Northern Territory Government

INVESTIGATION REPORT

ASSESSMENT OF HARM ON EDITH RIVER ASSOCIATED WITH TRAIN DERAILMENT AND WASTEWATER DISCHARGES FROM MOUNT TODD GOLD MINE (27 December 2011 – 5 January 2012)

December 2012

EN2011/0348-01~0006

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Executive Summary

The Edith River in the Northern Territory is located in the Daly River catchment and is an important water source for wildlife. The river and its flora and fauna are of regional significance. Water Quality Objectives have been declared for the Edith River to sustain the aquatic ecosystems of the Edith River.

The Adelaide to Darwin railway line crosses the Edith River about 42 kilometres northwest of Katherine, in the Northern Territory. The Edith River Bridge Crossing is located about 250 metres to the northeast of the Stuart Highway. Genesee & Wyoming Australia Pty Ltd (GWA) is the owner and operator of the railway line, and since 2009, OZ Minerals has exported copper concentrate from its Prominent Hill operations in South Australia, via the Adelaide to Darwin railway line to the Port of Darwin.

The Mount Todd Mine Site ('the mine') is located in the Edith River catchment, approximately 55 kilometres north of Katherine, 250 kilometres south of Darwin, and 10 kilometres upstream of the Edith River Bridge Crossing. It has been the site of mining activity for over a century. Mining operations ceased in mid-2001, and the Northern Territory Government assumed responsibility for the management and maintenance of the site. Vista Gold Australia Pty Ltd (VG), under an agreement signed with the Northern Territory Government, took over management of the site for the purposes of assessing the mineral potential of the area in 2007.

Discharge of surface waste water from the mine is regulated by way of a Waste Discharge Licence (WDL) issued under s.74 of the *Water Act* which conditions the release of waste water discharge to the Edith River.

On 27 December 2011, a freight train owned and operated by GWA and travelling north to the Port of Darwin derailed at the Edith River Bridge Crossing following high rainfall associated with Cyclone Grant. Approximately 240 tonnes of freight, a crew van, 16 containers, and an approximate total dry load of copper concentrate of 1500 dry metric tonnes (DMT) overturned into the Edith River. The derailment was reported to the Department of Lands, Planning and the Environment (DLPE).

On the same day VG reported an uncontrolled discharge from Retention Pond 1 (RP1) on the mine via a spillway to DLPE. Uncontrolled discharges from the mine continued from 27 December 2011 until 5 January 2012 (inclusive).

DLPE immediately responded to these reported incidents by commencing an investigation to assess environmental harm using multiple lines of evidence, including water monitoring, sediment monitoring, lead isotope analysis, direct toxicity assessments and biological monitoring. The objectives of the investigation were to assess the *potential* and *actual environmental harm* posed by the train derailment and by the discharges of waste water from the Mount Todd mine site. The findings of the investigation may be used to aid in determining whether further regulatory action is warranted.

All water and sediment monitoring results were made available on the former Department of Natural Resources, Environment, the Arts and Sport (NRETAS) website.

Monitoring and assessment using multiple lines of evidence was undertaken between 28 December 2011 and 17 July 2012 in the Edith River region, between the Mount Todd Mine Site and the Edith River derailment site, and up to 200 kilometres downstream in the Daly River.

The following is provided in relation to an assessment of *potential* and *actual* environmental harm posed by the train derailment (copper concentrate) and waste water discharge from the Mount Todd mine site based on a multiple line of evidence approach:

- A total of 80 exceedances of applicable water quality criteria on 33 separate days were identified downstream of the mine discharge point and in some cases downstream of the site of the train derailment;

- Isotope ratio analysis showed the impact of the copper concentrate spill from the train derailment was measurable for approximately 600 metres downstream of the train derailment site;

- Sediment samples analysed four days after the train derailment showed concentrations of copper in close proximity (150 to 600 metres) to the train derailment site to be above the applicable sediment quality criteria. Concentrations of copper in surface water samples in the same area tended to be above the applicable water quality criteria. This suggests that the copper concentrate may have been mobile and bioavailable in water;

- The concentrations of copper in water and sediment in close proximity to the location of the train derailment were such that the minimum level of protection may not have been achieved on some days. The copper may be attributed to the train derailment, although it occurred over a short duration (generally less than two consecutive days) and is therefore unlikely to have a long term environmental impact;

- Direct Toxicity Assessments (DTA) on water samples were obtained within 10 days after the derailment, including a water sample from SW10. This sample contained concentrations of copper above the applicable water quality criteria, and was associated with the copper concentrate as identified by lead isotope analysis. Sediment toxicant concentrations at this location were above the applicable sediment quality criteria. The results of the DTA for this sample found there was no effect on growth, inhibition or survival in the species tested with the exception of the inhibition of growth in an algal species (*Selenastrum capricornutum*). There was evidence to suggest that the inhibitory effect on growth in this species was due to factors other than toxicity;

- Isotope ratio analysis shows that some contamination is attributable to the Mt Todd mine discharge, and the isotopic signature of this discharge water can be measured at distances up to 10 kilometres from the mine site;

- Chemical assessment showed the key pollutants in the waste waters from the mine to be aluminium, cadmium, copper and zinc. These chemicals were found to occur in surface waters on some days at concentrations above the relevant water quality criteria for the 95% level of species protection;

- These chemicals are persistent and are bioavailable in the environment. However there is no evidence to suggest that there is a build up of these pollutants in sediment. In particular aluminium in sediment appears to be associated with elevated background levels;

- DTAs undertaken on samples with concentrations of contaminants above hardness modified trigger values (HMTVs) downstream of the mine, obtained when VG was discharging (5 January 2012) showed there was no effect on growth, inhibition or survival in the species tested with the exception of the inhibition of growth in an algal species (*Selenastrum capricornutum*). There was evidence to suggest that the inhibitory effect on growth in this species was due to factors other than toxicity;

- DTA was undertaken on a water sample downstream of the mine (Control 4) on 16 January 2012 after VG had ceased active discharge approximately 11 days previous. The results of this DTA were similar to previous assessments on 5 January 2012;

- Isotope analysis was not undertaken on all samples containing elevated concentrations of contaminants, and therefore the exact source of these contaminants for each occurrence could not always be determined.

The investigation found there was *potential* for environmental harm due to the 80 exceedances of applicable water quality criteria on 33 separate days. Isotope ratio analysis attributed *potential* environmental harm to copper concentrate from the train derailment in four samples, taken over three days, a short distance downstream from the location of the derailment, and at one location a short distance upstream from the location of the derailment. Isotope ratio analysis attributed *potential* environmental harm to discharge from the mine in two samples, taken on one day, approximately 5 kilometres, and 10 kilometres downstream of the discharge point.

Biological monitoring did not provide any evidence that *actual* environmental harm occurred as a result of the train derailment or wastewater discharge from the mine.

There is evidence that copper concentrate impacted material remains in heavily vegetated areas and within Aboriginal Areas Protection Authority (AAPA) restricted areas at the location of the train derailment. OZ Minerals has proposed to leave this material in-situ due to the extensive land disturbance that would be required to undertake further remediation works (Golders, 2012).

An ecological and human health risk assessment of the material to be left in-situ was commissioned by OZ Minerals (Golder Associates, 2012) with the objective to assess the potential impact and risks to humans and the environment associated with residual copper concentrate affected materials remaining in-situ in localised areas. OZ Minerals (2012) reported that the Golder study (2012) finds that the surface water concentrations downstream of the train derailment were below the Australian Drinking Water Guidelines, and no human health impacts are expected. OZ Minerals (2012) reported that the ecological risk associated with the potential leaching, erosion and run-off of copper due to elevated residual copper concentrations in soil remaining in-situ did not indicate any potential impacts on surface water or sediment concentrations. The consequential risk to aquatic organisms was determined to be low.

The impacts of further land disturbance and vegetation clearance in these areas are considered higher than the potential localised ecological impacts of leaving residual copper concentrate affected material in-situ. No stressors on vegetation have been observed to date (OZ Minerals, 2012).

Correspondence received by DLPE from GWA on 6 December 2012 indicated that any remaining freight in the Edith River downstream of the location of the train derailment poses a low environmental risk, with potential impacts limited to amenity only. GWA will return to the site of the train derailment in June-July 2013 to re-assess if any further clean-up is required.

1 Introduction

1.1 Location and Environmental Setting of Incidents

The Edith River in the Northern Territory is a freshwater ecosystem located in the Daly River catchment. The Daly River is one of the Northern Territory's largest rivers with a catchment area of 52,577 square kilometres, and is one of the few catchments in the Northern Territory that has perennial flows. The Edith River is an important tributary of the Daly River, with a catchment of 1,057 square kilometres. The Edith River flows to the Fergusson River before joining the Daly River (refer to Figure 1).

Previous studies on water quality in the Edith River system have found concentrations of metals generally well below the national guideline trigger levels provided in Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC) (2000) guidelines relevant for the 95% level of species protection for the Edith River catchment. Concentrations of aluminium, copper and zinc have occurred above trigger levels (GHD, 2011a).

Sediments in the Edith River are not thought to be sinks for heavy metals, and data (as discussed later) shows that sample sites downstream of the mine have the same chemical make-up as the soils in the surrounding area, with gravel and sand, and very low total organic carbon (TOC) (GHD, 2011a).

The Edith River is an important water source for wildlife, particularly at the end of the Dry season. There are permanent pools associated with riverine flora that serve as refuge habitats during the Dry. The river and its flora and fauna are of regional significance.

Water Quality Objectives, based on identified environmental values, have been declared for the Edith River (Beneficial uses declaration, Northern Territory Gazette No. G23, 11 June 1997, Appendix A). These are to sustain the aquatic ecosystems of the Edith River.

1.2 Railway Corridor

The Adelaide to Darwin railway line crosses the Edith River at the 2490.670 kilometre mark[1], which is about 42 kilometres northwest of Katherine, in the Northern Territory (Figure 1). The Edith River Bridge Crossing is located about 250 metres to the northeast of the Stuart Highway.

Genesee & Wyoming Australia Pty Ltd (GWA) is the owner and operator of the railway line.

Since 2009, OZ Minerals has exported copper concentrate from its Prominent Hill operations in South Australia, via the Adelaide to Darwin railway line to the Port of Darwin.

1.3 Mining in the Region

The Mount Todd Mine Site ('the mine') is located in the Edith River catchment, approximately 55 kilometres north of Katherine, 250 kilometres south of Darwin, and 10 kilometres upstream of the Edith River Bridge Crossing (Figure 1).

The mine has been the site of mining activity for over a century with minerals including gold, silver, lead, tin, wolfram, molybdenum, copper and bismuth mined at various times. Large scale gold mining and processing commenced in 1994. Two transfers of ownership occurred between 1994 and 2000 with a history of mine closure and reopening. In mid-2001, when mining operations ceased, the Northern Territory Government assumed responsibility for the

[1] Distance in kilometres from a track reference point located at Coonamia in South Australia

management and maintenance of the site. Vista Gold Australia Pty Ltd (VG), under an agreement signed with the Northern Territory Government, took over management of the site for the purposes of assessing the mineral potential of the area in 2007.

Significant on-site legacy issues (i.e. waste dumps, stockpiles, and retention ponds) remained when mining ceased in 2001. The wastes left on site reacted with oxygen and water (rainfall) to produce Acid and Metalliferous Drainage (AMD)[2]. Interactions between the large volumes of monsoonal rain and the legacy mining wastes resulted in periodic incidents of acidic and metal laden surface and possibly groundwater discharges into the Edith River– the main contaminant being copper.

The impact of contaminated mine sources is managed by capturing and controlling the water flowing from the waste rock dump catchment. Water is collected in retention ponds and then pumped or siphoned into the Edith River during high flow events. This process relies on the effects of dilution to ameliorate any downstream impacts.

Discharge of surface waste water from the mine is regulated by way of a Waste Discharge Licence (WDL) issued by the Department of Lands, Planning and the Environment (DLPE), (formerly known as the Department of Natural Resources, Environment, The Arts and Sport (NRETAS)) under s.74 of the *Water Act*. WDL number 178 was issued to VG on 21 January 2011, expiring on 30 October 2012. An updated WDL (178-1) was issued to VG on 9 March 2012, expiring 30 October 2012. Both WDL's conditioned the release of waste water discharge from the mine and required monitoring of surface water discharges for a range of pollutants (the key pollutants of concern being copper, zinc, aluminium, sulphate and manganese). This is a requirement for the daily discharging to the Edith River.

The lack of progress on strategic remediation measures at the mine resulted in an increased risk of uncontrolled discharges of contaminated water (discharge from Retention Pond 1 (RP1) via a spillway). Engineering design and earthworks was undertaken to reduce the potential for uncontrolled discharges of contaminated water from the mine site into the Edith River.

2 Background of Incidents

2.1 Train Derailment

On 27 December 2011, a freight train owned and operated by GWA and travelling north to the Port of Darwin derailed at the Edith River Bridge Crossing.

The derailment occurred following high rainfall associated with Cyclone Grant, resulting in a 9 metre rise above the base water level in the Edith River. The flood waters engulfed the Edith River Bridge Crossing at the peak flood level.

Approximately 240 tonnes of freight, a crew van, 16 containers, and 130 kibbles[3] carrying an approximate total dry load of copper concentrate of 1500 dry metric tonnes (DMT) (OZ Minerals, 2012), overturned into the Edith River. The copper concentrate in the kibbles originated from the OZ Minerals Prominent Hill copper-gold mine in South Australia and was being transported to the Port of Darwin for export.

The copper concentrate consists of grey/green lumps or small agglomerates which are transported with a moisture content of up to 15%. The Australian Dangerous Goods Code

[2] AMD – Acid and Metalliferous Drainage (AMD) is contaminated water runoff and seepage consisting of low pH water and/or elevated toxic metal concentrations, high sulphate concentrations and salinity.

[3] A tarpaulin covered bin-like container

(ADG) classifies copper concentrate as an Environmentally Hazardous Substance (Coffey Environments Australia, 2010). The determination of the dangerous goods status requires ecotoxicological assessment to test whether a particular metal in the concentrate is sufficiently soluble in fresh and marine water to exhibit toxicity to aquatic organisms.

The average composition of the copper concentrate from Prominent Hill is:

- Copper- 30 to 60%
- Iron- 15 to 20%
- Sulfur- 15 to 20%
- Gold- less than 5%
- Silver- less than 5%
- Silica- less than 5%
- Aluminium oxide- less than 5%
- Arsenic- less than 0.05%
- Lead
- Uranium- less than 0.008%

The copper concentrate is a solid that is insoluble in water, combustible and has no odour. Although copper sulphide compounds have low solubility in water, the soluble fraction of copper compounds are harmful to the environment. Using the Organization for Economic Cooperation and Development (OECD) guidelines, as stipulated in the Australian Dangerous Goods Code (National Transport Commission, 2011), tests indicate that there was sufficient solubility in fresh water to classify the Prominent Hill copper concentrate as Chronic Category 2, using *Ceriodaphnia*[4] for ecotoxicological testing.

The derailment was reported to the Pollution Hotline[5] by the Northern Territory Fire and Rescue Service on 27 December 2011. It was recorded under incident number 2959. DLPE immediately responded by commencing an investigation to assess environmental harm. Monitoring of the Edith River commenced on 28 December 2012.

NT WorkSafe issued a Direction on 6 January 2012 pursuant to s.51 of the *Transport of Dangerous Goods by Road and Rail (National Uniform Legislation) Act,* which directed OZ Minerals to remove copper concentrate from the Edith River derailment site. The Direction required OZ Minerals as the consignor of the copper concentrate, to transport by rail, as soon as practicable, and by no later than 31 January 2012, copper concentrate which is contained in intact sheeted bulk containers (BK1), so as to prevent dust escaping during transport; to the Northern Territory/ South Australian border.

On 23 November 2012, OZ Minerals reported that recovery of the copper concentrate was undertaken in three stages. An initial incident response included works to prevent the offsite

[4] Exhibiting acute toxicity in the 48 hr LC50 >1 to <10 mg/L (National Transport Commission, 2011)

[5] The Pollution Hotline is a free call number for the reporting of incidents that cause or have the potential to cause material or serious environmental harm. The Hotline is operated by the Department of Lands, Planning and the Environment (formerly the Department of Natural Resources, Environment, the Arts and Sport (NRETAS)).

migration of copper concentrate, as well as works to remove all visible copper concentrate impacted material. This material was removed from Edith River back to the Prominent Hill Project in South Australia. The second stage included delineation of Aboriginal Areas Protection Authority (AAPA) protected areas, and the further removal of visible copper concentrate. Stage three involved further rehabilitation works in mid-September 2012. These works included the removal of residual copper concentrate affected material, the removal of installed sedimentation controls and minor land shaping (OZ Minerals, 2012).

Approximately 1020 DMT of copper concentrate was returned to the Prominent Hill Mine in South Australia (OZ Minerals, 2012).

Small quantities of visible copper concentrate remain where rehabilitation works have not been undertaken in densely vegetated areas or areas restricted by AAPA. This area is heavily vegetated with suspected deposits between two to five millimetres thick through the grasses. In areas where the copper concentrate is exposed, there are minor signs of oxidation (OZ Minerals, 2012).

DLPE issued a Direction to GWA on 23 January 2012 under section 72(k) of the *Waste Management and Pollution Control Act* to clean up and rectify pollution (i.e. freight that fell from the train), and to prevent further pollution or environmental harm.

GWA (6 December 2012) reported that the crew van, numerous containers, and general freight with total weight in excess of 188 tonnes have been retrieved. GWA has been unable to retrieve all freight from the river due to inaccessibility.

A site was inspection undertaken by Authorised Officers of DLPE on 25 September 2012. Observations were made of various freight items remaining in the river, up to 5 kilometres downstream of the Edith River Bridge Crossing. This freight included large white goods, wooden pallets, container debris, and general rubbish in trees. Officers observed litter associated with campers at the Old Stuart Highway low-level Crossing.

2.2 Waste Water Discharge Mount Todd Mine

On 27 December 2011, VG reported a suspected "uncontrolled discharge"[6] (later confirmed) from the mine to the Pollution Hotline. It was recorded under incident number 2962.

Uncontrolled discharges from Retention Pond 1 (RP1) occur via a spillway within the VG mining lease boundaries. Water is released into West Creek and discharges into the Edith River approximately 2 kilometres downstream of the Edith Falls Road crossing. Controlled discharges from the RP1 siphons are released into Burrell Creek, which discharges into the Edith River approximately 1.5 kilometres downstream of the Edith Falls Road crossing. A map of the discharge locations from the mine is provided in Figure 2.

Uncontrolled discharges from the mine continued from 27 December 2011 until 5 January 2012 (inclusive). VG resumed discharge by pump and siphon from the mine from 21 January to 26 March 2012 (inclusive).

[6] VG defined an uncontrolled discharge as discharge from Retention Pond 1 (RP1) via a spillway, in an unregulated manner. This means that flow cannot be stopped manually and flow only ceases when the freeboard within the pond is greater than 0 metres. Conversely, discharge in a controlled manner means discharge can be mechanically regulated.

3 Report Scope

3.1 Investigation Framework

The investigation to assess the potential for environmental harm to the Edith River ecosystem posed by the pollutants associated with the train derailment and discharges from the mine was undertaken in accordance with the *Draft Compliance and Enforcement Policy Guidelines* (NRETAS, May 2012), using multiple lines of evidence, including water monitoring, sediment monitoring, lead isotope analysis, direct toxicity assessments and biological monitoring.

3.2 Report Objectives

The objectives of this report are:

1. To summarise the independent investigation undertaken by DLPE to assess the *potential environmental harm* posed by the train derailment;
2. To summarise the independent investigation undertaken by DLPE to assess the *potential environmental harm* posed by the discharges of waste water from the Mount Todd mine site; and
3. To review the results of biological monitoring to assess the *actual environmental harm* posed by the train derailment and the discharges of waste water from the Mount Todd mine site.

It is not an objective of this report to consider offences under the legislation administered by DLPE. This report may be used to aid in determining whether further regulatory action is warranted.

3.3 Legislation

DLPE administers:

- The *Waste Management and Pollution Control Act*; and
- Sections of the *Water Act*.

The *Waste Management and Pollution Control Act* and the *Water Act* require an assessment of the potential for environmental harm and/or actual environmental harm in order for regulatory action to be taken. This report aims to define the potential environmental harm and actual environmental harm caused by the train derailment and the discharges from the Mt Todd mine.

3.3.1 Waste Management and Pollution Control Act

The *Waste Management and Pollution Control Act* (WMPC Act) provides for the protection of the environment through encouragement of effective waste management and pollution prevention and control practices and for related purposes.

The objectives of the WMPC Act are:

a. to protect, and where practicable to restore and enhance the quality of, the Territory environment by:

    i. preventing pollution;
    ii. reducing the likelihood of pollution occurring;
    iii. effectively responding to pollution;
    iv. avoiding and reducing the generation of waste;
    v. increasing the re-use and re-cycling of waste; and
    vi. effectively managing waste disposal;

b. to encourage ecologically sustainable development; and

c. to facilitate the implementation of national environment protection measures made under the National Environment Protection Council (Northern Territory) Act.

The WMPC Act does not apply in relation to a contaminant or waste that results from a mining activity that is confined within land on which the activity is being carried out (ie. a mining lease). If contaminants or waste are not confined, the Act applies.

Under s.12 of the WMPC Act, all persons (body corporate and individuals) conducting an activity likely to cause pollution resulting in environmental harm or generating waste, must take measures that are reasonable and practicable to prevent or minimise the pollution or environmental harm and reduce the amount of waste.

3.3.2 Water Act

The *Water Act* provides for the investigation, allocation, use, control, protection, management and administration of water resources, and for related purposes.

Waste Discharge Licences issued under s.74 of the *Water Act*, authorise waste to come into contact with water, or water to be polluted.

3.3.3 Regulatory Tools

DLPE undertakes its regulatory role in the administration of this legislation in accordance with the *Draft Compliance and Enforcement Policy Guidelines* (NRETAS, May 2012) ('Compliance Guidelines').

The Compliance Guidelines describe the aim of DLPE's investigations as aiming to gather sufficient information to determine whether further action should be taken. Action can include compliance advice, warnings, corrective actions, infringement notices, pollution abatement notices, enforceable undertakings and prosecution.

4 Method for Assessment of Environmental Harm

The assessment of *potential* environmental harm focussed on investigations of key contaminants in surface water, sediment and freshwater ecosystems within defined areas of the Edith River.

The following aspects were identified as key considerations in the assessment of *potential* environmental harm:

1 the nature, degree and extent of the contaminant or waste in surface water and sediment; and

2 the receiving environment and the exposure pathway (the channel followed by pollutants from their source via air, soil and water to humans, animals, or their environment).

This report uses the above considerations to assess *potential* harm/potential adverse effects, and *actual* environmental harm on the environment of the Edith River. The report provides:

- an outline of the methods used in the assessment;
- criteria for assessing impact;
- the extent of contamination; and
- an overall assessment of harm or adverse effect on the environment of the Edith River.

4.1 References Used in the Assessment of Potential Harm

The *Australian Water Quality Guidelines for Fresh and Marine Waters*, Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource

Management Council of Australia and New Zealand (ANZECC), developed by the National Water Quality Management Strategy (ANZECC 2000) were used in the assessment of *potential* environmental harm.

This document is the National Water Quality Guideline, and provides:

- a framework for applying the ANZECC guidelines;
- a decision tree approach for assessing toxicants in water and sediment;
- trigger levels for contaminants in water to protect ecosystem function and the beneficial uses of waters; and
- interim sediment quality guidelines (low and high values).

ANZECC (2000) provides guideline water quality and sediment quality guideline trigger values[7] based on the results of ecotoxicological tests or by applying conversion factors from relevant ecotoxicity tests.

4.1.1 Water Quality Guidelines

The water quality guidelines provide trigger values for toxicants to be applied at a water monitoring point for alternative levels of protection, where the objective is to maintain biological diversity. These levels are:

- 99% species protection- for maintenance of ecosystems of high conservation/ecological value
- 95% species protection- for maintenance of slightly to moderately disturbed ecosystems
- 90% species protection- for highly disturbed systems
- 80% species protection- for highly disturbed systems

The protection level does not signify sacrifice of a percentage of the ecosystem, or death of a percentage of species. The protection level signifies the percentage of species expected to be protected from the effect of toxicants. The trigger values are based on toxicant concentrations that *do not cause toxicity* to growth, reproduction, development, etc for individual species. The trigger values are based on calculations of a statistical distribution of laboratory ecotoxicity data, and there is a substantial amount of conservatism built into the process of developing species protection values. They are broad estimates of concentrations that protect the environment.

The trigger values represent indicators that an ecosystem is sufficiently protected, not that species will be affected if the trigger value is exceeded. If a trigger value is exceeded, it provides an indication that some species might be affected at a chronic level (i.e. non-lethal responses such as growth, reproduction or development inhibition under extended exposure) and that further investigation should be undertaken.

Refer to Appendix B, Decision Tree for Metal Speciation Guidelines (ANZECC, 2000) for the method of application of the water quality guidelines.

[7] A trigger value is broadly defined as a concentration that, if exceeded, alerts water managers to a potential change and thus triggers a management response.

4.1.1 Sediment Quality Guidelines

The sediment guideline values or criteria are tabulated in section 3.5 of ANZECC (2000) as interim sediment quality guidelines (ISQG) and are provided as low and high ISQG values.

Risk posed by contaminant concentrations in sediment below the ISQG low values is likely to be low. Conversely, if the contaminant concentrations in sediment exceed the ISQG high, the risk to organisms in terms of effect is likely to be high. If contaminant concentrations in sediment are between the ISQG low and high then further assessment is recommended (see Appendix C, Decision Tree for the Assessment of Contaminated Sediments (ANZECC, 2000)).

4.2 Assessment of Data Quality

The *National Environment Protection Measure Guideline on Data Collection, Sample Design and Reporting (Schedule B[2])* (NEPC, 1999) specifies that the nature and quality of the data produced in an investigation will be determined by the Data Quality Objectives (DQOs). The DQOs and results of assessment of suitability of the data for this investigation are provided in Appendix D.

4.3 Assessment Strategy

DLPE commenced its assessment on 28 December 2011. The key components of the assessment of *potential* environmental harm were:

- Development and implementation of a sampling and analysis plan (SAP) for surface waters and sediment;
- Ecotoxicological testing;
- Lead Isotope Ratio Analysis; and
- Evaluation and interpretation of the results.

Biological monitoring undertaken by VG as part of WDL178-1 requirements for the 2011-2012 Wet and Dry seasons was used to assess *actual* environmental harm. The results of VG's biological monitoring were reviewed by DLPE. The results form part of this report.

4.4 Sampling and Analysis Plan

The monitoring program for this investigation was prepared by DLPE in response to the train derailment and discharges from the Mt Todd mine. The monitoring allowed for the assessment of multiple lines of evidence to enable appropriate determination of potential risks associated with the increase in toxicants in water and sediment that may have occurred as a result of the incidents.

Monitoring was undertaken in accordance with the *NRETAS Surface Water and Sediment Monitoring Plan* (Appendix E), and the *Investigation Plan: Edith River Train Derailment and Uncontrolled Discharge from Mount Todd Mine* (NRETAS internal document EN2011/0348-01~0041). These documents identified the location of monitoring sites, and outlined the sampling and analysis plan, including frequency of sampling, type of sampling (water/sediment), field procedures, and typical field and laboratory analysis. Monitoring sites and sampling frequency are discussed below.

All water and sediment monitoring results were made available on the former NRETAS website.

Assessment of monitoring results was in accordance with the ANZECC (2000) Decision Tree for Metal Speciation Guidelines (Appendix B), and the Decision Tree for the Assessment of Contaminated Sediments (Appendix C).

4.4.1 Sampling Locations

Sampling site locations for water and sediment were selected to ensure samples were obtained from upstream and downstream of the train derailment and discharges from the Mt Todd mine.

Sample locations allowed for the determination of representative “natural” background concentrations of contaminants of concern (i.e. upstream of the mine), in addition to locations between the mine and the Edith River Bridge, downstream of the derailment, and approximately 150 kilometres downstream at Daly River, where water is extracted for irrigation, stock watering and potable water supplies.

Sediment samples were taken from the edge of the river bank where flood waters were receding. Water samples were taken from approximately 1 metre from the bank.

The sampling site descriptions are provided in Table 1, mapped in Figure 3, and a photograph of each site is provided in Plates 1 to 10.

Table 1 Summary of sample locations

Site	Latitude	Longitude	Site Description	Plate reference
SW2	-14.1729°	132.119°	Approximately 2 kilometres upstream of West Creek (RP1 spillway discharge) and 1.5 kilometres upstream of Burrell Creek (RP1 siphon discharge) and approximately 10 kilometres upstream of the derailment.	Plate 1
SW4	-14.1721°	132.1°	Approximately 500 m downstream of West Creek (RP1 spillway discharge).	Plate 2
Control 4	-14.16666°	132.0666°	Approximately 5 kilometres upstream of the derailment and approximately 5 kilometres downstream of West Creek (RP1 spillway discharge).	Plate 3
Control 1	-14.1734°	132.039°	Approximately 1 kilometre upstream of the derailment and approximately 10 kilometres downstream of West Creek (RP1 spillway discharge).	Plate 4
Edith River R-R	-14.183°	132.035	Between the rail bridge (derailment site) and the Stuart Highway road bridge.	Plate 5
SW10	-14.1854°	132.03°	Approximately 650 m downstream of derailment site and approximately 10 kilometres downstream of West Creek (RP1 spillway discharge).	Plate 6
Control 5	-14.191°	132.025°	Approximately 1.5 kilometres downstream of derailment site.	Plate 7
Oolloo Crossing	-14.0726°	131.252°	Located on the Daly River, approximately 100 kilometres downstream of mine site and derailment.	Plate 8

Daly River	-13.7669°	130.709°	Located on the Daly River, at the Daly River town-site, approximately 200 kilometres downstream of mine site and derailment.	Plate 9
RP1	-14.1628°	132.105°	Retention Pond 1, Mount Todd Mine Site	Plate 10

4.4.2 Sampling Frequency

Sampling frequency was approximately twice per week from late December to mid-May with an additional round of sampling in late July. These represented Wet season, recessional and Dry season flows.

The sampling frequency is provided in Appendix E. The frequency of sampling aimed to cover the following key periods:

- immediately after the train derailment and discharges from the Mt Todd mine occurred;
- during preliminary copper concentrate clean-up efforts;
- during the period where clean-up efforts intensified as the river receded;
- after OZ Minerals cleaned up the visible concentrate and GWA removed accessible waste from the river;
- during normal flows in the system with periodic controlled discharges from the mine to the river;
- during recessional flows (when the river recedes from Wet season flow to Dry season flow); and
- after recessional flows (when the river is at “cease to flow” levels).

4.4.3 Chemical Assessment

Water and sediment samples were placed on ice and transported together with relevant chain of custody to laboratories accredited under National Association of Testing Authority (NATA). The samples were analysed for a range of metals and metalloids, as well as general chemistry, as listed in Appendix E.

5 Assessment of Environmental Harm- Water

DLPE used water monitoring as a line of evidence to evaluate the *potential* for environmental harm caused by the train derailment and discharges from the Mt Todd mine.

The steps below were followed to assess the water data obtained during the investigation using the Decision Tree for Metal Speciation Guidelines (Appendix B):

1. Preliminary identification of toxicants of concern from both the mine Retention Pond 1 (RP1) water and the copper concentrate from the train derailment.
2. The toxicants included, but were not limited to, copper, zinc, aluminium, cadmium, cobalt and nickel.
3. Natural background concentrations (or range) of toxicants were considered. If the background concentration of a toxicant was clearly established and it exceeded the guideline trigger value, the 80th percentile of the background concentration was accepted as the site-specific trigger value.

4 The Practical Quantization Limit/Level (PQL), or laboratory Limit of Reporting (LOR) was considered for all toxicants of concern to ensure all concentrations could be compared with the guideline values.

5 Assessment of the requirement to modify the default ANZECC (2000) trigger values, using suspended matter, organic matter, salinity, pH, temperature, hardness; and dissolved oxygen to develop hardness-modified trigger values (HMTV's).

6 All water samples were filtered by the laboratory through a 0.45µm filter to allow for the assessment of dissolved metal concentrations.

7 The Chelex method was used to determine the bioavailable fraction of the 0.45µm filtered sample to allow for the assessment of the speciation of certain metals in natural waters.

The Chelex method is discussed in a paper entitled *A Rapid Chelex Column Method for the Determination of Metal Speciation in Natural Waters* (Bowles, K. C., Apte, S. C., Batley, G. E., Hales, L. T., and Rogers, N. J., 2005).

The Chelex method is a useful measure in determining weakly complexed or free metal fraction. It is more useful than a dissolved measurement in determining potential bioavailability for cadmium, cobalt, copper, nickel, lead and zinc (pers. comm. Dr Graeme Batley, 7 September 2012).

Results of the Chelex method for other metals are considered either not-applicable or low reliability (in the case of arsenic, iron, aluminium and manganese).

8 Direct Toxicity Assessment (DTA) was undertaken on selected samples in accordance with s.8.3.5.19 of ANZECC (2000). DTA was undertaken with two objectives:

a. To assess adverse effects in Edith River waters at the toxicant concentration present; and

b. To derive site-specific trigger values in accord with ANZECC (2000) guidance, which is an endorsed approach when considering discharge of an effluent into a system that contains a mix of contaminants.

9 The assessment incorporated an indicative assessment of the toxicity of the mixture of metals i.e. total toxicity of mixtures (TTM) consistent with s.8.3.5.18 of ANZECC (2000).

TTM is a useful assessment tool when a large number of toxicants are present at levels at or below guideline trigger levels and where there is a concern that the toxicants may have an additive, antagonistic and/or synergistic effect.

TTM was calculated to determine if the minimum level of protection has been achieved (95% of aquatic ecosystems).

It would be reasonable to suggest that the minimum level of protection has not been achieved where the calculated TTM is greater than 1, as one or more of the applicable guideline trigger values have been exceeded.

Where there has been no exceedance of the applicable trigger values, the calculated TTM will be less than one, and it is reasonable to suggest that the minimum level of protection has been achieved.

5.1 Water Quality Guidelines

The default ANZECC (2000) water quality guidelines for the protection of 95% of aquatic freshwater ecosystems were used in the first instance. This is consistent with the protection of slightly to moderately disturbed aquatic ecosystems (environmental value), and modified based on hardness (as hardness can affect toxicity as outlined in section 5.5) and background concentrations.

Water in Edith River is generally <10 mg/L as calcium carbonate ($CaCO_3$). This is indicative of soft water (Hardness of 0-59mg/L). For soft water, there are no factors to apply to the guidelines (i.e. the use of the ANZECC (2000) guideline values is appropriate).

Information on background concentrations of key toxicants in water was obtained from GHD (2012). These data were obtained from samples obtained from approximately 2 kilometres upstream of West Creek (RP1 spillway discharge), 1.5 kilometres upstream of Burrell Creek (RP1 siphon discharge) and approximately 10 kilometres upstream of the derailment (SW2) between 2008 and 2011. These data show that the background concentrations of all toxicants in the data set were generally below the ANZECC 95% guideline value, with the exception of aluminium. The guideline trigger value for aluminium was modified to 149 µg/L to reflect naturally higher background concentrations.

The ANZECC (2000) default 95% protection levels for freshwater were retained for all metals and metalliods (as there was no requirement to re-calculate for hardness or background). The revised aluminium and manganese trigger values were incorporated into a new set of trigger values (Hardness Modified Trigger Levels (HMTVs)), in accordance with ANZECC (2000). These were used for the assessment of harm in water for the purpose of this investigation, as shown in Table 2.

Table 2 Hardness Modified Trigger Levels used in this Investigation- Water

Toxicant	Hardness Modified Trigger Level (µg/L)
Aluminium	149
Arsenic (V)	1
Cadmium	0.2
Chromium (VI)	0.01
Cobalt	90
Copper	1.4
Iron	300
Lead	3.4
Manganese	1700
Mercury	0.6
Nickel	11
Zinc	8.0
Uranium	0.5

5.2 Test against Hardness Modified Trigger Levels

All laboratory reports for water samples are provided in Appendix F. A summary of the water quality monitoring results compared with the HMTVs is provided in Appendix G. The summary tables provide the results of the Chelex analysis (with the exception of 28 December 2011). The Chelex method is only useful in providing a measure of the bioavailable fraction of cadmium, cobalt, copper, nickel, lead and zinc. Results presented for all other metals and metalloids are considered either not-applicable or low reliability. The results for all other metals and metalloids should be compared with the dissolved fraction, the results of which are in Appendix F.

A screen of the data collected indicated the frequent occurrence of concentrations above the HMTV for aluminium, cadmium, copper and zinc in a range of samples.

The concentrations above the HMTV occurred most often at:

- Control 4- approximately 5 kilometres downstream of West Creek (RP1 spillway discharge), and approximately 5 kilometres upstream of the derailment;
- Control 1- approximately 1 kilometre upstream of the derailment and approximately 10 kilometres downstream of West Creek (RP1 spillway discharge); and
- SW10- approximately 650 metres downstream of derailment site and approximately 10 kilometres downstream of West Creek (RP1 spillway discharge)

  with a smaller number occurring at:

- Control 5- approximately 1.5 kilometres downstream of derailment site;
- Oolloo Crossing- on the Daly River, approximately 100 kilometres downstream of mine site and derailment; and
- Daly River- at the Daly River town-site, approximately 200 kilometres downstream of mine site and derailment.

Nickel concentrations were recorded above the HMTV for at Control 4 on 3 January, and 2 February 2012; and uranium was recorded above the HMTV at Daly River[8] on 9, 11 and 16 January 2012.

5.3 Direct Toxicity Assessment (DTA)

DTAs were undertaken in order to assess the toxicity of the pollutants on a range of species representative of an ecosystem. This is in accordance with the ANZECC (2000) decision tree.

5.3.1 In-stream Toxicity Assessments

Three water samples were analysed using DTAs to measure the effect, if any, of toxicants present. These samples were obtained from Control 5 and SW10 on 5 January 2012, and Control 4 on 16 January 2012.

The DTA assessments undertaken on samples obtained on 5 January 2012 used six species representative of an Australian freshwater ecosystem. The assessment undertaken on the sample obtained on 16 January 2012 used seven species.

[8] Elevated uranium concentrations at Daly River were investigated and found to be naturally occurring and related to the geology of the region.

No effect on growth, inhibition or survival was observed on any of the species assessed from all samples (SW10 and Controls 4 and 5), with the exception of growth inhibition in the algal species *Selenastrum capricornutum*. There is evidence to suggest that the inhibitory effect on growth in this species was due to factors other than toxicity e.g. colour of the water samples[9].

The results of the DTA assessments for Control 5, Control 4 and SW10 are provided in Appendix H.

5.3.2 Site-Specific Toxicity Testing

Site-specific toxicity testing was undertaken on RP1 water to derive site-specific trigger values for the discharge of effluent from the mine. The undiluted sample was obtained from RP1 on the Mount Todd mining lease on 16 January 2012. This sample was considered representative of the effluent being discharged in an uncontrolled manner from 28 December 2011 to 5 January 2012.

The toxicity test included a full dilution series (1%, 0.5%, 0.25%, 0.13%, 0.06% and 100% diluent control (SW2)). This allowed determination of a minimum required dilution that would be protective of 95% of species. Testing was undertaken using eight species considered representative of an Australian freshwater ecosystem.

The results of the RP1 toxicity testing were forwarded to the Environmental Research Institute of the Supervising Scientist (ERISS), and a Species Sensitivity Distribution (SSD) for the RP1 water was developed.

The results from the DTA assessment and the SSD data are provided in Appendix I. A summary of the protective concentrations as derived from the SSD (and comparison with the MTVs) are provided in Table 3.

[9] The effect of the colour of a sample during toxicity testing is assessed using a colour control treatment, which is a negative control (i.e. culture media), with a petri-dish containing the coloured sample placed over the top. Given that the lighting provided during the test is from directly overhead of the test vessel, the colour of the sample in the petri-dish may filter or reflect light that would otherwise be available to the micro-algae in the test vial below. This altering of light intensity and quality (with respect to spectrum) would replicate the conditions in the actual coloured test sample. The ecotoxicology laboratory did not determine that the sample was sufficiently turbid as to warrant any filtration. Growth inhibition was likely affected by sample colour, as evidenced by the colour control value being similar to the test sample. That the effect in the sample treatment was not greater than in the colour control would suggest that colour was the primary or sole cause of that effect.

Table 3 Protective Concentrations- RP1 Discharge

Level of protection	RP1 metal concentrations (µg/L)					
	Al	Co	Cu	Mn	Ni	Zn
99%	6.4	0.23	1.3	1.6	0.23	5.6
95%	13	0.54	2.3	3.8	0.54	8.8
90%	18	0.82	3.2	5.7	0.82	12
80%	27	1.3	4.6	8.8	1.3	16
HMTV (refer to Table 2)	149	90	1.4	1700	11	8

5.4 Total Toxicity of a Mixture

TTM is a useful assessment tool when a large number of toxicants are present at levels at or below guideline trigger levels and where there is a concern that toxicants may have an additive, antagonistic and/or synergistic effect.

These effects can be seen in the effluent discharged from RP1 (sample obtained and referenced in section 5.3.2, and shown in Table 3). The HMTVs demonstrated less conservative protection levels for manganese, cobalt, nickel and aluminium. The HMTV is approximately equal to the protective concentration derived through toxicity testing for zinc, and the protective concentration of copper derived through toxicity testing is almost double the HMTV.

TTMs were calculated using the site specific concentrations of toxicants derived from the DTA assessment (site specific toxicity testing) on RP1 water. The protective concentration used was 95%, consistent with the objective to maintain ecosystem protection.

The results of the TTM calculations are provided in Appendix J, and a summary table of TTMs greater than 1 are presented in Table 4.

Table 4 TTM Calculation Results > 1

Date/Sample	TTM	Date/Sample	TTM
28/12/2011		17/02/2012	
Control 1	62.85304269	CONTROL 4	1.906565657
SW10	40.34223627	CONTROL 1	2.604247604
Oolloo Crossing	35.05016722	SW10	1.835016835
31/12/2011		21/02/2012	
CONTROL 1	27.04399063	CONTROL 4	1.607744108
SW10	32.13292344	CONTROL 1	1.237373737
DALY RIVER	9.665551839	SW10	1.237373737
3/01/2012		23/02/2012	
CONTROL 4	92.4743815	CONTROL 4	2.845117845
CONTROL 1	55.69316352	CONTROL 1	2.247474747
SW10	51.64855072	SW10	2.247474747
5/01/2012		28/02/2012	

Control 4	3.991179915	CONTROL 1	2.492877493
Control 1	15.54384424	SW10	9.035055122
SW10	2.801383399	1/03/2012	
Control 5	9.761015957	SW2	9.230769231
9/01/2012		CONTROL 4	4.956293706
CONTROL 1	2.346837945	CONTROL 1	1.993006993
SW10	1.999467923	8/03/2012	
11/01/2012		SW2	1.538461538
CONTROL 4	1.136363636	CONTROL 4	1.993006993
CONTROL 1	1.571146245	CONTROL 1	1.879370629
SW10	2.119565217	SW10	2.106643357
16/01/2012		13/03/2012	
SW10	2.36013986	CONTROL 4	15.90354493
23/01/2012		SW10	16.54327557
CONTROL 4	2.460474308	20/03/2012	
CONTROL 1	4.994144342	CONTROL 4	9.050412148
SW10	6.431891378	SW10	3.549260723
27/01/2012		22/03/2012	
SW2	1.538461538	CONTROL 4	12.05936173
CONTROL 4	34.15260464	SW10	7.824074074
CONTROL 1	21.89227841	27/03/2012	
SW10	26.44996509	CONTROL 4	11.64300474
DALY RIVER	3.190559441	SW10	22.67153137
31/01/2012		29/03/2012	
CONTROL 4	40.92190016	CONTROL 4	1.721380471
CONTROL 1	53.69705978	SW10	2.02020202
SW10	61.30606511	3/04/2012	
2/02/2012		CONTROL 4	1.679292929
CONTROL 4	97.2363124	SW10	1.422558923
CONTROL 1	68.73976667	10/04/2012	
SW10	41.58708039	CONTROL 4	1.01010101
8/02/2012		SW10	1.123737374
SW2	2.307692308	12/04/2012	
CONTROL 4	17.10236422	CONTROL 4	1.01010101
CONTROL 1	28.52392374	SW10	1.123737374
SW10	17.12725077	24/04/2012	
10/02/2012		CONTROL 4	2.02020202
SW2	7.692307692	26/04/2012	
CONTROL 4	40.78177258	CONTROL 4	1.452020202
CONTROL 1	63.7404564	SW10	2.548562549
SW10	57.64392813	1/05/2012	
14/02/2012		CONTROL 4	1.266835017
SW2	2.307692308	SW10	1.081649832
CONTROL 4	6.107226107	3/05/2012	
CONTROL 1	8.002460502	CONTROL 4	1.081649832
SW10	6.577635328	10/05/2012	

		CONTROL 4	1.081649832

Note TTM = (sum(concentration/trigger value)), where 'trigger value' is 95% species protection based on ecotoxicology testing on RP1 water.

The results show 86 samples, obtained from 33 days and 7 locations (including 6 samples upstream of the mine) may contain concentrations of contaminants that may not be protective of 95% of species (out of a total of 153 samples, obtained from 41 days and 9 locations).

5.5 Summary of Assessment of Potential Environmental Harm-Water

A determination of the *potential* for environmental harm, as defined by the *WMPC Act* and the *Water Act* has been made using the methodology defined in section 5.

A summary of the information relating to water quality as an assessment of harm is provided below.

1. Dissolved and bioavailable concentrations of aluminium, cadmium, copper, zinc, nickel uranium and chromium were elevated above modified trigger values at various locations downstream of the mine and derailment location including Control 4, Control 1, SW10, Control 5, Oolloo Crossing and Daly Waters.

2. Direct toxicity assessments on water samples obtained from Control 5 and SW10 on 5 January 2012, and Control 4 on 16 January 2012 show there was no observed effect on growth, inhibition or survival, with the exception of growth inhibition in the algal species *Selenastrum capricornutum*. There is evidence to suggest that the inhibitory effect on growth in this species was due to factors other than toxicity e.g. colour of the water samples.

3. Site specific toxicity testing undertaken on RP1 discharge water sampled on 16 January 2012 provided 95% protection concentrations significantly different from the hardness modified trigger values for aluminium, cobalt, copper, manganese and nickel (providing an indication that the use of ecotoxicology-derived protective concentrations are more appropriate for the purposes of this investigation than the use of the HMTVs) .

4. TTM calculations on samples indicate that 86 samples, obtained from 33 days and seven locations (including six samples upstream of the mine) contained concentrations of contaminants that may not be protective of 95% of species.

The contaminants of concern (most commonly above the protective concentrations of toxicants derived from ecotoxicological testing of RP1 water) were identified as aluminium, cadmium, copper and zinc. These contaminants are toxic, persistent in the environment and some have been shown to be bioavailable.

A brief summary of the potential toxicity of these contaminants is provided below:

- Aluminium toxicity to fish and invertebrates is increased at low (e.g. <5.5) and high pH (e.g. >9). In-situ pH testing (obtained using hand held water quality monitoring equipment at the locations where samples were obtained) indicates that pH was within the range of 5.5-9.0. RP1 water has a pH below 5.5, and discharges directly into the Edith River.

  Toxicity is reduced by complexing with humic substances (total organic carbon (TOC) and dissolved organic carbon (DOC) is used to calculate the concentration of humic acid from humic substances). TOC was recorded from non-detectable to 7mg/L and DOC was recorded from non-detectable to 4mg/L. Bioavailable concentrations of aluminium are representative of aluminium not complexed by TOC and DOC.

Aluminium toxicity is reduced at high water hardness (i.e. high calcium concentrations). Water in the Edith River is considered soft (<10mg/L CaCO3).

Increased temperature may increase aluminium toxicity. Water temperature at the time of sampling was indicative of a tropical freshwater system, with temperatures ranging from approximately 28 degrees Celsius to over 31 degrees Celsius

Toxicity of aluminium may be affected by presence of other metals. Aluminium was generally detected in elevated concentrations with cadmium, copper and zinc.

- Cadmium toxicity increases in freshwater with pH above 8. In-situ pH testing indicates that pH was within the range of 5.5-9.0.

  Cadmium toxicity is reduced at high water hardness. Water in the Edith River is considered soft.

  Cadmium toxicity is reduced with dissolved organic matter, and is complexed with humic substances. Bioavailable concentrations of cadmium are representative of cadmium not complexed by TOC and DOC.

- Copper toxicity is reduced at high water hardness. Water in the Edith River is considered soft.

  Levels of dissolved organic matter found in most freshwaters are generally sufficient to remove copper toxicity but often not in very soft waters. Copper is absorbed strongly by suspended material. Bioavailable concentrations of copper are representative of copper not complexed by TOC and DOC, and show the effect of the soft water.

  Copper toxicity in algae, invertebrates and fish generally increases as salinity decreases.

- Zinc toxicity is reduced at high water hardness. Water in the Edith River is considered soft.

  Levels of dissolved organic matter found in most freshwaters are generally sufficient to remove zinc toxicity but often not in very soft waters. Zinc is absorbed strongly by suspended material. Bioavailable concentrations of zinc are representative of zinc not complexed by TOC and DOC, and show the effect of the soft water.

  Zinc toxicity generally decreases with decreasing pH, at least below pH 8.

  Zinc uptake and toxicity generally decreases as salinity increases.

  (ANZECC, 2000)

The extent of contamination identified during the investigation is demonstrated through the calculated TTMs greater than 1. As discussed in section 5.4, where the calculated TTM is greater than 1, one or more of the applicable guideline trigger values have been exceeded, and it is reasonable to suggest that the minimum level of protection was not achieved.

TTMs greater than 1 were identified at SW2, Control 1, Control 4, SW10, Control 5, Daly River, and Oolloo Crossing, with a total extent of over 200 kilometres from the site of the train derailment and discharges from the mine.

Concentrations of contaminants detected may not provide the minimum level of protection to the aquatic ecosystem, identified as an environmental value.

6 Assessment of Environmental Harm- Sediment

DLPE used sediment monitoring as a line of evidence to evaluate the *potential* for environmental harm caused by the train derailment and discharges from the Mt Todd mine.

The Decision Tree for the Assessment of Contaminated Sediments (Appendix C), was as follows:

1. Characterisation of the sediments.

   GHD (2012) characterised the sediments in the Edith River below SW2 as having large particle sizes and minimal clay content. This configuration of particle sizes and low total organic carbon (TOC) means that there are limited binding sites (usually organic particles such as humic acids) for metals to adsorb to the sediments and metals are unlikely to remain in the system.

2. Preliminary identification of toxicants of concern from both the mine RP1 water and the copper concentrate from the train derailment.

   These toxicants included, but were not limited to copper, sulphur, aluminium, arsenic, lead, and uranium.

3. Natural background concentrations (or range) of toxicants were considered. An exceedance of a guideline trigger value is acceptable if it is at or below the normal background concentration for a site.

4. Assessment of simultaneously extractable metals/acid volatile sulphide (SEM/AVS) provides for an estimate of the bioavailable fraction of contaminants in sediment given that total metal concentration in sediment is often associated with the detrital mineral phase. ANZECC (2000) notes that the application of the SEM/AVS method to copper is not preferred, and therefore the bioavailable fraction of the copper is uncertain.

6.1 Sediment Quality Guidelines

The default ANZECC (2000) interim sediment quality guidelines (low and high) were used in the first instance, to identify sediments where contaminant concentrations may be likely to result in adverse effects on sediment ecological health.

Information on background concentrations of key toxicants in sediment was obtained from GHD (2012), which presented sediment sample results from May 2011 from several sites in the Edith River and creeks/streams on the Mount Todd mining lease. These data show that the background concentrations of all toxicants in the data set were generally below the ANZECC ISQG-low, where applicable. There are no default trigger values for aluminium, cobalt or manganese. Therefore guidelines were derived on the basis of natural background concentration multiplied by an appropriate factor (in this case by 2[10]). These derived guidelines were used as ISQG-low.

The Sediment Quality Guidelines (SQGs) used for the purposes of this investigation are shown in Table 5.

[10] The approach endorsed by ANZECC (2000) to derive a value on the basis of natural background (reference) concentration multiplied by an appropriate factor (a factor of two is recommended).

Table 5 Sediment Quality Guidelines (SQGs) used in this Investigation

Toxicant	ISQG-low (mg/Kg)	ISQG-high (mg/Kg)
Aluminium	3990*	-
Antimony	2	25
Cadmium	1.5	10
Chromium	80	370
Cobalt	<10*	-
Copper	65	270
Lead	50	220
Manganese	922*	
Mercury	0.15	1
Nickel	21	52
Zinc	200	410

* average background concentration (GHD, 2012) multiplied by a factor (2)

There are no applicable guidelines for arsenic, barium, beryllium, bismuth, boron, gold, molybdenum, selenium, silver, thallium, tin, uranium and vanadium.

6.2 Test against Sediment Quality Guidelines

All laboratory reports for sediment samples are provided in Appendix F. A summary of the sediment monitoring results compared with the SQG's is provided in Appendix K.

Exceedance of the SQGs were most commonly associated with aluminium, with three occurrences:

- Edith River R-R- between the derailment site and the Stuart Highway road bridge on 31 December 2011; and
- SW2- approximately 2 kilometres upstream of West Creek (RP1 spillway discharge) and 1.5 kilometres upstream of Burrell Creek (RP1 siphon discharge) and approximately 10 kilometres upstream of the derailment on 5 January and 11 January 2012.

Other exceedances included one ISQG-low for copper at SW10 and one ISQG-high for copper at Edith River R-R on 31 December 2012.

After 31 December 2011, there were no recorded exceedances of the SQGs (low or high) downstream of the train derailment or the Mt Todd mine discharge locations.

6.3 Simultaneously Extractable Metals/Acid Volatile Sulfide

The SEM/AVS ratio was calculated for samples which had an exceedance of the SQG. Samples that had a calculated SEM/AVS ratio greater than 1 (indicating potentially bioavailable fraction of contaminants in sediment) are presented in Table 6.

Table 6 SEM/AVS Calculation Results

Date	Sample Location	SEM/AVS Calculation Result	Metals
31/12/11	Edith River R-R *Downstream of the incidents*	26.44	Aluminium- 4400 mg/kg (SQG 3990 mg/kg) Copper- 430 mg/kg (SGQ [ISQG-high] 270 mg/)kg
	SW10 *Downstream of the incidents*	3.73	Copper- 110 mg/kg (SQG [ISQG-low] 65 mg/kg)
5/1/12	SW2 *Upstream of the incidents*	>1[a]	Aluminium- 4000 mg.kg (SQG 3990 mg/kg)
11/1/12	SW2 *Upstream of the incidents*	>1[b]	Aluminium- 6000 mg.kg (SQG 3990 mg/kg)

a. AVS < 1, sum SEM 8.22

b. AVS < 1, sum SEM 6.42

6.4 Summary of Assessment of Potential Environmental Harm Sediment

A determination of the *potential* for environmental harm, as defined by the *WMPC Act* and the *Water Act* was made using the methodology defined in section 6.

The assessment of *potential* harm is summarised below.

1. Total concentrations of aluminium and copper were above the ISQGs on a small number of occasions at Edith River R-R, SW10 and SW2.

2. Calculated SEM/AVS ratios for SW2 (upstream site) indicate that background concentrations of aluminium in sediment may be bioavailable. Ratios for sites downstream of the incidents indicate contaminants may be bioavailable in sediments at Edith River R-R and SW10.

The contaminants of concern (most commonly above ISQGs in sediment samples) were identified as aluminium and copper. These contaminants are toxic, persistent in the environment and some have been shown to be bioavailable. A brief summary of the potential toxicity of these contaminants is provided in section 5.5.

The extent of aluminium and copper contamination (downstream of the incidents) identified during the investigation is demonstrated through the calculated SEM/AVS greater than 1 at sites downstream of SW2. Contamination ranged from approximately 150 metres to approximately 600 metres downstream of the derailment.

Sampling of sediments at SW2 indicates that naturally high concentrations of aluminium occurred at concentrations greater than that detected in Edith River R-R sample obtained on 31 December 2011 (4,400 mg/kg). The total concentration of aluminium detected at SW2 on the same day was 1,800 mg/kg (refer to Appendices F and K). It would be difficult to determine whether the elevated total concentrations results were natural or associated with the train derailment and discharges from Mt Todd mine.

Copper contamination in sediments was evident on only one day of sampling. The SEM/AVS method is not preferred for determining the bioavailable concentration of copper. The minimum level of protection to the aquatic ecosystem may not have been achieved on this date.

7 Assessment of Environmental Harm- Biological

DLPE used the results of biological monitoring undertaken by VG (as a condition of WDL178-1) as a line of evidence to evaluate *actual* environmental harm caused by the train derailment and discharges from the Mt Todd mine.

The *Mt Todd Macroinvertebrate and Sediment Monitoring Report 2011 – 2012 Wet season* (Envirotech Monitoring, undated) was provided to DLPE on 31 October 2012. It presented the results of aquatic macroinvertebrate, sediment and water quality sampling conducted at sites located on the Edith and Fergusson Rivers, nearby to the mine site.

Macroinvertebrate sampling was conducted towards the end of the Wet season during the recessional flow period in the Edith and Fergusson Rivers, from 17 May to 14 June 2012. Methods followed the standard Northern Territory *Australian Rivers Assessment System* (AusRivAS) field and laboratory protocols.

The aim of the surveys and assessments was to identify and quantify any changes to the downstream Edith River ecosystem as a result of licensed discharging activities. Potential changes in overall macroinvertebrate community composition, pollution-sensitive taxa diversity, pollution-sensitive taxa abundance for both pelagic and benthic macroinvertebrate communities were investigated along with the chemical and physical composition of the sediments surrounding both communities (Envirotech Monitoring, undated).

Envirotech reported on all macroinvertebrate community indicators for pelagic and benthic fauna. There was no conclusive statistically significant impact of waste water discharge to downstream Edith River communities. The timing of the sampling captured the period of potential harm caused by the train derailment. Results are indicative of impact from this event and the wastewater discharge from the mine.

8 Determination of Source

Isotope ratio analysis is widely used in natural sciences and is a recognised tool for identifying and discriminating isotope types from within a source or from different sources. It has been used successfully world-wide to characterise the extent of metal contamination in the environment (e.g. footprint or signature). There are several recognised laboratory methods for isotope ratio analysis, with lead isotopic fingerprinting being one of the common methods used to link a metal (e.g. copper, lead, zinc) ore contaminant with its source.

DLPE commissioned the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the University of Melbourne to undertake lead isotopic analyses of sampled river water and river sediment to ascertain the extent of lead contamination from the spilt copper concentrate (originating from the Prominent Hill mine in South Australia), and to differentiate this lead source from other local sources, particularly the nearby mine.

Representative samples for analysis of Lead Isotopes were chosen based on the high concentrations of toxicants detected in water or sediment. Not all samples obtained during the course of this investigation were assessed due to the high cost involved for analysis and interpretation.

The results of the University of Melbourne analysis and the CSIRO interpretative report is provided in Appendix L. Samples tested for lead isotopes are presented in Table 7, and the source of the lead based on lead isotope ratio analysis is provided.

Table 7 Lead Isotope Samples

Date	Sample ID	Sample matrix	Source as identified through Lead Isotope analysis
3/1/12	Cu Concentrate	Solid	Copper concentrate
	SW2	Water	Background
	Control 4	Water	Mount Todd Mine, Background
	Control 1	Water	Mount Todd Mine, Background
	Daly River	Water	Background
	SW10	Water	Copper concentrate, Background
5/1/12	RP1	Water	Mount Todd Mine
	SW2	Water	Background
	SW10	Water	Copper concentrate, Background
16/1/12	Control 4	Water	Background
19/1/12	Control 1	Water	Copper concentrate, Background
23/1/12	SW2	Soil	Background
	Control 4	Soil	Background
	Control 1	Water	Copper concentrate, Background
	Control 1	Soil	Mount Todd Mine, Background
	SW10	Soil	Mount Todd Mine, Background
	SW10	Water	Copper concentrate, Background
27/1/12	SW4	Water	Mount Todd Mine, Background
	SW10	Water	Background
	Daly River	Water	Background

A summary of the CSIRO report is provided below:

- Samples obtained from SW2 have ratios different from the mine waters and are consistent with derivation of lead from local, background rock units.
- The SW4 sample taken on 27 January 2012 contains a significant proportion of lead derived from the mine.
- The water samples from Control 4 on 3 January 2012 contains a significant proportion of lead derived from the mine. In contrast water assessed from the same site taken on 16 January 2012 contains a significant proportion of lead derived from local background bedrock.
- The results show that the bulk of the lead dissolved in the river waters derives from local background bedrock.

- Lead derived from the mine was detected at distances up to 5 km from the discharge point (at Control 4).
- The impact of the copper concentrate spill can be measured at SW10 (approximately 600 metres downstream from the site of the train derailment) where over the sampling period it contributed up to a maximum of 5% of the total lead content of the river water, and was present in sediment.
- Copper concentrate was detected in water approximately 1 kilometre upstream of the derailment on 19 and 23 January 2012 (over 3 weeks after the train derailment), as well as downstream of the site of the derailment, at SW10 (on 23 January 2012). DLPE assessed that this upstream anomaly may have been a result of the OZ Minerals clean-up efforts removing copper concentrate from the river bed and re-suspending sediments during the process, and/or the eddies created by the flood waters.

Lead detected for the purpose of isotope ratio analysis was not detected in concentrations that were a concern.

9 Discussion

Multiple lines of evidence were used to assess impact in water and sediments and the *potential* for environmental harm over the period 28 December 2011 and 17 July 2012 in the Edith River region between the Mount Todd Mine Site and the Edith River derailment site, and up to 200 kilometres downstream in the Daly River.

Multiple lines of evidence suggest that the required minimum level of protection (95% protection of aquatic ecosystems for water, and contamination in sediment potentially causing an effect) for the Edith/Daly Rivers downstream of the mine and derailment locations was not achieved on 33 days (between 31 December 2011 and 10 May 2012), at seven surface water sampling locations (Control 1, Control 4, Edith River R-R, SW10, Control 5, Daly River, and Oolloo Crossing). This occurred over a total extent of over 200 kilometres downstream from the site of the train derailment and Mt Todd mine.

The minimum level of protection was not achieved on six occasions upstream of the mine site at SW2.

The source of contamination was identified for some occurrences using lead isotope ratio analysis. A summary of days and locations downstream of the train derailment and mine discharge where the required level of protection may not have been achieved, is provided in Table 8.

Table 8 Minimum Level of Protection Not Achieved

Date/Sample Location	Matrix	Source
28/12/2011		
Control 1	Water	Not determined
SW10	Water	Not determined
Oolloo Crossing	Water	Not determined
31/12/2011		
Control 1	Water	Not determined
SW10	Water	Not determined
Daly River	Water	Not determined

Date/Sample Location	Matrix	Source
Edith River R-R	Sediment	Not determined
SW10	Sediment	Not determined
3/01/2012		
Control 4	Water	Mount Todd Mine + Background
Control 1	Water	Mount Todd Mine + Background
SW10	Water	Copper concentrate + Background
5/01/2012		
Control 4	Water	Not determined
Control 1	Water	Not determined
SW10	Water	Copper concentrate + Background
Control 5	Water	Not determined
9/01/2012		
Control 1	Water	Not determined
SW10	Water	Not determined
11/01/2012		
Control 4	Water	Not determined
Control 1	Water	Not determined
SW10	Water	Not determined
16/01/2012		
SW10	Water	Not determined
23/01/2012		
Control 4	Water	Not determined
Control 1	Water	Copper concentrate + Background
SW10	Water	Copper concentrate + Background
27/01/2012		
Control 4	Water	Not determined
Control 1	Water	Not determined
SW10	Water	Background
Daly River	Water	Background
31/01/2012		
Control 4	Water	Not determined

Date/Sample Location	Matrix	Source
Control 1	Water	Not determined
SW10	Water	Not determined
2/02/2012		
Control 4	Water	Not determined
Control 1	Water	Not determined
SW10	Water	Not determined
8/02/2012		
Control 4	Water	Not determined
Control 1	Water	Not determined
SW10	Water	Not determined
10/02/2012		
Control 4	Water	Not determined
Control 1	Water	Not determined
SW10	Water	Not determined
14/02/2012		
Control 4	Water	Not determined
Control 1	Water	Not determined
SW10	Water	Not determined
17/02/2012		
Control 4	Water	Not determined
Control 1	Water	Not determined
SW10	Water	Not determined
21/02/2012		
Control 4	Water	Not determined
Control 1	Water	Not determined
SW10	Water	Not determined
23/02/2012		
Control 4	Water	Not determined
Control 1	Water	Not determined
SW10	Water	Not determined
28/02/2012		

Date/Sample Location	Matrix	Source
Control 1	Water	Not determined
SW10	Water	Not determined
1/03/2012		
Control 4	Water	Not determined
Control 1	Water	Not determined
8/03/2012		
Control 4	Water	Not determined
Control 1	Water	Not determined
SW10	Water	Not determined
13/03/2012		
Control 4	Water	Not determined
SW10	Water	Not determined
20/03/2012		
Control 4	Water	Not determined
SW10	Water	Not determined
22/03/2012		
Control 4	Water	Not determined
SW10	Water	Not determined
27/03/2012		
Control 4	Water	Not determined
SW10	Water	Not determined
29/03/2012		
Control 4	Water	Not determined
SW10	Water	Not determined
3/04/2012		
Control 4	Water	Not determined
SW10	Water	Not determined
10/04/2012		
Control 4	Water	Not determined
SW10	Water	Not determined
12/04/2012		

Date/Sample Location	Matrix	Source
Control 4	Water	Not determined
SW10	Water	Not determined
24/04/2012		
Control 4	Water	Not determined
26/04/2012		
Control 4	Water	Not determined
SW10	Water	Not determined
1/05/2012		
Control 4	Water	Not determined
SW10	Water	Not determined
3/05/2012		
Control 4	Water	Not determined
10/05/2012		
Control 4	Water	Not determined

Note "Not determined" indicates lead isotope ratio analysis not undertaken on sample.

In summary:

- A total of 80 water samples and two sediment samples obtained from locations downstream of the reported incidents contain concentrations of contaminants that may not be protective of 95% of species. Samples were obtained from 33 days, and seven locations;

- Exceedances indicated there was the *potential* for environmental harm;

- Isotope ratio analysis shows that discharge from the Mount Todd Mine Site contributed to the minimum level of protection not being met (in water) at Control 4 and Control 1 on 3 January 2012;

- Isotope ratio analysis shows that copper concentrate, spilled as a result of the train derailment, contributed to the minimum level of protection not being met at SW10 on 3 January 2012 (water), SW10 on 5 January 2012 (water), Control 1 and SW10 on 23 January 2012 (water);

- Lead isotope analysis was not undertaken for all other exceedances of the minimum level of protection in water and sediment, and the contributing source of contamination could not be identified;

- Biological monitoring undertaken after the train derailment and discharges from Mt Todd mine found there was no conclusive statistically significant difference between downstream Edith River communities and reference sites in the region;

- Biological monitoring did not provide any evidence that *actual* environmental harm occurred as a result of the train derailment or wastewater discharge from the mine.

10 Conclusions

Multiple line of evidence provide an assessment of *potential* and *actual* environmental harm posed by the train derailment (copper concentrate) and waste water discharge from the Mount Todd mine site.

A total of 80 exceedances of applicable water quality criteria on 33 separate days were identified downstream of the mine discharge point and in some cases downstream of the site of the train derailment. These exceedances indicated there was the *potential* for environmental harm. The mixture and concentrations of toxicants present in the samples considered suggests that at times the required minimum level of 95% protection may have not been achieved during the period of the investigation.

All water samples were below the water quality criteria for drinking water (Australian Drinking Water Guidelines).

10.1 Edith River Train Derailment

Isotope ratio analysis shows the impact of the copper concentrate spill from the train derailment was at times measurable for approximately 600 metres downstream of the train derailment site.

The copper concentrate is considered generally insoluble, with low mobility and low biological availability in the environment. There is sufficient solubility in fresh water to classify the copper concentrate as environmentally hazardous.

Sediment samples analysed four days after the train derailment show concentrations of copper in close proximity (150 to 600 metres) to the train derailment site to be above the applicable sediment quality criteria. Concentrations of copper in surface water samples in the same area also tended to be above the applicable water quality criteria. This suggests that the copper concentrate may have been mobile and bioavailable in water.

Concentrations of copper in water and sediment in close proximity to the location of the train derailment indicated that the minimum level of protection may not have achieved on some days. The copper may be attributed to the train derailment, although it occurred over a short duration (generally less than two consecutive days) and therefore was unlikely to have a long term environmental impact.

Direct Toxicity Assessments on water samples were obtained within 10 days after the derailment, including a water sample from SW10. This sample contained concentrations of copper above the applicable water quality criteria, and was associated with the copper concentrate as identified by lead isotope analysis. Sediment toxicant concentrations at this location were above the applicable sediment quality criteria. The results of the DTA for this sample found there was no effect on growth, inhibition or survival in the species tested with the exception of the inhibition of growth in an algal species (*Selenastrum capricornutum*). There was evidence to suggest that the inhibitory effect on growth in this species was due to factors other than toxicity.

Isotope ratio analysis attributed *potential* environmental harm to copper concentrate from the train derailment. This occurred in four samples taken over three days from a short distance downstream of the location of the derailment, and at one location a short distance upstream of the location of the derailment.

Biological monitoring did not provide any evidence that *actual* environmental harm occurred as a result of the derailment.

There is evidence that copper concentrate impacted material remains in heavily vegetated areas and AAPA restricted areas at the location of the train derailment. OZ Minerals proposed to leave this material in-situ due to the extensive land disturbance that would be required to undertake further remediation works (Golders, 2012).

An ecological and human health risk assessment of the material to be left in-situ was commissioned by OZ Minerals (Golder Associates, 2012). The objective was to assess the potential impact and risks to humans and the environment associated with residual copper concentrate affected materials remaining in-situ in localised areas. OZ Minerals (2012) reported the findings of the Golder (2012) study, finding that the surface water concentrations downstream of the train derailment were below the Australian Drinking Water Guidelines, and no human health impacts are expected. OZ Minerals (2012) reported that the ecological risk associated with the potential leaching, erosion and run-off of copper due to elevated residual copper concentrations in soil remaining in-situ did not indicate any potential impacts on surface water or sediment concentrations, and the consequential risk to aquatic organisms was determined to be low.

The impacts of further land disturbance and vegetation clearance in these areas are considered higher than the potential localised ecological impacts of leaving residual copper concentrate affected material in-situ. No stressors have been observed on vegetation to date (OZ Minerals, 2012).

Correspondence received by DLPE from GWA on 6 December 2012 indicated that any remaining freight in the Edith River downstream of the location of the train derailment poses a low environmental risk, with potential impacts limited to amenity. GWA will return to the site of the train derailment in June-July 2013 to re-assess if further clean-up is required.

10.2 Waste Water Discharge Mount Todd Mine

Isotope ratio analysis shows that at least a proportion of pollutants in the Edith River waters are associated with local background bedrock with some contamination attributable to the Mt Todd mine discharge. The isotopic signature of the mine's discharge water could at times be measured at distances up to 10 kilometres from the mine site.

Chemical assessment showed the key pollutants in the waste waters from the mine to be aluminium, cadmium, copper and zinc. These chemicals were found to occur in surface waters at concentrations above the relevant water quality criteria for the 95% level of species protection.

These chemicals are persistent and are bioavailable in the environment. However there is no evidence to suggest that there is a build up of these pollutants in sediment. In particular aluminium in sediment appears to be associated with elevated background levels.

DTAs undertaken on samples with concentrations of contaminants above HMTVs downstream of the mine when VG was discharging (5 January 2012) showed there was no effect on growth, inhibition or survival in the species tested with the exception of the inhibition of growth in an algal species (*Selenastrum capricornutum*). There was evidence to suggest that the inhibitory effect on growth in this species was due to factors other than toxicity.

DTA was undertaken on a water sample downstream of the mine (Control 4) on 16 January 2012 after VG had ceased active discharge approximately 11 days previous. The results of this DTA were similar to previous assessments on 5 January 2012.

Isotope analysis was not undertaken on all samples containing elevated concentrations of contaminants, and therefore the exact source of these contaminants for each occurrence could not always be determined. Isotope testing that was undertaken attributed *potential* environmental harm to discharge from the mine in two samples, taken on one day, approximately 5 kilometres, and 10 kilometres downstream of the discharge point.

Biological monitoring did not provide any evidence that *actual* environmental harm occurred as a result of the wastewater discharge from the mine.

11 References

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