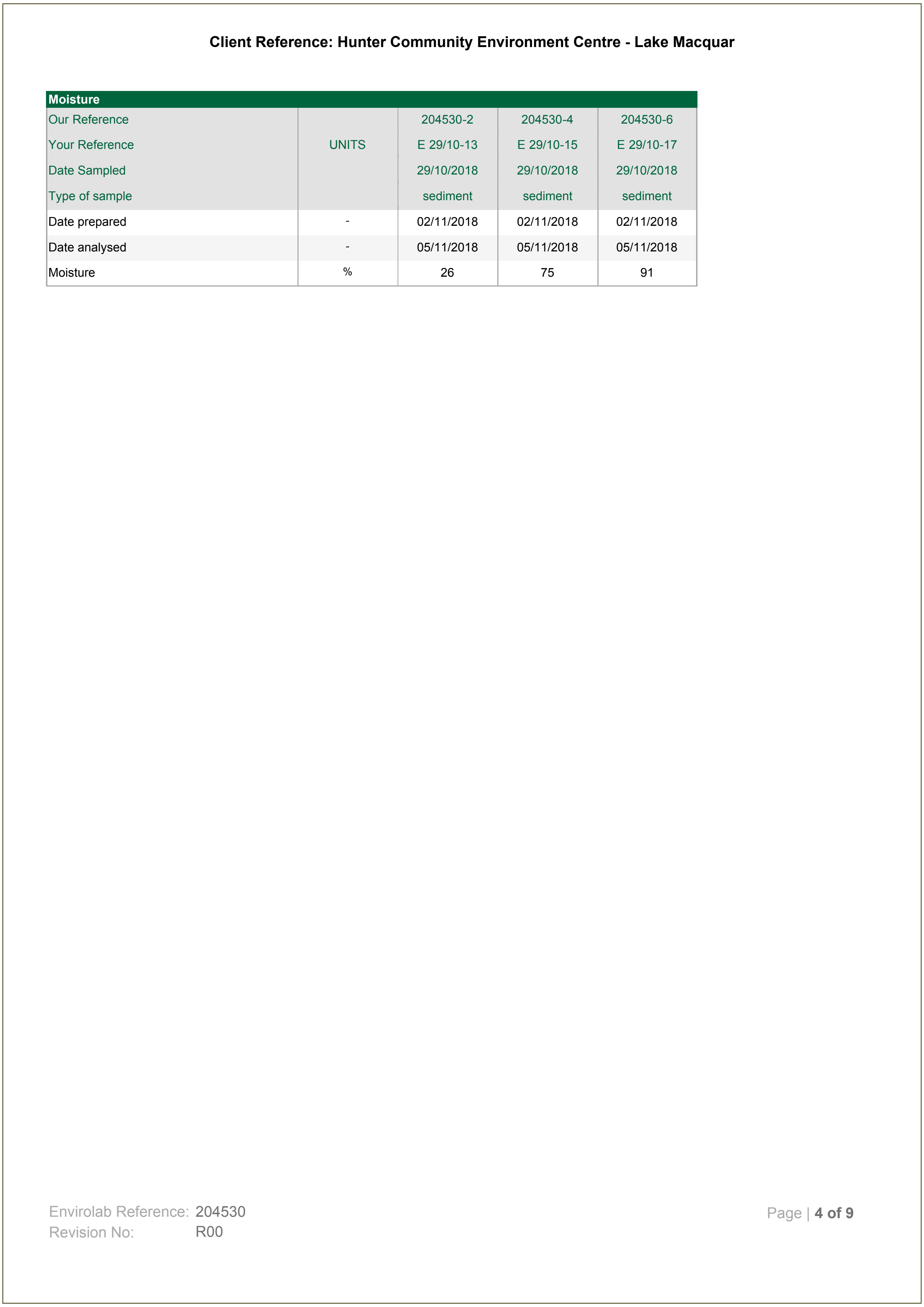
Client Reference: Hunter Community Environment Centre - Lake Macquar

All metals in water - total				
Our Reference		204530-1	204530-3	204530-5
Your Reference	UNITS	E 29/10-12	E 29/10-14	E 29/10-16
Date Sampled		29/10/2018	29/10/2018	29/10/2018
Type of sample		water	water	water
Date prepared	-	02/11/2018	02/11/2018	02/11/2018
Date analysed	-	02/11/2018	02/11/2018	02/11/2018
Silver-Total	µg/L	<1	<1	<1
Aluminium-Total	µg/L	510	1,000	4,200
Arsenic-Total	µg/L	1	3	4
Boron-Total	µg/L	740	980	640
Cadmium-Total	µg/L	<0.1	<0.1	<0.1
Chromium-Total	µg/L	<1	<1	<1
Copper-Total	µg/L	3	4	2
Iron-Total	µg/L	4,400	12,000	9,600
Mercury-Total	µg/L	<0.05	<0.05	<0.05
Manganese-Total	µg/L	940	960	2,200
Nickel-Total	µg/L	6	3	11
Lead-Total	µg/L	3	<1	2
Selenium-Total	µg/L	<1	<1	1
Thallium-Total	µg/L	<1	<1	<1
Vanadium-Total	µg/L	<1	2	5
Zinc-Total	µg/L	29	10	40

Client Reference: Hunter Community Environment Centre - Lake Macquar

Acid Extractractable metals in soil

Our Reference		204530-2	204530-4	204530-6
Your Reference	UNITS	E 29/10-13	E 29/10-15	E 29/10-17
Date Sampled		29/10/2018	29/10/2018	29/10/2018
Type of sample		sediment	sediment	sediment
Date prepared	-	02/11/2018	02/11/2018	02/11/2018
Date analysed	-	02/11/2018	02/11/2018	02/11/2018
Silver	mg/kg	<1	<1	<1
Aluminium	mg/kg	2,900	7,300	65,000
Arsenic	mg/kg	<4	7	160
Boron	mg/kg	<3	10	77
Cadmium	mg/kg	<0.4	<0.4	0.9
Chromium	mg/kg	4	7	87
Copper	mg/kg	13	13	38
Iron	mg/kg	7,500	6,800	100,000
Lead	mg/kg	36	16	29
Manganese	mg/kg	100	56	720
Mercury	mg/kg	<0.1	<0.1	<0.1
Nickel	mg/kg	4	6	42
Selenium	mg/kg	<2	6	110
Thallium	mg/kg	<2	<2	<2
Vanadium	mg/kg	10	33	580
Zinc	mg/kg	110	18	240

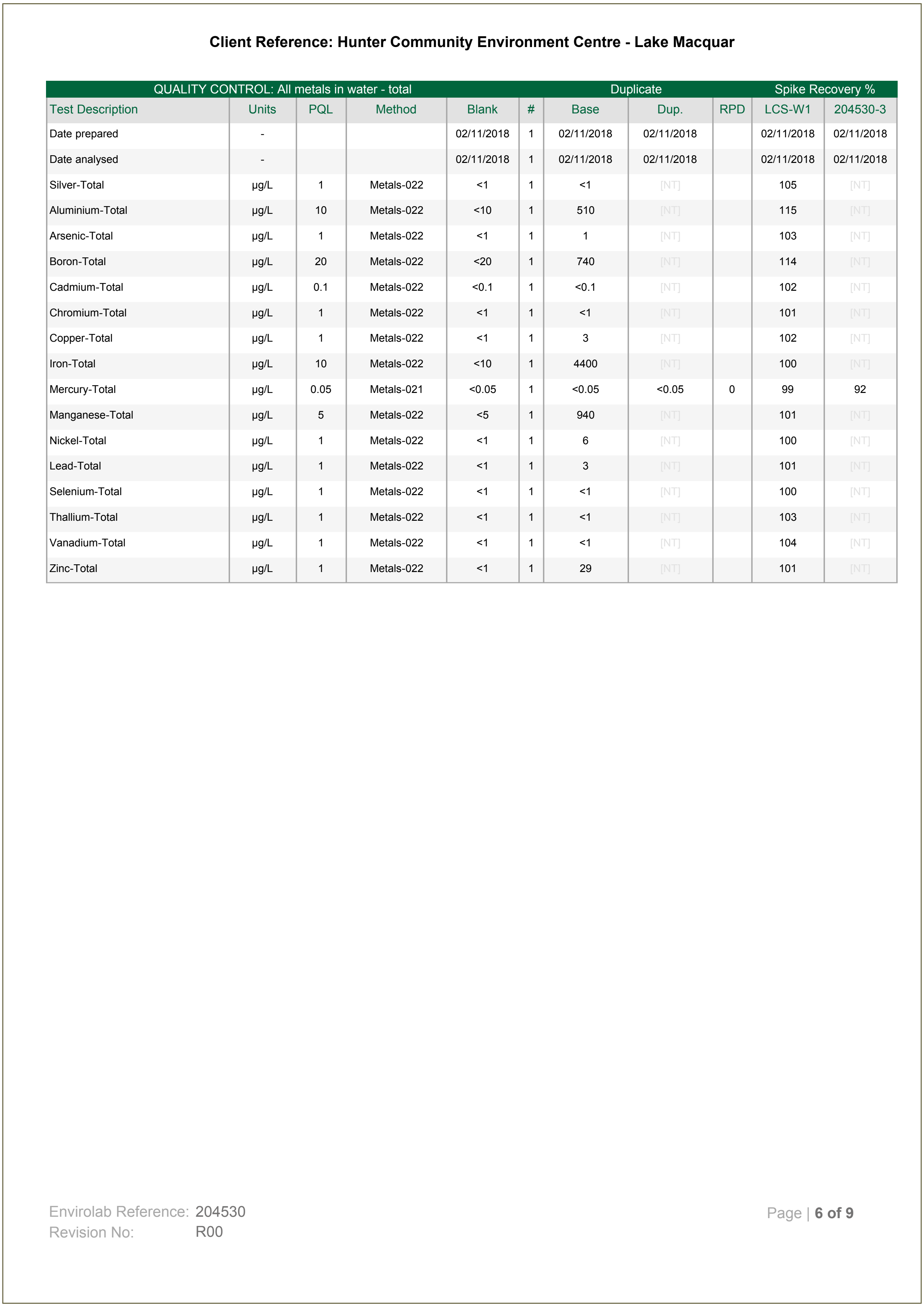


Client Reference: Hunter Community Environment Centre - Lake Macquar

Moisture				
Our Reference		204530-2	204530-4	204530-6
Your Reference	UNITS	E 29/10-13	E 29/10-15	E 29/10-17
Date Sampled		29/10/2018	29/10/2018	29/10/2018
Type of sample		sediment	sediment	sediment
Date prepared	-	02/11/2018	02/11/2018	02/11/2018
Date analysed	-	05/11/2018	05/11/2018	05/11/2018
Moisture	%	26	75	91

Client Reference: Hunter Community Environment Centre - Lake Macquar

Method ID	Methodology Summary
Inorg-008	Moisture content determined by heating at 105+/-5 °C for a minimum of 12 hours.
Metals-020	Determination of various metals by ICP-AES.
Metals-021	Determination of Mercury by Cold Vapour AAS.
Metals-022	Determination of various metals by ICP-MS.



Client Reference: Hunter Community Environment Centre - Lake Macquar

QUALITY CONTROL: All metals in water - total					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W1	204530-3
Date prepared	-			02/11/2018	1	02/11/2018	02/11/2018		02/11/2018	02/11/2018
Date analysed	-			02/11/2018	1	02/11/2018	02/11/2018		02/11/2018	02/11/2018
Silver-Total	µg/L	1	Metals-022	<1	1	<1	[NT]		105	[NT]
Aluminium-Total	µg/L	10	Metals-022	<10	1	510	[NT]		115	[NT]
Arsenic-Total	µg/L	1	Metals-022	<1	1	1	[NT]		103	[NT]
Boron-Total	µg/L	20	Metals-022	<20	1	740	[NT]		114	[NT]
Cadmium-Total	µg/L	0.1	Metals-022	<0.1	1	<0.1	[NT]		102	[NT]
Chromium-Total	µg/L	1	Metals-022	<1	1	<1	[NT]		101	[NT]
Copper-Total	µg/L	1	Metals-022	<1	1	3	[NT]		102	[NT]
Iron-Total	µg/L	10	Metals-022	<10	1	4400	[NT]		100	[NT]
Mercury-Total	µg/L	0.05	Metals-021	<0.05	1	<0.05	<0.05	0	99	92
Manganese-Total	µg/L	5	Metals-022	<5	1	940	[NT]		101	[NT]
Nickel-Total	µg/L	1	Metals-022	<1	1	6	[NT]		100	[NT]
Lead-Total	µg/L	1	Metals-022	<1	1	3	[NT]		101	[NT]
Selenium-Total	µg/L	1	Metals-022	<1	1	<1	[NT]		100	[NT]
Thallium-Total	µg/L	1	Metals-022	<1	1	<1	[NT]		103	[NT]
Vanadium-Total	µg/L	1	Metals-022	<1	1	<1	[NT]		104	[NT]
Zinc-Total	µg/L	1	Metals-022	<1	1	29	[NT]		101	[NT]

Client Reference: Hunter Community Environment Centre - Lake Macquar

QUALITY CONTROL: Acid Extractractable metals in soil						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-5	[NT]
Date prepared	-			02/11/2018	[NT]	[NT]	[NT]	[NT]	02/11/2018	[NT]
Date analysed	-			02/11/2018	[NT]	[NT]	[NT]	[NT]	02/11/2018	[NT]
Silver	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	112	[NT]
Aluminium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	105	[NT]
Arsenic	mg/kg	4	Metals-020	<4	[NT]	[NT]	[NT]	[NT]	110	[NT]
Boron	mg/kg	3	Metals-020	<3	[NT]	[NT]	[NT]	[NT]	111	[NT]
Cadmium	mg/kg	0.4	Metals-020	<0.4	[NT]	[NT]	[NT]	[NT]	98	[NT]
Chromium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	104	[NT]
Copper	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	117	[NT]
Iron	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	110	[NT]
Lead	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	103	[NT]
Manganese	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	103	[NT]
Mercury	mg/kg	0.1	Metals-021	<0.1	[NT]	[NT]	[NT]	[NT]	99	[NT]
Nickel	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	105	[NT]
Selenium	mg/kg	2	Metals-020	<2	[NT]	[NT]	[NT]	[NT]	104	[NT]
Thallium	mg/kg	2	Metals-020	<2	[NT]	[NT]	[NT]	[NT]	98	[NT]
Vanadium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	111	[NT]
Zinc	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	96	[NT]

Client Reference: Hunter Community Environment Centre - Lake Macquar

Laboratory Acceptance Criteria

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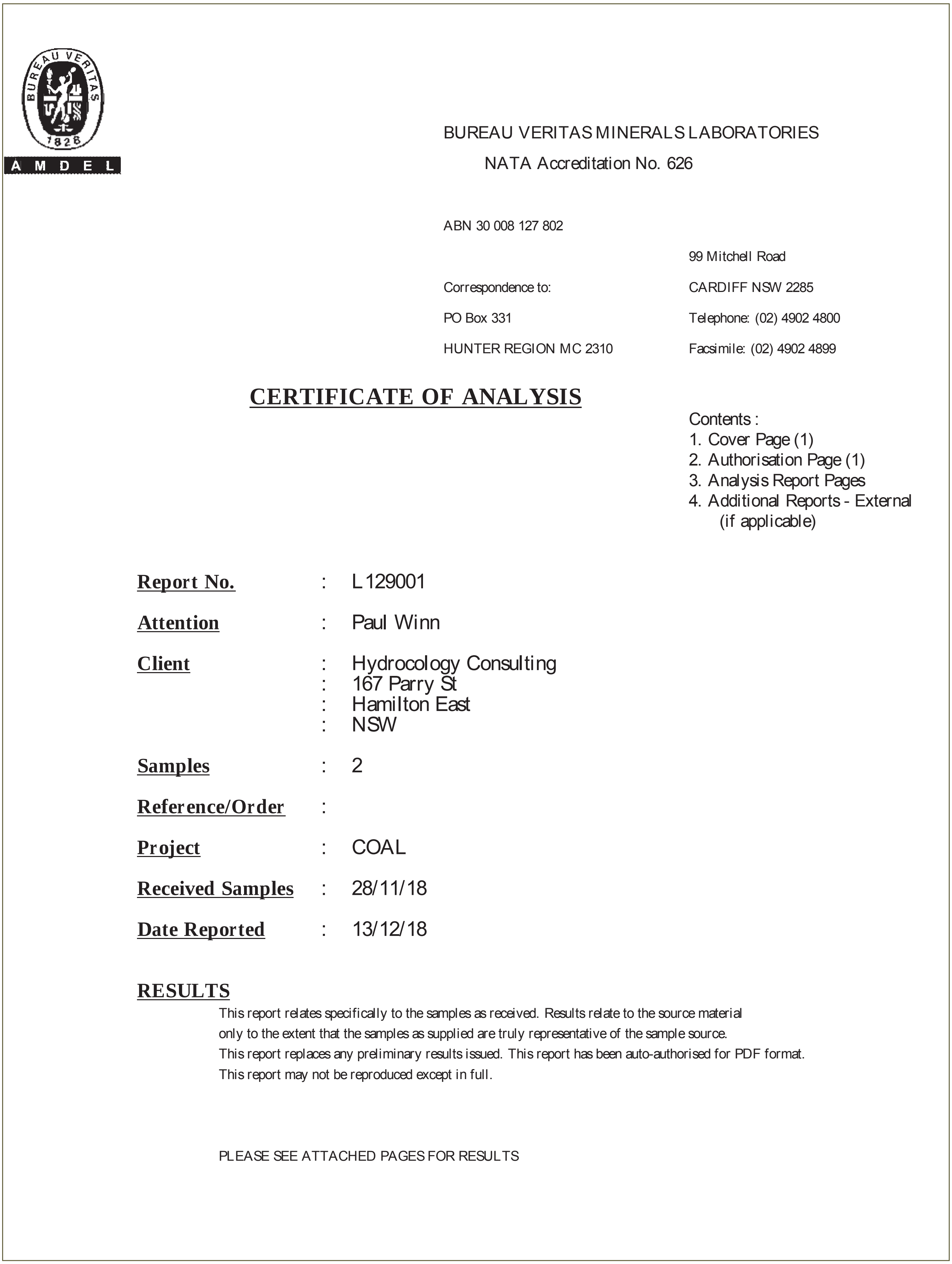
Appendix 2.- Analytical report - Coal samples



BUREAU VERITAS MINERALS LABORATORIES
NATA Accreditation No. 626

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PO Box 331
HUNTER REGION MC 2310

CERTIFICATE OF ANALYSIS

Contents :
1. Cover Page (1)
2. Authorisation Page (1)
3. Analysis Report Pages
4. Additional Reports - External
   (if applicable)

Report No. : L129001

Attention : Paul Winn

Client : Hydrocology Consulting
: 167 Parry St
: Hamilton East
: NSW

Samples : 2

Reference/Order :

Project : COAL

Received Samples : 28/11/18

Date Reported : 13/12/18

RESULTS

This report relates specifically to the samples as received. Results relate to the source material only to the extent that the samples as supplied are truly representative of the sample source.
This report replaces any preliminary results issued. This report has been auto-authorised for PDF format.
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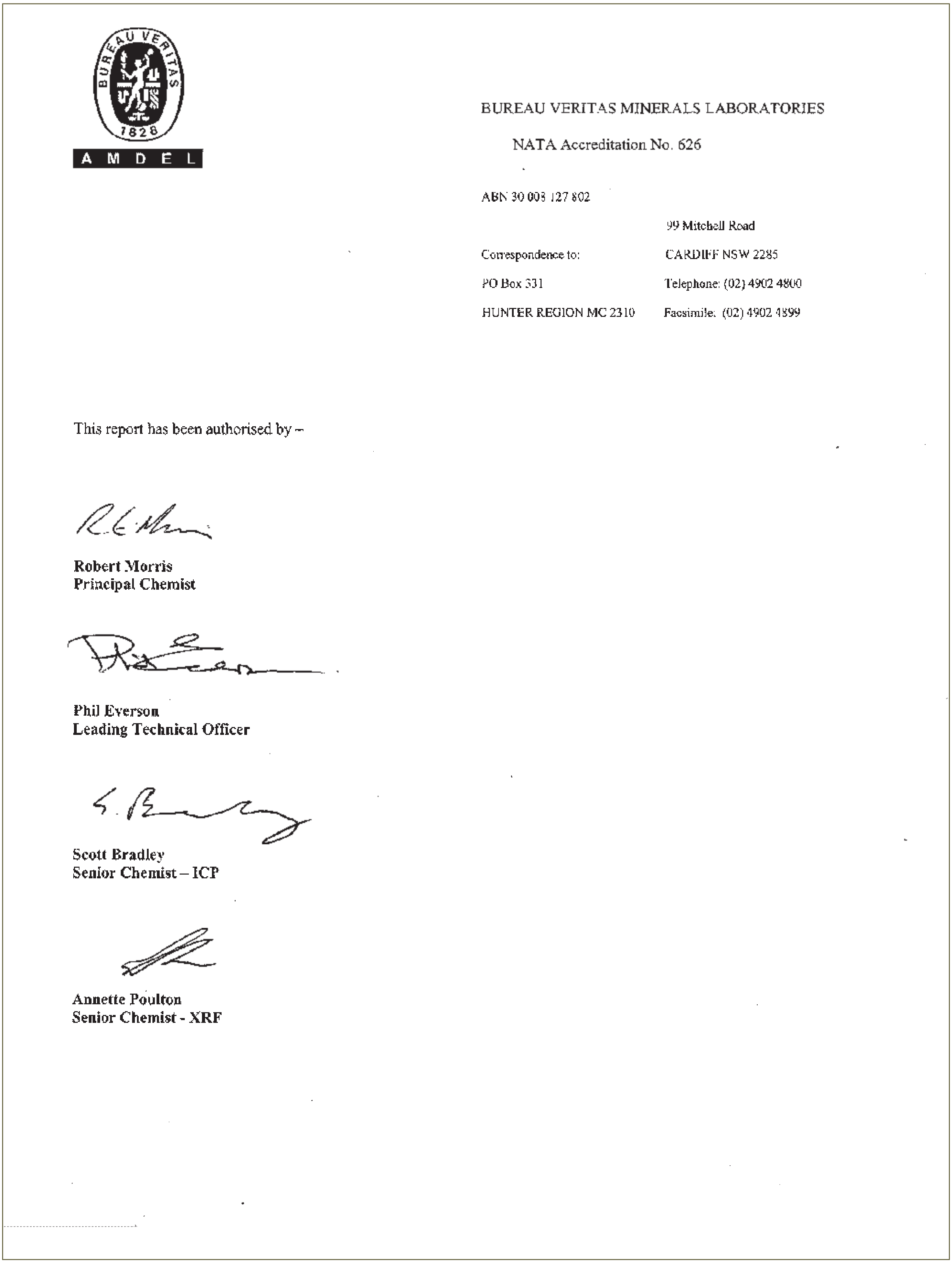
PLEASE SEE ATTACHED PAGES FOR RESULTS



BUREAU VERITAS MINERALS LABORATORIES

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ABN 30 008 127 802

99 Mitchell Road
Correspondence to: CARDIFF NSW 2285
PO Box 531 Telephone: (02) 4902 4800
HUNTER REGION MC 2310 Facsimile: (02) 4902 4899

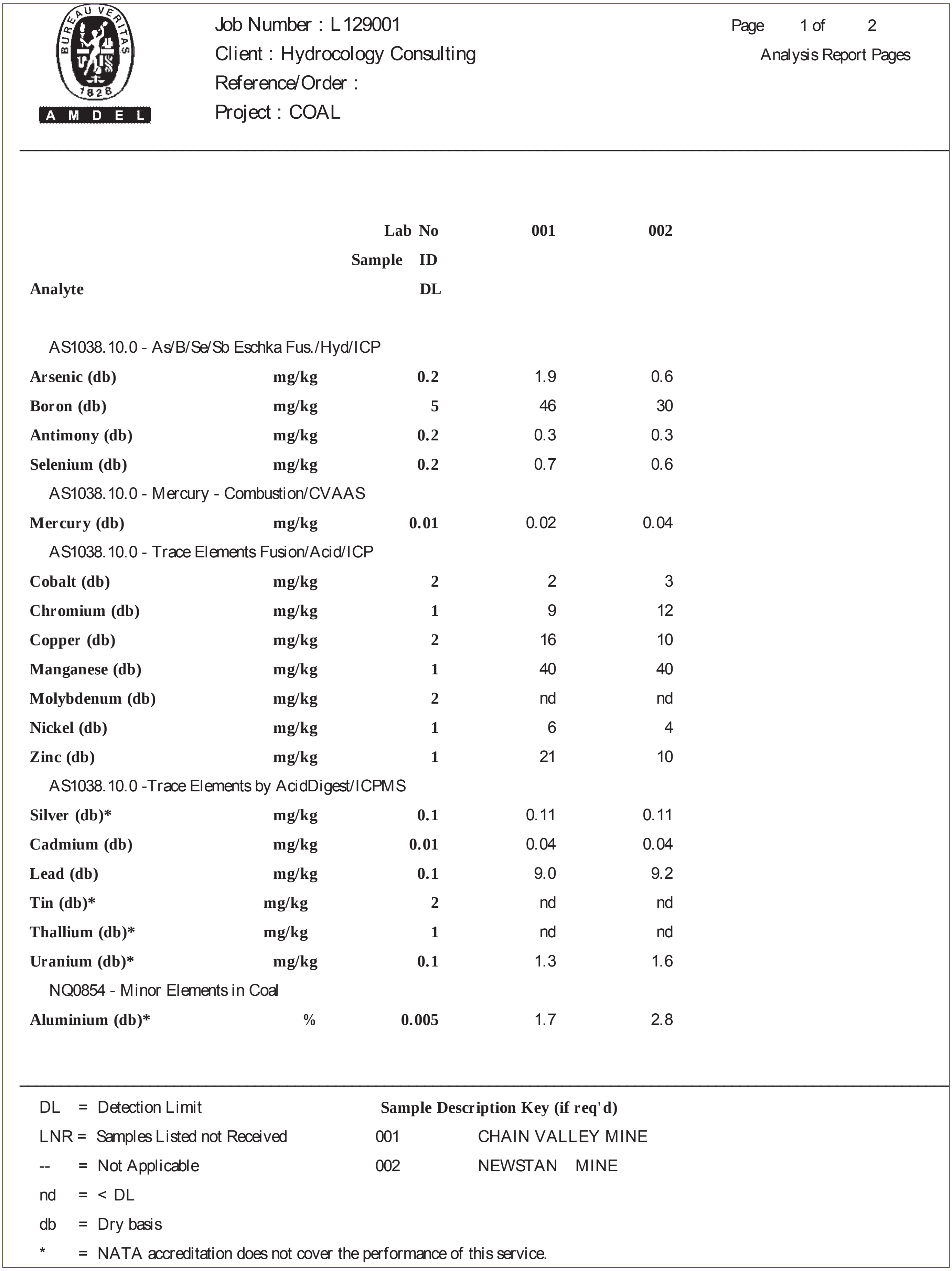
This report has been authorised by –

Robert Morris
Principal Chemist

Phil Everson
Leading Technical Officer

Scott Bradley
Senior Chemist – ICP

Annette Poulton
Senior Chemist - XRF



Job Number : L129001
Client : Hydrocology Consulting
Reference/Order :
Project : COAL

Page 1 of 2
Analysis Report Pages

Analyte		**Lab No** **Sample ID** **DL**	**001**	**002**
AS1038.10.0 - As/B/Se/Sb Eschka Fus./Hyd/ICP				
Arsenic (db)	**mg/kg**	**0.2**	1.9	0.6
Boron (db)	**mg/kg**	**5**	46	30
Antimony (db)	**mg/kg**	**0.2**	0.3	0.3
Selenium (db)	**mg/kg**	**0.2**	0.7	0.6
AS1038.10.0 - Mercury - Combustion/CVAAS				
Mercury (db)	**mg/kg**	**0.01**	0.02	0.04
AS1038.10.0 - Trace Elements Fusion/Acid/ICP				
Cobalt (db)	**mg/kg**	**2**	2	3
Chromium (db)	**mg/kg**	**1**	9	12
Copper (db)	**mg/kg**	**2**	16	10
Manganese (db)	**mg/kg**	**1**	40	40
Molybdenum (db)	**mg/kg**	**2**	nd	nd
Nickel (db)	**mg/kg**	**1**	6	4
Zinc (db)	**mg/kg**	**1**	21	10
AS1038.10.0 -Trace Elements by AcidDigest/ICPMS				
Silver (db)*	**mg/kg**	**0.1**	0.11	0.11
Cadmium (db)	**mg/kg**	**0.01**	0.04	0.04
Lead (db)	**mg/kg**	**0.1**	9.0	9.2
Tin (db)*	**mg/kg**	**2**	nd	nd
Thallium (db)*	**mg/kg**	**1**	nd	nd
Uranium (db)*	**mg/kg**	**0.1**	1.3	1.6
NQ0854 - Minor Elements in Coal				
Aluminium (db)*	**%**	**0.005**	1.7	2.8

DL = Detection Limit
LNR = Samples Listed not Received
-- = Not Applicable
nd = < DL
db = Dry basis
* = NATA accreditation does not cover the performance of this service.

Sample Description Key (if req'd)

001	CHAIN VALLEY MINE
002	NEWSTAN MINE

Job Number : L129001
Client : Hydrocology Consulting
Reference/Order :
Project : COAL

Page 2 of 2
Analysis Report Pages

Analyte		Lab No Sample ID DL	001	002
Iron (db)*	%	**0.005**	0.28	0.26

DL = Detection Limit
LNR = Samples Listed not Received
-- = Not Applicable
nd = < DL
db = Dry basis
* = NATA accreditation does not cover the performance of this service.

Sample Description Key (if req'd)

001	CHAIN VALLEY MINE
002	NEWSTAN MINE

Hunter Community
Environment Centre