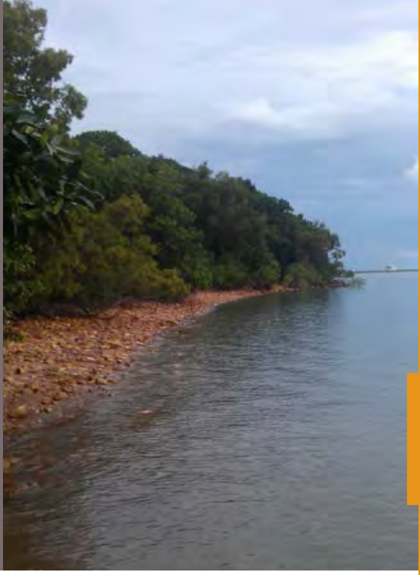

2012–2013 Annual Report

Environmental Impact Monitoring Program
Ichthys On-Shore Liquefied Natural Gas (LNG) Facilities






Prepared for **JKC Australia LNG Pty Ltd** • July 2013

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Abbreviations

Abbreviation	Description
AAS	Atomic Absorption Spectrometry
AGL	Above Ground Level
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment Conservation Council
APHA	American Public Health Association
ARL	Analytical Reference Laboratories
ALS	Analytical Laboratory Services
ASS	Acid Sulphate Soil
ASCS	Australian Soil Classification System
BDL	Below Detection Limit
BGL	Below Ground Level
BPDD	Blaydin Point Dust Deposition
BPPM	Blaydin Point Particulate Mater
BPGW	Blaydin Point Groundwater
BPMC	Blaydin Point Mangrove Community
BPSW	Blaydin Point Surface Water
BOM	Bureau of Meteorology
BTEXN	Benzene, Toluene, Ethylbenzene, Xylenes, Napththalene
COC	Chain of Custody
CEMP	Construction Environmental Management Plan
CSMC	Control Site Mangrove Community
CSSW	Control Site Surface Water
CVL2	Site Development Civil Works
CWA	Civil Works Area
DO	Dissolved Oxygen
EC	Electrical Conductivity
EIMP	Environmental Impact Monitoring Program
EIS	Environmental Impact Statement
ESDAT	Environmental Data Management System
DLNG	Darwin Liquefied Natural Gas
DLPE	Department of Lands, Planning and the Environment
DR	Dynamic Replacement
DQO	Data Quality Objective
FID	Flame Ionisation Detector
GIIP	Good International Industry Practice
GME	Groundwater Monitoring Event
GPS	Global Positioning System
HSES	Health Safety Environmental System
HSEMP	Health Safety Environmental Management Plan

Abbreviations

Abbreviation	Description
LAeq	Equivalent Continuous A-weighted Sound Pressure Level
LNG	Liquefied Natural Gas
LOR	Limit of Reporting
LO'R	Laing O'Rourke
MS	Mass Spectrometer
MSLP	Mean Sea Level Pressure
NMT	Noise Monitoring Terminals
NATA	National Association of Testing Authorities
NTEPA	Northern Territory Evironmental Protection Agency
NTU	Nephelometric Turbidity Units
PADD	Palmerston Dust Deposition
PAH	Polycyclic Aromatic Hydrocarbons
PAPM	Palmerston Particulate Mater
PQL	Practical Quantitation Limit
QA/QC	Quality Assurance / Quality Control
RPD	Relative Percentage Difference
SAP	Sampling Analysis Plan
SWL	Static Water Level
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
TPH	Total Petroleum Hydrocarbons
TRH	Total Recoverable Hydrocarbons
UPVC	Plasticized Polyvinyl Chloride
USEPA	United States Environmental Protection Agency
UXO	Unexploded Ordinance

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The Ichthys onshore processing plant will be located on Blaydin Point in Darwin Harbour, Northern Territory (NT). The onshore development area comprises Blaydin Point, where most of the construction work and infrastructure will be associated (the site). Also included near the site are the Blaydin Point isthmus where the operations complex will be located, a site access road connected to Wickham Point Road, and the gas export pipeline (GEP) which has not yet been developed. A Construction Environmental Management Plan (CEMP) has been prepared for the site which details the environmental protection management measures and controls necessary to avoid, reduce or mitigate the environmental impacts during the construction phase of the onshore component of the project.

This report discusses works performed as required by the *Environmental Impact Monitoring Program* (EIMP)*, Doc # L290-AH-PLN-10013*, as approved by Northern Territory Environmental Protection Agency (NTEPA) on 20 December 2012, between April 2012 and April 2013 and presents a summary of potential environmental impacts which may have resulted from construction works at the site. Implementation of the EIMP is a requirement of Appendix B of the CEMP. Off-site Project Ichthys development works conducted in Darwin Harbour and off-shore areas adjacent the site, including dredging, are not included in the monitoring plan set out in the EIMP and are therefore not evaluated in this report.

The following monitoring programs have been developed in association with the Project:

- Surface Water Monitoring;
- Groundwater Quality Monitoring;
- Sediments and Bio-Indicator Monitoring;
- Mangrove Community Health Monitoring;
- Air Quality (Dust) Monitoring; and
- Airborne Noise Monitoring.

In addition to the monitoring program scope detailed in this report, the following third party information has been included as required by the EIMP:

- Acid sulfate soil (ASS) monitoring;
- Flora and fauna monitoring; and
- Weed monitoring.

The site is located approximately 16 km southeast of the City of Darwin, NT, in the southern area of Darwin Harbour and occupies an area of approximately 406 ha of land. The site is located on land designated as Blaydin Point on the Middle Arm Peninsula. Blaydin Point is surrounded on three sides by water; to the east is the Elizabeth River, to the north the East Arm (both within the East Arm of Darwin Harbour) and Lightning Creek to the west.

Blaydin Point site works conducted between April 2012 and April 2013 consisted primarily of bulk earth works and civil infrastructure works. Based on field observations and laboratory results, the following activities were identified to be the potential influences of environmental disturbance to off-site areas:

- Vegetation clearing;
- Cut and fill;
- Dynamic replacement ground improvement;
- Drainage works;

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- ASS treatment areas;
- Installation of hard stands; and
- Road works and facility installation.

The findings of environmental monitoring works conducted between April 2012 and April 2013 are detailed below. It is noted that due to logistical constraints, some segments of the monitoring program could not commence until June 2012.

Surface Water

The purpose of the surface water monitoring was to determine impacts of surface water discharge on the receiving environment. The monthly surface water monitoring was intended to monitor the potential impacts from discharges from basins, spills and leaks from temporary facilities, ASS/PASS impacts and impacts upstream and downstream of the impact sites.

In accordance with the EIMP, samples were collected from the receiving environment and sediment basins (where sufficient water was present) on a monthly basis. These samples underwent both in-situ and laboratory analysis. The monitoring data from each location was compared spatially, temporally and against the environmental approvals trigger criteria.

The EIMP stated that monthly surface water monitoring was going to be conducted at 33 primary locations located upstream, downstream and at the point of discharge and at two control site locations. Surface water monitoring was undertaken at:

- 13 marine primary sampling sites located in the Darwin Harbour around the Blaydin Point site;
- Two marine control sites located in Darwin Harbour near East Arm; and
- Up to nine surface water sediment basins (wet season only) located at Blaydin Point (when water was present).

Fifteen marine sampling locations were sampled monthly on the spring tide between June 2012 and March 2013. Six sediment basins were sampled in January and March 2013, and nine in February 2013 at the site. All samples were submitted for laboratory analytical testing.

Field and laboratory analytical results obtained during the monthly marine surface water monitoring undertaken between June 2012 and March 2013 generally reported standard values for an estuarine environment. Measured in situ field parameters of the marine surface water sampling sites located in the vicinity of Blaydin Point are generally comparable to the control sites.

A seasonal trend could be established for some of the analytes, which mostly follows the occurrence of rainfall in the Darwin area. Trends observed for the reported analytes suggest a seasonal variation rather than due to site activities.

The measured turbidity between June 2012 and March 2013 was within the reported range of turbidity usually recorded in Darwin Harbour. Maximum turbidity records were also found to be consistent with reported turbidity at spring tides in the Middle Arm of Darwin Harbour. Turbidity is expected to be higher in the upper reaches of the Harbour, which are in closest proximity to the tidal mud flats and shallower waters where water residence times and sediment suspension is greater. This explains why higher turbidity is observed within some of the monitoring sites compared to the control sites. Padovan (2003) reported turbidity to range on average between 1 and 35 NTU in the main body of the Darwin Harbour. Dissolved oxygen serves as an indicator of the physical, chemical and biological activities of the estuary. The monitoring results during June 2012 to March 2013 indicate that Darwin Harbour is typically well oxygenated and that there was no discernible difference in dissolved oxygen trends between the control, near shore and the mangrove sites. The monitoring locations and the control sites have very similar variability of DO every month.

The pH characteristics of surface water change with time due to variations in temperature, salinity and biological activity. Most of the Darwin estuarine water has been recorded as alkaline (pH greater than 7) due to the presence of carbonates in marine environments. The monitoring results indicate there was no discernible difference in pH trends between the control, near shore and the mangrove sites. Overall, pH levels appear relatively stable with monitoring sites and the control sites having very similar variability every month.

No metals were reported as exceeding their trigger criteria during the 2012/2013 monitoring period, except for dissolved copper which was reported above trigger criteria in June 2012 at 26% of the sampling sites, and in July 2012 at 66% of the sampling sites. No clear explanation of those levels can be provided at this stage, nor can these concentrations be immediately correlated to site activities. All other analysed metal concentrations are generally stable between June 2012 and March 2013. Arsenic and vanadium is observed at high concentrations (for a natural environment) within Darwin Harbour, which is a reflection of the local geology of the Darwin Harbour rather than anthropogenic causes.

Overall, nutrient levels in the surface waters were considered to be typically low. Similarly biological indicators are reported at low levels which is consistent with reported figures for Darwin Harbour.

Field and laboratory analytical results from the sediment basins are not able to be compared to control sites; however, data showed that the sediment ponds were generally alkaline, with high turbidity, high levels of nutrients which might be explained by decomposition of organic material in the soil, normal levels of dissolved oxygen and elevated levels of *Enterococci* and *Escherichia coli*. Elevated bacterial levels may be explained by the previous undisturbed land use of the site, where fauna would have been the cause of the *Enterococci* levels, and also the likelihood of daily visitation by birds which may contribute to the *Enterococci* levels through their faeces.

Surface water discharge information in the form of discharge permits conducted for off-site discharges between October 2012 and April 2013 have been included as required by the EIMP. These permits detail volume and water quality, although discharge location is not specified. Reported discharges were surface discharges at ground level and off-site. In accordance with the CEMP, discharges were managed and approved by JKC.

Groundwater

The aim of the groundwater monitoring program is to establish background groundwater quality at the site and to conduct on-going monitoring to assess potential changes from these initial conditions. Initial monitoring data was collected from an existing groundwater monitoring bore network, in June, July and August 2012. The monitoring bore network was expanded and during the September 2012 through March 2013 monitoring rounds, groundwater samples were collected from up to 34 bore locations.

Groundwater pH has remained relatively constant across the period of monitoring. However, except for a few isolated instances, all pH values recorded at the site to date have been below the groundwater quality trigger criterion range of 7.0 to 8.5. Apparent decreasing trends in pH have been

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noted at monitoring bores BPGW01, BPGW02, BPGW11, BPGW12, BPGW24, BPGW25 and BPGW32. With the possible exception of BPGW32, these decreasing trends appear to correspond with the onset of the wet season and might, therefore, be attributable to the flushing of near-surface humic acids into the shallow underlying groundwater.

Datalogger records and water quality measurement conducted at the time of sampling indicate that EC has remained relatively constant at most bore locations across the period of monitoring.

Except for a few one-time occurrences, total recoverable hydrcarbons (TRH) and benzene, toluene, ethylbenzene, xylenes and naphthalene (BTEXN) compounds have not been reported in groundwater at the site. However, groundwater can be characterised as having elevated concentrations of dissolved metals (cobalt, manganese, zinc and, at a smaller percentage of bore locations, aluminium, arsenic, cadmium, copper, lead, nickel and silver), nutrients (ammonia as N and, at a smaller percentage of bore locations, total nitrogen as N, nitrate & nitrite (as N), reactive phosphorous and total phosphorous) and a pH that is in almost all instances below the lower end of the trigger criteria range. No clear trends in metals and nutrients concentrations for the site as a whole are apparent, although a number of the bores show individual trends. Possible explanations for these elevated concentrations and low pH include:

- Natural background groundwater quality conditions;
- Impacts associated with ground improvement works;
- Historical site usage; and
- Transport with groundwater from off-site, upgradient locations.

Dissolved metals concentrations have been decreasing at numerous monitoring bore locations after apparent highs in October, November or December 2012. These decreases in metals concentration are likely attributable to the influx (recharge) of fresh water during the wet season. In contrast, dissolved metals concentrations have been gradually increasing at monitoring bores BPGW11, BPGW12, BPGW25 and BPGW29. It is unclear if these increases are related to site works. However, as noted above, decreasing trends in pH have been noted at monitoring bores BPGW11, BPGW12 and BPGW25.

There is currently no evidence to suggest that groundwater quality at the site is related to historical site usage or transport from off-site locations. The elevated concentrations of dissolved metals, nutrients and low pH are therefore expected to be the result of either natural background conditions or impacts associated with ground improvement works. Groundwater monitoring conducted in 2008 and 2009 indicated elevated concentrations of total metals including arsenic, aluminium, cadmium, copper, manganese, nickel and zinc. The occurance of these metals may be reflective of natural background conditions. Currently, there is insufficient data to identify temporal trends, or correlate reported 2012/2013 metals concentrations to site works.

Acid Sulfate Soils

Acid sulfate soils (ASS) were identified within the areas of the proposed site during the site investigations prior to development. To manage the risk of ASS affecting groundwater and surface water quality environmental monitoring of groundwater and surface water was to be undertaken to detect any changes to water quality parameters as a result of ASS. The EIMP and CEMP stated that ASS was to be monitored by:

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- Groundwater: In situ analysis of groundwater in the vicinity of high ASS risk areas using a calibrated hand-held water quality meter. Groundwater elevations will also be monitored.
- Surface water: In situ analysis of surface water at four buoys located within Darwin Harbour.

ASS monitoring was conducted at the site in 2012 and 2013. Laboratory analytical reports, treatment register tables and results summary table for ASS monitoring detail the soil testing and treatment that occurred on site. A series of figures illustrating the ASS Reaction Rating of soil samples collected from various locations across the site indicate that high and extreme risk ASS areas exist in portions of the site, particularly near the MOF, along the causeway, and in the coastal areas. It should be noted that the vast majority of samples analysed were collected from locations along the coast at depths less than two metres below ground level. ASS soil validation and management was managed by JKC and that data will reportedly be conveyed separately to NTEPA.

Mangrove Monitoring

A network of monitoring sites has been established in mangroves adjacent to the Blaydin Point on-shore construction works (23 sites) and at control sites (six sites) located further away to provide monitoring data related to mangrove community health, sedimentation/erosion, sediment quality and bio-indicators. Baseline data was collected in May/June 2012 and subsequent monitoring has been undertaken at quarterly intervals.

The results of the data collected from the monitoring sites during the quarterly surveys and laboratory analyses of mangrove sediments indicate that generally the mangrove systems at Blaydin Point and control sites are in a healthy condition and have remained relatively undisturbed from human impacts.

The mangrove health surveys did not indicate dust deposition was having an adverse effect on the mangrove community immediately off-site. Additional observations around the site suggest that some areas have experienced modified tidal flow that has resulted in localised ponding impacts to mangroves within and outside of the site boundary. Rehabilitation of these areas is being investigated with emphasis based on restoring the appropriate tidal hydrology and utilising natural mangrove propagule (mangrove seed/seedling) recruitment for re-vegetation and on-going monitoring.

Key points summarising the mangrove monitoring undertaken from June 2012 to March 2013 are:

- Mangrove community health and tree condition data indicate that mangroves at the monitoring sites adjacent to the Blaydin Point site have remained in a healthy condition with no evidence of deterioration in mangrove health related to the construction activities. The extent of variation in the canopy density data between the sampling dates was similar for both the Blaydin Point sites and control sites and consistent with canopy density values recorded from similar mangrove zones elsewhere in Darwin Harbour. Differences in canopy density between the mangrove zones reflect the range of mangrove community structures that occur.
- Relative ground or sediment level data show no evidence of sediment deposition or erosion amongst mangroves that may be related to site earthworks or construction activities. Ground level changes at the monitoring sites have been very minor and they reflect natural micro-scale variation in the ground (mud flat) surface topography typically caused by invertebrate fauna (bioturbation) and tidal processes.
- Sediment quality data obtained from the sampling helps to provide an improved understanding of natural variation in particle size distribution, hydrocarbon and heavy metal concentrations in the mangrove sediments, thereby helping to develop a local baseline for future assessment. Variations

in metals concentrations were recorded between the sampling dates at each site with no apparent trends or differences between sites at Blaydin Point and the control sites. The data shows no evidence of contamination in mangrove sediments. Elevated arsenic concentrations at several sites (including a control site) are consistent with those recorded from the broader Darwin Harbour region. Historically, arsenic concentrations in Darwin harbour are known to be typically above the ISQG-low level trigger values and this has been attributed to local geological influence rather than anthropogenic sources.
- To date the sampling of mudwhelks, as a bio-indicator, has only occurred doing the baseline monitoring phase in June 2012. This sampling will be repeated during the 2013 dry season. Laboratory analyses of the baseline samples shows that metal concentrations were below the recommended guideline levels for all analytes at all sites with the exception of mercury at two sites. The lack of disturbance at these sites at the time of sampling would suggest that the concentrations recorded reflect natural variability rather than anthropogenic factors.

Air Quality (Dust)

The Project's air quality (dust) monitoring objective is to record PM_{10} and $PM_{2.5}$ concentrations as well as dust deposition rates experienced at the site and the nearby residential area of Palmerston against National Environmental Protection Measure (NEPM) and relevant criteria (respectively). The data are to inform site management activities so that impacts from dust on the environment, on the workforce and nearby non-project related receptors may be minimised if required. The primary aim of the monitoring is to indicate compliance with the air quality criteria set out in the EIMP. Sampling will help to identify site specific issues and also provide data for fugitive dust modelling to address issues with specific conditions or phenomena.

The air quality (dust) monitoring program comprised:

- Continuous sampling incorporating light scatter analysis of PM_{10} at three locations at Blaydin Point and one location at Palmerston, and $PM_{2.5}$ at one location at Balydin Point. Those stations located at the site reflect ambient conditions at the boundary, while the station at Palmerston reflects ambient dust concentrations on the edge of the suburban residential area; and
- Monthly dust deposition monitoring at 14 primary locations (13 at the site boundary and one located on the south-eastern boundary of Palmerston). The dust deposition stations distributed around the site boundary monitor the rate of deposition of dust in the vicinity of vegetation, especially adjacent to mangrove communities. The dust deposition station located adjacent to Palmerston is primarily to measure amenity impacts on third party property from deposited dust. Dust deposition samples were taken over a month-long period followed by gravimetric determination of sample weight for the monitoring period.

The monitoring data indicate that while there have been elevated levels of dust deposition recorded, there have been no dust related adverse effects on the mangrove communities or dust related third-party amenity issues as a result of the construction program to date.

Mangroves forests abut much of the site boundary and the dust deposition monitoring sites are located to monitor the dust rates in relation to the mangrove health monitoring sites. To date, no adverse effect on mangrove health has been sustained as a result of elevated dust deposition rates in the vicinity.

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The respirable dust concentrations recorded over the monitoring program shows exceedances of the air quality criteria occurring regularly on site, peaking in October at the end of the Northern Territory dry season. The exceedances recorded at Palmerston are more likely to be due to localised activities in that suburban environment, than due to construction activities at Blaydin point.

Regarding impacts to human amenity criteria therefore, to date there have not been any dust related complaints with regards to the work carried out at Blaydin Point. This is primarily due to the site's distance from its nearest residential receptors in Palmerston. No exceedance of the dust deposition criterion has been observed at the Palmerston monitoring site, which also recorded the lowest average dust deposition rate.

Airborne Noise

The EIMP identified specific requirements for airborne noise monitoring, noise criteria and potential monitoring locations. Noise monitoring has been undertaken to assess compliance with the noise limits set out in the EIMP which have been taken from relevant Noise Policies and State Guidelines.

Two long-term sound level meters have been deployed to continuously measure construction noise levels at Blaydin Point and at Palmerston, between June 2012 and April 2013. The continuous noise readings have been periodically analysed to indicate compliance with the noise limits established in the EIMP. The identified most sensitive receptor that may be within reach of construction noise generated at the site are residents in the City of Palmerston. Other potential sensitive receptors are either further away or present lower risk for nuisance, as it is the case for industrial or commercial premises. Thus, it was determined that the noise measurements at Palmerston would indicate overall noise limit compliance during construction works.

The measured noise levels have been compared against the noise limits to determine any levels above such limits, and in case of any exceeding values were found, further statistical analysis was undertaken to determine the source of the exceeding noise levels.

The analysis focuses on the trends in the noise data collected over the eleven months of noise monitoring and assumes a baseline from observations during typical quiet days (e.g. Sundays).

The noise monitoring at the CWA site, indicates a progressive increase in noise levels, which aligns with an increase in construction activities and extent over the monitoring period. The noise levels have in general increased; however, this has not triggered any change in Palmerston and overall full compliance with the noise limits has been achieved. It is assumed that activities such as site clearing, excavations, ground improvement and general vehicle transit would have dominated the noise levels within the site. An activity with high risk of generating elevated noise emissions is piling. Test piling was undertaken between August and September 2012 within the site. No changes in noise trends were recorded from the CWA site noise monitoring data. Spikes registered in Palmerston during this time are considered to be unrelated to this test piling event.

Overall, the monitoring results at Palmerston indicate the same noise level patterns between June 2012 and March 2013 implying that no impact has been observed from construction noise at the site. A number of exceedances of the noise limits have been recorded at Palmerston; however data analysis indictes that none of the exceedances are attributable to construction activities within the site. No correlation between the noise levels at the sensitive receptors in the City of Palmerston and those on the site has been found.

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Flora and Fauna Monitoring

The flora and fauna management Project objective was to avoid disturbance to flora and fauna outside the approved clearing footprint.

The purpose of the vegetation monitoring was to detect changes in the health and composition of vegetation communities through a monitoring program by visual inspection, collection of Global Positioning System (GPS) data and a review of trends through time. Additionally, an assessment of compliance with clearance limits was undertaken. Additional fauna management objectives listed in the CEMP include avoiding injury/death to native fauna resulting from clearing, vehicle strikes and entrapment. The fauna monitoring methodology is not explicitly stated in the EIMP however the CEMP states that the mitigation measure for the fauna management objectives included engaging wildlife handlers during clearing operations to salvage and relocate native animals to areas away from the site.

The flora and fauna monitoring program was undertaken by third parties and as such no analyses are undertaken in this report.

Progressive post-clearing surveys were undertaken through 2012. Surveys were undertaken by licenced surveyors. Maps of each of the surveys were recorded.

Wildlife handlers were present on site and worked ahead of and with clearing machinery during clearing operations conducted in April, May and July 2012. This work was undertaken by specialist consultants in accordance with NT wildlife permits (Permit to Interfere with Protected Fauna, *Territory Parks and Wildlife Conservation Act*). A report was prepared by the consultancy at the conclusion of the staged clearing operation that provided details on native animal relocations, injuries and deaths. Mammals (including bats), reptiles, birds and amphibians were recorded during the surveys. In July 2012, a permit was obtained to conduct wildlife management by the primary sub-contractor on site. In accordance with the CEMP, records of mammal and reptile relocation were recorded, and injured animals were reported and passed to a wildlife carer. Native animal deaths were recorded.

Weed Monitoring

The purpose of the weed monitoring is to protect the vegetation fringing the site. Monitoring of the vegetation was achieved through visual inspection, collection of GPS data and review of trends in health and weed species compositions.

The weed monitoring program was undertaken by third parties and as such no analyses is undertaken in this report.

A pre-clearance field survey of weeds in terrestrial habitats was conducted by consultant scientists. The survey documented the distribution, diversity and abundance/density of weeds within the Blaydin Point project area and provided GPS records of weed locations. This survey found that the number of weed species had not increased on the site however the distribution of weeds had increased.

An annual survey was conducted by consultant scientists to reassess the distribution, diversity and abundance/density of weeds within and adjacent to the site and to assess the effectiveness of the weed treatment progam. This survey found that the number of weed species had not increased on the site, and that the area of weed occurrence had decreased indicating that site clearing, earthworks and weed treatment had been effective to control the spread of weeds off site.

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Introduction

1.1 Project Background

The Ichthys onshore processing plant will be located on Blaydin Point in Darwin Harbour, Northern Territory (NT). The onshore development area comprises Blaydin Point, where most of the construction work and infrastructure will be associated. Also included near the site include the Blaydin Point isthmus where the operations complex will be located, site access road connected to Wickham Point Road, and the gas export pipeline (GEP) which has not yet been developed (the site). The site location is presented in **Figure 1-1**.

Figure 1-1 Site Locality

The *Construction Environmental Management Plan,* (CEMP) has been prepared for the site, and approved by NRETAS on 19 April 2012, which details the environmental protection management measures and controls necessary to avoid, reduce or mitigate the environmental impacts during the construction phase of the onshore component of the project which includes the following:

- Installation of the erosion and sediment control structures and devices;
- Clearing and grubbing;
- Construction of access road and site roads;
- Bulk earthworks and shore protection;
- Transport of fill and rock materials;
- Ground improvement;
- Drainage and general civil works;
- Construction of temporary support facilities; and
- Site clean-up and rehabilitation.

This report discusses works performed as required by the *Environmental Impact Monitoring Program* (EIMP), *Doc # L290-AH-PLN-10013*, as approved by Northern Territory Environmental Protection Agency (NTEPA) on 20 December 2012, between April 2012 and April 2013 and presents a summary of potential environmental impacts which may have resulted from construction works at the site. Implementation of the EIMP is a requirement of Appendix B of the CEMP. Off-site Project Ichthys development works conducted in Darwin Harbour and off-shore areas adjacent the site, including dredging, are not included in the monitoring plan set out in the EIMP and are therefore not evaluated in this report.

The EIMP document will be updated in order to reflect on-going site construction footprint and work method changes throughout the construction phase of the project.

1.2 Purpose

The purpose this annual monitoring report is for the provision of trend analysis and interpretation of field and analytical data, collected as part of the EIMP scope. The EIMP scope is based on the monitoring requirements set out in the CEMP.

1.3 Environmental Management Strategy

The CEMP details the environmental risk assessment process and environmental management planning that has been applied to the proposed construction and commissioning stages of the Project at the site. These assessments have taken an outcome-focused risk-based approach and have made reference to the management of applicable risk categories together with ranking the potential environmental consequences resulting from the proposed construction activities.

As a consequence of the risks identified in the CEMP, a series of management plans have been produced detailing the strategies which will minimise impacts to environmental amenity and achieve the established objectives and targets. Fifteen specific environmental management strategies have been identified to control the risks. Of these it has been determined through completion of the CEMP that the following will require monitoring during the site preparation works, clearing and earthworks undertaken at the site areas as follows.

- Flora and fauna management;
- Weed and pest management;
- Surface-water management;
- Erosion and sediment control;
- Acid sulfate soil management;
- Groundwater management;
- Rehabilitation and re-vegetation management;
- Dust and air quality management; and
- Noise and vibration management.

1.4 Environmental Monitoring Programs

Of the fifteen environmental management strategies described in **Section 1.3**, monitoring programs around the following aspects of the Project have been developed:

- Surface Water Monitoring;
- Groundwater Quality Monitoring;
- Sediments and Bio-Indicator Monitoring;
- Mangrove Community Health Monitoring;

- Air Quality (Dust) Monitoring; and
- Airborne Noise Monitoring.

In addition to the monitoring program scope detailed in this report, the following third party information has been included as required by the EIMP:

- Acid sulfate soil management;
- Flora and fauna management; and
- Weed management.

The environmental monitoring program conducted from April 2012 to April 2013 was intended to enable provision of a data set for development of site-specfic guidelines. This report serves to provide evaluation of the EIMP and identify potential refinements to the monitoring program. Additionally, monitoring results presented in this report will be utilised in the process of developing site-specifc guidelines. .

1.5 Scope of Work

1.5.1 Statement of Scope

The scope of work outlined below has been generated based on criteria and assumptions contained within the site. The monitoring program has been broken down into the following discreet tasks:

- **Task 1** – Provision of monitoring infrastructure, establishment of the monitoring network and initial monitoring;
- **Task 2** – Implementation of the following monitoring programs (during the onshore civil works phase within the site):
  - Surface Water Monitoring;
  - Groundwater Quality Monitoring;
  - Sediments and Bio-Indicator Monitoring;
  - Mangrove Community Health Monitoring;
  - Air Quality Monitoring; and
  - Airborne Noise Monitoring.

The monitoring programs included in Task 2 are designed to provide a robust data set against which potential impacts resulting from the construction works within the site areas can be measured. Each of these programs is consistent with the minimum requirements set out within the CEMP and EIMP.

Tasks 1 and 2 are described in more detail in **Section 2.2** and **2.3** of this report.

1.5.2 Task 1 Provision of Monitoring Infrastructure, Establishment of the Monitoring Network and Initial Monitoring

Task 1 involved the establishment of the monitoring network equipment and infrastructure for surface water, sediment, groundwater, noise, vegetation, and air (dust) quality and determination background concentrations of key parameters prior to implementation of the full scale monitoring program. This included determination of background concentrations of speciated metals and metalloids, specifically chromium and arsenic in surface and groundwater. Total recoverable hydrocarbons (TRH) and

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polycyclic aromatic hydrocarbons (PAH) concentrations in sediments and bio-indicators were also determined.

URS on-site environmental monitoring infrastructure locations are presented in **Figure 1** and **Figure 2**, attached. URS off-site monitoring infrastructure locations are presented in **Figure 3**.

Table 1-1 below provides further explanation of the aim of Task 1, with specific reference to each of the relevant monitoring programs covered by this monitoring program and background data required by the CEMP and EIMP.

Table 1-1 Initial Monitoring Scope of Works

Monitoring Program	Aim
Surface Water	Establish current surface water quality, including Darwin Harbour and the area around Blaydin Point for comparison with future water quality data.
Groundwater Quality	Establish current groundwater quality at the site areas for comparison with future water quality data.
Sediment and Bio-indicators	Establish current data relating to the depth, composition and quality of sediments and the bio-accumulation of metals and hydrocarbons in bio-indicator species.
Mangrove Community Health	Establish current and reference site data relating to the health of the mangrove forest areas around the site including Middle Arm Peninsula and Blaydin Point.
Airborne Noise	Establish current airborne noise data for the site areas and sensitive receptors for comparison with future data.
Air Quality (Dust)	Establish current airborne dust concentration data for the site areas for comparison with future data.

Table 1-2, below details the specific objectives of each environmental strategy.

Table 1-2 Objectives and Targets for the Proposed Management Strategies

Management Strategy	Objectives	Performance Targets
Surface Water Management	To minimise transport of sediment across the site into immediate surroundings including adjacent land, intertidal areas and receiving surface water bodies.	Stormwater and construction water discharged from the site does not alter sediment elevation in the receiving environment by more than 50 mm
	To minimise changes in surface-water quality resulting from the disturbance or dewatering of acid sulfate soils. To minimise the discharge of water contaminated with nutrients, hydrocarbons or other contaminants off site	Detectable changes in surface-water quality should not exceed 10% of concurrently measured concentrations at buoys at BPSW30, BPSW31, BPSW32 and BPSW33. Monitoring data from these locations is to be relayed telemetrically for real time analysis. Installation of buoys is to be conducted by Company or its environmental monitoring specialist.
Groundwater Management	To minimise changes in groundwater levels and/or quality resulting from construction activities	No statistically significant deterioration of groundwater levels and/or quality
	To minimise to disturbance to and alteration of mangrove communities as a result of changes to groundwater levels or quality arising from construction activities.	Zero decline in health of fringing mangrove communities as a result of changes to groundwater flows in the site
	To minimise disturbance to and alteration of mangrove	Zero decline in health of fringing mangrove communities as a result of changes to

1 Introduction

Management Strategy	Objectives	Performance Targets
	communities as a result of changes to groundwater quality arising from construction activities	groundwater quality in the site
	To minimise disturbance to and alteration of mangrove communities as a result of oxidation of acid sulfate soils from construction activities	Zero decline in health of fringing mangrove communities as a result of metal accumulation in intertidal sediments
Erosion and Sedimentation Management	To minimise transport of sediment across the site into immediate surroundings including adjacent land, intertidal areas and receiving surface waters	Stormwater and construction water discharged from the site to receiving waters comply with water quality criteria No decline in mangrove community health as a result of construction-related sediment accumulation in intertidal areas
Dust and Air Quality Management	To minimise adverse impacts from dust-generation on the environment and the health of the workforce during construction	Zero impacts on vegetation health attributable to dust. No significant visible dust attributable to the project outside the Site. Comply with project air quality criteria
Noise and Vibration Management	To minimise the impacts of construction noise and vibration on local communities (nearest sensitive receptors)	No exceedance of the Project noise limits

1.5.3 Task 2 Implementation of Monitoring Programs

Once the initial monitoring component was completed as part of Task 1, it was necessary to calibrate the EIMP with pre-construction data as this is a key step in the formulation of a robust and regulatory compliant monitoring plan. This process was carried out in consultation with Company, Contractor and DLPE as required. Final monitoring locations and reference sites were confirmed following completion of the initial monitoring phase.

1.5.4 Scope of Environmental Impact Monitoring Program

The scope of the EIMP are summarised in **Table 1-3** and detailed further in the respective sections of this report.

Table 1-3 Environmental Impact Monitoring Program

Monitoring Program	Frequency	Monitoring Methodology
Flora and Fauna Monitoring (n/a)	Following initial clearance of handover area	Visual assessment of clearance against the clearance permit Clearing limits using DGPS. Monitoring of vegetation health of non-mangrove vegetation communities along the perimeter of the site to determine impacts on health. Data compared to control site data gathered within the locality.
Weed Monitoring	Quarterly	Visual inspection to review onsite weed management efficacy. Weed locations captured by DGPS and newly identified weed locations incorporated into the weed inventory.
Surface Water Monitoring	Before each discharge	Visual inspection of water undertaken to determine the presence or absence of oil, grease, iron floc and floating discharge. In-situ analysis undertaken using a calibrated hand-held water

1 Introduction

Monitoring Program	Frequency	Monitoring Methodology
		quality meter. Collection of a sample for later verification if monthly results indicate impacts, as hold times permit.
Surface Water Monitoring	Monthly	Determination of impacts of surface water discharge on the receiving environment through sampling locations upstream, downstream and at the point of discharge. Control site samples collected for laboratory analysis to supplement in-situ analysis of key parameters.
Groundwater and Acid Sulfate Soils Monitoring	Weekly	Insitu analysis of groundwater in the vicinity of high ASS risk areas using a calibrated hand-held water quality meter. Additional monitoring of groundwater elevations.
Groundwater Quality Monitoring	Monthly	Groundwater sampling undertaken using low-flow sampling techniques and, where practical use of dedicated or disposable equipment. Equiping of several monitoring locations with groundwater elevation and conductivity meters. Undertake field analysis using a calibrated hand-held water quality meter.
Mangrove Community Health, Sediment Quality, Sedimentation and Bio-indicators Monitoring	Quarterly to Annually	Assessment of the vitality of mangrove communities through comparison of initial and reference site data on parameters including canopy cover and biodiversity. Sediment collection from the top 1 to 5 cm of sediment within intertidal areas using a sterile scoop. If potential impacts are observed a sample may be collected for determination of pore water quality, acid soluble metals and/or acid volatile sulphides analysis can be undertaken to determine the level of risk posed by the site. Sediment depth monitoring by relative elevation of sediments measured by surveyed benchmarks. This is supported by cores to investigate the presence and thickness of veneers of different material overlying the mangrove substrates. Elevation measurement of marker stakes to determine the effects, if any, on ground surface. *Telescopium telescopium* collection and analysis for bioaccumulation of metals. Data assessment for trends and against reference sites.
Air Quality (Dust)	Continuous sampling and gravimetric determination undertaken monthly	Continuous sampling of dust deposition with monthly analysis of samples collected to determine particle weight. Continuous sampling and light scatter analysis of Particulate Matter less than 2.5µm ($PM_{2.5}$) and Particulate Matter less than 10µm (PM_{10}). Monthly gravimetric analysis of $PM_{2.5}$ and PM_{10}.
Airborne Noise Monitoring	Continuously throughout the construction program	Assessment of sound levels dB(A) and comparison to background data. Permanent sound monitor deployment, continuously record sound. Recording reference if project noise limits are exceeded or complaints are received.

The scope of these programs is consistent with the requirements of the CEMP and the EIMP.

The EIMP will be periodically reviewed and updated in line with the CEMP reviews as construction activities at Blaydin Point progress.

2

Background

2.1 Site Identification

The site is located approximately 16 km southeast of the City of Darwin, Northern Territory, in the southern area of Darwin Harbour and occupies an area of approximately 406 ha of land. The centre of the site is located at 708635 E, 8615187 N (GDA94 MGA Zone 52 coordinate system)on land designated as Blaydin Point on the Middle Arm Peninsula (**Figure 1-1**).

The site is accessed off Wickham Point road, a service road to the larger Channel Island Road. The site comprises 1000 and 1232 Channel Island Road, Wickham as well as adjacent Crown Land and Sections of Darwin Harbour (Sections 1980 and 1814).

2.2 Site History

The site is zoned as development under the NT Planning scheme. Extensive archaeological investigations have been conducted throughout the Ichthys project area. In addition to the aboriginal sites identified on Blaydin Point, the investigations also identified seven World War II sites which include concrete slabs, insulators, a bomb shelter trench and a portable search light battery position. As such it is possible that previous historical contaminating, activities and site practices may have occurred on site which may also include the presence of potential unexploded ordnance (UXO) from the World War II bombing campaigns that occurred around Darwin.

Acid Sulphate Soils (ASS) have been identified within the areas of the proposed site. The ASS are primarily located in the mangrove swamps, melaleuca, saline flats and coastal sand dunes. The majority of the civil works that will be undertaken in the areas of the site will occur where there is either no or low potential for the occurrence of ASS.

The Middle Arm Peninsular on which the site is being developed is surrounded on the north, east and west by the Darwin Harbour. Fringing mangroves form a natural barrier on the three sides of the peninsula to the estuary. To the south of the site is a salt flat which spans the Blaydin Point isthmus, which is flooded during spring tides. The main access road for the site has been constructed on the salt flat.

A search of the Department of Lands, Planning and the Environment (DLPE) contaminated site website (April 2012) did not return any information on any land classified as potentially contaminated or contaminated at or in the vicinity of the site.

The Minister for Land and Planning has granted a Development Permit for the development of the site (DP12/0065). Environmental Protection Authority EPA7 was obtained on 19 April 2012 (Ref: EN20,110234~0058).

2.3 Surrounding Environment

Blaydin Point is surrounded on three sides by water; to the east is the Elizabeth River, to the north the East Arm (both within the East Arm of Darwin Harbour) and Lightning Creek to the west. Water quality in Darwin harbour is deemed to be good but turbid. It is noted that water quality parameters in Darwin Harbour can vary significantly based on both seasonal and spatial variations. Rainfall during the wet season forms ephemeral overland streams that discharge into Lightening Creek and East Arm. Surface water generally flows from the high point along the centre of the Peninsula to the east, north and west. To the south of the site is a salt flat, which is flooded during spring tides. The site falls within the Darwin Harbour Region and Elizabeth-Howard Rivers Region Groundwater beneficial use areas which afford protection for the following uses:

- Darwin Harbour Region (saline water):
  - Aquaculture;
  - Environment; and
  - Cultural.
- Elizabeth-Howard Rivers Region Groundwater:
  - Agriculture;
  - Environment;
  - Public water supply; and
  - Rural stock and domestic.

The site is situated approximately 2.5 km to the west of a residential area of Marlow Lagoon and approximately 3.0 km southeast of East Arm Peninsular which is developed with light industry, warehouses and a cement manufacture plant. Two small uninhabited islands are located within the East Arm channel 2.5 km northwest and 4.0 km west-northwest from the site. The existing Darwin Liquefied Natural Gas (DLNG) plant is located approximately 3.0 km to the west of the site.

2.4 Site Activities – April 2012 to April 2013

The construction phase of work associated with the Project commenced on April 30 2012.

Construction activities within the site during the reporting period April 2012 to April 2013 period are summarised below.

Vegetation Clearing

Clearing activities at the site consisted of:

- Clearance of native flora (including grubbing out of rootstock); and
- Mulching of cleared material and placement into windrows.

Bulk Earthworks

Bulk Earthworks activities at the site consisted of:

- Removal and placement of native soils in designated areas;
- Placement of off-site material in on-site areas;
- Placement of materials in on-site areas; and
- Re-distribution of on-site soils to other areas of the site.

Ground Improvement

Ground improvement activities utilised dynamic replacement (DR) methods, which comprised:

- Dynamic compaction of 0 - 350 mm graded material (crushed rock) using a ~23 tonne weight within select locations at the site which were identified to require further geotechnical stabilisation;
- Locations were distributed at approximately 4 per 7 m^2 in low-lying areas at the boundaries of the site; and

2 Background

- Repeated dropping of the weight at each location to drive the emplaced graded materials into the underlying substrate to improve the loadbearing and settlement characteristics of the formation.

Drainage works and ASS Treatment Areas / Hard stands

Drainage, ASS treatment and hard stand works conducted on site include:

- Temporary and permanent road drainage construction;
- Construction of turkey's nest;
- Construction of sediment basins;
- Construction of external drainage and discharge points;
- Construction of regulating reservoir (perimeter drain);
- Construction of ASS treatment pads; and
- Construction of lay down and hard stand areas.

Road works

Road works on site include:

- Construction of the Channel Island Road intersection;
- Construction and sealing of the main site access road; and
- Construction and maintenance of various temporary un-sealed site access tracks.

Facilities

Work associated with site facilities include:

- Construction of the temporary office facilities;
- Construction of temporary workshop and fuel storage areas;
- Excavation works for water main; and
- Module office construction.

A schedule of site activities in relation to on-site areas (**Figure 1** and **Figure 2**), is presented in **Chart 1**, attached.

Climatic Conditions

The onshore development area lies in the monsoonal tropics of northern Australia and experiences two distinct seasons – a hot wet season from November to March and a warm dry season from May to September. April and October are transitional months between the wet and dry seasons. Maximum temperatures are defined as hot all year round. Based on the BoM Darwin Airport historical data, November is the hottest month with a range of 25.3 ºC minimum to 33.3 ºC maximum . Darwin has a mean annual rainfall of 1736 mm, with rain falling on an average of 94 days, mainly in the wet season.

3.1 Site

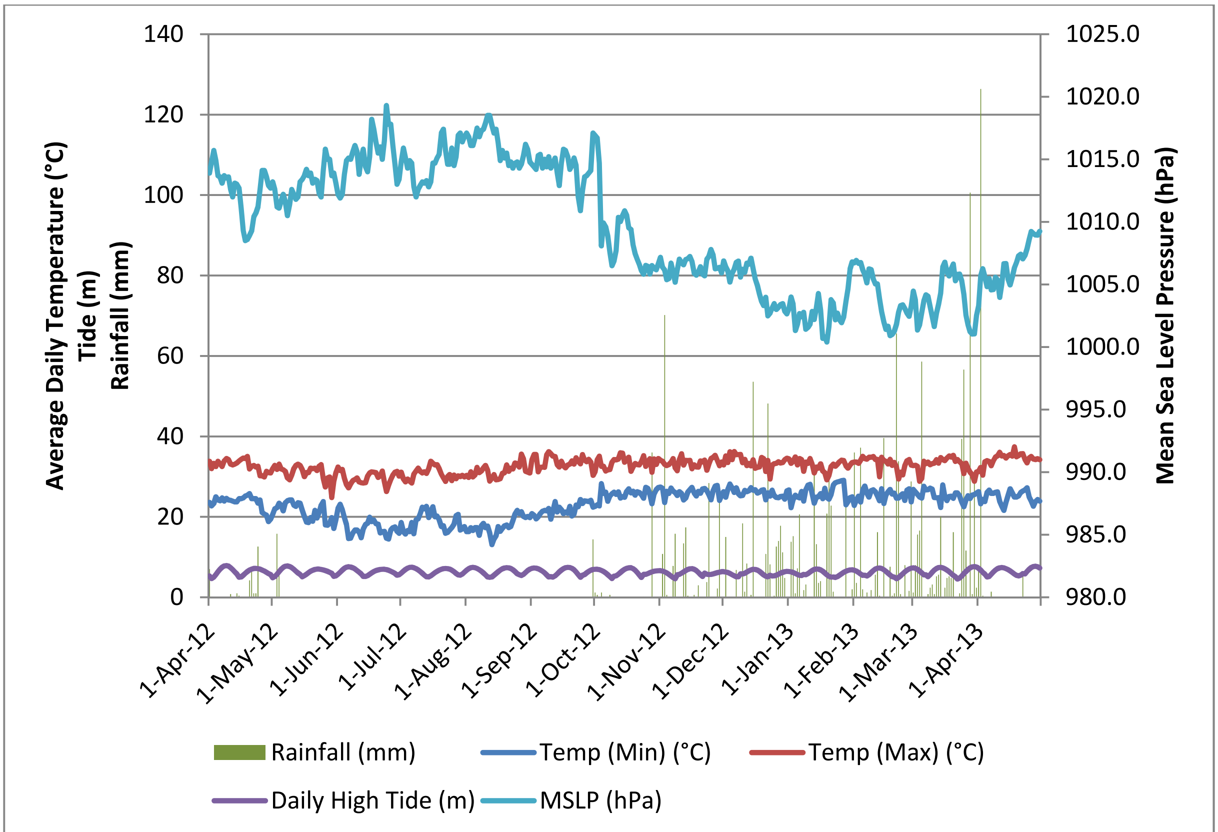
Surrounding weather and tide conditions influence the physical parameters recorded on site.

Climatic data has been recorded on site since 6 October 2012. Prior to that, climatic data from The Chase and Darwin Airport Bureau of Meteorology (BoM) stations have been used as follows:

- Darwin Airport BoM station (014015), 11 km from the site for climatic data except rainfall between 1 April and 5 October 2012;
- The Chase BoM station (014070), 8 km from the site for rainfall data between 1 April and 5 October 2012;
- Blaydin Point weather station between 6 October 2012 and 30 April 2013.

Chart 3-1 presents the climate data for the period 1 April 2012 to 30 April 2013. Meteorologological data is presented in **Appendix A.** Tide Charts for 2012 and 2013 are included in **Appendix B.**

Chart 3-1 Weather records of Darwin from 1 April 2012 to 30 April 2013 (BoM 2012 and URS 2012/13)



3 Climatic Conditions

Chart 3-1 is consistent with the tropical dry and wet seasons in the Darwin region, typified by:

- A ‘dry season’ with minimal rainfall recorded between May and September 2012;
- A ‘wet season’ with regular rain events commencing in November 2012 through to March 2013;
- Transitional months occuring in September - October 2012 and April 2013 where rainfall was recorded and atmospheric pressures changed;
- Higher minimum and maximum temperatures in the wet season compared to the dry season; and
- A decrease in atmospheric pressure in the wet season due to the monsoon trough or inter-tropical convergence zone.

April 2012 to April 2013 reported no cyclones or extreme weather events which may have affected the site.

3.1.1 Rainfall

The total rainfall recorded between 1 April 2012 and 30 April 2013 was 1,611.2 mm (BoM 2012 and URS 2012/13) which is below the annual average for the region (1727.5 mm; BoM, 2013). The monthly rainfall totals are presented in **Table 3-1** and graphed in **Chart 3-1**.

Table 3-1 Total monthly rainfall (BoM 2012 and URS 2012/13)

Year	Month	Total Rainfall (mm)
2012	April	34.8
	May	22
	June	0
	July	0
	August	0.2
	September	14.4
	October	39.8
	November	199.8
	December	232.4
2013	January	219.8
	February	291.2
	March	415.2
	April	141.6
	TOTAL (mm)	1,611.2

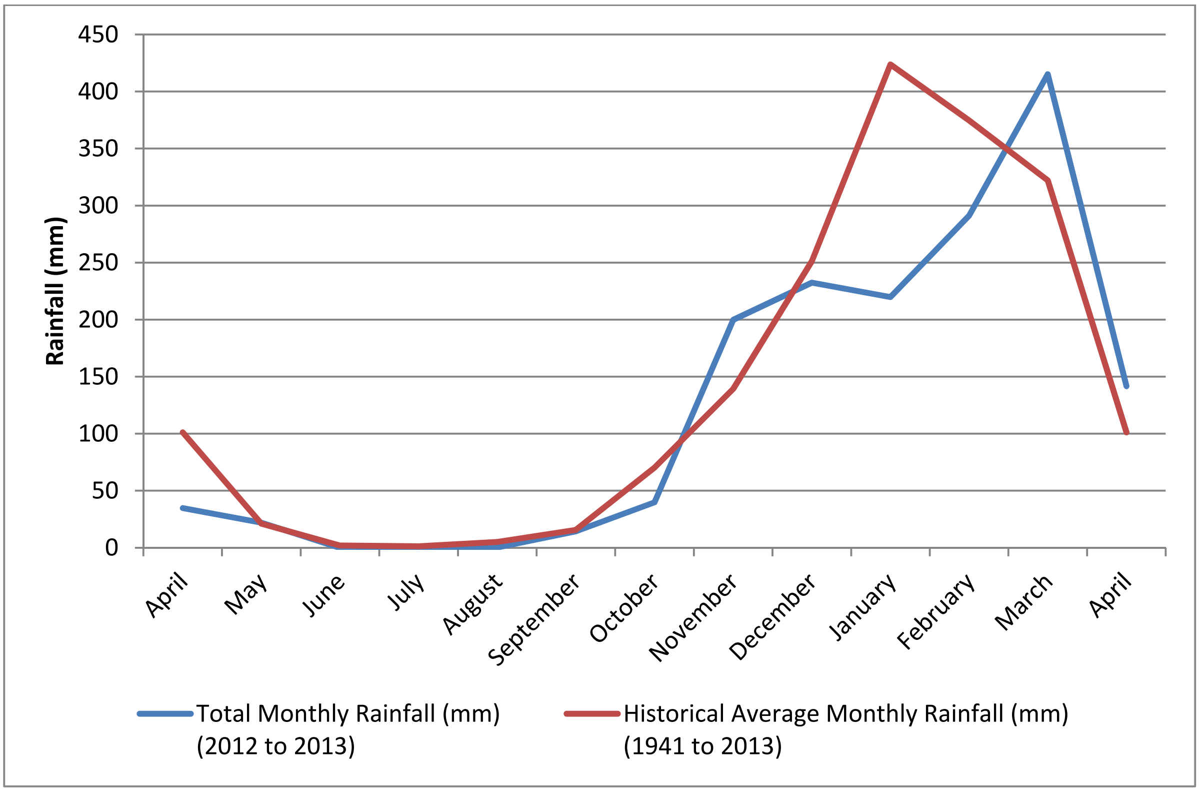
The 2012 dry season was dry for the most part with no rainfall recorded on site from mid-May to the end of September. In early May the site received two rainfall events totalling 22 mm and on 30 September the site received its first rainfall after the dry period of 14.4 mm.

The 2012/13 wet season up to the end of February was hot and dry with many areas across the Top End having the lowest wet season rainfall on record to that point in the season. In March, especially the last half of March, wet, monsoonal weather occurred in the NT and increased rainfall totals and the season average (BoM, 2013).

3 Climatic Conditions

Chart 3-2 depicts the total monthly rainfall recorded in 2012/13 against the historical average monthly rainfall recorded between 1941 and 2013 at the Darwin Airport BoM station. **Chart 3-2** shows that overall the site received average rainfall for the Darwin region.

Chart 3-2 2012/13 Total monthly rainfall and Historical average monthly rainfall (BoM, 2013; URS 2012/13)



3 Climatic Conditions

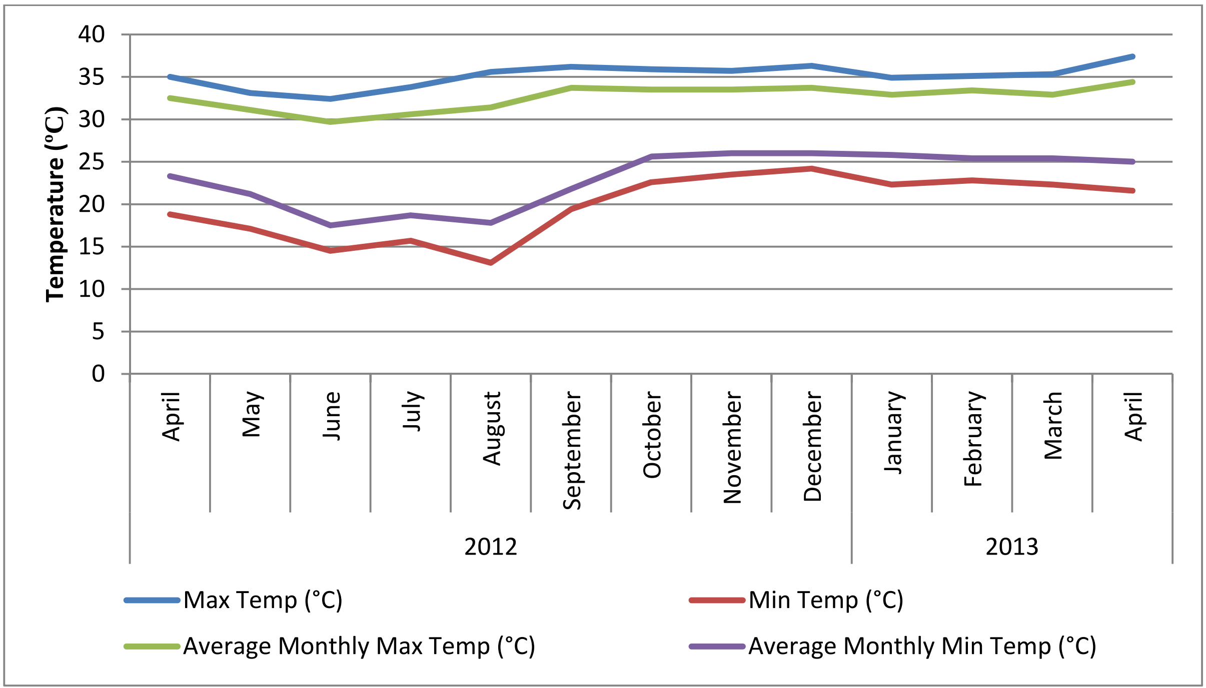
3.1.2 Temperature

The dry season maximum temperatures across the NT were generally near average (BoM, 2012). The site also experienced average dry season maximum temperatures. Overall the dry season minimum temperatures recorded on site were around the average with some months recording below average temperatures and other months recording above average temperatures.

The wet season maximum temperatures were near average for the site. The wet season minimum temperatures however were above average by 4 to 5 °C due to the high humidity.

Chart 3-3 illustrates the monthly minimum and maximum temperatures recorded and the calculated average temperatures each month.

Chart 3-3 Monthly minimum, maximum and average temparatures 1 April 2012 – 30 April 2013 (BoM 2012 and URS 2012/13)



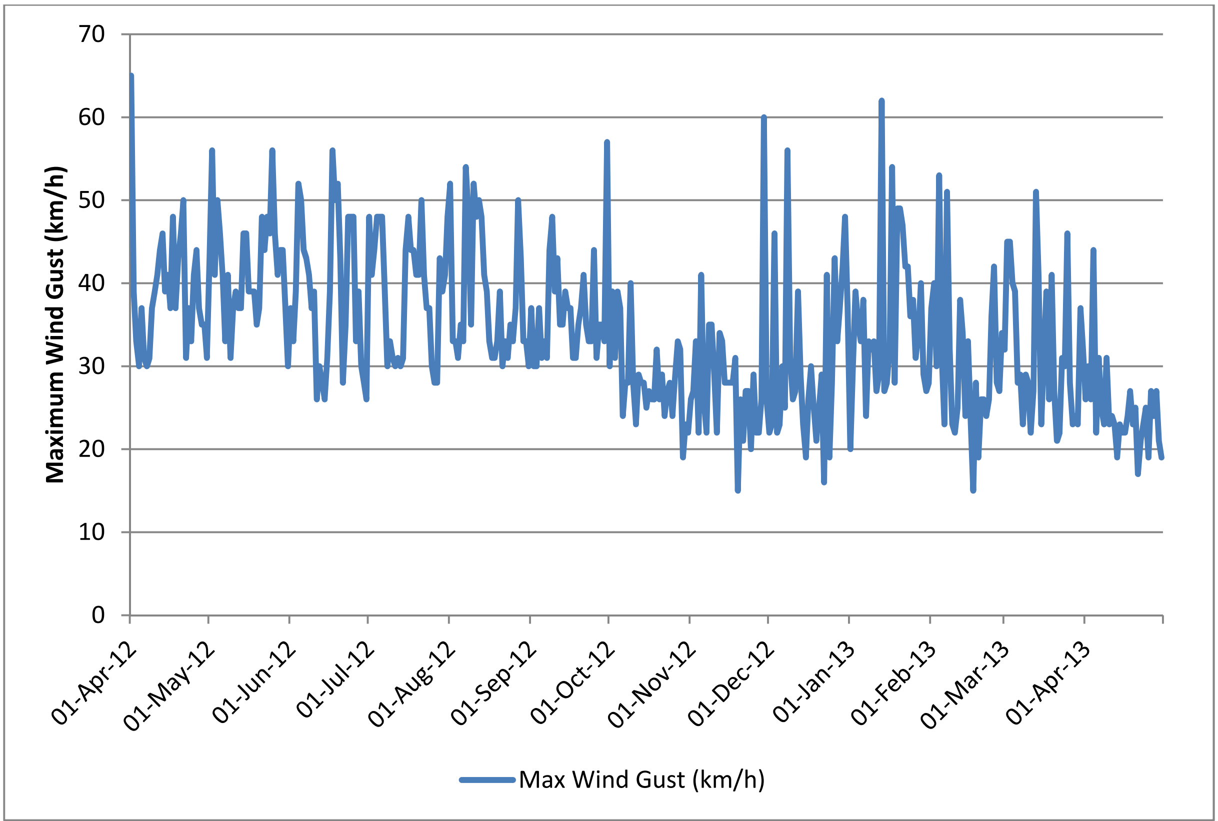
3 Climatic Conditions

3.1.3 Wind Speed

The site experienced dry, gusty conditions throughout the dry season. The wet season wind speeds whilst lower then the dry season were gusty also. **Chart 3-4** illustrates the maximum wind gusts recorded in Darwin and on site.

Wind directions were typical of the overall seasonal trends showing winds tending from the south east in the dry season and from the north west in the wet season (BoM, 2012 and 2013). Section 7 provides detailed site wind directions and analyses.

Chart 3-4 Maximum wind gusts 1 April 2012 – 30 April 2013 (BoM 2012 and URS 2012/13)



3.2 Palmerston

Surrounding weather conditions also influence the physical parameters recorded at sensitive receptors.

Climate data for Palmerston is largely the same for that presented for the site however rainfall data from The Chase BoM station located 1.4 km from the centre of Palmerston has been collated and presented here to provide accurate rainfall for the Palmerston area.

3 Climatic Conditions

3.2.1 Rainfall

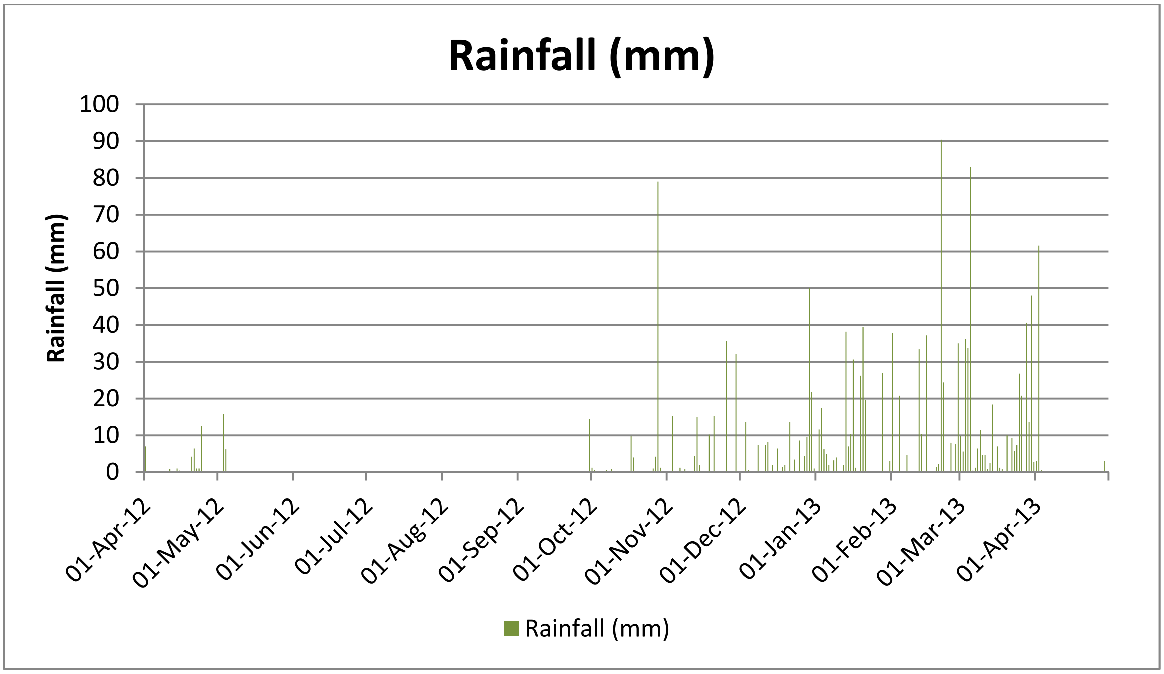
The total rainfall recorded between 1 April 2012 and 30 April 2013 at Palmerston was 1,518.2 mm (BoM 2012 and URS 2012/13). The 2012/13 total monthly rainfall are presented in **Table 3-2.** The daily rainfall is presented in **Chart 3-5**. **Chart 3-6** presents the monthly rainfall totals recorded in 2012/13 against the average for the Palmerston BoM station (2004 to 2013).

Table 3-2 Total monthly rainfall recorded at Palmerston (BoM 2012/13)

Year	Month	Total Rainfall (mm)
2012	April	34.8
	May	22
	June	0
	July	0
	August	0.2
	September	14.4
	October	103
	November	132.2
	December	162
2013	January	254.4
	February	313.8
	March	412.8
	April	68.2
	TOTAL (mm)	1,517.8

The daily rainfall is depicted in **Chart 3-5**. The Palmerston rainfall records are very similar to those recorded on site.

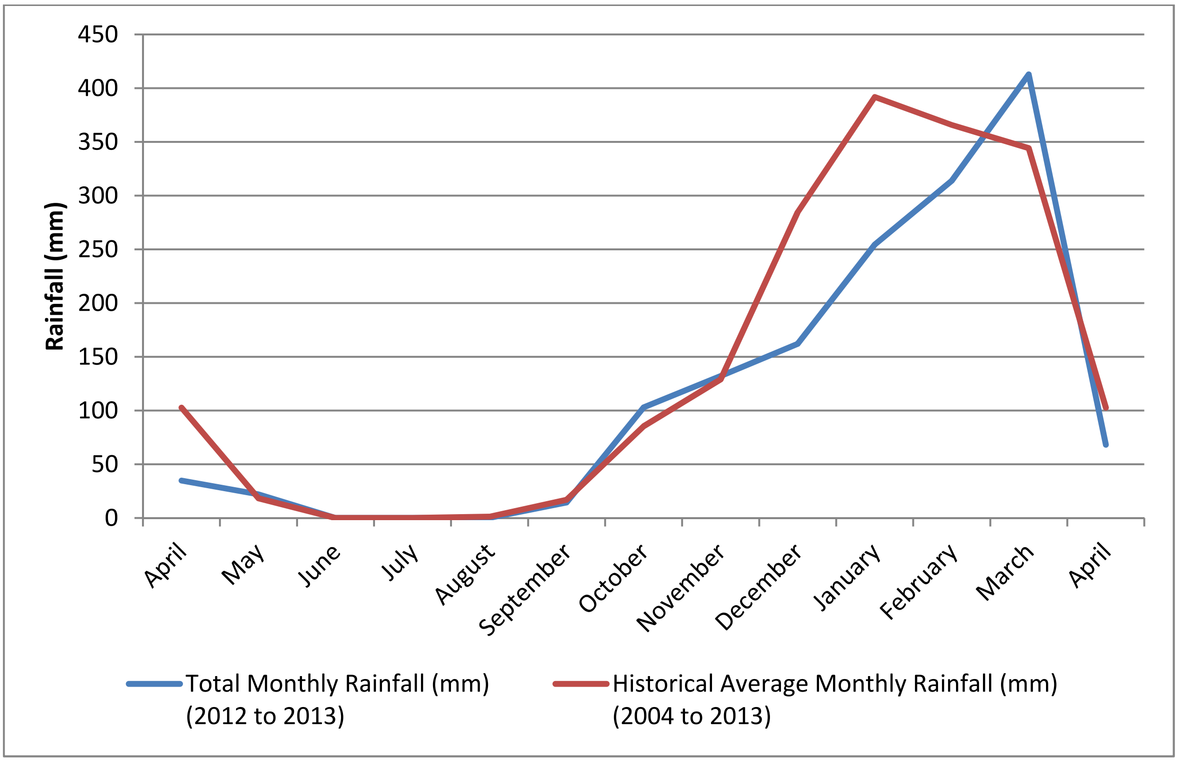
Chart 3-5 Daily rainfall recorded at Palmerston (BoM 2012/13)



3 Climatic Conditions

Chart 3-6 presents the total monthly rainfall recorded in 2012/13 against the historical average monthly rainfall recorded between 204 and 2013 at The Chase, Palmerston BoM station. **Chart 3-6** shows that overall Palmerston received average rainfall for the Darwin region.

Chart 3-6 2012/13 Total monthly rainfall and Historical average monthly rainfall for Palmerston BoM station (BoM, 2013)



4

Surface Water

4.1 Scope of Work

The purpose of the surface water monitoring program is to establish initial baseline surface water quality data at the site and conduct on-going monitoring and assessment of impacts. The scope of works for the surface water assessment is set out in the EIMP and detailed below.

The EIMP states that monthly surface water monitoring is to be conducted at 33 primary locations (BPSW01 to BPSW033) located upstream, downstream and at the point of discharge and 2 control site locations (CSSW01-CSSW02). In line with these requirements, the following works were undertaken between April 2012 and April 2013:

- 13 marine primary sampling sites located around the subject site (Blaydin Point Surface Water locations [BPSW]);
- Two marine control sites (Control Sites Surface Water [CSSW]); and
- Six to nine surface water sediment basins.

The location and quantity of sediment basin locations varied from the locations originally indicated in the CEMP do due the reconfiguration of on-site surface water drainage. **Figure 1** presents the surface water monitoring locations.

The aim of the surface water monitoring program was to:

- Determine impacts of surface water discharge on the receiving environment; and,
- Determine background fluctuations in surface water quality at the site.

The monthly surface water monitoring is intended to monitor the potential impacts from discharges from basins, potential spills and leaks from temporary facilities, potential acid sulphate soil impacts and potential impacts upstream and downstream of the impact sites.

The overall surface water management strategy for the site seeks to undertake all reasonable measures to minimise water quality impacts through a framework which includes both administrative and physical controls. The strategy outlined in the CEMP for the site is to adopt a pollution prevention emphasis rather than pollution control. The surface water management strategy aims to minimise offsite impacts and maximise water use efficiency.

In accordance with the EIMP, samples were collected from the receiving environment and sediment basins (where sufficient water was present) on a monthly basis. These samples underwent both in-situ and laboratory analysis. The aim of the monitoring was to demonstrate the level of deviation from background conditions due to the discharge. The monitoring data will be compared spatially, temporally and against the trigger criteria.

4.2 EIMP Performance Criteria

Objectives and targets of the surface water monitoring as per the EIMP are presented in **Table 4-1** and **4-2**.

4 Surface Water

Table 4-1 Surface Water Quality Parameters and Trigger Criteria

Management Strategy	Objectives	Performance Targets
Surface Water Management	To minimise transport of sediment across the CWA into immediate surroundings including adjacent land, intertidal areas and receiving surface water bodies.	Stormwater and construction water discharged from the CWA does not alter sediment elevation in the receiving environment by more than 50 mm
	To minimise changes in surface-water quality resulting from the disturbance or dewatering of acid sulfate soils. To minimise the discharge of water contaminated with nutrients, hydrocarbons or other contaminants off site	Detectable changes in surface-water quality should not exceed 10% of concurrently measured concentrations at buoys at BPSW30, BPSW31, BPSW32 and BPSW33. Monitoring data from these locations is to be relayed telemetrically for real time analysis. Installation of buoys is to be conducted by Company or its environmental monitoring specialist.

URS understands the realtime water quality monitoring at BPSW30, BPSW31, BPSW32 and BPSW33 using telemetry was not undertaken. Concurrent measurements of discharge water and the receiving environment during discharge have therefore not been undertaken to date; however, continuous monitoring is understood to be planned during future works.

Table 4-2 Surface Water Quality EIMP Parameters and Trigger Criteria

Parameter	Detection method	Trigger criteria	Reference
Total Suspended Solids (TSS)	Laboratory	>10 mg/L	NRETAS. 2010. Water Quality Objectives for the Darwin Harbour Region—Background Document. NRETAS, Darwin, NT.
Dissolved Oxygen	In situ	<75%	
Oxides of Nitrogen	Laboratory	>20µg N/L	
Ammonium	Laboratory	>20µg /L	
Total nitrogen	Laboratory	>300µg N/L	
Total phosphorus	Laboratory	>30µg P/L	
Filterable Reactive Phosphorus	Laboratory	>10µg P/L	
Chlorophyll a	Laboratory	>4 mg/m3 (equal to 4 µg/L)	
Escherichia coli (E.coli)	Laboratory	>200 E.Coli per 100mL	
Enterococci	Laboratory	>50 Enterococci per 100mL	
pH	In situ	<6 or >8.5	
TRH	Laboratory	>600 µg/L	Project Specific Guideline
Benzene	Laboratory	>500 µg/L	ANZECC. 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. ANZECC, Canberra, ACT
Toluene	Laboratory	>180 µg/L	
Ethylbenzene	Laboratory	>80 µg/L	
Xylene	Laboratory	>75 µg/L	
Naphthalene	Laboratory	>50 µg/L	
Aluminium	Laboratory	>55 µg/L	
Arsenic (III)	Laboratory	>24 µg/L	
Arsenic (V)	Laboratory	>13 µg/L	
Cadmium	Laboratory	>0.7 µg/L	
Chromium (III)	Laboratory	>27.4 µg/L	
Chromium (VI)	Laboratory	>4.4 µg/L	
Cobalt	Laboratory	>1 µg/L	
Copper	Laboratory	>1.3 µg/L	
Lead	Laboratory	>4.4 µg/L	
Manganese	Laboratory	>1900 µg/L	
Mercury	Laboratory	>0.1 µg/L	
Nickel	Laboratory	>7 µg/L	
Silver	Laboratory	>1.4 µg/L	
Vanadium	Laboratory	>100 µg/L	
Zinc	Laboratory	>15 µg/L	

Note: *For impacts from sediment basins deviation from background will be assessed through the comparison of a control site, up and down gradient locations to the point of discharge. Impacts from diffuse discharge of potentially contaminated groundwater will be assessed through the comparison of up and up and down gradient locations to monitoring locations adjacent to the CWA.*

4.3 Field Methodology

Field and sampling methodologies are as described in Section 4.3 of the EIMP:

Surface water samples will be collected using industry standard practices for surface water sampling as detailed below and in general accordance with AS/NZS 5667.4:1998 “Water Quality – Sampling, Part 4: Guidance on sampling from lakes, natural and man-made” (AS/NZS 5667.4:1998), and AS/NZS 5667.6.1998 “Water Quality – Sampling, Part 6: Guidance on sampling of rivers and streams” (AS/NZS 5667.6.1996).

The key procedures to be undertaken in the field are described below:

- Visual inspection of surface water collection points and sediment basins to determine the presence or absence of oil, grease, iron floc and floating discharge;
- In-situ quality measurements (pH, total dissolved solids [TDS], electrical conductivity [EC], dissolved oxygen [DO], temperature, turbidity and redox potential) will be undertaken prior to sample collection using a multi-parameter instrument. All field equipment will be calibrated in accordance with the manufacturer’s instructions;
- Collection of surface water samples and field QA/QC samples for laboratory analysis after field quality parameter measurement;
- Decontamination of all non-dedicated sampling equipment between sample locations; and
- Proper disposal of used disposable sampling equipment.

Field protocols outlined in the EIMP were followed in the sampling undertaken between June 2012 and March 2013. Sampling equipment calibration records are presented in **Appendix C**.

4.3.1 Method of Sampling

For the marine surface water sampling, the sampling team used:

- A larger vessel for quick access to the sampling locations and a shallow draft vessel for accessing shallow estuary tributaries, provided by sub-contractor Broadsword, for the sampling in June and July 2012.
- A shallow draft vessel, provided by sub-contractor Territorial Waters, for the subsequent sampling round of surface water sampling (August 2012 to March 2013).

Samples were taken as “grab” samples off the boat, using an extension pole mounted with a sampling bottle. Samples were taken 0.25 to 0.5 m below the water surface.

For the terrestrial sampling, the team took samples by standing on the edge of the surface water sediment basins and used a sampling bottle mounted on an extendable pole.

4.4 Field Observations

The following analytes were recorded in situ, due to their physical characteristics, time sensitivity and susceptibility to change following contact with air:

- Temperature;
- Electrical conductivity;
- pH;
- Turbidity;
- Dissolved oxygen;
- Redox potential; and

- Salinity.

Table 4-3 presents the surface water sampling schedule followed during the 2012/2013 monitoring. Between June and December 2012, marine surface water monitoring only was undertaken. Between January and March 2013, both marine and terrestrial sampling were undertaken. Surface water sampling consisted of marine sampling at 15 locations between June and December 2012 with additional terrestrial sampling at six locations in January and March 2013, and at nine locations in February 2013. Marine and terrestrial surface water sampling results are presented in separate sections below.

Table 4-3 Summary of Surface Water Testing Undertaken for the 2012/2013 Annual Report

Month	Jun 2012	Jul 2012	Aug 2012	Sept 2012	Oct 2012	Nov 2012	Dec 2012	Jan 2013	Feb 2013	Mar 2013
Marine Sampling	26/06	24/07	5/09	19/09	21/10	19/11	17/12	16/01	13/02	18/03
Terrestrial Sampling	-	-	-	-	-	-	-	21/01	20/02	20/03

Marine and terrestrial surface water sampling results are presented in separate sections below.

4.4.1 Marine Field Observations

Fifteen sampling locations were sampled monthly on the spring tide between June 2012 and March 2013. The summary statistics for each analyte are presented in **Tables 4-4** and **4-5**. **Table 4-4** presents the statictics for the surface water sampling sites located around the subject site (Blaydin Point Surface Water locations [BPSW]), and **Table 4-5** the statistics for the control sites. **Tables A1** to **A8** present the monthly in situ results since June 2012, and **Appendix D** presents the corresponding field sheets. **Figure A1** presents the location of the sampling sites.

Table 4-4 Summary of Statistics for Marine In Situ Surface Water Testing at the Blaydin Point Site Locations (2012-2013)

Parameters	EC	Dissolved Oxygen	Redox Potential	pH	Temperature	Salinity	Turbidity
Units	mS/cm	%	mV	-	°C	PSS	NTU
Minimum	36.3 (BPSW23)	73.8 (BPSW29)	50 (BPSW33)	6.37 (BPSW33)	22.2 (BPSW23)	26.7 (BPSW23)	0.1 (BPSW33)
Maximum	57.8 (BPSW26)	159 (BPSW31)	192 (BPSW29)	8.44 (BPSW31)	32.3 (BPSW30)	37.4 (BPSW28)	71.1 (BPSW24)
Median	52.25	94.7	93	7.87	30.1	34.3	20.7

Field sampling had trigger criteria set for pH and DO. No marine field results exceeded the trigger criteria available for pH (between 6 and 8.5); however dissolved oxygen was reported below the trigger criteria of 75% at site BPSW29 (73.8%) in March 2013.

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Table 4-5 Summary of Statistics for Marine In Situ Surface Water Testing at the Control Sites (2012 – 2013)

Parameters	EC	Dissolved Oxygen	Redox Potential	pH	Temperature	Salinity	Turbidity
Units	mS/cm	%	mV	-	°C	PSS	NTU
Minimum	40.7 (CSSW02)	85.8 (CSSW01)	59 (all sites)	6.87 (CSSW01)	22.6 (CSSW02)	29.8 (CSSW01)	0.7 (CSSW01)
Maximum	54.2 (CSSW02)	104.3 (CSSW02)	169 (CSSW02)	8.42 (CSSW02)	32.0 (CSSW01)	36.8 (CSSW01)	23.9 (CSSW02)
Median	52.3	99.1	94	7.96	30.4	34.3	13.9

No marine field results exceeded the trigger criteria available for pH (between 6 and 8.5), and dissolved oxygen (<75%).

4.4.2 Terrestrial Field Results

Six sediment basins were sampled prior to discharge in January and March 2013, and nine in February 2013 at the CWA site. The summary statistics for each parameter are presented in **Table 4-6**. **Tables A9** to **A16** present the terrestrial in situ results collected to date, and **Appendix D** presents the corresponding field sheets. **Figure A1** presents the location of the sampling sites.

Table 4-6 Summary of Terrestrial In Situ Surface Water Testing (2012 – 2013)

Parameters	EC	Dissolved Oxygen	Redox Potential	pH	Temperature	Salinity	Turbidity
Units	µS/cm	%	mV	-	°C	ppm	NTU
Minimum	41.5 (BPSW04)	69.1 (BPSW34A)	19 (BPSW05)	6.35 (BPSW02)	27.1 (BPSW01)	0.02 (BPSW04)	20.3 (BPSW06)
Maximum	2160 (BPSW34A)	316.1 (BPSW05)	97 (BPSW34A)	9.54 (BPSW03)	33.7 (BPSW05)	1.39 (BPSW34A)	2249 (BPSW02)
Median	121.8	90.4	43	7.61	30.1	0.07	157.9

No terrestrial field results exceeded the trigger criteria available for pH (6-8.5); however, dissolved oxygen was reported below the trigger criteria of 75% at site BPSW34A (69.1%) in March 2013.

4.5 Analytical Results

The primary and duplicate surface water samples, trip, field and equipment rinsate blanks were submitted to ALS laboratories in Sydney NSW for laboratory analytical testing. The triplicate surface water samples were submitted to ALS laboratories in Stafford QLD. Copies of the CoCs and laboratory analytical reports are provided in **Appendix E**.

Each of the collected surface water samples were analysed for:

- Total and dissolved metals;
- Total dissolved and suspended solids (TDS and TSS);
- Alkalinity;
- Nutrients (ammonia, nitrate, nitrite, total kjeldahl nitrogen, total nitrogen, reactive phosphorous and total phosphorous);
- Major ions; and,
- Hardness.

In addition, the following surface water locations were analysed for additional parameters:

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- For the marine sampling: monitoring locations BPSW24, BPSW25, BPSW30 through to BPSW33, and CSSW01 and CSSW02; and,
- For the terrestrial sampling: monitoring locations BPSW04 through to BPSW07, and BPSW36 through to BPSW38.

Those sampling locations were analysed for:

- Total recoverable hydrocarbons (TRH);
- Benzene, toluene, ethyl-benzene, xylenes and naphthalene (BTEXN); and,
- Biological Indicators (*E.coli, Enterococci*, and chlorophyll a).

This section presents a summary of the laboratory results reported by ALS Sydney for the 2012 - 2013 sampling period.

Most of the analytes were below the limit of reporting or below the selected trigger criteria (modified Ecosystems Environment Trigger values (ANZECC, 2000) and Water Quality Objectives for the Darwin Harbour Region (NRETAS, 2010)) except as detailed in **Table A17**.

4.5.1 Marine Analytical Results

Results of the laboratory analysis for the 2012-2013 marine surface water monitoring are presented in **Table A17**. The laboratory certificates are presented in **Appendix E.**

Most of the analytes were below the limit of reporting or below the selected trigger criteria (modified Ecosystems Environment Trigger values (ANZECC, 2000) and Water Quality Objectives for the Darwin Harbour Region (NRETAS, 2010)). This section presents only the parameters reported as exceeding their trigger value during the June 2012 to March 2013 surface water monitoring.

4.5.1.1 Dissolved Copper

Table 4-7 Marine Sampling Exceedances for Dissolved Copper (2012 – 2013)

Trigger Criteria (mg/L)	Limit of Reporting (mg/L)	Sites of Exceedances	Max Exceeding Value	Monitoring Round	Percent of BPSW Sites Above Trigger Criteria	Percent of Control Sites Above Trigger Criteria
0.0013	0.001	BPSW31, BPSW32, CSSW02	0.002	June 2012	23%	50%
		All except BPSW22, BPSW26, CSSW01 and CSSW02	0.002	July 2012	77%	0%

4.5.1.2 Dissolved Zinc

BPSW26 exceeded its dissolved zinc trigger criteria of 0.015 mg/L in September 2012 with a reported level of 0.02 mg/L.

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4.5.1.3 Ammonia

Table 4-8 Marine Sampling Exceedances for Ammonia (2012 – 2013)

Trigger Criteria (mg/L)	Limit of Reporting (mg/L)	Sites of Exceedances	Max Exceeding Value	Monitoring Round	Percent of BPSW Sites Above Trigger Criteria	Percent of Control Sites Above Trigger Criteria
0.020	0.005	BPSW33	0.030	June 2012	7%	0%
		BPSW31, CSSW01, CSSW02	0.030	November 2012	7%	100%
		CSSW01	0.033	January 2013	0%	50%
		BPSW24, BPSW29, BPSW32	0.026	March 2013	23%	0%

4.5.1.4 Oxides of Nitrogen

Table 4-9 Marine Sampling Exceedances for Oxides of Nitrogen (2012 – 2013)

Trigger Criteria (mg/L)	Limit of Reporting (mg/L)	Sites of Exceedances	Max Exceeding Value	Monitoring Round	Percent of BPSW Sites Above Trigger Criteria	Percent of Control Sites Above Trigger Criteria
0.020	0.002	BPSW22	0.023	August 2012	7%	0%
		BPSW29, BPSW30, BPSW31, BPSW32, CSSW01, CSSW02	0.034	November 2012	30%	100%
		BPSW29	0.028	December 2012	7%	0%
		All sites except BPSW20, BPSW22, BPSW24, BPSW26, BPSW27, BPSW28	0.048	January 2013	54%	100%
		BPSW33, CSSW01, CSSW02	0.025	February 2013	7%	100%
		All sites except BPSW31, BPSW33, CSSW01	0.039	March 2013	85%	50%

4.5.1.5 Reactive Phosphorus

BPSW25 exceeded its reactive phosphorus trigger criteria of 0.010 mg/L in November 2012 with a reported level of 0.012 mg/L.

4.5.1.6 Escherichia Coli

CSSW02 exceeded its *Escherichia coli* trigger criteria of 200 CFU/100mL in February 2013 with a reported level of approximately 670 CFU/100 mL.

4.5.1.7 Chlorophyll a

BPSW24 exceeded its Chlorophyll a trigger criteria of 4 mg/m^3 in November and December 2012 with respective reported levels of 9 and 6 mg/m^3.

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4.5.1.8 Total Suspended Solids

Table 4-10 Marine Sampling Exceedances for Total Suspended Solids (2012 – 2013)

Trigger Criteria (mg/L)	Limit of Reporting (mg/L)	Sites of Exceedances	Max Exceeding Value	Monitoring Round	Percent of BPSW Sites Above Trigger Criteria	Percent of Control Sites Above Trigger Criteria
10	1	All sites except BPSW28, BPSW31, BPSW32, CSSW01, CSSW02	38	June 2012	76%	0%
		All sites except BPSW22, BPSW28, BPSW29, BPSW33	30	July 2012	69%	100%
		BPSW20, BPSW23, BPSW27, BPSW28, BPSW29	35	August 2012	38%	0%
		BPSW28, BPSW29	23	November 2012	15%	0%
		All sites except BPSW30, CSSW01	37	December 2012	92%	50%
		All sites except BPSW23, BPSW25, BPSW27	56	January 2013	77%	100%
		All sites except CSSW01	68	February 2013	100%	50%

4.5.2 Terrestrial Analytical Results

Six sediment basins were sampled in January and March 2013, and nine in February 2013 at the CWA site. Laboratory results for the 2012-2013 terrestrial surface water monitoring are presented in **Table A18**. The laboratory certificates are presented in **Appendix E.** Note the sediment basins are sampled whilst holding water prior to discharge, therefore the sampling results presented in this report may not be representative of the water quality at the time of discharge. Water quality at the time of discharge is still unknown.

Most of the analytes were below the limit of reporting or below the selected trigger criteria (modified Ecosystems Environment Trigger values (ANZECC, 2000) and Water Quality Objectives for the Darwin Harbour Region (NRETAS, 2010)). This section presents only the parameters reported as exceeding their trigger criteria during the June 2012 to March 2013 surface water monitoring. Sediment basins were sampled between January and March 2013 only, due to a late rainfall onset in 2012.

4.5.2.1 Dissolved Aluminium

Table 4-11 Terrestrial Sampling Exceedances for Dissolved Aluminium (2012 – 2013)

Trigger Criteria (mg/L)	Limit of Reporting (mg/L)	Sites of Exceedances	Max Exceeding Value	Monitoring Round	Percent of Samples Above Trigger criteria
0.055	0.010	All sites except BPSW06	0.463	January 2013	83%
		All sites except BPSW05, BPSW06, BPSW34A, BPSW38	0.754	February 2013	55%

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4.5.2.2 Dissolved Cobalt

BPSW34A exceeded its dissolved cobalt trigger criteria of 0.001 mg/L in March 2013 with reported levels of 0.0012 mg/L.

4.5.2.3 Ammonia

Table 4-12 Terrestrial Sampling Exceedances for Ammonia (2012 – 2013)

Trigger Criteria (mg/L)	Limit of Reporting (mg/L)	Sites of Exceedances	Max Exceeding Value	Monitoring Round	Percent of Samples Above Trigger criteria
0.02	0.005	All sites	0.148	January 2013	100%
		All sites	0.102	February 2013	100%
		All sites except BPSW01	0.402	March 2013	83%

4.5.2.4 Oxides of Nitrogen

Table 4-13 Terrestrial Sampling Exceedances for Oxides of Nitrogen (2012 – 2013)

Trigger Criteria (mg/L)	Limit of Reporting (mg/L)	Sites of Exceedances	Max Exceeding Value	Monitoring Round	Percent of Samples Above Trigger criteria
0.02	0.002	All sites	0.558	January 2013	100%
		All sites	2.260	February 2013	100%
		All sites	3.550	March 2013	100%

4.5.2.5 Total Nitrogen

Table 4-14 Terrestrial Sampling Exceedances for Total Nitrogen (2012 – 2013)

Trigger Criteria (mg/L)	Limit of Reporting (mg/L)	Sites of Exceedances	Max Exceeding Value	Monitoring Round	Percent of Samples Above Trigger criteria
0.30	0.05	BPSW02, BPSW05, BPSW06	0.70	January 2013	50%
		All sites except BPSW01, BPSW02, BPSW38	2.28	February 2013	66%
		All sites except BPSW01	4.41	March 2013	83%

4.5.2.6 Total Phosphorus

Table 4-15 Terrestrial Sampling Exceedances for Total Phosphorus (2012 – 2013)

Trigger Criteria (mg/L)	Limit of Reporting (mg/L)	Sites of Exceedances	Max Exceeding Value	Monitoring Round	Percent of Samples Above Trigger criteria
0.030	0.005	BPSW01, BPSW02, BPSW04	0.065	January 2013	50%

50% of the sampling sites exceeded their total nitrogen trigger criteria in January 2013. Exceedances ranged between 0.039 and 0.065 mg/L; the median for total phosphorus in January 2013 was 0.033 mg/L.

4.5.2.7 *Escherichia Coli*

BPSW04 and BPSW05 exceeded their *Escherichia coli* trigger criteria of 200 CFU/100mL in January 2013 with respective reported levels of approximately 900 and 600 CFU/100 mL.

4.5.2.8 *Enterococci*

Biological indicators such as *Enterococci* were only tested in sediment basins BPSW04, BPSW05 and BPSW06 between January and March 2013.

Table 4-16 Terrestrial Sampling Exceedances for Enterococci (2012 – 2013)

Trigger Criteria (CFU/100mL)	Limit of Reporting (CFU/100mL)	Sites of Exceedances	Max Exceeding Value	Monitoring Round	Percent of Samples Above Trigger criteria
50	1	All sites	700	January 2013	100%
		BPSW04, BPSW06	89	March 2013	66%

4.5.2.9 *Chlorophyll a*

BPSW36 and BPSW37 exceeded their *chlorophyll a* trigger criteria of 4 mg/m^3 in February 2013 with respective reported levels of 8 and 5 mg/m^3.

4.5.2.10 *Total Suspended Solids*

Table 4-17 Terrestrial Sampling Exceedances for Total Suspended Solids (2012 – 2013)

Trigger Criteria (mg/L)	Limit of Reporting (mg/L)	Sites of Exceedances	Max Exceeding Value	Monitoring Round	Percent of Samples Above Trigger criteria
10	1	All sites	322	January 2013	100%
		BPSW02, BPSW04, BPSW37, BPSW38	261	February 2013	44%
		BPSW02, BPSW04, BPSW06, BPSW34A	128	March 2013	66%

4.5.3 Analytical Data Validation

To assess the reliability of the laboratory analysis results, URS examined the frequency of laboratory QA/QC, the number of tests reported versus that required, sample handling, preservation and holding times, the use of appropriate laboratory LORs, analysis of blanks, RPDs between primary, duplicate and triplicate sample results, field blank results, the use of matrix spikes and surrogate recoveries during each month of monitoring. Our examination indicates that the surface water analytical data can be used as a basis for interpretation subject to the limitations outlined in the monthly Data Validation Summary Reports provided in **Appendix F**.

Data validation revealed a number of recurring non-compliance issues. These issues, along with URS efforts to resolve them, are summarised below:

- Matrix spikes (MS) were not always performed by the laboratory, or anonymous samples were reported for some compounds. To rectify this, URS personnel have begun collecting additional sample containers in the field and notating them on the CoCs for use in matrix spikes;

- RPDs occasionally exceed the control limits between primary and duplicate samples, and/or between primary and triplicate samples. This is an inherent problem associated with the heterogeneous nature of the estuarine environment. URS has endeavoured to minimise this through employment of consistent sample collection techniques;
- Metals have occasionally been reported at trigger criteria or at low concentrations within some of the field blanks. At the request of URS, the laboratory has initiated an internal review to assess possible sources of these "hits"; and,
- Metals have occasionally been reported at trigger criteria or at low concentrations within some of the equipment rinsate blanks. In response, URS has initiated more vigorous decontamination techniques.

4.6 Third Party Data

Surface water discharge information was received from JKC in the form of discharge permits conducted at the site between October 2012 and April 2013. Those discharges permits were compiled into a spreadsheet, available in **Appendix G**. Most of the reported discharges were surface discharges at ground level and off-site.

4.7 Discussion

Marine field and analytical results obtained during the monthly surface water monitoring undertaken between June 2012 and March 2013 are considered generally representative of standard values for an estuarine environment. Analysis of the terrestrial surface water monitoring results is presented in a separate section.

4.7.1 Trend Analysis

4.7.1.1 Marine Trend Analysis

Temperature

Chart A1 presents an increase in water temperature during the June 2012 to March 2013 monitoring period, following the transition from the dry cool season to the wet hot season and acts to increase the ambient water temperatures.

Since December 2012, the recorded water temperature has remained relatively stable, with only a marginal decline. This is interpreted to result from increasing rainfall and associated cloud cover typical of the wet season. The surrounding atmosphere temperature as presented in **Section 3** shows a similar stabilisation of temperature between December 2012 and March 2013. Marine temperature trends are therefore considered a natural trend during the 2012/2013 surface water monitoring.

Analysis of **Table A1** suggests water temperatures are generally observed to be higher within the main channel of the harbour.

Salinity

Chart A1 presents the salinity recorded on site from June 2012 to March 2013. There is only a minor fluctuation in salinity levels, with median values ranging between 31 and 36 g/L between June 2012 and March 2013, potentially explained by freshwater discharges into the harbor during the wet season. Standard sea water salinity ranges between 30 and 50 g/L.

Salinity is observed at slightly higher levels at the BPSW sites located in close proximity to the mangrove environments, i.e. BPSW22, BPSW25, BPSW26 and BPSW28 and also at the CSSW02 site (**Table A2**). The increased salinity is expected within the inter tidal mangrove environments due to evapo-concentration of seawater within the water and sediments at low tide.

Electrical Conductivity

Electrical conductivity (EC) is a measure of the dissolved salts, and thus is an indicator of the salinity of the estuarine environment. Seawater EC is generally found at about 51.5 mS/cm, which is similar to the values for the harbour reported between June and September 2012. EC in the harbour then peaks in October 2012 at 54.1 mS/cm, which can be linked to the observed increase in salinity. EC eventually decreases in the subsequent months, following the decrease in salinity, as described above.

Generally EC is observed at higher levels at the BPSW sites located in close proximity to the mangrove environments, i.e. BPSW23, BPSW24, BPSW25, and BPSW29 (**Table A3**), which can be explained as per the salinity levels presented above.

Turbidity

This discussion is based on a rationalised dataset using data collected in July, August, September, October, and December 2012, and February and March 2013. The dataset was rationalised because the June and November 2012 sampling rounds reported high turbidity levels (over 100 NTU), which have been attributed to equipment failure. The results were not considered representative as such a high turbidity reading would have been confirmed visually by a change in translucency of the samples, which was not been observed at the time. Turbidity data for the June and November monitoring events are therefore not presented. An equipment malfunction was also observed in January 2013, and therefore the turbidity results for that month are not presented. Since, the sampling team carries two water quality meters on the boat in case of equipment failure during monitoring.

Turbidity is expected to be higher in the upper reaches of the harbour, which are in closest proximity to the tidal mud flats and shallower waters where high energy environments and sediment suspension are greater. This may explain why higher turbidity is observed within some of the BPSW sites (BPSW24, BPSW25, BPSW26) compared to the control sites (**Figure A2**).

Padovan (2003) reported turbidity to range on average between 1 and 35 NTU in the main body of the Darwin Harbour. The measured turbidity between June 2012 and March 2013 has an average value of 19 NTU, which is within the reported range of turbidity usually recorded in Darwin Harbour.

A maximum turbidity of 71 NTU has been reported in the September round of monitoring at location BPSW24. This is consistent with Padovan (2003), which states that turbidity as high as 70 NTU can be recorded at Spring Tides in the Middle Arm of Darwin Harbour.

Chart A1 presents the observed trend in turbidity. From October 2012, turbidity levels show a decreasing trend, which is not the expected pattern following the onset of the wet season. Increasing turbidity due to rainfall run-off was expected, as demonstrated by the increase in TSS (**Chart A4**). This pattern suggests that the run-off from the site is unlikely to be influencing turbidity for the sampling period. It is suspected that the tidal processes are dominating the datasets collected.

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Turbidity refers to the optical properties of water and is not a measurement of the concentration of suspended sediments. Turbidity is not only affected by TSS, but also by the shape of particles, size distribution, refractive index, colour and absorption spectra. Complex seawater contributors could be the explanation to the difference between TSS and turbidity. Turbidity was observed within normal range in Darwin Harbour and was expected to be higher in the upper reaches of the harbour, which are in closest proximity to the tidal mud flats and shallower waters. This may explain why the trigger value of 10 mg/L has been exceeded and that the Darwin Harbour Water Quality Objectives (DHWQO) may not be representative of upper estuary inter tidal environments. When a suitable local reference dataset is collected there may be an opportunity to calculate a site specific trigger value for turbidity.

Dissolved Oxygen

Dissolved oxygen serves as an indicator of the physical, chemical and biological activities of the estuary. The two main sources of dissolved oxygen are diffusion of oxygen from the air, and photosynthetic activity. Temperature and salinity affect the dissolution of oxygen in water.

Dissolved oxygen levels recorded in Darwin Harbour during June 2012 to March 2013 fluctuated between 74 and 150% (**Chart A2**) with an average for the 2012/2013 monitoring period of 97%. **Chart A2** does not suggest a trend in the dissolved oxygen results for the 2012/2013 monitoring period, but rather a generally constant level. The results indicate that Darwin Harbour is typically well oxygenated and that there was no discernible difference in dissolved oxygen trends between the control, near shore and the mangrove sites. The observed trend is that the BPSW sampling locations and the control sites have very similar variability every month. **Figure A3** presents the monitoring locations exceeding their dissolved oxygen trigger criteria.

Redox Potential

Redox potential is known to be highly variable and influenced by temperature and pH. The September 2012 monitoring event stands out with higher redox potential values recorded at all monitoring locations (**Chart A2**) which may be a consequence of a recorded increase of dissolved oxygen in Darwin Harbour. Positive redox potential reveals an aerobic environment which confirms that the areas sampled are well oxygenated. **Chart A2** does not suggest a trend in the redox potential results for the 2012/2013 monitoring period, but rather a generally stable level. The observed trend is that the BPSW sampling locations and the control sites have very similar variability every month.

pH

The pH characteristics of surface water change with time due to variations in temperature, salinity and biological activity. Most of the Darwin estuarine water has been recorded as alkaline (pH greater than 7) due to the presence of carbonates in marine environments.

Between June 2012 and March 2013, pH averages fluctuated between 6.4 and 8.4 (**Chart A2**), with higher pH levels observed in June, September and November 2012, and February 2013, and lower pH levels reported in July and October 2012, and January 2013. The results indicate there was no discernible difference in pH trends between the control, near shore and the mangrove sites. Overall, pH levels seem relatively stable. The observed trend is that the BPSW sampling locations and the control sites have very similar variability every month. **Figure A4** presents all monitoring locations as being within the trigger criteria.

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Nutrients

Chart A3 presents the temporal variation for the oxides of nitrogen, ammonia, total phosphorus and reactive phosphorus. Between June 2012 and March 2013, there is an observed increasing trend in levels of ammonia, and in oxides of nitrogen levels at both BPSW and control sites. The higher average concentrations were in November 2012 (0.034 mg/L) and January 2013 (0.038 mg/L), recorded at the control sites, interpreted to relate to runoff following the first significant rain events of the wet season. The observed decrease in nutrients in December 2012 could be due to the low amount of rainfall recorded between November and December 2012 monitoring rounds, therefore limiting the amount of run-off reaching the harbour.

The highest concentrations of oxides of nitrogen at BPSW sites were reported in March 2013, with 85% of the BPSW samples exceeding the DHWQO, interpreted to relate to runoff following the increasing rain events of the wet season. Also the reported levels at the control sites are about three times higher than the levels recorded at the BPSW sites. **Figure A5** presents the spatial variation for oxides of nitrogen. The spatial variation thresholds used are the trigger criteria and the 80th percentile.

The observed increase in nutrients within the main body of the harbour could be attributed to run-off from upstream rural/sub-urban areas. Padovan (2003) also reports on higher nutrient levels in the Darwin Harbour during the wet season.

The highest concentrations of ammonia were recorded at the control sites in November 2012 and January 2013, similarly to the oxides of nitrogen concentration pattern. The highest concentration of ammonia at the BPSW sites was recorded in March 2013. **Figure A6** presents the spatial variation for ammonia. It is noted the Palmerston Water Treatment facility exists approximately 800 m northeast of the site on the opposite bank of the Elizabeth River. During the wet season the treatment facility license allows restricted discharge when at capacity. Effluent from the treatment facility may increase nutrient concentrations in the surrounding surface water within Darwin Harbour.

Total phosphorus and reactive phosphorus levels present a generally decreasing trend between June 2012 and March 2013.

Dredging undertaken in Darwin Harbor might also influence nutrient levels, more specifically the phosphorus levels. It is however difficult to interpret in detail as the on-going dredging locations and dates have only been provided since March 2013.

Overall, nutrient levels in the surface waters were considered to be typically low.

Total Suspended Solids

It appears that on average, the BPSW sites have Total Suspended Solids (TSS) levels higher than the CSSW sites (**Chart A4**), similar to the turbidity pattern presented in **Chart A1**.

TSS levels were observed to decrease from an average at the BPSW sites of 25 mg/L to an average of 7 mg/L between July and November 2012, due to the extended dry period experienced between June and September 2012. This does not follow the increasing trend observed for the turbidity as presented on **Chart A1**.

Following the rains observed between November 2012 and March 2013, TSS levels increased in December 2012 reaching an average maximum of 36 mg/L in January 2013 for the BPSW sites, as rainfall run-off reaching the harbour brings debris and dirt to the surface water environment. In regards to the turbidity results, a peak was observed in February 2013 for turbidity, compared with a peak observed in January for TSS. This is followed by a decrease in turbidity and TSS in March 2013. There appears to be a weak correlation between TSS levels and turbidity. Further investigation will be required to assess TSS and turbidity levels. **Figure A7** presents the spatial variation of TSS. The spatial variation thresholds used are the trigger criteria and the 80th percentile for the maximums recorded at each site for the June 2012 to March 2013 monitoring period.

Metals

No metals were reported as exceeding their trigger criteria during the 2012/2013 monitoring period, except for dissolved copper (**Figure A8**) which was reported above trigger criteria in June 2012 at 26% of the sampling sites, and in July 2012 at 66% of the sampling sites. No clear explanation of those levels can be provided at this stage.

Other metals such as dissolved zinc, dissolved arsenic and dissolved vanadium were reported monthly (**Chart A5**). All observed metal concentrations are generally stable between June 2012 and March 2013, with an average dissolved zinc concentration of 0.00165 mg/L, and average dissolved arsenic concentration of 0.00165 mg/L, and an average dissolved vanadium concentration of 0.0015 mg/L, all well below their trigger criteria. A slight increase in November 2012 is observed following the rains recorded earlier that month, followed by a decrease in metal concentrations in December 2012 due to lesser rain amount in early December 2012. Metal levels are likely, therefore, to be attributed to rainfall run-off contributing to the metals in suspension in the harbour.

Arsenic is observed at high concentrations (for a natural environment) within Darwin Harbour, which is a reflection of the local geology of the Darwin Harbour rather than anthropogenic causes (Padovan, 2003).

Similarly, vanadium occurs naturally within an estuarine environment and is derived from the local geology as opposed to anthropogenic sources. An increase in dissolved vanadium between the months of September and November 2012 could be linked to an observed increase in Chlorophyll a, as vanadium is known to be involved in metabolic processes such as chlorophyll synthesis.

Biological Indicators

Chart A4 and **Table A17** present the biological indicators levels measured between the months of June 2012 to March 2013. Levels of *Escherichia Coli* are reported at low levels, ranging between 1 and 64 CFU/100mL, except in February 2013 where levels of 670 CFU/100 mL were reported at one of the control sites. *Enterococci* levels are reported below trigger criteria during the 2012/2013 monitoring period, ranging between 1 and 14 CFU/100 mL. As noted above in association with nutrient concentrations, the increase in bacterial concentrations may be attributed to seasonal effluent discharge by the Palmerston Water Treatment facility.

Padovan (2003) confirms natural low level of biological indicators within Darwin Harbor. Allen (1984) correlated increased bacterial numbers with rainfall, and found extremely high bacterial numbers in stormwater from urbanised areas. He concluded that this seasonal effect could not be attributed to discharge of treated effluent, and was most likely due to wet season run-off from urbanised areas transporting land-based faecal material to the estuary (Padovan, 2003). This statement can be confirmed at the end of the wet season, with observed levels decreasing in March 2013.

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Chart A4 presents the algal numbers measured during the months of June 2012 to March 2013. Chlorophyll a levels were reported between 1 and 4 CFU/100mL, exceeding trigger criteria between November 2012 and March 2013.

The observed increase in chlorophyll a in November and December 2012 could be due to the algae being stimulated by nutrients in the rainfall run-off.

4.7.1.2 Terrestrial Trend Analysis

This section presents an interpretation of **Chart A6** to **Chart A9** and **Table A9** to **Table A16**.

Field Result Discussion

The following interpretations can be drawn from the field results:

- Electrical conductivity is low (**Chart A6**), with median values reading 92 µS/cm and 152 µS /cm between January and March 2013. This is characteristic of fresh water. Temporary basins sampled in January and February 2013 (BPSW34A, BPSW36 and BPSW38) reported the highest EC values ranging between 1.19 mS/cm and 2.16 mS/cm, characteristic of fresh to brackish water;
- Water temperature recorded onsite during the January to March 2013 monitoring periods ranged between 27 ˚C and 34 ˚C, similar to the ambient air temperature (**Chart A6**);
- High turbidity was reported in sediment basins at Blaydin Point in January 2013, with a median value of 405 NTU. Turbidity decreased during the February and March 2013 monitoring periods, with median turbidity recorded at 66 and 103 NTU (respectively), with the exception turbidity reported at BPSW04 was 1890 NTU in February 2013. A probable explanation for the elevated turbidity observed in January 2013 would be the heavy rain recorded in the area two days prior to sampling, which would have brought sediment and dirt into the basins, as demonstrated by higher TSS levels in January 2013 also, as discussed in the TSS section on the next page;
- Terrestrial surface water is generally alkaline (**Chart A7**), with an average pH of 8.1 recorded in January 2013, decreasing to 7.6 in February and March 2013. pH levels recorded in January where observed to be higher in the basins located within the CWA at Blaydin Point;
- Median redox potential (**Chart A7**) recorded in February and March 2013 is indicative of reducing environments, 45 mV and 40 mV respectively. Negative redox values recorded in January data is attributed to an equipment fault;
- Dissolved oxygen (DO) data recorded in January 2013 is considered unrealistic at an average of 25 mg/L. A normal DO for ponding surface water would be of about 8 mg/L at 25 ˚C. The DO levels recorded for February and March 2013 were within this range, with a median level of 7.17 mg/L and 6.34 mg/L, respectively. The January data is attributed to an equipment fault. Since, the sampling team carries two water quality meters on the boat in case of equipment failure during monitoring.

Nutrients

Chart A8 presents the temporal variation for ammonia, oxides of nitrogen, total phosphorus and total nitrogen.

Since January 2013, there has been increasing levels of oxides of nitrogen and total nitrogen, recording above the trigger criteria of 0.02 mg/L and 0.3 mg/L, respectively. The highest concentrations of oxides of nitrogen and total nitrogen were reported in March 2013, with median concentrations of 0.48 mg/L and 0.66 mg/L respectively.

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High nutrients observed in the sediment basins could be explained by decomposition of organic material in the soil from the forested land prior to site clearing. Also the sediment basins are likely to be visited by birds, whose faeces and urine could also explain the high nutrient concentrations.

Discharge of effluent with high concentrations of nutrients may cause a shift in natural growth patterns and cause a focus on upward, above-ground growth rather than growth of roots and rhizomes below ground. Overtime this could loosen the receiving environment's banks, making it more vulnerable to erosion and collapse and increase the vulnerability of the mangrove community to environmental stresses.

High nutrient concentrations that travel downstream could result in eutrophication of creeks with the mangrove community and surrounding surface water body.

Total Suspended Solids

Chart A9 presents the temporal variation for total suspended solids (TSS). TSS were observed to decrease from January 2013 to March 2013, with the average TSS level reported in January 2013 at 165 mg/L, reducing below 30 mg/L in February and March 2013.

As discussed previously, a probable explanation for the elevated TSS and turbidity in January 2013 would be the heavy rain recorded in the area two days prior sampling, which would have brought sediment into the basins..

Some of the potential impacts of discharging effluent with high TSS include increased sedimentation within the surrounding mangrove ecosystem and surface water body due to deposition of suspended sediments.

Metals

Dissolved and total metals were reported in samples collected in all monitoring rounds and confirm the presence of heavy metals on site.

Chart A9 presents the temporal variation for dissolved aluminium, reported as exceeding its trigger criteria. The majority of sampling sites reported dissolved aluminium concentrations over the trigger criteria of 0.055 mg/L in January and February 2013. Overall, dissolved aluminium levels have generally decreased since monitoring begun, with no concentration reporting above the trigger criteria in March 2013.

Biological Indicators

Table A18 presents the biological numbers measured during the months of January to March 2013.

Chart A9 presents the temporal variation for *Enterococci*. *Enterococci* Median concentrations ranged between 4 CFU/100mL and 87 CFU/100mL, exceeding the trigger criteria of 50 CFU/100mL in January 2013 and March 2013. The *Enterococci* levels are therefore considered as potentially elevated.

Escherichia Coli was found to be present at levels above the trigger criteria of 200 CFU/100 mL in January 2013, with a median concentration of 600 CFU/100 mL. Concentrations decreased below the trigger criteria in February and March 2013.

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A possible explanation to the levels of *Enterococci* could be the previous bush land use of the site, where fauna would have been the cause of the *Enterococci* levels, and also the likelihood of daily visitation by birds which may contribute to the *Enterococci* levels through their faeces.

4.7.2 Performance against EIMP Criteria

The purpose of the surface water monitoring was to determine impacts of surface water discharge on the receiving environment. The monthly surface water monitoring was intended to monitor the potential impacts from discharges from basins, spills and leaks from temporary facilities, ASS/PASS impacts and impacts upstream and downstream of the impact sites.

In accordance with the EIMP and CEMP, samples were collected from the receiving environment and sediment basins (where sufficient water was present) on a monthly basis. These samples underwent both in-situ and laboratory analysis. The monitoring data from each location was compared spatially, temporally and against the environmental approvals trigger criteria.

The EIMP stated that monthly surface water monitoring would be conducted at 33 primary locations located upstream, downstream and at the point of discharge and at two control site locations. Surface water monitoring was undertaken at:

- 13 marine primary sampling sites located in the Darwin Harbour around the Blaydin Point site;
- Two marine control sites located in Darwin Harbour near East Arm; and
- Up to nine surface water sediment basins (wet season only) located at Blaydin Point (when water was present).

The reduction in surface water sediment basin monitoring locations at the site is due to revised surface water management stragegies employed at the site since EIMP approval.

Field and laboratory analytical results obtained during the monthly marine surface water monitoring undertaken between June 2012 and March 2013 generally reported standard values for an estuarine environment. Measured in situ field parameters of the marine surface water sampling sites located in the vicinity of Blaydin Point are generally comparable to the control sites.

The data collected comprises a single value per analyte per month; therefore the data may not represent an average condition at the time of sampling, but rather provides a ‘snapshot’ of conditions at a specific point in time. Logistical issues have prevented the measurement of environmental conditions concurrently with, or immediately following, discharge. This has resulted in a lack of understanding of the impact of discharges on the receiving environment beyond the trends observable in monthly/seasonal data.

Padovan states that pH is naturally high in the Darwin Harbor, ranging between 8.3 and 8.6; therefore the higher end of the trigger criteria for pH should be changed to 8.7, no exceedances of pH have been observed at any current monitoring location in the receiving environment.

4.7.3 Correlation of Data with Site Works

The first round of marine surface water monitoring undertaken at the site took place on the 26 June 2012. According to the Ichthys site work schedule provided to URS, site clearance started on the 1 June 2012; therefore, no surface water monitoring was undertaken prior to the site disturbances, limiting the comparison of the water quality data to baseline or pre-disturbance water quality data. The surface water monitoring was undertaken over a 10 month period and it has been possible to identify

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trends and to compare the observed values to historical records to assess any potential impacts due to the site works undertaken at Ichthys.

Temperature

The observed harbour water temperature trend follows the surrounding atmosphere temperature trend (Section 3), therefore the water temperature trend observed between June 2012 and March 2013 around the Ichthys site is considered a natural trend.

Water temperatures recorded within the sediment basins during the January to March 2013 monitoring period also suggest a natural trend with recorded temperatures similar to the ambient air temperature.

Salinity

Only a minor fluctuation in salinity levels has been observed during the monitoring period, with the monthly median salinity across all sites ranging between 31 and 36 g/L. The seasonal variation is most likely influenced by freshwater discharges into the harbor during the wet season. [Add reference to Padovan data]

Salinity is observed at slightly higher levels at some of the BPSW sites located in close proximity to the mangrove environments, The higher salinity in the mangrove creeks is reported by Padovan (2003) within the inter-tidal mangrove environments and attributed by Padovan to evapo-concentration of seawater within the water and sediments at low tide.

Low salinity levels within the sediment basins suggest a freshwater source, such as rainfall.

Electrical Conductivity

Electrical conductivity (EC) is a measure of the dissolved salts, and thus is an indicator of the salinity of the estuarine environment. Seawater EC is generally found at about 51.5 mS/cm, which is similar to the values for the harbour reported between June 2012 and March 2013. The onset of the wet season potentially creates a diluting effect within the harbor waters, and therefore creating a localised variation in EC and the salinity.

Generally EC is observed at higher levels at some of the BPSW sites located in close proximity to the mangrove environments, which can be explained by evapo-concentration of seawater within the water and sediments at low tide, as reported by Padovan (2003)..

Turbidity

The observed trend in turbidity from October 2012 show a decreasing trend, which is not the expected pattern following the onset of the wet season. Increasing turbidity due to rainfall run-off was expected, as demonstrated by the increase in TSS. This pattern suggests that the run-off from the site is unlikely to be influencing turbidity for the sampling period. It is suspected that the tidal processes are dominating the datasets collected.

High turbidity levels observed within the sediment basins between January and March 2013 can be attributed to rainfall run-off bringing sediment and dirt to the basins. The amount of dirt and debris will be directly linked to the earthworks undertaken at the site.

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Dissolved Oxygen

Dissolved oxygen records do not suggest a trend in the dissolved oxygen results for the 2012/2013 monitoring period, but rather a generally constant level. The results indicate that Darwin Harbour is typically well oxygenated and that there was no discernible difference in dissolved oxygen trends between the control, near shore and the mangrove sites. Therefore site activities do not seem to have influenced the dissolved oxygen levels within the harbour.

Dissolved oxygen levels reported within the sediment basins appear at standard levels for ponding waters.

Redox Potential

Positive redox potential reveals an aerobic environment which confirms that the areas sampled are well oxygenated. Monitoring data does not suggest a trend in the redox potential results for the 2012/2013 monitoring period, but rather a generally stable level. The observed trend is that the BPSW sampling locations and the control sites have very similar variability every month. Therefore it is unlikely that site activities have impacted on redox potential levels.

pH

The pH characteristics of surface water change with time due to variations in temperature, salinity and biological activity. Most of the Darwin estuarine water has been recorded as alkaline (pH greater than 7) due to the presence of carbonates in marine environments. Between June 2012 and March 2013, monthly pH median values fluctuated between 7.1 and 8.4. The results indicate there was no discernible difference in pH trends between the control, near shore and the mangrove sites. Therefore it is unlikely that site activities have influenced pH levels within the harbor.

pH recorded within the sediment basins has been observed as decreasing between January and March 2013, especially between January and February 2013. Further monitoring of the sediment basins will be required at the next wet season to assess the cause of decreasing levels of pH, as increasing salinity has also been observed, which would create a more basic environment. Therefore the potential impact of site activities on sediment basin pH is not clear at this time.

Nutrients

There has been observed increasing trend in levels of ammonia and in oxides of nitrogen levels at both BPSW and control sites. The higher concentrations were observed in general at the control sites. Also, the observed trend in nutrient levels at the BPSW sites and at the control sites are very similar, therefore it is unlikely that site activities have influenced nutrient levels within the harbor. Anomalous results in nutrient concentrations may be attributed to effluent discharge from the Palmerston Water Treatment facility.

The observed increase in nutrients within the main body of the harbour could be attributed to run-off from upstream rural/sub-urban areas. Padovan (2003) also reports on higher nutrient levels in the Darwin Harbour during the wet season.

Dredging undertaken in Darwin Harbor might also influence nutrient levels, more specifically the phosphorus levels. It is however difficult to interpret in detail as the on-going dredging locations and dates have only been provided since March 2013. Overall, nutrient levels in Darwin Harbor were considered to be typically low.

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High levels of total nitrogen and oxides of nitrogen observed in the sediment basins could be explained by decomposition of organic material in the soil from the forested land prior to site clearing. Also the sediment basins have been reported to be visited by birds, whose faeces and urine could also explain the high nutrient concentrations.

Total Suspended Solids

It appears that on average, the BPSW sites have Total Suspended Solids (TSS) levels higher than the control sites, similar to the turbidity pattern. Due to no pre-disturbance surface water monitoring data, it is therefore not possible to justify natural higher TSS and turbidity levels in the BPSW sites. However, it is known that natural higher turbidity levels are expected within the inter-tidal reaches of the harbor (Padovan, 2013). Further monitoring is required to assess the potential impact of the site activities on the turbidity levels of Darwin Harbor.

In the sediment basins, TSS were observed to decrease from January 2013 to March 2013, linked to the heavy rains recorded in the area two days prior sampling in January 2013, which would have brought sediment into the basins. The amount of dirt and debris will be directly linked to the earthworks undertaken at the site.

Metals

No metals were reported as exceeding their trigger criteria during the 2012/2013 monitoring period within Darwin Harbor waters, except for dissolved copper, which was reported above trigger criteria in June 2012 at 26% of the sampling sites, and in July 2012 at 66% of the sampling sites. No clear explanation of those levels can be provided at this stage, nor can these concentrations be immediately correlated to site activities.

Other metals such as dissolved zinc, dissolved arsenic and dissolved vanadium were reported monthly at generally stable levels between June 2012 and March 2013, and all well below their trigger criteria.

A slight increase in November 2012 is observed following the rains recorded earlier that month, followed by a decrease in metal concentrations in December 2012 due to lesser rain amount in early December 2012. Metal levels are likely, therefore, to be attributed to rainfall run-off contributing to the metals in suspension in the harbour.

Arsenic is observed at high concentrations (for a natural environment) within Darwin Harbour, which is a reflection of the local geology of the Darwin Harbour rather than anthropogenic causes (Padovan, 2003).

Similarly, vanadium occurs naturally within an estuarine environment and is derived from the local geology as opposed to anthropogenic sources. An increase in dissolved vanadium between the months of September and November 2012 could be linked to an observed increase in Chlorophyll a, as vanadium is known to be involved in metabolic processes such as chlorophyll synthesis.

In the sediment basins, dissolved and total metals were reported in samples collected in all monitoring rounds and confirm the presence of heavy metals on site. Dissolved aluminium was reported as exceeding its trigger criteria in January and February 2013. With no pre-disturbance surface water monitoring data for the site to compare to, it is unclear at this stage if site works influenced dissolved aluminium levels in the sediment basins.

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Biological Indicators

Escherichia coli was reported above the trigger criteria in basins BPSW04 and BPSW05 in January 2013, and slightly higher levels of *E coli* were observed in the Harbor in January and February 2013 at all sampling locations, including one of the control sites. Anomalous results in biological indicator concentrations may be attributed to effluent discharge from the Palmerston Water Treatment facility, dreding activities, and/or surface run-off from existing off-site sources.

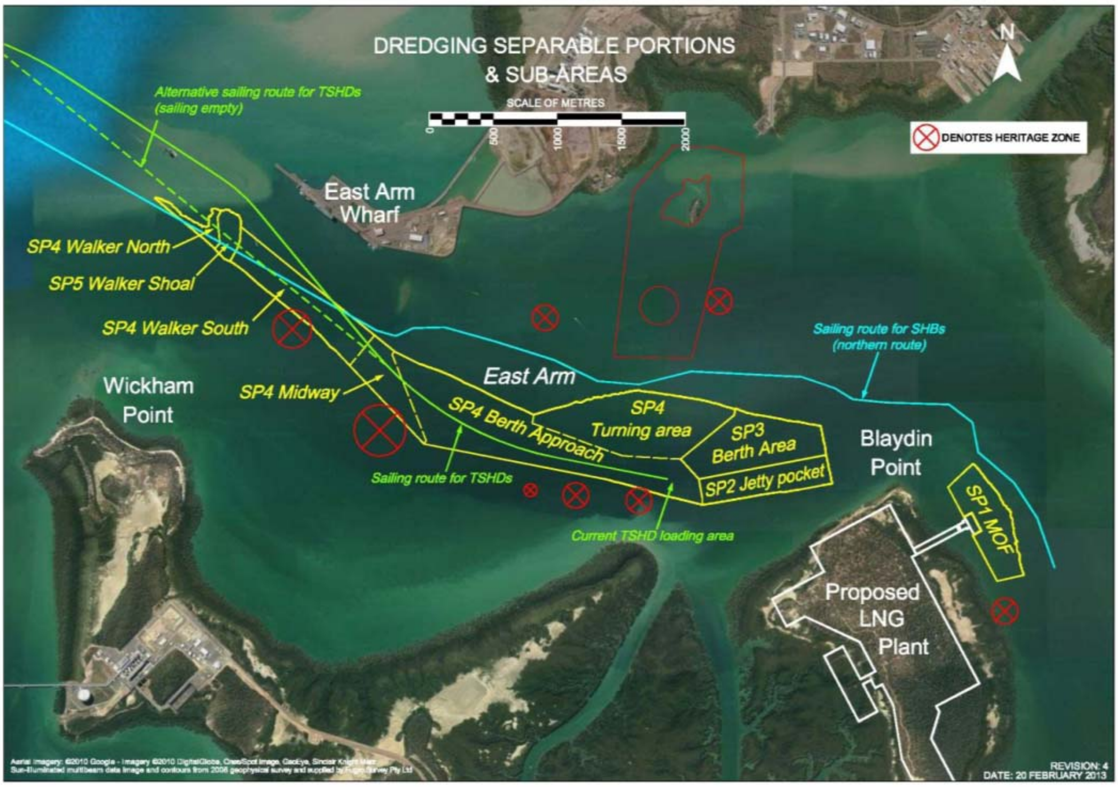
Similar trends and patterns were observed for *Enterococci,* with median levels in the sediment basins above trigger criteria in January and March 2013. *Enterococci* levels within the Harbor were reported below trigger criteria during the 2012/2013 monitoring period, ranging between 1 and 14 CFU/100 mL.

The algal numbers measured during the months of June 2012 to March 2013 exceeded the trigger criteria between November 2012 and March 2013, which could be due to the algae being stimulated by nutrients in the rainfall run-off.

4.7.3.1 Dredging

Limited information has been provided regarding the activities taking place in the Darwin Harbour as part of the Ichthys development, as near shore works have been undertaken separately to the onshore works associated with the current EIMP and CEMP. Dredeging is understood to have commenced in October 2012. Daily harbour activity reports have been provided from early March 2013, therefore marine activities conducted in addition to dredging have not been considered further. **Plate 4-1** below presents the locations of the dredging activities undertaken in the Darwin Harbour.

Plate 4-1 Ichthys Dredging Harbor Locations (*Source: INPEX*)



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Dredging is known to create short-term increases in the level of suspended sediment, which can give rise to changes in water quality, such as increased turbidity and the possible release of organic matter, nutrients and or contaminants depending upon the nature of the material in the dredging area.

In March 2013, dredging was reported at locations SP1 between 8 and 12 March, and at location SP2 between 8 and 18 March, prior to the surface water monitoring undertaken on the 18 March. An observed increase in ammonia and oxides of nitrogen in the marine environment in March 2013 (**Chart A3**) may suggest dredging may have released nutrients from the sea bed. This statement is only based on the March 2013 results; therefore additional monitoring data is required prior to confirming this statement. TSS and turbidity have not been reported as increasing in March 2013. Further nutrient, TSS and turbidity monitoring should determine if dredging has any impact on the marine water quality around the Blaydin Point site.

Trends observed for other parameters such as pH, dissolved oxygen, redox potential, electrical conductivity, temperature and salinity suggest a seasonal variation rather than due to site activities.

Discussion of potential correlation of the monitoring plan to specific site activities is presented in **Chapter 11**.

5

Groundwater

5.1 Scope of Work

The purpose of the groundwater monitoring program is to establish background groundwater quality at the site and to conduct on-going monitoring to assess potential changes from these initial conditions.

As set out in the EIMP, the scope of works for the groundwater monitoring program includes the following:

- Installation and development of up to 40 new groundwater monitoring wells at the site;
- Gauging, purging and sampling of monitoring wells (up to 58 in total) with samples analysed for:
  - Total and dissolved metals including arsenic, aluminium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, silver, vanadium and zinc;
  - Cation/anion and sulphate concentrations;
  - Total petroleum hydrocarbons, benzene, toluene, ethylbenzene, xylenes and naphthalene; and
- In-situ quality measurements (pH, total dissolved solids [TDS], electrical conductivity [EC], dissolved oxygen [DO], temperature, redox potential and turbidity [NTU]) will be undertaken prior to sample collection using a multi-parameter instrument. All field equipment will be calibrated according to manufacturer's instructions.

A denser groundwater monitoring network may be established around areas of dynamic replacement, this network will be monitored weekly for changes in groundwater elevation (pH, TDS, EC, DO, temperature, redox potential and turbidity (NTU).

In line with these requirements, the following works were undertaken between April 2012 and April 2013 as the construction program allowed:

- Drilling, installation and development of 30 new groundwater monitoring bores;
- Decommissioning of eight groundwater monitoring bores;
- Extension of four groundwater monitoring bores;
- Installation and maintenance of data loggers within 15 groundwater monitoring bores;
- Monthly gauging, purging and sampling of up to 34 groundwater monitoring bores;
- Measurement of in-situ water quality parameters (pH, EC, DO, temperature, redox potential and turbidity [NTU]) at the time of sampling;
- Laboratory analytical testing of the collected groundwater samples;
- Analytical data validation; and
- Monthly factual and quarterly interpretative reporting.

5.2 EIMP Performance Criteria

Groundwater quality trigger criteria values, as presented in **Table 5-1**, are reflective of source water and beneficial uses, i.e. fresh groundwater must use ANZECC 2000 freshwater criteria or NHMRC drinking water guidelines, whichever are the more stringent, and saline groundwater must use ANZECC 2000 marine water criteria. As discussed in **Section 1-4**, the conservative, non-site-specific freshwater, marine water or drinking water criteria have been selected. The appropriate level of protection for ecosystems is afforded through the selection of those criteria recommended for moderately disturbed environments (99% and 95% protection levels). Upon the collection and analysis of twenty-four (24) consecutive months of monitoring data, the trigger criteria presented in **Table 5-1** below will be updated with site-specific background values. During these 24 months, groundwater quality performance will be assessed by comparing concurrently measured values to each other and to the values listed in **Table 5-1** and analysing temporal trends across collected data. Dataset concentration trends will be analysed to determine if the works are negatively impacting upon groundwater. This will initially require a high frequency of monitoring to establish a suitably robust dataset.

In the absence of groundwater specific criteria, surface water criteria have been selected for oxides of nitrogen, ammonium, total nitrogen, total phosphorous and filterable reactive phosphorous. Trigger criteria are applied only to dissolved (filtered) metals results.

It is noted that the groundwater quality trigger criteria changed in January 2013 with the update of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. The updated trigger criteria are provided below.

Table 5-1 Groundwater Quality Trigger Criteria

Parameter	Detection Method	Trigger Criteria	Reference
Oxides of Nitrogen	Laboratory	>20µg N/L	NRETAS
Ammonium	Laboratory	>20µg /L	NRETAS
Total nitrogen	Laboratory	>300µg N/L	NRETAS
Total phosphorus	Laboratory	>30µg P/L	NRETAS
Filterable Reactive Phosphorus	Laboratory	>10µg P/L	NRETAS
pH	In situ	<7 or >8.5	NRETAS
TRH	Laboratory	>600 µg/L	Project
Benzene	Laboratory	>1 µg/L	ADWG
Toluene	Laboratory	>25 µg/L	ADWG
Ethylbenzene	Laboratory	>3 µg/L	ADWG
Xylenes	Laboratory	>20 µg/L	ADWG
Naphthalene	Laboratory	>16 µg/L	Fresh
Arsenic (Total)	Laboratory	>10 µg/L	ADWG
Arsenic (III)	Laboratory	>24 µg/L	Fresh
Arsenic (V)	Laboratory	>13 µg/L	Fresh
Aluminium (I)	Laboratory	>55 µg/L	Fresh
Cadmium	Laboratory	>0.2 µg/L	Fresh
Chromium (III)	Laboratory	>27.4 µg/L	Marine
Chromium (VI)	Laboratory	>1 µg/L	Fresh
Cobalt	Laboratory	>1 µg/L	Marine
Copper	Laboratory	>1.3 µg/L	Marine
Lead	Laboratory	>3.4 µg/L	Fresh
Manganese	Laboratory	>100 µg/L	ADWG
Mercury	Laboratory	>0.06 µg/L	Fresh
Nickel	Laboratory	>7 µg/L	Marine
Silver	Laboratory	>0.05 µg/L	Fresh
Vanadium	Laboratory	>100 µg/L	Marine
Zinc	Laboratory	>8 µg/L	Fresh
Redox (ORP)	In situ	Assessed for temporal variation	Not applicable
Dissolved Oxygen	In situ		

Source:
NRETAS: NRETAS. 2010. Water Quality Objectives for the Darwin Harbour Region—Background Document. NRETAS, Darwin, NT.
Fresh: Freshwater criteria taken from ANZECC. 2000. *Australian and New Zealand guidelines for fresh and marine water quality.* ANZECC, Canberra, ACT.
Marine: Marine criteria taken from ANZECC. 2000. *Australian and New Zealand guidelines for fresh and marine water quality.* ANZECC, Canberra, ACT.
ADWG: Australian Drinking Water Guidelines 2011, NHMRC, Canberra, ACT.
Project: Project specific guideline

5.3 Field Methodology

Field protocols and sampling methodologies were undertaken in accordance with Section 4.4 of the EIMP.

5.3.1 Sampling Methodology

Beginning in June 2012 and continuing through March 2013, monitoring of the new and existing groundwater monitoring bores was conducted by URS personnel on a monthly basis. During the monitoring events, groundwater samples were collected primarily using a peristaltic pump and low flow sampling techniques (as described in US EPA Standard Operating Procedure GW0001 Low Stress [low-flow] Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells) pursuant to standard URS practices for groundwater sampling as detailed below and in general accordance with *AS/NZS 5667.11:1998 "Water Quality – Sampling, Part 11: Guidance on Sampling of Groundwaters"* (AS/NZS 5667.11:1998). Where groundwater recharge rates were insufficient to allow employment of low-flow sampling techniques, the bores were purged dry, allowed to recharge and then sampled later that day or the following day using dedicated, disposable bailers.

Key procedures undertaken in the field are described below:

- Measurement of the depth to water and depth to the base of the bore with a water level dip meter;
- Groundwater purging of each bore;
- During purging, groundwater level measurements were recorded to confirm that drawdown within the sampled well was being maintained at a minimum;
- Groundwater quality measurements (pH, total dissolved solids [TDS], electrical conductivity [EC], dissolved oxygen [DO], temperature and redox potential) were undertaken continually during the low flow purging process of each bore using a multi-parameter instrument fitted with a flow-through-cell. All field equipment was calibrated in accordance with manufacturer's instructions;
- Collection of groundwater samples and field QA/QC samples for laboratory analysis after the field quality parameters have stabilised (consistent readings);
- Decontamination of all non-dedicated sampling equipment between sample locations; and
- Proper disposal of used disposable sampling equipment and purged water.

Copies of the field sheets, on which groundwater monitoring details were recorded, are attached as **Appendix J**.

5.3.2 Drilling and Installation of Groundwater Monitoring Bores

Thirty (30) new groundwater monitoring bores were installed at the site by a licensed NT drilling contractor (Bores NT) using air rotary/hammer drilling techniques under the supervision of URS personnel. The bores were drilled in accordance with Bore Construction Permit BCPD1514, which was issued by the DLPE on 13 July 2012. A copy of the permit is attached as **Appendix I**.

Drilling and bore construction details are summarised below:

- The monitoring bores were drilled and installed to depths up to 10 m below ground level;
- The monitoring bores were constructed using threaded 50 mm Class 18 uPVC bore casing;
- The bores were constructed with 1 m of blank casing and the remaining depth was constructed with screened casing (1 mm slots) to capture groundwater level oscillations between the wet and dry seasons;
- The annulus around the screen was backfilled with a 2 mm gravel filter pack;

- The screened sections were isolated from the surface using a bentonite seal, with the remaining void to ground surface filled with cement grout.
- The bores were completed with locking steel monument covers, self-draining concrete pads and lockable well caps;
- Following installation, the groundwater monitoring bores were developed using air lift to remove fines introduced during the installation process; and

Lithology and construction details for each monitoring bore are detailed on bore logs in **Appendix H**.

Following installation, the location and elevation of each monitoring bore were surveyed by JKC. The locations of the groundwater monitoring bores are presented on **Figures B1** and **Figure B2**.

5.3.3 Groundwater Monitoring Bore Decommissioning

On 2 July 2012, bore decommissioning was undertaken on historic groundwater bores ONBH04, ONBH10, VWP118, VWP158 and VWP401. Monitoring bores BPGW22 and BPGW38 were decommissioned on 14 December 2012 after the bores were damaged during ground improvement works. Monitoring bore BPGW19 was decommissioned (and subsequently replaced with BPGW19A) on 17 September 2012 to allow for ground improvement works to be conducted in the area. Registered bores were decommissioned under the supervision of URS personnel by Bores NT in accordance with DLPE requirements. Copies of the bore decommissioning permits are provided in **Appendix I**.

5.3.4 Groundwater Monitoring Bore Extensions

At the request of JKC, groundwater monitoring bores BPGW08, BPGW10, VWP328 and VWP341 were extended to higher elevations to accommodate ground improvement works. These bores were extended by Bores NT under the direction of URS personnel. Following the extensions, the top of casing elevations were re-surveyed by JKC.

5.3.5 Datalogger Installation

Beginning in October 2012 and continuing until present, URS has maintained dataloggers at a number of monitoring bore locations at the site, noting that the exact number and location of instruments operating at any given time has changed depending on the need for repairs or maintenance, bore inaccessibility, bore extension works and/or requests by JKC to move the devices to alternative locations. The dataloggers record and store continuous records of water level, EC and temperature.

5.4 Field Observations

5.4.1 Existing Monitoring Bore Network

The status of the groundwater monitoring bore network is summarised in **Table 5-2**. The locations of the monitoring bores are indicated on **Figures B1** and **Figure B2**.

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Table 5-2 Groundwater Monitoring Bore Status

Bore ID	Date Installed	Status	Datalogger	Comments
BPGW01	21/8/12	Operational	N	
BPGW02	9/8/12	Operational	N	
BPGW03	8/8/12	Operational	N	
BPGW04	8/8/12	Operational	N	
BPGW05	8/8/12	Operational	Y	
BPGW06	18/8/12	Operational	N	Unable to be sampled January, February and March 2013 due to inundation.
BPGW07	19/9/12	Operational	Y	
BPGW08	18/8/12	Operational	Y	First bore extension 15/01/13. Second bore extension 21/03/13.
BPGW09	19/9/12	Operational	N	
BPGW10	17/8/12	Operational	N	Bore extended 25/9/12.
BPGW11	16/8/12	Operational	N	
BPGW12	10/8/12	Operational	N	
BPGW13	10/8/12	Operational	N	
BPGW14	10/8/12	Destroyed	N	Bore destroyed, has not been decommissioned.
BPGW16	13/12/12	Operational	Y	
BPGW18	24/9/12	Operational	Y	
BPGW19	13/8/12	Decommissioned	N	Decommissioned 17/9/12.
BPGW19A	17/9/12	Operational	Y	Replacement for BPGW19.
BPGW22	16/8/12	Decommissioned	N	Decommissioned on 14/12/12.
BPGW23	11/8/12	Operational	N	
BPGW24	14/8/12	Operational	Y	
BPGW25	14/8/12	Operational	N	
BPGW26	14/8/12	Operational	N	
BPGW27	13/8/12	Operational	N	
BPGW28	24/9/12	Operational	N	Unable to access for sampling in March 2013.
BPGW29	21/8/12	Operational	N	
BPGW32	16/8/12	Operational	N	
BPGW38	17/8/12	Decommissioned	N	Decommissioned on 14/12/12.
BPGW40	25/9/12	Operational	Y	
BPGW41	24/9/12	Operational	Y	
BH602	May 2009	Operational	N	Existing bore.
ONBH03	May 2008	Operational	N	Existing bore. Unable to access for sampling in March 2013.
VWP328	August 2009	Operational	N	Existing bore. Bore extended 15/01/13. Unable to access for sampling in February and March 2013.
VWP341	September 2009	Operational	Y	Existing bore. Bore extended 15/01/13.
ONBH04	May 2008	Decommissioned	N	Existing bore. Bore decommissioned 02/07/12.
ONBH10	June 2008	Decommissioned	N	Existing bore. Bore decommissioned 02/07/12.
VWP118	October 2009	Decommissioned	N	Existing bore. Bore decommissioned 02/07/12.
VWP121	August 2009	Lost	N	Existing bore.
VWP401	September 2009	Decommissioned	N	Existing bore. Bore decommissioned 02/07/12.

5.4.2 Field Parameters

Field parameters and static water levels measured and recorded at the time of the June 2012 through March 2013 GMEs are presented in **Tables B1** and **Table B2**, respectively.

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Potentiometric surface maps constructed using the surveyed bore elevations and groundwater levels measured at the end of the dry season (September 2012) and the end of the wet season (March 2013) are provided as **Figure B3-A** and **Figure B3-B**, respectively. As indicated in the figures, groundwater levels in March were generally higher than in September but the configuration of the groundwater surface is not markedly different between the two seasons. In areas north of the causeway, the groundwater surface is relatively flat, whereas a groundwater divide is apparent in the area proximal to bores BH602, BPGW02 and BPGW06.

All pH values recorded at the site to date have been below the groundwater quality trigger criterion range of 7.0 to 8.5 except for single instances at bores BPGW13 (7.01, February 2013), BPGW14 (7.33, November 2012), BPGW32 (7.31, January 2013), BPGW40 (7.00, December 2012) and ONBH10 (7.20, June 2012). Isopleth maps illustrating the distribution of pH at the end of the dry season (September 2012) and the end of the wet season (March 2013) are provided as **Figure B4-A** and **Figure B4-B**, respectively. As indicated in the figures, the lowest pH values in both months were recorded at monitoring bores BH602 and BPGW32. In September 2012, a low pH value (4.47) was also recorded at monitoring bore ONBH03; however, this bore could not be sampled in March 2013.

A discussion on the remaining field parameter results, including trends, is provided in **Section 5.7.1**.

5.4.3 Datalogger Results

Plots of groundwater elevation and EC as a function of time for each of the dataloggers are presented in **Appendix K**, with the exception of BPGW07, BPGW10 and BPGW16, as detailed in this section. At each bore location, temperature remained relatively constant across the period of monitoring and, for clarity in presentation, is not illustrated on the charts. However, sampling events, datalogger retrieval and significant rainfall events are notated, as these activities tend to affect the data record.

BPGW03

Groundwater elevation at BPGW03 gradually increased from approximately 1.7 m AHD on 30 October 2012 to approximately 4.3 m AHD on 21 December, at which time it rose rapidly to approximately 6.8 m AHD, where it more or less stayed through 19 February 2013. EC over the same period was largely constant at about 27 mS/cm from 30 October to 21 December, whereupon it suddenly dropped to less than 1 mS/cm at about the same time that groundwater elevation experienced a sudden rise. These changes in groundwater elevation and EC are likely related to period of prolonged rainfall that began around 21 December. A temporary dip in EC that occurred between 5 and 12 November appears to correspond to groundwater sampling activities. At the request of JKC, the datalogger in BPGW03 was moved to BPGW41 on 20 February 2013.

BPGW05

Groundwater elevation at BPGW05 gradually increased from approximately 3.0 m AHD on 30 October 2012 to approximately 4.6 m AHD during the first week of January 2013. In contrast, EC over the same period of time decreased rapidly from approximately 73 mS/cm on 30 October to less than 5 mS/cm around 14 November, where it more or less stayed through 23 December before gradually declining further. This marked decrease in EC reflects the movement of the fresh water into the bore. On 10 January 2013, the datalogger was found to have malfunctioned and was removed from the bore. Attempts to repair the datalogger were unsuccessful and a new datalogger was installed within

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BPGW05 on 25 March 2013. From 27 March to 15 April 2013, groundwater elevation declined to approximate 4.0 m AHD while EC had risen to more than 50 mS/cm.

BPGW06

Groundwater elevation at BPGW06 gradually increased from approximately 3.6 m AHD on 30 October 2012 to approximately 9.5 m AHD. Over the same period, EC remained relatively constant at approximately 1.2 to 1.4 mS/cm. Purging and sampling activities on 5 November and 3 December appear to have had a significant, although temporary, effect on both groundwater elevation and EC. Monitoring bore BPGW06 was inaccessible from mid-December due to significant ponding of surface water runoff around the bore head. Data collection ceased on 7 January 2013 once the data logger reached storage capacity.

BPGW07

On 20 February 2013, at the request of JKC, the datalogger that had originally been installed at monitoring bore BPGW10 was moved to BPGW07. Based upon the datalogger record, groundwater elevation at BPGW07 steadily declined from approximately 5.0 m AHD on 20 February to 2.7 m AHD on 11 March, at which point it rose rapidly again to 3.9 m AHD. However, these trends are not evident in the SWL measurements conducted at the time of sampling (refer **Table B1**), which showed that groundwater elevation was largely constant over the monitoring period. The datalogger record from BPGW10 indicates a malfunction in the instrument prior to when it was moved to BPGW07. It is therefore suspected that the elevation record is erroneous from BPGW07. Over the period from 20 February to 15 April, EC was generally constant at approximately 75 mS/cm.

BPGW08

Groundwater elevation at BPGW08 rose from approximately 2.1 m AHD on 30 October 2012 to approximately 3.8 m AHD in the beginning of March, at which time groundwater elevation began a slow decline. EC values in the early part of the record appear to have been greatly affected by well gauging and sampling activities, particularly on 8 November when EC rose from approximately 57 mS/cm to 73 mS/cm. A similar effect is not apparent following sampling on 3 December, which suggests that the EC values recorded by the datalogger prior to the November GME were not reflective of true groundwater conditions. Between 8 November 2012 and the beginning of January 2013, EC gradually increased to approximately 75-80 mS/cm, which was then more or less maintained through April.

BPGW10

Groundwater elevation at BPGW10 gradually increased from approximately 3.5 m AHD on 30 October 2012 to approximately 3.8 m AHD on 9 January 2013. From 9 January 2013, results are assumed to be erroneous as recorded groundwater elevations are unlikely due to well construction. As with BPGW08, EC was greatly influenced by sampling activities in November, when values rose from approximately 60 mS/cm to about 75 mS/cm. From 5 November 2012 to the beginning of February 2013, EC values decreased slightly but then increased again to about 75 mS/cm following the February GME.

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BPGW16

Groundwater elevation at BPGW16 was relatively constant at approximately 3.7 to 3.8 m AHD from 17 January to 11 March 2013. From 11 March 2013, results are assumed to be erroneous as recorded groundwater elevations are unlikely, due to well construction. EC values across the period of record were for the most part constant at approximately 82.5 mS/cm.

BPGW18

Overall, groundwater elevation at BPGW18 rose by less than 0.5 m between 30 October 2012 and 15 April 2013. The high degree of variability in the elevation record appears to be the result of both rainfall events and tidal variation. Over the same time period, EC rose from approximately 84 mS/cm to approximately 90 mS/cm and was also quite variable.

BPGW19A

Overall, groundwater elevation at BPGW19A changed very little between 30 October 2012 and 15 April 2013. As with BPGW18, there is a high degree of variability in the record, which is likely due to a combination of both rainfall and tidal variation. The EC record is quite variable, especially in the early part of the record, but averaged approximately 80 mS/cm.

BPGW24

Groundwater elevation at BPGW24 increased from approximately 3.4 m AHD on 30 October 2012 to approximately 4.1 m AHD on 15 April 2013. The variability in groundwater elevation is likely due to both rainfall events and tidal variation. EC varied a great deal across the record, with marked jumps and falls that largely follow changes in groundwater elevation.

BPGW29

Groundwater elevation at BPGW29 gradually increased from approximately 3.1 m AHD on 30 October 2012 to approximately 4.2 m AHD on 19 February 2013. During that same time period, EC increased only slightly. However, the EC record appears to be greatly disturbed by well gauging, purging and sampling activities. At the request of JKC, the datalogger at this location was moved to monitoring bore VWP341 on 20 February 2013.

BPGW40

Groundwater elevation at BPGW40 rose from approximately 3.2 m AHD on 30 October 2012 to approximately 3.8 m AHD on 11 March 2013, from which time it began to decline slightly. A great deal of variability is apparent in the elevation record, which appears to be related to both rainfall events and tidal variation. The drop in EC values starting in mid-March EC appear to be due to placement of the datalogger at a different location within the bore. Overall, however, EC averaged approximately 75-78 mS/cm.

BPGW41

At the request of JKC, the datalogger in monitoring bore BPGW03 was moved to BPGW41 on 20 February 2013. Groundwater elevation at BPGW41 changed very little between 20 February and 15 April 2013 and varied between 4.0 and 4.5 m AHD. EC over the same time period declined consistently from approximately 78 mS/cm to 76 mS/cm.

VWP328

Groundwater elevation at VWP328 expressed a moderate degree of variability across the period of record but, overall, changed very little between 30 October 2012 and 14 January 2013, at which point the datalogger was moved to monitoring bore BPGW16. Groundwater elevation was generally around 3.6 m AHD across the record, except for five days near the end of November, when groundwater elevation rose to more than 4.5 m AHD. This rise likely corresponds to a series of rainfall events recorded around the same time period. Except during this five day period, EC over the three month period changed very little and averaged approximately 84 mS/cm.

VWP341

Groundwater elevation at VWP341 was increased from approximately 3.8 m AHD in February to 4.2 m AHD in April. EC over the same period was relatively constant at about 60 mS/cm and any changes tended to be inversely proportional to groundwater elevation.

5.5 Analytical Results

The primary and duplicate groundwater samples and trip, field and equipment rinsate blanks collected during each groundwater monitoring event were submitted using Chain-of-Custody (CoC) procedures to ALS laboratories in Smithfield, NSW for laboratory analytical testing. The corresponding triplicate groundwater samples were submitted to ALS laboratories in Stafford, QLD. Copies of the CoCs and laboratory analytical reports are provided in **Appendix M**.

During each month of monitoring, the collected groundwater samples for were analysed for:

- Total and dissolved metals;
- Total Dissolved Solids (TDS);
- Alkalinity;
- Nutrients (ammonia, nitrate, nitrite, total kjeldahl nitrogen, total nitrogen, reactive phosphorous and total phosphorous);
- Major ions; and
- Hardness.

In addition, the groundwater samples collected from select monitoring bores were analysed for:

- Total Recoverable Hydrocarbons (TRH); and
- Benzene, Toluene, Ethylbenzene, total Xylenes and Naphthalene (BTEXN).

In the first GME following a given bore installation, the groundwater samples collected from that bore were also analysed for speciated arsenic and hexavalent chromium.

Laboratory analytical results for the groundwater samples for each monitoring event to date are summarised in **Table B3**. Reported exceedances of the groundwater trigger criteria for each month of monitoring are summarised in **Table 5-3**. Only those analytes whose trigger criterion was exceeded at least once are included in the table.

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Table 5-3 Groundwater Monitoring Exceedance Summary, June 2012 – March 2013

Analyte	Percentage of Bores with Analyte Concentration Exceeding Trigger Criteria										
Date	**1 Jun**	**19 Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
No. Bores Sampled	**3**	**8**	**4**	**4**	**26**	**34**	**31**	**30**	**30**	**28**	**26**
Benzene	0	0	0	0	0	0	0	0	3	0	0
Aluminium (dissolved)	50	25	50	25	15	18	13	20	20	25	27
Arsenic (dissolved)	0	25	50	25	15	26	19	30	27	39	42
Cadmium (dissolved)	50	25	50	25	27	26	13	37	40	25	27
Cobalt (dissolved)	100	100	100	100	96	97	87	80	83	79	88
Copper (dissolved)	25	25	50	50	19	18	13	17	7	11	12
Lead (dissolved)	25	13	25	25	50	44	10	17	10	18	15
Manganese (dissolved)	-	-	-	-	-	-	-	-	83	86	77
Nickel (dissolved)	-	-	-	-	-	-	-	-	47	46	42
Silver (dissolved)	25	0	0	0	0	0	3	13	10	14	15
Zinc (dissolved)	100	88	75	75	65	65	45	63	57	54	46
Ammonia as N	0	38	75	50	92	91	84	80	88	75	92
Nitrate & Nitrite (as N)	-	38	75	25	35	29	39	47	33	25	31
Total Nitrogen as N	25	38	75	50	46	29	39	53	63	68	62
Reactive Phosphorus (as P)	-	13	25	100	50	59	61	43	63	43	58
Total Phosphorus as P	25	25	50	50	58	71	52	30	60	25	35

As indicated in **Table 5-3,** elevated concentrations (exceeding their respective groundwater quality trigger criteria) of dissolved metals (aluminium, arsenic, cadmium, cobalt, copper, lead, manganese, nickel, silver and zinc) and nutrients (ammonia as N, nitrate & nitrite (as N), total nitrogen as N, reactive phosphorous (as P) and total phosphorous as P) have been reported in the groundwater samples collected during each month of monitoring. Benzene was reported on one occasion only, in the groundwater samples collected from monitoring bore BPGW11 in January 2013 at a concentration (3 µg/L) slightly exceeding the trigger criterion (1 µg/L).

A number of analytes have been consistently reported at a high percentage of bore locations across the period of monitoring: dissolved cobalt, dissolved zinc, ammonia as N, total nitrogen as N and total phosphorous as P (which includes reactive phosphorous). A brief discussion on the reported exceedances each of these analytes is presented below.

Dissolved Cobalt

In each month of monitoring, concentrations of dissolved cobalt exceeding the groundwater quality trigger criterion of 0.001 mg/L have been reported at the majority (>79%) of monitoring bores sampled.

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Dissolved cobalt concentrations at BPGW32 have, historically, been the highest of any monitoring bore at the site, with a maximum reported concentration of 0.801 mg/L in November 2012.

Dissolved Zinc

Concentrations of dissolved zinc exceeding the groundwater quality trigger criteria of 0.008 mg/L have generally been reported at half or more of the monitoring bores sampled during each month of monitoring. Dissolved zinc concentrations at BH602 and BPGW32 have, historically, been the highest of any location across the site, with maximum reported concentrations of 1.92 mg/L (October 2012) and 1.54 mg/L (December 2012), respectively.

Ammonia as N

Concentrations of ammonia as N exceeding the groundwater quality trigger criteria of 0.02 mg/L are typically reported in about 75% of the monitoring bores sampled during any given month of monitoring. ammonia as N concentrations at monitoring bores BPGW10 and BPGW19A have, historically, been the highest of any location across the site, with maximum reported concentrations of 2.76 mg/L (November 2012) and 2.4 mg/L (November 2012), respectively.

Total Nitrogen as N

Concentrations of total nitrogen as N exceeding the groundwater quality trigger criteria of 0.3 mg/L are generally reported at about half of the monitoring bores sampled during any given month of monitoring. The maximum reported concentration of total nitrogen as N at the site to date was 5.02 mg/L, which was reported in the samples collected from monitoring bore BPGW03 in January 2013.

Total Phosphorus as P

Concentrations of total phosphorous as P exceeding the groundwater quality trigger criteria of 0.03 mg/L are generally reported at about half of the monitoring bores sampled during any given month of monitoring. Total phosphorous concentrations at BPGW03 and BPGW19A have, historically, been the highest of any location across the site, with maximum reported concentrations of 0.375 mg/L (November 2012) and 1.17 mg/L (November 2012), respectively.

5.5.1 Analytical Data Validation

To assess the reliability of the laboratory analytical results, URS examined the frequency of laboratory QA/QC, the number of tests reported versus that required, sample handling, preservation and holding times, the use of appropriate laboratory LORs, analysis of blanks, RPDs between primary, duplicate and triplicate sample results, field blank results, the use of matrix spikes and surrogate recoveries during each month of monitoring. Our examination indicates that the groundwater analytical data can be used as a basis for interpretation subject to the limitations outlined in the monthly Data Validation Summary Reports provided in **Appendix N**.

Data validation revealed a number of recurring non-compliance issues. These issues, along with URS efforts to resolve them, are summarised below:

- Matrix spikes (MS) were not always been performed by the lab, or anonymous samples were reported for some compounds. To rectify this, URS personnel have begun collecting additional sample containers in the field and notating them on the CoCs for use in matrix spikes;

- Laboratory duplicates were occasionally reported at less than the required frequency for some compounds. URS has been in contact with the laboratory to help insure that the required QA/QC procedures are followed;
- LORs for a given compound occasionally exceed the trigger criteria; concentrations of these analytes may therefore exceed the trigger criteria. Unfortunately, this problem cannot be resolved due to the high TDS concentrations of some samples, which requires dilution by the laboratory and which, in turn, raises the LOR;
- RPDs occasionally exceed the control limits between primary and duplicate samples, and/or between primary and triplicate samples. This is an inherent problem associated with the heterogeneous nature of groundwater. URS has endeavoured to minimise this through employment of consistent sample collection techniques;
- Metals have been reported at low concentrations within some of the field blanks. At the request of URS, the laboratory has initiated an internal review to assess possible sources of these “hits”; and
- Metals have been reported at low concentrations within some of the equipment rinsate blanks. In response, URS has initiated more vigorous decontamination techniques.

5.6 Third Party Data

5.6.1 Acid Sulphate Soil Monitoring

ASS monitoring was conducted at the site in 2012 and 2013 under the supervision of JKC. Laboratory analytical reports, treatment register tables and results summary table for ASS monitoring detail the soil testing and treatment that occurred on site. A series of figures illustrating the ASS Reaction Rating of soil samples collected from various locations across the site indicate that high and extreme risk ASS areas exist in portions of the site, particularly near the MOF, along the causeway, and adjacent to the intertidal areas. Copies of these attachments are provided in **Appendix O**. It should be noted that the majority of samples analysed were collected from locations adjacent to intertidal areas at depths less than two metres below ground level. ASS soil validation and management was managed by JKC. No reports or in situ groundwater analysis were provided for inclusion in this report.

5.7 Discussion

5.7.1 Trend Analysis

Due to the cyclical nature of weather patterns at the site, i.e., wet season vs. dry season, groundwater elevation, water quality parameters, and groundwater quality data are expected to have seasonal variability. Removal of seasonal trends is required prior to statistical analysis of site data, which can be conducted provided that the seasonal trends are well established in advance. Presently, the existing data set is limited to seven monitoring events at most bore locations, ten events at four bore locations, and as little as three events at others. Consequently, it is not considered prudent at the present time to conduct statistical analysis on the groundwater data; analysis for trends has therefore been limited to graphical presentation.

Groundwater Elevation

Throughout the 10-month period of monitoring, groundwater elevation has historically been highest to the southeast of the site, with groundwater levels at monitoring bores BH602, BPGW01 and/or

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BPGW06 typically being the highest of any bore during any given month (refer **Figures B3-A** and **Figure B3-B**). At monitoring bores BH602, BPGW01, BPGW02, BPGW03 and BPGW04, groundwater levels reached year-end lows in late October or early November, after which time they have generally been rising. This increase in groundwater elevation is most likely due to the onset of the wet season and, thus, increased recharge to underlying shallow aquifer. A similar trend in groundwater elevation was noted at monitoring bores ONBH03, VWP328 and VWP341, except that groundwater elevation lows were instead observed in August (VWP328, VWP341) and October (ONBH03).

Elsewhere across the site, groundwater levels have generally been rising from June 2012 through March 2013. This trend is likely attributable to the fact that most of the monitoring bores are situated at a lower elevation and adjacent to intertidal areas. Groundwater levels are, therefore, more likely to be influenced by groundwater/seawater interaction, including movement of seawater into the aquifer when tide levels are higher than the corresponding groundwater levels. Exceptions to this trend are monitoring bores BPGW07, BPGW09, BPGW18, BPGW28 and BPGW32. Monitoring bores BPGW07, BPGW09, BPGW18 and BPGW28 are located immediately adjacent to the mangrove fringe and groundwater elevations at these locations have been variable across the period of monitoring. The datalogger records from monitoring bores BPGW07 and BPGW18 indicate that groundwater levels are strongly influenced by rainfall events and tidal variations; groundwater levels at monitoring bores BPGW18 and BPGW28 are therefore expected to respond similarly. At monitoring bore BPGW32, groundwater elevation was largely unchanged between September and November before rising approximately 1 m in both December 2012 and January 2013 before declining again in February and March 2013. Groundwater elevation data for each of the monitoring bores are presented graphically in **Chart B1**.

At monitoring bore BPGW16, SWL has been measured at the top of the PVC bore casing in each of the three GMEs performed following installation. During each sampling event, groundwater has been observed slowly flowing out of the bore casing, indicating an upward hydraulic flow gradient and artesian conditions.

In the coming months, groundwater levels at all monitoring bores are expected to decline with the on-set of the dry season. The datalogger records from monitoring bores BPGW05, BPGW08, BPGW40 and BPGW41 suggest that this may already be happening in some areas of the site.

Groundwater pH

Groundwater pH has remained relatively constant at most bore locations over the period of monitoring, although decreasing trends in pH have been noted at BPGW01, BPGW02, BPGW11, BPGW12, BPGW24, BPGW25 and BPGW32, while increasing trends in pH are apparent at monitoring bores BPGW09, BPGW28 and ONBH03. Except for a few isolated occurrences, all pH values recorded at the site to date have been below the groundwater quality trigger criterion range of 7.0 to 8.5. During any given month, the lowest pH values have been reported at monitoring bores BH602, BPGW32 and ONBH03. Where evident, trends in groundwater pH are illustrated in **Chart B2**.

Electrical Conductivity (EC)

Datalogger records and water quality measurement conducted at the time of sampling indicate that EC has remained relatively constant at most bore locations across the 10-month period of monitoring. An exception to the southeast of the site, where EC has decreased at most bore locations since the on-set of the wet season. Elsewhere across the site, EC has also decreased at monitoring bores

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BPGW12, BPGW13, BPGW14, BPGW23 and BPGW41. Apparent increases in EC have been observed at monitoring bores BPGW11, BPGW18, BPGW28, and BPGW29. At monitoring bore BPGW28, EC increased dramatically between November and December before decreasing somewhat in January and February (the bore could not be accessed for sampling in March 2013). Where evident, trends in EC are illustrated in **Chart B3**.

Dissolved Oxygen (DO) and Oxygen Reduction Potential (Redox)

No trends in DO are apparent, although DO concentrations are typically highest to the southeast of the site. Similarly, oxygen reduction potential (redox) values have remained relatively constant at most bores across the period of monitoring, although redox values increased at monitoring bores BPGW11 and BPGW13 with the on-set of the wet season. At monitoring bores BPGW02, BPGW04, BPGW27 and BH602, redox values have generally been increasing across the period of monitoring. Where evident, trends in redox are illustrated in **Chart B4**.

Dissolved Metals

Groundwater at the site can be characterised as having elevated concentrations of dissolved metals above their respective groundwater quality trigger criteria, specifically: cobalt, zinc, manganese and, at a lower percentage of bore locations, aluminium, arsenic, cadmium, copper, lead, nickel and silver. Of these metals, cobalt and zinc have been reported at concentrations exceeding the groundwater quality trigger criteria at monitoring bores across the site. Isopleth maps illustrating the distribution of dissolved cobalt and zinc at the time of the September 2012 (dry season) and March 2013 (wet season) GMEs are provided as **Figures B5-A, Figure B5-B, Figure B6-A** and **Figure B6-B**, respectively. As illustrated in the figures, the distribution of dissolved cobalt and zinc across the site is relatively similar in both seasons.

The highest concentrations of dissolved metals have historically been reported at monitoring bores BH602 and BPGW32, which also have the lowest reported pH values (typically <5.00). At monitoring bore BH602, metals concentrations tend to increase with corresponding decreases in pH. Likewise, pH tends to decrease with decreasing groundwater elevation. Consequently, at monitoring bore BH602, higher metals concentrations appear to correlate with lower groundwater elevations. At monitoring bore BPGW32, higher metals concentrations also appear to correlate with lower groundwater elevations, but the relationship between metals concentration and pH is less clear.

No clear trends in metals concentrations for the site as a whole are apparent, although a number of the bores show individual trends, e.g. monitoring bores BPGW11, BPGW25 and BPGW29, where cobalt and zinc concentrations have generally been increasing, and monitoring bore BPGW24, where cobalt and zinc concentrations have generally been decreasing. Where evident, trends in dissolved cobalt and zinc concentration are illustrated in **Chart B5** and **Chart B6**, respectively.

Nutrients

Groundwater at the site can be characterised as having elevated concentrations of nutrients above their respective groundwater quality trigger criteria, specifically: ammonia as N and, at a lower percentage of bore locations, total nitrogen as N, nitrate & nitrite (as N), reactive phosphorous and total phosphorous.

Ammonia as N has been reported at concentrations exceeding the groundwater quality trigger criterion at the majority of monitoring bores across the site during each month of sampling. No clear trends in concentration are apparent for the site as a whole, although a number of bores show individual trends. Specifically, ammonia as N concentrations have generally been increasing at monitoring bores BPGW11, BPGW18, BPGW25, BPGW29 and BPGW40 and decreasing at monitoring bores BPGW09, BPGW12 and BPGW23. At other bore locations, ammonia as N concentrations tended to be at their highest at the end of the dry season before decreasing with the onset of the wet season. Where evident, trends in ammonia as N concentration are illustrated in **Chart B7**. Isopleth maps illustrating the distribution of ammonia as N concentrations at the time of the September 2012 (dry season) and March 2013 (wet season) GMEs are provided as **Figures B7-A** and **Chart B7-B**, respectively. As illustrated in the figures, ammonia as N concentrations in both months were generally higher in those areas located higher north of the causeway.

After ammonia as N, total nitrogen as N has the second highest occurrence of elevated concentrations exceeding the trigger criteria. While most bores exhibit no apparent trends, concentrations of Total Nitrogen spiked at some bores at the start of the wet season (November, December and January) while at other locations, concentrations dipped during this period. At monitoring bores BPGW11, BPGW18, BPGW40 and BPGW41, total nitrogen concentrations have generally been rising across the entire period of monitoring. At monitoring bore BPGW12, total nitrogen as N concentrations have been steadily rising since December 2012. Where evident, trends in total nitrogen concentration are illustrated in **Chart B8**.

Total phosphorous concentrations at monitoring bores BPGW03 and BPGW19A have, historically, been the highest of any location across the site. Concentrations at both bores were highest in November 2012, after which time they were variable but have generally decreased. Elsewhere across the site, total phosphorous concentrations have generally been decreasing at monitoring bores BPGW11, BPGW24, BPGW25 and BPGW29 across the period of monitoring. At monitoring bore ONBH03, total phosphorous concentrations peaked in August 2012 but have been gradually decreasing since that time. No obvious trends in total phosphorous concentration are apparent at the remaining monitoring bores. Where evident, trends in total phosphorous concentration are illustrated in **Chart B9**. Isopleth maps illustrating the distribution of total phosphorous concentrations at the time of the September 2012 (dry season) and March 2013 (wet season) GMEs are provided as **Figures B8-A** and **Figure B8-B**, respectively. As illustrated in the figures, total phosphorous concentrations appear to be higher in the dry season than in the wet season.

Major Ions

Major ions proportions for the months of September 2012 (dry season) and March 2013 (wet season) are presented as Piper plots in **Chart 10**. Additionally, **Chart 10** presents data collected from July 2008 and March 2009, gathered during groundwater monitoring conducted in association with the Draft Environmental Impact Statement (INPEX 2010). In the plots, cations are plotted in the lower left triangle while anions are plotted on the lower right triangle. The points in the triangles are projected upward into the central diamond, which then provides a graphical representation of the overall geochemical character (facies) of the groundwater system.

The piper plots are nearly identical, which indicates that the chemistry of the groundwater changes very little between the two seasons. Furthermore, and with but two outliers, groundwater does not vary from location to location. The plots indicate that sodium and potassium are the dominant cations while chloride is the dominant anion. The predominant position of the monitoring data on the right apex of the diamond indicates that, with the exception of the outliers, groundwater at the site can be classified as Na-Cl water, which indicates influence by seawater. The outlier in the September 2012 piper plot comprises the data from BPGW06 while that in the March plot comprises the data from BPGW03. Their position on the plots indicates that groundwater at these location during these months was of mixed origin (fresh water and seawater).

A qualitative comparison of 2008/2009 (pre-development), and 2012/2013 (during development) piper plots indicates that these groundwater characteristics have remained relatively consistent between monitoring periods.

5.7.2 Performance against EIMP Criteria

Groundwater monitoring activities conducted to date indicate the groundwater at the site can be characterised as having elevated concentrations of dissolved metals and nutrients exceeding the groundwater quality trigger criteria, and a pH that is in almost all instances below the lower end of the trigger criteria range. Possible explanations for these elevated concentrations and low pH include:

- Natural background groundwater quality conditions;
- Impacts associated with ground improvement works;
- Historical site usage; and
- Influence of groundwater from off-site, upgradient locations.

One of the stated purposes of the EIMP is to establish background groundwater quality at the site, against which potential impacts may be assessed. However, all but four (BH602, ONBH03, VWP328 and VWP341) of the monitoring bores currently located at the site were monitored after construction works commenced. Additionally, none of the historic bores installed previous to site development, including BH602, ONBH03, VWP328 and VWP341, were monitored for dissolved metals or nutrients, which recent monitoring has indicated are widely present in concentrations exceeding the EIMP groundwater quality trigger criteria. It should be noted that groundwater monitoring conducted in 2008 and 2009 revealed elevated concentrations of total metals including arsenic, aluminium, cadmium, copper, manganese, nickel and zinc. Although not strictly comparable to dissolved metals, and due to varied sample collection techniques, these pre-construction monitoring data are suggestive of natural background conditions.

Most bores have been sampled only seven times and, in a few cases, as little as three times. This, in combination with the expected seasonality, (i.e. wet versus dry seasons) in conditions, makes characterisation of background groundwater quality with any degree of certainty difficult. Derivation of site-specific groundwater quality trigger criteria after 24 months of monitoring is warranted as concentrations have been shown to exceed the default values, however site specific trigger criteria should be developed using background concentrations. Historical site usage and, in particular agriculture, horticulture and grazing, may have affected the reported nutrients concentrations. However, it is not known if these activities have been conducted on site and to what degree.

The potentiometric surface maps (refer **Figure 3A** and **Figure 3B**) indicate that the shallow groundwater system is recharged by precipitation and, to a lesser degree, seawater. There is no indication that movement of groundwater onto site from upgradient locations is occurring. Therefore, it is considered unlikely that the elevated concentrations of metals and nutrients originate from off-site.

The EIMP states that 40 new groundwater monitoring bores will be installed and developed at the site. To date, however, only 30 bores have been installed, two of which (BPGW22 and BPGW28) have since been decommissioned, one (BPGW14) destroyed, and a third (BPGW19) decommissioned and subsequently replaced with a new bore (BPGW19A). Of those bores (BPGW15, BPGW17, BPGW20,

BPGW21, BPGW30, BPGW31, BPGW34, BPGW36, BPGW37 and BPGW39) that have yet to be installed, most are proposed for the centre of the site (refer **Figure B1** and **Figure B2**). The lack of current monitoring infrastructure in this area means that background groundwater quality in the centre of the site is largely undetermined. Most of the existing groundwater monitoring bores are located along the mangrove fringe, where fresh water/seawater interaction is evidenced in the groundwater analytical data and where the geology has been shown to be much different. Consequently, the data obtained from these bores is potentially much different from that which might be obtained from the centre of the site. Because of this, any potential impacts, either already occurring or, which may occur in the future, will be difficult to realise. Lastly, the lack of monitoring structure in the centre of site means that localised groundwater flow direction and gradient are currently unknown.

The EIMP states that a denser groundwater monitoring network will be established around areas of dynamic replacement and monitored weekly for changes in groundwater elevation, pH, TDS, EC, DO, temperature, redox potential and turbidity. To the knowledge of URS, the weekly monitoring has not been conducted. Trends in monthly groundwater monitoring indicating impacts in the vicinity of dynamic replacement works were not discerned, this is mainly due to insufficient temporal data and/or sampling density.

5.7.3 Correlation of Data with Site Works

Because of the lack of robust background groundwater quality data, a relatively limited number of monitoring events, and the expected seasonality of groundwater elevation and water quality, correlation of the groundwater data summarised in **Table B1**, **Table B2**, and **Table B3** with site works is difficult. Nonetheless, URS has examined the apparent trends in **Chart B1** through **Chart B9** to identify potential relationships between these data and site work information provided to URS by JKC.

Groundwater Elevation

Groundwater elevation has been increasing in most of the site monitoring bores since late-October/early November 2012 and, in some cases, from September 2012. This rise in groundwater elevation is expected to be primary due to the onset of the wet season, although fresh water/seawater interaction is also believed to have influenced groundwater levels within those bores located at lower elevations adjacent to intertidal areas. Site works, including clearing of vegetation and removal of topsoil, is also expected to affect groundwater levels due to loss of aquifer storage volume and changes in infiltration, runoff and evapotranspiration. Given these complex, and in some cases, opposing contributors of potential change, it is not presently possible to correlate groundwater elevation data with the provided site works information.

Groundwater EC

With the onset of the wet season, reductions in EC have been recorded at many areas of the site. However, apparent increasing trends in EC have been noted at monitoring bores BPGW11, BPGW28, BPGW29 and VWP328. Monitoring bores BPGW11 and BPGW29 are located in Area 13, proximal to the temporary facilities complex. EC has been slowly increasing at both locations from September 2012 through March 2013 and it is possible that these increases are related to the ground improvement works and construction activities that have been occurring in this area. Likewise, the apparent increase in EC over the same time period at monitoring bore VWP328 may be related to the ground improvement works that have been conducted in Area 7. At monitoring bore BPGW28, EC increased dramatically between November and December before decreasing somewhat in January and February (the bore could not be accessed for sampling in March 2013). The sharp rise in EC is likely related to the drainage issues and subsequent ponding that was noted within the mangroves adjacent to Area 11A in November 2012.

Groundwater pH

Apparent decreasing trends in pH have been noted at monitoring bores BPGW01, BPGW02, BPGW11, BPGW12, BPGW24, BPGW25 and BPGW32. With the possible exception of BPGW32, these decreasing trends appear to correspond with the onset of the wet season and might, therefore, be attributable to the flushing of near-surface humic acids into the shallow underlying groundwater. At monitoring bore BPGW32, which is located in Area 13, pH has generally been decreasing since October 2012. It is unclear, however, whether this decrease is directly related to site works. As noted in Section 5.6.1, high and extreme risk ASS have been reported in this location.

In the absence of decreasing pH and increasing metals gradients in the Blaydin Point groundwater, it does not appear that a large scale acidity and metal mobilisation event has occurred to date. However, there remains a paucity in the datasets and consequently, it is not considered prudent at the present time to conduct statistical analysis on the groundwater data. Further statistical analyses, assessment and interpretation will occur when the 2013/14 reporting years datasets are collected.

Oxygen Reduction Potential

Increasing trends in Oxygen Reduction Potential (redox) values have been noted at monitoring bores BH602, BPGW02, BPGW04, BPGW11, BPGW13 and BPGW27. Prior to the bore being destroyed, redox values at BPGW14 decreased between the months of September 2012 and January 2013. Based upon the information provided by JKC, it is unclear whether any of these trends are attributable to site works however.

Dissolved Metals

Dissolved metals concentrations have been decreasing at numerous monitoring bore locations after apparent highs in October, November or December 2012. These decreases in metals concentration are likely attributable to the influx (recharge) of fresh water during the wet season. In contrast, dissolved metals concentrations have been gradually increasing at monitoring bores BPGW11, BPGW12, BPGW25 and BPGW29. It is unclear if these increases are related to site works. However, as noted above, decreasing trends in pH have been noted at monitoring bores BPGW11, BPGW12 and BPGW25.

Nutrients

Nutrients concentrations have varied greatly across the period of monitoring. At many locations, concentrations have decreased with the onset of the wet season while, at other locations, they have increased. Only a small number of bores show consistent trends:

- BPGW11, where both ammonia as N and total nitrogen concentrations have been increasing but total phosphorous concentrations have been decreasing;
- BPGW18, where both ammonia as N and total nitrogen concentrations have been increasing;
- BPGW25, where ammonia as N concentrations have been increasing but total phosphorous concentrations have been decreasing;
- BPGW09, BPGW12 and BPGW23, where ammonia as N concentrations have been decreasing;

5 Groundwater

- BPGW29 and BPGW40, where ammonia as N concentrations have been increasing;
- BPGW24, where total phosphorous concentrations have been decreasing; and
- BPGW40 and BPGW41, where total nitrogen concentrations have been increasing.

Based upon the information provided by JKC, it is unclear whether any of these trends are attributable to site works.

Mangrove Community Health, Sediments and Bio-Indicators

6.1 Scope of Work

The EIMP includes monitoring objectives and targets related to mangrove protection, the aim of which is to ensure that there are no impacts to mangroves outside of the site boundary. The EIMP outlines the scope and frequency of monitoring in the mangroves for the construction phase and this is provided in **Table 6-1**.

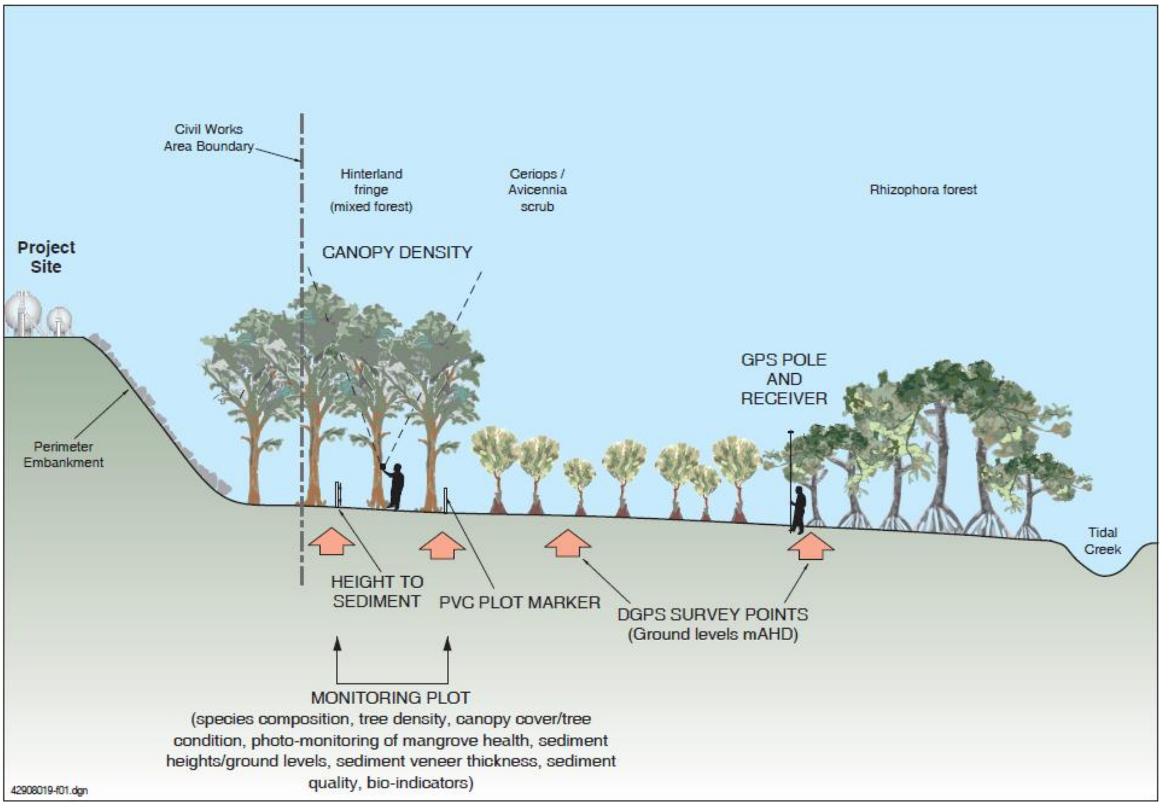
Table 6-1 Outline of the construction phase monitoring program for mangrove community health, sedimentation/erosion, sediment quality and bio-indicators

Monitoring Component	Objective/Scope	Timing/Frequency
Mangrove health	Assessment of mangrove health to detect short-term and localised changes in tree condition and extent of canopy cover within monitoring plots established to collect data on mangrove health, sedimentation/erosion, sediment quality and bio-indicators. Photographs of mangrove condition taken from standard reference points at monitoring sites.	Once during background phase, then quarterly during construction phase.
Mangrove community structure	Collect data on tree species composition and density from monitoring plots for long-term change to mangrove community structure.	Once during the background surveys, then at end of construction phase.
Sedimentation/ erosion monitoring	Monitor for potential sedimentation and erosion effects by two techniques - surveying of ground levels profiles (transects) through tidal flat and mangroves areas and the monitoring of relative sediment heights from within the monitoring plots using fixed marker stakes. In addition, mini-cores will be done to determine the extent of foreign sediment veneers if required (i.e. if sediment wash off into mangroves from the CWA is apparent). Sedimentation/erosion monitoring sites will be linked to the monitoring of mangrove health so that the response of vegetation to changes in ground levels/sediment heights, ground disturbance (mudwaves) and the presence of foreign sediment veneers/can be determined.	Once during background phase and then annual frequency (for surveying of ground level profiles) and quarterly frequency for monitoring of sediment heights and mini-cores.
Sediment quality	Sediment sampling and analyses to determine: grain size distribution concentrations of the metals arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, silver, vanadium and zinc, and concentrations of hydrocarbons Sampling of sediments to be undertaken at the same monitoring plots established to collect data on mangrove health, sedimentation/erosion and bio-indicators.	Once during background phase (all parameters) and then quarterly for all parameters except hydrocarbons which will be monitored if detected in adjacent surface water or groundwater samples.
Bio-indicators	Collection of mangrove biota (mud whelks) and analysis to determine: concentrations of the metals arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, silver, vanadium and zinc, concentrations of hydrocarbons Lipid and moisture content Sampling of bio-indicators to be undertaken at the same monitoring plots established to collect data on mangrove health, sedimentation/erosion and sediment quality.	Once during background phase and then annual frequency except hydrocarbons which will be monitored if detected in adjacent surface water or groundwater samples.

Baseline surveys were undertaken in May and June 2012 to finalise the location of monitoring sites, establish monitoring plots and collect data on the full suite of monitoring parameters for above components. A total of 23 transects and monitoring sites were established at Blaydin Point with a further six monitoring sites established within similar mangrove communities at two control locations (see **Figure C1** and **Figure C2** for the location of monitoring sites). By the time of completion of these surveys there had been no earthworks or construction works within mangrove areas and the civil works at Blaydin Point had been confined to the clearing of terrestrial vegetation to a level of approximately 5.0 m AHD or above. Due to the lack of disturbance to mangrove areas it is considered that the data collected in May and June 2012 can serve as comparative baseline or background data for assessing future change. For full details on the monitoring program design, methodologies and results from the May/June 2012 baseline monitoring refer to the baseline mangrove monitoring report (URS 2012).

The schematic diagram shown in **Figure 6-1** illustrates the relationship between the survey transects, monitoring plots at a typical monitoring site and the parameters that link potential changes in site conditions to corresponding effects on mangrove health. While this figure shows the location of the monitoring plot to be within the hinterland fringe mangrove zone, the actual mangrove zone encompassed by the monitoring plot depends on the alignment of the site boundary at each monitoring site.

Figure 6-1 Schematic diagram showing the key monitoring parameters at a monitoring site



The design of the monitoring program provides for the monitoring of core parameters at a quarterly frequency while the monitoring for other components related to more gradual or long-term changes will be undertaken on a less frequent basis (e.g., annual frequency). Quarterly monitoring has been undertaken in September 2012, December 2012 and March 2013 when each site was visited and the following field data and samples were collected:

- Mangrove community health – canopy density (using a forest densiometer), tree condition (tree condition index) and photo-monitoring of mangrove health from standard reference points;
- Monitoring of sedimentation/erosion and ground disturbance in mangroves - collection of data on relative sediment heights using fixed marker stakes; and
- Sediment quality – collection of mangrove sediments and laboratory analysis to determine concentrations of metals and hydrocarbons.

This annual report provides the data collected from the quarterly monitoring of the above components and provides comparison to the baseline data.

Sampling of mudwhelks (bio-indicators) and the surveying of ground level profiles along transects (part of sedimentation/erosion monitoring) is undertaken at an annual frequency and hence these components have not been included in the post baseline quarterly surveys to date but are scheduled to be included within the June 2013 mangrove monitoring survey. Therefore there is no additional data related to these two components that can be included in this annual report beyond the data provided previously in the baseline mangrove monitoring report (URS 2012). Annual results related to these two components will be reported in the June 2013 interpretive report.

6.2 EIMP Criteria for Mangrove Monitoring – Overview

The concept of acceptability criteria or trigger levels has been applied to numerous marine-related projects such as dredging-related turbidity and monitoring of seagrasses or corals, but there have been very few projects in which the concept has been applied to mangrove habitats. In this respect, there is very little previous experience on which to assess the applicability of this concept for the Project. While sources such as English (1997), Moritz-Zimmerman (2002) and others provide information on appropriate 'research based' parameters and methods that can be monitored to characterise mangroves and mangrove habitats, there is a lack of information for Australian mangroves that provide ready-made acceptability criteria/trigger levels that can be applied to the Project or other similar developments. In this context, the interim criteria and trigger levels suggested below will be reviewed and updated, as required, during monitoring.

One case study involving the development and application of interim acceptability criteria for mangrove health and habitat condition has been for the mangrove monitoring program established at the Fortescue Metals Group port site at Port Hedland, Western Australia. Interim acceptability criteria were developed during the background monitoring phase (early 2006) and, after completion of the construction phase monitoring in 2009, the monitoring data were reviewed (URS, 2010). The review confirms that the majority of the original criteria are appropriate in terms of providing a warning of the potential for impacts to mangroves and hence an exceedance of the criteria identifies the need for further investigation or additional monitoring. It was noted that a particular criteria exceedance may or may not actually result in any measurable effect on mangrove health or condition, and hence the need to implement contingency measures to mitigate impacts should be assessed on a case-by-case basis.

Where appropriate, the results of the Port Hedland trigger level review are used to identify the guideline levels in **Table 6-2** for mangrove mat health and habitat condition. Criteria related to sediment quality and bio-indicators are included for these factors by reference to existing guidelines (these parameters were not monitored as part of the Port Hedland program).

Table 6-2 Interim guidelines for mangrove community health, sedimentation/erosion, sediment quality and bio-indicators

Monitoring Parameter	Trigger Level	Comment
Mangrove condition (canopy density, tree condition)	20% reduction in canopy density and/or tree condition	Criterion was revised from 30% decrease to a 20% decrease on the basis that it represents a significant and detectable change and that natural variability within sites has been confined to 10-15%.
Sediment deposition	5 cm increase in mean ground level over a 12 month period and/or evidence of 5 cm sediment (veneer) deposition from mini-cores and comparison to control sites.	Criterion is appropriate – in terms of potential sediment smothering impacts, an increase of 5 cm in ground level (indicating 5 cm of sediment deposition) within a 12 month period is likely to be conservative as it is not possible to accurately account for factors such as the rate of sediment deposition and the type of sediment deposited (e.g. sand versus finer material such as clays/silts).
Sediment quality (metals & hydrocarbons concentrations)	Exceedance of ANZECC and ARMCANZ (2000) sediment guidelines.	In the absence of site specific data the ANZECC & ARMCANZ (2000) interim sediment quality guidelines will be used in the first instance as a guide to acceptability. In the event of an exceedance, site conditions and reference site data will be used to guide further actions.
Bio-indicators	Exceedance of the National Food Standards (FSANZ 2005) Generally Expected Levels (GELs) for molluscs	In the absence of site specific data the FSANZ (2005) interim sediment quality guidelines will be used in the first instance as a guide to acceptability.

Further clarification on the interim criteria is provided in the relevant sections below.

6.3 Mangrove Community Health

6.3.1 EIMP Performance Criteria

Interim guideline values for mangrove health are based on monitoring showing a net reduction in canopy density of 20% or tree condition shows an increase in the number of ‘unhealthy’ mangroves by 20% by comparison with control sites.

For canopy density, a 20% reduction implies a 20% decrease relative to the background canopy density levels and not a reduction to a canopy density of 20%. The 20% reduction trigger level was chosen as a practical and realistic interim level to be used as a preliminary measure (to be confirmed/refined after background survey) given consideration of the spatial and temporal factors.

6.3.2 Field Methodology

The two methods employed to provide measures of mangrove community and tree health are:

- Canopy density (densiometer technique) - a quantitative measure indicating the percentage of the site occupied by the mid and upper vegetation strata (i.e. foliage cover comprised of leaves and branches). This parameter is considered to be a useful indicator of environmental stress as leaf defoliation and leaf growth are sensitive to a wide range of environmental indicators; and
- Tree condition - the health of each individual tree within a monitoring plot is classified into three categories of tree condition: (healthy, stressed, dead) as per the criteria outlined in Duke et al. (2005). Percentage survivorship and mortality rates can be subsequently calculated.

6 Mangrove Community Health, Sediments and Bio-Indicators

To complement the collection of the above data, photographs are taken of mangroves within the monitoring sites from standard reference points.

For full details of the above methodologies refer to the EIMP and baseline mangrove monitoring report (URS 2012).

6.3.3 Field Observations

A summary of the key monitoring data (canopy density, tree condition, sediment height) for each site is presented graphically in **Appendix Q**. A format of one site per page has been used in **Appendix Q** to help link site conditions (e.g. changes in sediment height indicating potential sediment deposition/erosion) to the indicators of mangrove health (canopy density and tree condition) and allow for potential trends to be assessed.

The mean canopy density and tree condition data from the baseline and quarterly surveys are presented in **Tables 6-3** and **6-4**. Field data sheets are provided in **Appendix P**.

Table 6-3 Mean canopy density (%) for each monitoring site

Site Number	June 2012	September 2012	December 2012	March 2013
BPMC1	78	81	77	76
BPMC2	82	83	84	87
BPMC3	73	77	76	77
BPMC4	75	77	78	77
BPMC5	73	74	72	73
BPMC6	89	91	90	91
BPMC7	73	72	72	69
BPMC8	61	58	61	65
BPMC9	63	67	68	72
BPMC10	68	71	66	76
BPMC11	89	88	83	90
BPMC12	77	73	77	76
BPMC13	84	83	86	89
BPMC14	88	90	87	90
BPMC15	84	84	84	89
BPMC16	85	86	86	84
BPMC17	88	89	86	90
BPMC18	86	87	88	88
BPMC19	84	86	87	87
BPMC20	88	91	89	89
BPMC21	56	64	60	58
BPMC22	48	56	64	62
BPMC23	80	79	77	86
CSMC1	91	92	87	89
CSMC2	56	61	59	58
CSMC3	72	67	64	69
CSMC4	80	86	85	85
CSMC5	52	55	63	59
CSMC6	84	88	81	89

6 Mangrove Community Health, Sediments and Bio-Indicators

Table 6-4 Tree condition - proportion (%) of healthy trees at each site

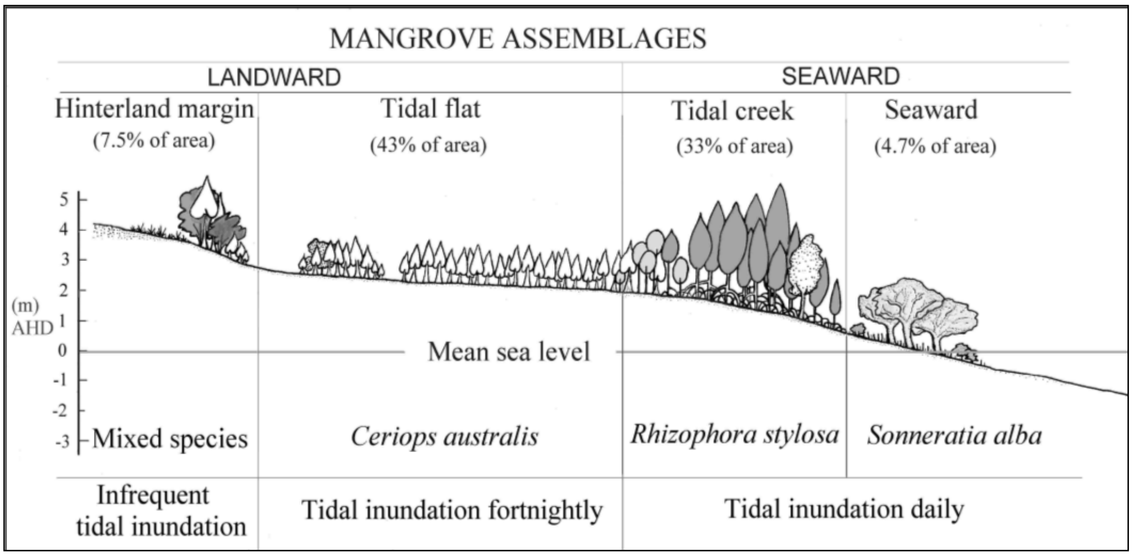
Site Number	June 2012	September 2012	December 2012	March 2013
BPMC1	95	95	95	94
BPMC2	95	95	95	95
BPMC3	93	93	93	93
BPMC4	97	97	97	97
BPMC5	97	97	97	97
BPMC6	95	95	95	95
BPMC7	92	92	92	92
BPMC8	99	99	99	99
BPMC9	98	98	98	98
BPMC10	97	97	97	97
BPMC11	97	97	97	97
BPMC12	99	99	99	99
BPMC13	100	100	100	100
BPMC14	100	100	100	100
BPMC15	100	100	100	99
BPMC16	94	94	94	94
BPMC17	93	93	93	93
BPMC18	96	96	96	96
BPMC19	100	100	100	100
BPMC20	95	95	95	95
BPMC21	96	96	96	96
BPMC22	99	99	98	98
BPMC23	97	97	97	97
CSMC1	96	96	96	96
CSMC2	98	98	98	98
CSMC3	93	93	93	93
CSMC4	95	95	95	95
CSMC5	93	93	93	93
CSMC6	90	90	90	90

6 Mangrove Community Health, Sediments and Bio-Indicators

The mangroves at Blaydin Point and elsewhere in Darwin Harbour occur as a series of identifiable zones where distinct structural/floristic communities have developed in response to differing environmental conditions that occur across the intertidal gradient (see **Figure 6-2**). Within each zone, differences in tidal level, inundation frequency, tidal erosion, tidal sedimentation, wave action and freshwater recharge create a variety of environmental conditions (e.g. gradients in salinity and different substrates). To help characterise the natural differences in canopy density between mangrove zones and assess potential future changes, the monitoring site canopy density data has been summarised in **Chart 6-1** by pooling together the data on a zone by zone basis to present the mean and standard error of canopy densities for each site located within the following three main mangrove zones that commonly occur immediately adjacent to the construction site:

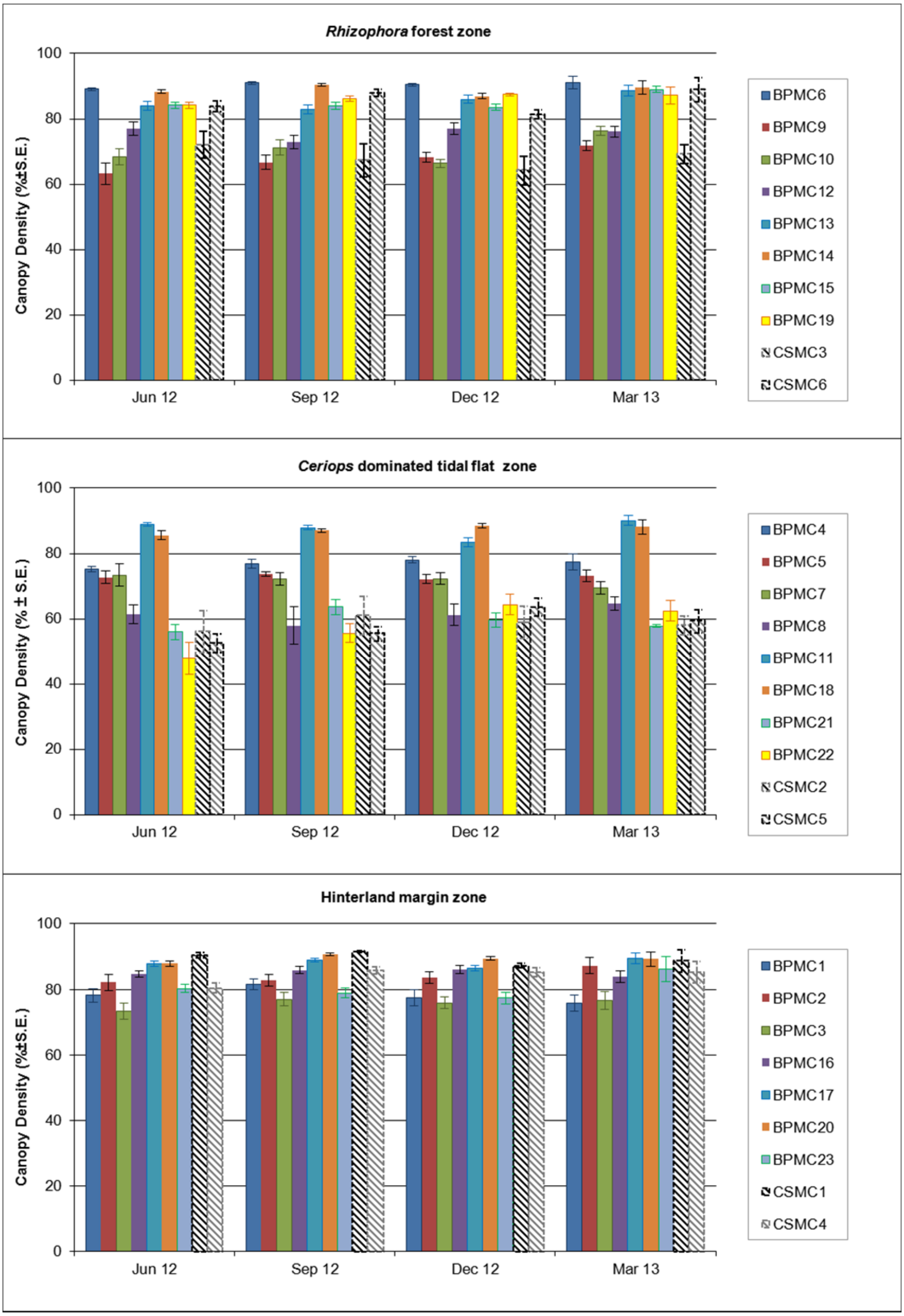
- *Rhizophora* zone - typically dense forests (4 to- 6 m high) that occur close to creek margins and along the mangrove shoreline (behind or landward of *Sonneratia* zone);
- *Ceriops* zone – dense scrubland and thickets (2 to 4 m high) occurring across tidal flats areas landward of the *Rhizophora* zone; and
- Hinterland fringe zone - mixed species forests (4 to 6 m high) occurring along the upper margin of the mangrove zone (i.e. where the mangrove zone abuts the hinterland).

Figure 6-2 Zonation of mangroves in Darwin harbour



6 Mangrove Community Health, Sediments and Bio-Indicators

Chart 6-1 Canopy density summarised for each mangrove zone



6.3.4 Additional Observations Related to Mangrove Health

6.3.4.1 Dust on mangrove canopies

During the September 2012 survey, following four months of no rain, it was identified that dust generated from the earthworks had coated the canopies of adjacent mangroves for a distance of approximately 30 m from the landward edge of the mangroves at sites BPMC2, BPMC3, BPMC17 and BPMC20. There was no indication that physiological function of the mangroves had been impaired or the health of the mangroves had deteriorated due to the dust and it was expected that the dust coatings will be of a transient nature determined by the extent of earthworks activity at particular locations and the onset of the wet season. This was confirmed during the December 2012 and March 2013 surveys when significant rainfall had washed dust from the canopies and the dust coatings were no longer evident. In addition there had been no reduction in mangrove health at sites BPMC2, BPMC3, BPMC17 and BPMC20 which could be attributed to the dust coatings.

Monitoring of airborne dust levels has been undertaken at various locations around the site and the results are reported in **Section 7**. Dust monitoring sites include several locations close to the landward edge of the mangroves. There has been no indication that the dust levels recorded from these sites have impacted mangrove health. This includes the mangroves at site BPMC20 located close to the dust monitoring site BPDD06 which has recorded one of the highest dust deposition rates (average total solids).

6.3.4.2 Ponding impact to mangroves

Mangroves adjacent to Area 11A

As part of routine site inspections in November 2012, JKC environmental staff noted an area of mangrove stress/mortality and water ponding in mangroves immediately next to Area 11A. The area is located between the mangrove monitoring sites BPMC09 and BPMC10 (see **Figure C3**). During the quarterly December 2012 survey, URS mangrove survey personnel visited the area and a summary of the observations made at that time are provided below:

- The rockfill pad constructed at Area 11A is connected to a naturally occurring sand chenier (or sand ridge) and this prevents tidal waters from exiting around the western end of the chenier during spring tides. During spring tides seawater floods the area from the eastern side of the chenier but as the tide recedes (falls) some of the water is trapped and the observed ponding effect occurs. The existing mangroves that are affected would have been adapted to a wetting/drying regime not an extended ponding regime that would impair physiological function related to gas exchange through the mangrove aerial root structures. The area of ponding is shown in **Figure C3** (note this was the approximate area of ponding when inspected on Monday 10 December 2012, during a neap tide phase);
- Ponding was deepest (20 cm) in the western section of the ponded area and shallowest at the eastern end. This suggests that the joining of the Area 11A rockfill pad to the sand chenier is the point at which the exit of ebbing tidal waters has been constricted or blocked (hence ponding occurs);
- Mangrove mortality has occurred in the western section of the ponded area (i.e. most trees in this area were dead). The middle section had partial mortality (i.e. some trees were dead, some were stressed, some were healthy) and trees in the eastern section were healthy. Areas 1, 2 and 3 in

Figure C3 approximately correspond to these three sections (note that the boundaries between the sections shown in the figure are only approximate). It is likely that some of the mangrove mortality has occurred outside of the site boundary. Surveying would confirm the actual alignment of the site boundary on the ground and the relative position of the ponded area and mangrove stress/mortality;

- The main mangrove zone or community affected by the ponding is a dense *Ceriops* shrubland (2 to 3 m high) with some scattered emergent *Avicennia* trees (3 to 4 m high). This mangrove zone, and the main species (*Ceriops australis*), occur widely throughout Darwin harbour;
- Water in the ponded area was stagnant and a high density of mosquito larvae was observed within the water column; and
- If the pre-ponding tidal regime can be re-established (e.g. via excavating a channel in the western end of the sand chenier) then it is likely that the area will become re-vegetated by a similar *Ceriops* shrubland via natural recruitment. A nearby example of such re-vegetation via natural recruitment can be seen on the Wickham Point Road where there was accidental clearing of *Ceriops* shrubland mangroves by a bulldozer during the initial road construction in 2002. The re-vegetation process would take approximately 5 to 10 years.

The area was re-visited during the March 2013 survey and the following observations were made:

- It was apparent that by March 2013 the majority of the mangroves were dead in the area that had ponded water in December 2012 (this can be seen by comparing the two figures within **Figure C3**); and
- Since the December 2012 survey a small trench had been excavated at the point where Area 11A was connected to the sand chenier (see **Figure C3**). The small trench appears to have provided a drainage point for some of the ponded water. On 6 March 2013 there was far less ponded water by comparison with December 2012 (note: both December 2012 and March 2013 observations were done during neap tides when the area had not been recently inundated by the tide). Typically there were numerous puddles of 1 to 3 cm deep water rather than the previously observed (December 2012) ponding of between 1 to 20 cm water depths.

Mangroves adjacent to the ground flare area

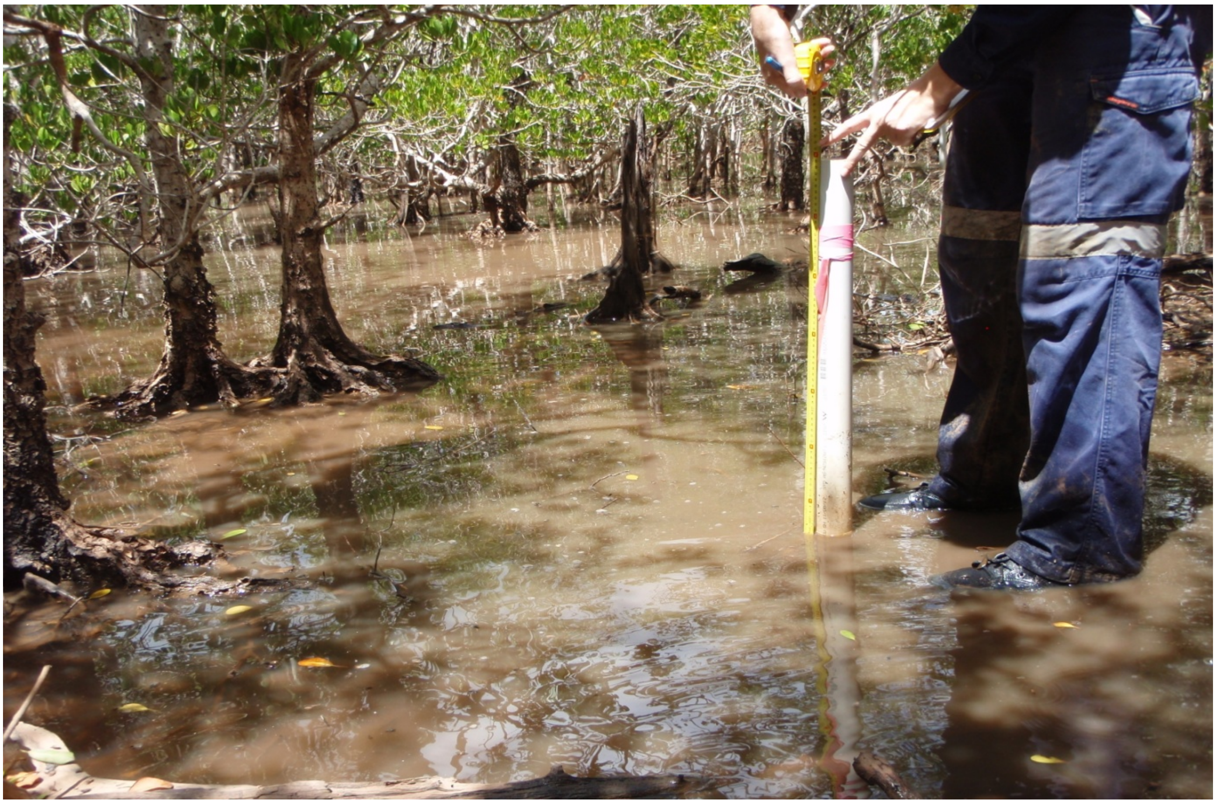
As part of site inspections in February 2013, JKC environmental staff had noted an area of mangrove stress/mortality and water ponding in mangroves between the ground flare and the main project site area. During the quarterly March 2013 survey, URS mangrove survey personnel visited the area and a summary of the observations made at that time are provided below. **Figure C4** has been prepared to help explain some of the comments below (please note that the boundaries delineated in the figure are only approximate and do not represent surveyed data).

- The construction of the ground flare area appears to have modified the existing pattern of receding tidal flows out of some mangrove areas between the ground flare and main project site area. The alignment of the ground flare has prevented tidal waters from exiting around the north-east and south-east corners of the ground flare area. During spring tides, seawater floods the mangroves areas but as the tide recedes (falls) some of the water is trapped and the observed ponding effect occurs. The area of ponding and mangrove mortality is shown in **Figure C4** (note: this was the approximate area of ponding when we inspected the area on Thursday 7 March, during a neap tide phase);
- Ponding was deepest (20 cm) towards the middle of the ground flare area and shallowest closer to the north-east and south-east corners of the ground flare area. This is likely to reflect slight

differences in ground level elevation across the ponded area. Mangrove mortality had occurred in the areas where ponding was deepest. The main mangrove zone or community affected by the ponding is a dense *Ceriops* shrubland (2 to 3 m high) with some scattered emergent *Avicennia* trees (3 to 4 m high);

- At the monitoring site BPMC7 (located between survey points 7003 and 7004 - see **Figure C4**) ponding of approximately 5 cm depth was noted (see **Plate 6-1**). The mangrove health data recorded from this site in March 2013 indicates there had not yet been any deterioration in mangrove health from the ponding (see **Table 6-3** and **Table 6-4**); and
- The area of ponding includes mangrove areas outside of the CWA boundary and, on the basis of a similar ponding effect observed adjacent to Area 11A, it is possible that the mangrove mortality will extend to mangrove areas outside of the site boundary.

Plate 6-1 Ponding of tidal waters amongst *Ceriops australis* mangroves at Site BPMC7 in March 2013



6.3.5 Discussion

6.3.5.1 Trend Analysis

Canopy density values recorded from the quarterly monitoring surveys were similar to baseline values (June 2012) at all the sites, indicating no trends in reduction of mangrove health. Variations in mean canopy density between sampling dates at individual sites were all minor and were typically in the 10% range (with both slight increases and decrease in canopy density being recorded across the range of sites). This extent of variation, experienced at both Blaydin Point and control locations, is expected to reflect natural variability and the precision of the sampling technique.

The canopy density data collected is consistent with canopy density values recorded from similar mangrove zones elsewhere in Darwin Harbour (Brocklehurst and Edmeades 1996) and confirms observations and site photographs showing that the mangroves are in healthy condition with no sign of deterioration or abnormal stress. Differences in canopy density between the zones illustrated in **Chart 6-1** reflect the range of mangrove community structures that occur. Typically the closed forests and woodlands that are found in the *Rhizophora* zone and hinterland fringe zone produce relatively high canopy density values (approximately 70-90%) compared to the lower and more open or lower canopy *Ceriops* scrubland which occupies much of the mid-upper tidal flat zone.

The tree condition data provided in **Table 6-4** show no evidence of current stress being displayed in mangrove trees and most trees were classified into the “healthy” category, hence the proportions of healthy trees within the sites were typically in the 90-100% range. At some sites there were a few old trees or remnants of trees that had presumably died from natural senescence or other causes.

Photographs of mangrove condition at each site and visual observations also confirm these data and the canopy density values discussed above.

6.3.5.2 Performance against EIMP Criteria

Both the canopy density and tree condition data do not show any trends indicating a reduction in mangrove health between June 2012 and March 2013 at any of the sites and there has not been any reduction in these parameters that exceeded the interim trigger criteria (20% reduction) proposed in the EIMP.

The execution, findings and effectiveness of the monitoring program for mangrove health, sedimentation/erosion, sediment quality and bio-indicators employed during the first year of civil works activities was reviewed with the view to identifying potential gaps or additional components that could be included to augment the current program. The following two items were identified.

Regular surveillance inspections of mangroves around the perimeter of the site to look for evidence of mangrove stress/dieback and ponding (e.g. monthly frequency). This could be aligned with regular perimeter inspections that are already been undertaken by on-site environmental staff as part of other CEMP related monitoring and management commitments.

While the data obtained from the program to date has begun to develop a baseline data set for Blaydin Point that will be used for comparative purposes in future years it would be significantly enhanced by including reference to data that has been collected from similar mangrove communities for the DLNG mangrove monitoring program over the last 10 years. Access to the DLNG data related to mangrove canopy density, sedimentation/erosion, sediment quality and bio-indicators could provide:

- Regional context to data recorded from Blaydin Point and control sites;
- An assessment (and potential refinement) of the guideline values and their applicability; and
- Guidance or assistance with interpreting the potential consequences of guideline exceedances.

6.3.5.3 Correlation of Data with Site Works

For the monitoring parameters related to mangrove health there has been no trends or criteria exceedances that can be correlated to particular site works activities or phases.

The ponding of tidal waters amongst mangroves at both Area 11A and the ground flare area was first observed by JKC on-site environmental staff following the placement of fill that covered the full extent (footprint) in those areas.

6.4 Sedimentation and Erosion Monitoring

6.4.1 EIMP Performance Criteria

On the basis of the sediment burial/mangrove impact studies and other factors discussed below, it is suggested that the interim criteria for sediment deposition amongst mangroves be set as 5 cm within a 12 month period (i.e. 5 cm increase in ground level within mangroves or 5 cm of sediment/veneer deposition). Criterion for erosion effects is suggested as being a 5 cm decrease in ground levels within mangroves.

Excess input of sediment to mangroves can cause impacts ranging from reduced vigour to death, depending on the amount and type of sedimentation, and the species involved (Ellison 2009). Impacts start to occur with sudden deposition of at least 5 cm of sediment, even if aerial roots are taller (Ellison 2009). A review of case studies of impacts from sediment burial of mangroves (Ellison 1998) provides examples of mangrove degradation and/or death from depths between 5 and 200 cm. The response of different mangrove species to root burial does not appear to be standardised and is likely to be a function of root architecture, tidal range, and sediment composition and grain size. Pneumatophore (aerial root) burial of around 10 cm appears to have caused the death of *Avicennia*, however most case studies reviewed in Ellison (1998) documented burial of *Avicennia* by sediment depths ranging between 10 and 100 cm. There are occurrences of sand deposition sufficiently high to cover *Avicennia marina* pneumatophores completely but which does not result in any ill effects. This usually occurs in extremely well-drained sands where mangroves have colonised road or natural rock margins (Pedretti & Paling 2010).

The application of sediment deposition thresholds in the INPEX EIS to predict possible areas of mangrove impact (from dredging related deposition) was based on the depth of sediment deposition, due to the lack of information on the rate of sediment deposition and the ability of mangroves to cope with different rates of deposition. Many authors acknowledge that mangroves occur in sedimentary conditions where muds are accumulating and hence have root systems that must be able to respond (i.e. grow upwards) in order to meet root aeration requirements (Saenger 1982). The ability of mangrove species to cope with root burial of several centimetres a year probably varies between species as a function of root architecture (Ellison 1998). The pneumatophores of *Avicennia* and *Sonneratia* may be able to extend upwards (Hutchings and Saenger 1987). Other species cope with sediment accumulation by forming extra arches of the stilt roots (*Rhizophora*), additional knee roots (*Bruguiera* and *Ceriops*) or the upward thickening of roots. These responses take time, but mangrove trees could adjust to gradual burial in this manner.

Many of the sediment burial events resulting in mangrove stress or mortality described by Ellison (1998 & 2009) were from instances of rapid sediment deposition (e.g. from floods, cyclone or short term human disturbance) that occurred over a few days or weeks. Hence the application of sediment burial thresholds from these data to the onshore construction works (i.e. that may cause a more gradual sediment input or veneer deposition over two to three years) should be viewed as a very conservative approach until further data can be obtained to refine such estimates. Sediment deposition rates in mangroves from run-off from the onshore construction works are likely to be gradual (and occurring over a wet season period) compared to the case studies of mangrove impacts from sediment deposition (Ellison 1998) where typically 10 cm or greater of deposition occur from a single event of a few days duration.

6.4.2 Field Methodology

During the May/June 2012 surveys, baseline data on ground levels was collected using two complimentary techniques that would enable for future changes in ground level to be determined as an indicator of potential sediment deposition or erosion. These two techniques were:

- Measuring of relative ground levels or sediment heights using fixed reference markers; and
- Surveying of ground levels along transects through the mangroves (i.e. surveyed ground levels related to the Australian Height Datum, AHD).

For full details of the above methodologies refer to the EIMP and baseline mangrove monitoring report. The surveying of ground levels along transects is carried out on an annual basis and will be undertaken in June 2013.

The measuring of relative ground levels is undertaken at a quarterly frequency. At each monitoring site, the plot corner markers (PVC pipes firmly entrenched in the ground) serve as sediment height reference markers and sediment heights are recorded relative to each corner marker by measuring the vertical distance between the top of the corner marker and the ground. The overall ground level for a site during a sampling event is calculated as the mean of the readings recorded from each corner and evidence for sediment deposition or erosion can be assessed by comparing this value to baseline data (i.e. by subtracting the present mean relative ground level from the baseline ground level).

In addition, small mini-cores were obtained at two sites (BPMC2 & BPMC20) in the December 2012 and three sites (BPMC2, BPMC17 and BPMC20) March 2013 as it was evident that thin veneers of sediment had washed into these sites from the nearby project area. The mini-cores enable the thickness of the veneers to be measured. Sediment veneers were not observed at any other sites in December 2012 and March 2013 and at any of the sites in September 2012.

6.4.3 Field Observations

6.4.3.1 Relative sediment heights

The mean sediment height data for each monitoring site is provided in **Table 6-5**.

In **Appendix Q**, this information is shown graphically for each site as a net height difference in mean height values between the quarterly survey dates and the June 2012 (baseline) date when each site was established. A positive net difference in sediment height indicates a higher ground level or sediment height level (and potentially sediment deposition), whereas a negative net difference indicates a lower ground level (and potentially sediment erosion) (note: these values are also in **Table 6-5)**. At all of the monitoring sites there were only very small net differences in sediment height (i.e. mostly <1.0 cm) recorded between the baseline and the quarterly monitoring survey periods and at many sites the mean relative sediment heights remained unchanged. Hence there was no evidence from these data that any sediment deposition or erosion had occurred that may affect mangrove health.

In December 2012 and March 2013 veneers of orange/brown silt were observed over the underlying grey/brown mangrove muds at sites BPMC2, BPMC17 and BPMC20. The veneers were from fine material washed downslope from the edge of the project area. The thickness of the veneers ranged from 1-3 mm.

Table 6-5 Relative mean sediment height (cm) for each monitoring site

Site Number	June 2012	Sept 2012	Dec 2012	March 2013
BPMC1	83.0	82.5 **(0.5)**	82.8 **(0.3)**	82.0 **(1.0)**
BPMC2	76.5	76.8 **(-0.3)**	77.3 **(-0.8)**	77.3 **(-0.8)**
BPMC3	76.5	76.3 **(0.3)**	75.8 **(0.8)**	75.5 **(1.0)**
BPMC4	70.5	69.8 **(0.8)**	70.3 **(0.3)**	70.5 **(0.0)**
BPMC5	66.5	67.0 **(-0.5)**	66.8 **(-0.3)**	66.5 **(0.0)**
BPMC6	72.0	72.3 **(-0.3)**	72.0 **(-0.3)**	71.0 **(1.0)**
BPMC7	72.0	72.0 **(0.0)**	71.8 **(0.3)**	72.0 **(0.0)**
BPMC8	68.8	68.3 **(0.5)**	69.0 **(-0.3)**	68.0 **(0.8)**
BPMC9	68.8	68.8 **(0.0)**	69.0 **(-0.3)**	67.8 **(1.0)**
BPMC10	71.0	71.0 **(0.0)**	70.5 **(0.5)**	70.8 **(0.3)**
BPMC11	74.5	74.0 **(0.5)**	74.3 **(0.3)**	74.0 **(0.5)**
BPMC12	66.0	66.0 **(0.0)**	66.3 **(-0.3)**	66.3 **(-0.3)**
BPMC13	64.5	63.3 **(1.3)**	64.5 **(0.0)**	64.5 **(0.0)**
BPMC14	61.0	61.3 **(-0.3)**	59.5 **(1.5)**	59.5 **(1.5)**
BPMC15	63.0	62.8 **(0.3)**	63.0 **(0.0)**	62.8 **(0.3)**
BPMC16	73.5	73.8 **(-0.3)**	73.8 **(-0.3)**	73.5 **(0.0)**
BPMC17	81.8	81.8 **(0.0)**	81.5 **(0.3)**	82.0 **(-0.3)**
BPMC18	70.8	70.5 **(0.3)**	72.5 **(-1.8)**	71.3 **(-0.5)**
BPMC19	67.3	68.0 **(-0.8)**	67.5 **(-0.3)**	67.0 **(0.3)**
BPMC20	81.0	81.0 **(0.0)**	81.3 **(-0.3)**	81.0 **(0.0)**
BPMC21	74.5	74.5 **(0.0)**	74.8 **(-0.3)**	74.5 **(0.0)**
BPMC22	73.8	74.3 **(-0.5)**	73.8 **(0.0)**	74.0 **(-0.3)**
BPMC23	90.8	90.8 **(0.0)**	91.0 **(-0.5)**	90.5 **(0.0)**
CSMC1	69.8	70.3 **(-0.5)**	70.0 **(-0.3)**	69.8 **(0.0)**
CSMC2	64.3	64.5 **(-0.3)**	64.3 **(0.0)**	64.5 **(-0.3)**
CSMC3	64.5	64.5 **(0.0)**	64.3 **(0.3)**	64.8 **(-0.3)**
CSMC4	73.0	72.8 **(0.3)**	72.3 **(0.8)**	71.3 **(1.8)**
CSMC5	82.0	82.3 **(-0.3)**	82.5 **(-0.5)**	81.8 **(0.3)**
CSMC6	68.0	68.0 **(0.0)**	67.5 **(0.5)**	67.3 **(0.8)**

NB: data in brackets represent the net height difference in mean height values between the quarterly survey dates and the June 2012 (baseline) date

6.4.3.2 DGPS Surveying of Transects

The mapping of mangrove communities at Blaydin Point shown in the INPEX EIS displays the characteristic zonation patterns described previously for Darwin Harbour by Semeniuk (1985), Brocklehurst and Edmeades (1996) and Metcalfe (1999), and more regionally for the Northern Territory coastline (Wightman 2006). The zonation patterns of mangrove communities reflect the interaction of tidal elevation, substrate type, soilwater and groundwater conditions. These factors establish physical and chemical changes (or gradients) across the intertidal area that determines the occurrence of mangroves and the distribution of structural and floristic types (Robertson & Alongi 1992).

The baseline DGPS survey data collected from the transects in May and June 2012 at Blaydin Point and the control sites was provided in the baseline mangrove report. During the construction phase the survey points will be re-visited on an annual basis to determine if any significant change to ground levels indicating either sediment accumulation or erosion has occurred since the baseline survey period. Given that the first post-baseline surveying of ground levels along the transects is not due to occur until the 2013 dry season there is no data available to include in this annual report beyond the data provided previously in the baseline mangrove monitoring report (URS 2012).

Ground level data (m AHD) collected from the baseline phase of the EIMP mangrove monitoring program have provided a range of survey points for each of the main mangrove zones around Blaydin Point as the surveying extended across the tidal gradient from the hinterland fringe, through the mangrove belt and out towards the mangrove shoreline or tidal creeks. These data have been summarised in **Table 6-6** to illustrate the relationship between tidal elevation (i.e. position within the intertidal zone) and mangrove zonation by listing the zones in sequence of increasing tidal elevation.

The mean and range of ground level heights given in **Table 6-6** confirm the tight correlation between surface elevation (or position along the intertidal gradient) and mangrove zonation. When the ground levels (m AHD) are correlated with Darwin Harbour tidal datum the variation in tidal inundation frequency amongst the different zones becomes apparent. The relative position of each zone on the tidal gradient determines the frequency of tidal inundation and hence the prevailing salinity regimes which, in turn, largely influence the mangrove community types that occur. For example, the reduced frequency of tidal inundation in the *Ceriops* zone (compared to the *Rhizophora* zone) results in higher salinities and corresponding smaller tree size and lower canopies. Much of the hinterland fringe zone is located above the area inundated by most spring tides (i.e. MHWS) and therefore would rarely become inundated by seawater. This serves to highlight the importance of freshwater input in maintaining the hinterland fringe zone mangroves and the lack of tidal inundation (due to its position on the tidal gradient) as discussed by Semeniuk (1985).

Table 6-6 Ground surface levels in mangrove zones derived from surveyed transects (May/June 2012)

Mangrove Zone	Survey Points	Ground Levels (m AHD) Mean and Range	Ground Levels (m Tidal Datum) Mean and Range
Rhizophora forest Zone 2	9003 – 9005 10005-10007 12001-12005 13001-13003 14001-14003 15001-15003 C1006-C1007	Mean = 1.65 m Range = 0.11 to 2.21 m	Mean = 5.62 m Range = 4.02 to 6.17 m
Mid-upper tidal flat (*Ceriops* dominated thickets/scrub) Zones 4 & 5	1005, 2005 4001-4004 5001-5004 8002-8005 9002 10002-10004 11003-11005 18002-18005 21002-21005 22005-22006 C1004-C1005 C2003-C2004	Mean = 2.71 m Range = 2.28 to 3.32 m	Mean = 6.67 m Range = 6.24 to 7.28 m
Salt Flat	1004, 2004 3002-3004 8001, 10001 16004-16005 17004-17005 18001-18002 21001	Mean = 2.87 m Range = 2.55 m to 3.35 m	Mean = 6.83 m Range = 6.51 m to 7.32 m

Mangrove Zone	Survey Points	Ground Levels (m AHD) Mean and Range	Ground Levels (m Tidal Datum) Mean and Range
	22001-22004		
Hinterland fringe (mixed species forest/woodland) Zone 6	1001-1003 2001-2003 3001-3002 7001-7005 16001-16003 17001-17003 20001-20003 23001-23004	Mean = 3.46 m Range = 2.96 m to 3.73 m	Mean = 7.43 m Range = 6.92 m to 7.70 m

Note: Height relationship between Darwin Harbour Tidal Datum and Australian Height Datum (AHD) is summarised below (note: 3.96m Tidal Datum = 0.0 AHD):

- Lowest Astronomical Tide (LAT) = -3.96 m AHD
- Mean Low Water Springs (MLWS) = -2.66 m AHD
- Mean Low Water Neaps (MLWN) = -0.66 m AHD
- Mean Sea Level (MSL) = 0.24 m AHD
- Mean High Water Neaps (MHWN) = 1.04 m AHD
- Mean High Water Springs (MHWS) = 3.04 m AHD
- Highest Astronomical Tide (HAT) = 4.04 m AHD

6.4.4 Discussion

6.4.4.1 Trend Analysis

These data do not show any trends indicating significant sediment deposition or erosion between June 2012 and March 2013 that may affect mangrove health or any exceedance of the interim trigger level (5 cm ground level change) proposed in the EIMP. The very minor sediment height or ground level changes recorded from the quarterly surveys are likely to reflect natural micro-scale variation in the ground (mud flat) surface topography typically caused by invertebrate fauna bioturbation and tidal processes.

In addition, the minor variations in sediment height recorded between the sampling dates are likely to be within the expected sampling error of the technique given consideration of the soft mud environment and irregular ground surface. Ongoing bioturbation of the mud flat surface and mangrove root structures result in ground surface irregularities and it is considered that the level of accuracy (±1 cm) achieved by the method is reasonable and realistic in the context of the observed unevenness of the ground surface over small spatial scales (e.g. natural variation in ground level with a 1 m^2 area could be ±5 cm and possibly greater in some mangrove zones as illustrated in **Plate 6-2**). An example of this was noted during the March 2013 at Site BPMC9 when a mud lobster mound had developed next to one of the plot corner markers resulting in an increase in ground level of 6 cm.

Observations made during the September 2012 survey gave no indication that veneers of foreign sediment had been deposited over the existing mangrove muds at the monitoring sites (i.e. veneers resulting from sediment washed from the construction site into mangroves). With the onset of wet season rainfall between the September and December surveys, surface water flows had mobilised fine silts along the edge of the project site resulting in thin veneers being deposited over mangrove muds at two sites in the December 2012 survey (1 mm maximum thickness). By the time of the March 2013 survey evidence of veneers was still confined to three sites with a maximum of 3 mm thickness being recorded. Thin veneers of this thickness present no potential threat to the mangroves and it is expected that the veneers will be re-worked by the suite of invertebrate fauna that inhabit the mangrove substrates (bioturbation processes).

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The use of mulch banks around the perimeter of the site have formed an effective barrier to sediment contained within surface water from moving into adjacent mangrove areas. In many areas around the site it was evident that fine silts had been deposited on the landward side of the mulch banks with little or no silt deposition occurring on the mangrove or seaward side of the banks (see **Plate 6-3)**.

Plate 6-2 Typical view of the variation in ground surface levels within mangroves due to bioturbation and root structures

Plate 6-3 Mulch bank (in middle to background) located on the perimeter of the site

6.4.4.2 Performance against EIMP Criteria

There have been no criteria level exceedances related to sedimentation and erosion at the mangrove monitoring sites between June 2012 and March 2013.

6.4.4.3 Correlation of data with Site Works

For the monitoring parameters related to sedimentation and erosion there has been no trends or criteria exceedances that can be correlated to particular site works activities or phases.

6.5 Sediment Quality

6.5.1 EIMP Performance Criteria

The data obtained for the sediment samples is compared against the ANZECC & ARMCANZ (2000) interim guidelines. Although these guidelines provide values against which comparison with the received data is possible, they stress that it is necessary to develop background data/trigger values for the areas under investigation (local data). While the sediment quality data collected during the background monitoring and construction phase will begin to establish the preliminary values for local background information, the ANZECC guideline values provide the best option for interpretative and comparative purposes.

The interim sediment guidelines provide two quality criteria values, the ‘Trigger’ and ‘High’ values. Trigger values are defined as concentrations below which there is a low risk that adverse biological effects will occur. They are levels that trigger the need for continued monitoring (in low risk situations) or further ecosystem-specific investigations (in high risk situations). Sediment trigger criteria are presented in **Table 6-7**.

The application of the guidelines is undertaken in a staged manner which is in line with the CSIRO's Centre for Environmental Contaminants Research guidance "Handbook for sediment quality assessment" 2006. The approach differs slightly for organic and inorganic contaminants; flow charts of each staged approach are presented in the EIMP.

Table 6-7 Sediment quality guidelines

Parameter	Detection Method	Trigger Criteria – Low mg/kg	Trigger Criteria – High mg/kg	Reference
Antimony	Laboratory	>2.0	>25	ANZECC. 2000. Australian and New Zealand guidelines for fresh and marine water quality. ANZECC, Canberra, ACT.
Arsenic		>20	>70	
Cadmium		>1.5	>10	
Chromium		>80	>370	
Copper		>65	>270	
Lead		>50	>220	
Mercury		>0.15	>1.0	
Nickel		>21	>52	
Silver		>1.0	>3.7	
Zinc		>200	>410	

6.5.2 Field Methodology

Within each mangrove monitoring site, sediment samples from the mudflat surface were collected for laboratory analysis to determine particle size distribution, metals and hydrocarbon concentrations. Hydrocarbon concentrations in mangrove sediments were determined from baseline sampling (June 2012) and then will only subsequently be monitored if detected in adjacent surface water or groundwater samples (note: to date there has only been one groundwater sample in which hydrocarbons were detected and this was not considered to present a potential risk of contaminating mangrove areas. All other parameters/analytes are to be assessed on a quarterly basis.

The results of the laboratory analysis are assessed against the screening criteria provided in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000) for those metals where criteria are available.

For full details of the sediment quality methodologies, laboratory analysis and assessment criteria refer to the EIMP and baseline mangrove monitoring report.

6.5.3 Analytical Results

The analytical results for the sediment sampling are presented in **Table C1**.

In recognition of the differing environmental and substrate conditions that occur across the intertidal gradient and between mangroves zones (described previously in **Section 6.3.3**) it is helpful to summarise the particle size distribution and metals concentrations data on the basis of the three main mangroves zones. This has been done graphically in **Chart C1** to **Chart C3** for particle size distribution and in **Appendix R** for metals concentrations by combining all of the data on the one page for either particle size distribution or an individual metal analyte for all monitoring sites located within a particular mangrove zone.

Laboratory and data validation reports are provided in **Appendix S** and **Appendix U**.

By application of the methodology and screening criteria for sediment quality assessment identified in the EIMP it is evident that all samples were either below the ISQG-Low guideline or can be regarded as low risk and non-toxic (following Acid Soluble Metals analysis). **Table 6-8** summarises the occurrences in which the two analytes (arsenic and chromium) exceeded the screening criteria from the Total Metals analysis and then, when tested using the Acid Soluble Metals analysis, potentially available concentrations were reported below the ISQG – Low guideline value, thus indicating low risk/non-toxicity.

Table 6-8 Summary of exceedances of ISQG guidelines for each sampling date and application of the sediment quality assessment process

Sampling Date	Analyte	Maximum Reported Concentration (mg/kg)	ISQG Low Level (mg/kg)	ISQG High Level (mg/kg)	Comment
June 2012	Arsenic (Total Metals analysis)	97.1	20	70	Acid Soluble Metals analysis required.
	Arsenic (Acid Soluble Metals analysis)	1.0	20	70	Below ISQG-low level. No further analysis required.
September 2012	Arsenic (Total Metals analysis)	56.5	20	70	Acid Soluble Metals analysis required.
	Arsenic (Acid Soluble Metals analysis)	3.8	20	20	Below ISQG-Low level. No further analysis required.
December 2012	Arsenic (Total Metals analysis)	78.7	20	70	Acid Soluble Metals analysis required.
	Arsenic (Acid Soluble Metals analysis)	6.5	20	70	Below ISQG – Low level. No further analysis required.
December 2012	Chromium (Total Metals analysis)	85.5	80	370	Acid Soluble analysis required.
	Chromium (Acid Soluble Metals analysis)	2.1	80	370	Below ISQG – Low level. No further analysis required.
March 2013	Arsenic (Total Metals analysis)	132	20	70	Acid Soluble Metals analysis required.
	Arsenic (Acid Soluble Metals analysis)	3.2	20	70	Below ISQG – Low level. No further analysis required.

6.5.4 Discussion

6.5.4.1 Trend Analysis

Soil moisture

The soil moisture data obtained from sampling in June, September and December 2012 correlates with the relative position or elevation of the main mangrove zone within which each monitoring site is located and hence the extent of tidal inundation (frequency and duration of inundation) experienced at that monitoring location or mangrove zone (see **Figure 6-2**). The monitoring surveys were undertaken during neap tides when tidal inundation occurred within the *Rhiziphora* and *Ceriops* zones but not within the hinterland fringe zone. Variation in sediment particle size distribution is also expected to have some influence on the soil moisture content within each mangrove zone. The typical range in soil moisture contents recorded from each mangrove zone is summarised below together with the mean ground surface levels that were determined from the surveying of transects during the baseline surveys (as provided in **Table 6-6**):

- *Rhizophora* mangrove zone: 50 to 70% moisture, mean ground level of 1.65 m AHD or 5.62 m tidal datum;
- *Ceriops* tidal flat mangrove zone: 20 to 50% moisture, mean ground level of 2.27 m AHD or 6.67 m tidal datum; and
- Hinterland fringe mangrove zone: 10 to 25% moisture, mean ground level of 3.46 m AHD or 7.43 m tidal datum.

The soil moisture data from the March 2013 sampling is consistent with previous sampling for the *Rhizophora* and *Ceriops* zones however a wet season influence is noted from the hinterland fringe zone where soil moisture levels increased to a range of 18 to 50%. This correlates with observations made during the March 2013 survey when freshwater surface water and seepage into the hinterland fringe zone was noted at many sites within that zone as puddles of surface water that had emanated from flows along the mangrove/terrestrial boundary (see **Plate 6-4**). As described in **Section 6.4.3.2** this wet season freshwater input from adjacent terrestrial areas is required for the maintenance of the hinterland fringe mangrove zone (Semeniuk 1983 and 1985). It is expected that similar seasonal trends will be recorded from future sampling in the hinterland fringe zone with a reduction in soil moisture levels occurring during the dry season followed by increases as the subsequent wet season progresses.

Plate 6-4 Pooled water amongst mangroves at Site BPMC17 (March 2013). Water emanated from freshwater surface and seepage flows into hinterland fringe mangroves from adjacent terrestrial areas

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Particle size distribution

Analysis of the PSD data from the baseline and subsequent quarterly monitoring dates has shown consistent results within monitoring sites indicating that there has been no marked change in soil composition that may potentially be related sediment input from the construction site. At 11 out of the 29 monitoring sites the total amount of fine material (silt and clay) exceeded the coarser material (sands and gravel). The sites that are predominantly fine grained can be grouped on the basis of two factors:

1. Seven out of the 11 sites that had more than 50% fine grains (<63 µm) were from the *Rhizophora* mangrove zone (see **Chart C1**) which is typically dominated by fine grained mangrove muds with less sand or gravel material.
2. Along the western edge of the flare pad, very high proportions (94 to 97%) of silt/clay were reported at all three monitoring sites in that area (BPMC04, 05 and 06) (see **Chart C1** and **Chart C2**).

At monitoring sites located within the hinterland fringe mangrove zone the sediments were composed mostly of fine to medium grained sands (except for site BPMC23) (see **Chart C3**). This possibly reflecting the influence of the nearby terrestrial hinterland as a source fine to medium sands that can be transported downslope into the landward mangrove edge during wet seasons.

While the PSD results were generally similar between the three sampling dates there was some variation occurring that is indicative of the extent of small-scale variability in sediment structures within sampling sites. This is considered a natural phenomenon (Boyd *et al*. 2005).

Metals

Generally the metals concentrations from the baseline and subsequent quarterly monitoring sampling were low and well below guideline (ISQG-Low) values (except for arsenic). Variations in concentrations were commonly recorded between the sampling dates at each site with no apparent trends or differences between sites at Blaydin Point and the control sites. The data shows no evidence of contamination in mangrove sediments and the elevated arsenic concentrations are consistent with ambient concentrations recorded from the broader Darwin Harbour region (see further text below).

It is suggested (Batley 1995) that metals preferentially bind to finer sediment particles and hence it might be expected that the metal concentrations would be higher at sites such as those in the *Rhizophora* zone (e.g. sites BPMC06, 12-15, 19 and CSMC 03, 06) and the *Ceriops* zone sites along the western edge of the flare pad (BPMC04 & 05). The data from does show some correlation that supports this assumption however this pattern does not consistently occur over the range of metals analysed. Lead, cobalt, nickel and zinc all are generally found in higher concentrations in the finer grained sediments than in the coarse sediments. Silver and cadmium concentrations were reported below LOR for all samples irrespective of particle size while copper, mercury, and vanadium do not appear to follow any discernible trend regarding particle size.

Several areas of the CWA site and a control site reported metal concentrations above the ISQG-Low Trigger guidelines for arsenic. Upon subsequent Acid Soluble Metals analysis it was determined that the arsenic concentrations were low risk and non-toxic (refer **Table 6-8**). To date there has been no anthropogenic source of arsenic at the CWA site from clearing or construction works and it is likely that the elevated levels of arsenic are naturally occurring in the mangrove soils. It should be noted that previous studies in Darwin Harbour have also reported elevated arsenic concentrations from sampling in areas that have no known anthropogenic sources and given the spatial extent of the elevated arsenic levels, it has been concluded that the arsenic concentrations are attributed to local geological influence (Fortune 2006 and Padovan 2003).

Hydrocarbons

Hydrocarbon concentrations (TRH) in mangrove sediments from the June 2012 sampling were reported in the baseline mangrove monitoring report. Low levels of hydrocarbons (mostly <50 mg/kg) were recorded in June 2012 at many Blaydin Point and control sites and these were considered to be of natural origin (many mangrove soils have low levels of naturally occurring hydrocarbons from plant oils and the breakdown of organic matter). As per the EIMP scope, the analyses suite from the quarterly monitoring samples has not included determination of hydrocarbon concentrations.

6.5.4.2 Performance against EIMP Crietria

As discussed above, exceedances of guideline levels occurred in two analytes (arsenic and chromium) for the Total Metals analysis and then, when tested using the Acid Soluble Metals analysis, potentially available concentrations were reported below the ISQG – Low guideline value, thus indicating low risk/non-toxicity. By application of the methodology and screening criteria for sediment quality assessment identified in the EIMP it is evident that all samples were either below the ISQG-Low guideline or can be regarded as low risk and non-toxic (following Acid Soluble Metals analysis).

6.5.4.3 Correlation of data with Site Works

For the monitoring parameters related to sediment quality there has been no trends or criteria exceedances that can be correlated to particular site works activities or phases.

6.6 Bio-Indicators

High concentrations of metals and hydrocarbons are known to affect benthic macro fauna as many metals and hydrocarbons are potentially toxic to organisms that live within the sediment matrix or at the sediment-water interface (Clark 2001). Furthermore, many organisms that live in or on the sediment are known to accumulate metals and hydrocarbons in their tissue (bioaccumulation) and can cause a threat to human health if consumed. The measurement of metals and hydrocarbons in the tissue of organisms can therefore be used as an indicator for bioavailability of contaminants in the environment (Gay & Maher 2003).

For this particular assessment a large snail, the mudwhelk (*Telescopium telescopium*) was selected as an indicator of bioaccumulation for the following reasons:

- Mudwhelks are edible snails and have been consumed (both historically and currently) by local indigenous populations and occur in reasonable abundance within the mangroves of Darwin Harbour (Peerzada, Eastbrook & Guinea 1990);
- Mudwhelks are algal grazers moving across the surface of mangrove sediments, thereby providing a measure of the bioavailable fraction of contaminants on or within the underlying sediments (Peerzada, Eastbrook & Guinea 1990);
- Mudwhelks have limited mobility and it is assumed that the present populations will not significantly move outside the potential zone of influence from site–related impact sources;

- In 1990 a study was undertaken to establish background information on heavy metal concentrations in *Telescopium* from the Darwin Harbour (Peerzada, Eastbrook & Guinea 1990). Since 2006, similar data have also been determined from regular sampling of mud whelks as part of the DLNG mangrove monitoring program. These data have the potential to be used for direct comparison; and
- Mudwhelks belong to the mollusc group for which food standards exist, providing the opportunity for comparison against the Maximum Levels and General Expected Levels (GELs) referenced in the Food Standards Code (FSANZ 2001, 2011).

6.6.1 EIMP Performance Criteria

Limited data exist for the mudwhelk species *Telescopium telescopium* in Darwin Harbour and background values will be developed within the framework of this monitoring program as data become available from construction phase monitoring.

Possible contamination may be assessed against these background data. In order to assess obtained results from analysis of mudwhelk tissue, two different approaches have been chosen. Firstly, the data are compared against The National Food Standards (FSANZ 2005) for molluscs and, secondly, the data are assessed against historical data obtained for Telescopium in Darwin Harbour in 1990 (Peerzada, Eastbrook & Guinea 1990). These data were collected in order to establish natural background levels of ten metals/metalloids (Al, Fe, Mn, Hg, Ni, As, Cd, Cr, Zn and Se) in the mudwhelk to assess any potential pollution in the harbour area. Trigger criteria are available for four of these ten metals/metalloids.

Table 6-9 FSANZ guidelines for molluscs

Parameter	Detection Method	Trigger Criteria mg/kg (wet weight)	Reference
Arsenic	Laboratory	>1.0	Food Standards Australia New Zealand (2011)
Cadmium		>2.0	
Lead		>2.0	
Mercury		Mean of >0.5	

6.6.2 Field Methodology

During the baseline sampling phase (June 2012), mudwhelk samples were collected from nine sites at Blaydin Point and two control sites. Sufficient mudwhelks were collected to fill two large whirlpak bags (~12–15 mudwhelks per bag), one bag for metals analysis and the other for analysis of hydrocarbons. It is anticipated that subsequent annual sampling of mudwhelks will be used to determine metals concentrations only and that hydrocarbon analyses will not be included unless an incident such as a spill occurs that would trigger the need for hydrocarbon analyses to be included. The full whirlpak bag was then placed inside a press-seal bag and stored on ice. No mudwhelk tissue material was extracted from the mudwhelk shells during the field survey (that occurred during laboratory analysis). The snail inhabiting the shells typically retracts back into the inner parts of the shell once collected and placed into the whirlpak bags, thus minimising any potential for contamination through contact with the plastic.

6.6.3 Analytical results

During the construction phase the sampling of mudwhelks will be undertaken on an annual basis to assess potential contamination within this selected mangrove fauna. Given that the first post-baseline sampling of mudwhelks is not due to occur until June 2013 there is no additional data available to include in this annual report beyond the data provided previously in the baseline mangrove monitoring report.

Laboratory and data validation reports are provided in **Appendix T** and **Appendix U**.

To enable comparison with the Food Standards Code Maximum and Generally Expected Levels guidelines and the historical data, the metals concentrations are converted to wet weights (by using the % moisture data) and these values are shown in **Table 6-10**, together with the guideline levels for each metal if available. Maximum Levels (MLs) are levels of contaminants which should not be exceeded in the specified foodstuff. It should be noted that for different foodstuffs different MLs may apply. Generally Expected Levels (GELs) were introduced by FSANZ to provide a benchmark against which to measure contaminant levels in food. GELs were derived from analyses of uncontaminated samples of various foods, with the 90th percentile representing the value below which 90% of the values fell. It should be emphasised that the criteria levels relate to potential human health risk and do not imply that the health of the molluscs would be adversely affected at metals concentrations exceeding these levels.

Table 6-10 Metals concentrations in mudwhelks (mg/kg wet weight)

Metal	LOR	FSANZ maximum level	GEL 90th per-centile	CSMC02_M MW_110612	CSMC05_M MW_110612	BPMC22_M MW_12061 2	QC01_MM W_120612	BPMC04_M MW_12061 2	BPMC12_M MW_13061 2	BPMC15_M MW_13061 2	BPMC10_M MW_13061 2	BPMC09_M MW_13061 2	BPMC08_M MW_13061 2	BPMC05_M MW_14061 2	BPMC19_M MW_15061 2
Arsenic	0.1	1	—	0.1	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	0.1	2	—	0.1	0.1	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Chromium	0.2	—	—	0.2	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.5
Copper	0.5	—	30	6	12	16	24	12	12	19	9	7	14	5	10
Mercury	0.02	0.5	1	0.05	0.07	0.07	0.04	0.78	0.14	0.26	0.12	0.37	0.70	0.35	0.18
Nickel	0.1	—	—	<0.1	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.1	0.1	0.1	0.1
Lead	0.1	2	—	<0.1	0.2	0.2	0.1	0.1	<0.1	<0.1	0.1	0.1	0.1	0.1	0.1
Zinc	0.5	—	290	10	6	10	10	18	9	12	13	13	19	16	62
Aluminium	1	—	—	31	187	14	60	46	24	42	55	34	54	87	96
Iron	1	—	—	50	190	20	86	58	23	42	92	34	108	93	161
Manganese	1	—	—	8	9	3	5	22	5	8	11	6	9	22	59
Selenium	0.5	—	—	0.2	0.1	0.2	0.2	0.2	0.3	0.2	0.1	0.4	0.4	0.2	0.1

The data provided in **Table 6-10** shows that metal concentrations detected from the June 2012 mudwhelk samples were below the recommended ML or GEL for all analytes at all sites with the exception of mercury at two sites, BPMC04 and BPMC08, where wet weight concentrations were 0.78 mg/kg and 0.70 mg/kg respectively. Both these values were above the FSANZ maximum level (0.5 mg/kg) but below the GELs (1 mg/kg). It should be noted that the FSANZ maximum level for mercury is based on the mean level of mercury in a prescribed number of sample units (5). No previous data are available on mercury levels in mudwhelks for Darwin Harbour to provide context and the lack of disturbance at these sites would suggest that the concentrations recorded reflect natural variability rather than anthropogenic factors.

A previous study that provided the concentration of heavy metals in mudwhelks (*Telescopium telescopium*) in Darwin Harbour (Peerzada, Eastbrook & Guinea 1990) concluded that the low concentration of heavy metals in mudwhelks points towards the general low trend of these metals and low pollution levels as also shown in oysters (Peerzada & Dickinson 1988), sediments (Peerzada & Rohoza 1989) and waters (Peerzada & Ryan 1987). It appears that the metal concentrations recorded from the June 2012 sampling at Blaydin Point and control sites are within the range of those recorded by the 1990 study. This observation, in addition to the lack of any Food Standards Code exceedances (with the exception of mercury as discussed above) in June 2012, indicates that the mudwhelk colonies occurring in mangroves at Blaydin Point have not been subject to any significant contamination.

6.6.4 Discussion

6.6.4.1 Trend analysis

To date only baseline data (June 2012) is available for bio-indicators and hence an assessment of potential trends is not possible. Subsequent data will become available from sampling proposed to be undertaken during the 2013 dry season.

6.6.4.2 Performance against EIMP Criteria

Exceedances of guideline levels will be assessed by comparing metals concentrations against the FSANZ guidelines when further sampling of mudwhelks occurs in the 2013 dry season.

6.6.4.3 Correlation of Data with Site Works

Future monitoring will enable an assessment of the monitoring parameters related to bio-indicators to be made in relation to site works.

Air Quality (Dust)

7.1 Scope of Work

This section presents a summary and commentary on the air quality (dust) monitoring results obtained between 1 June 2012 and 12 April 2013. The data were collected from multiple monitoring stations that reflect ambient dust concentrations in the vicinity of the works at the site.

The Project's air quality (dust) monitoring objective is to record PM_{10} and $PM_{2.5}$ concentrations as well as dust deposition rates experienced at the site and the nearby residential area of Palmerston. The data are to inform site management activities so that impacts from dust on the environment and nearby non-project related receptors may be minimised if required. The primary aim of the monitoring is to indicate compliance with the air quality criteria set out in the EIMP and listed in **Section 7.2**. Sampling will help to identify site specific issues and also provide data for fugitive dust modelling to address issues with specific conditions or phenomena. Data recorded for this monitoring program are not intended for occupational health and safety purposes (OHS). OHS dust monitoring involves different monitoring techniques and different air quality standards. This monitoring program provides ambient dust concentrations, to which site personnel are exposed.

The scope of the air quality (dust) monitoring program includes the following:

- Installation and setup of the air quality (dust) monitoring network;
- Continuous sampling incorporating light scatter analysis of PM_{10} at four selected locations and $PM_{2.5}$ at one selected location. These monitoring stations provide real-time concentrations to the site team via web-access. Those stations located at the site reflect ambient conditions at the boundary, while the station at Palmerston reflects ambient dust concentrations on the edge of a suburban residential area; and
- Batch sampling of dust deposition rates at 14 primary locations (13 at the site boundary and one located on the south-eastern boundary of Palmerston). The dust deposition stations distributed around the site boundary monitor the rate of deposition of dust in the vicinity of vegetation, especially adjacent to mangrove communities. The dust deposition station located adjacent to Palmerston is primarily to measure amenity impacts on third party property from deposited dust. Dust deposition samples are taken over a month-long period followed by gravimetric determination of sample weight.

Further details of the air quality (dust) monitoring are provided in Section 4.6 of the EIMP.

7.2 EIMP Performance Criteria

The EIMP for the site sets out air quality (dust) criteria (see Table 5.7 in EIMP) that are applied and discussed in this report.

The EIMP criterion for PM_{10} is a 24-hour mean concentration of 50 µg/m^3, which corresponds to the standard applied by the National Environmental Protection Measure (NEPM) for ambient air quality. This standard is applicable to dust entering or present within urban environments. Although no criterion was set in the EIMP for $PM_{2.5}$, The NEPM advisory standard, subject to review, is applied of 25 µg/m^3 for 24 hours and 8 µg/m^3 as a yearly average.

The EIMP criterion for dust deposition is an annual average of 2.0 g/m^2/month above background level, as set by the New South Wales Department of Environment and Climate Change (NSWDECC). Where there is no background level measured, as is this case for Blaydin Point, the project has applied the appropriate variation to this value of 4.0 g/m^2/month in accordance with NSWDECC.

7.3 Field Methodology

7.3.1 Rationale

The sampling pattern has been designed to target emissions at the Project boundary and at sensitive receptors identified in the EIS. The identified receptors are the mangrove vegetation adjacent to the site and the residences at the City of Palmerston.

As outlined in the EIMP, samples for analysis will include:

- PM_{10};
- $PM_{2.5}$; and
- Dust deposition.

7.3.2 Sampling Site Locations

This air quality (dust) monitoring section includes data recorded during the monitoring period for respirable dust across four sites and dust deposition across 14 sites. These sites and parameters are summarised in **Table 7-1** and their locations are presented on attached **Figure D1**. Blaydin Point monitoring locations are located on the perimeter of site works, and approximately 50m inside the site approval boundary, in proximity to dust generating activities. Monitoring equipment and sampling locations have been revised and modified from the EIMP.

Table 7-1 Dust Sampling Locations at Blaydin Point and Palmerston

Location IDs	Coordinates	Parameter	Rationale
BPPM01 BPPM02 BPPB03 PAPM01	709428, 8614378	Respirable dust (PM_{10})	High risk areas where a rapid identification of dust events / elevated dust levels will trigger timely management response to mitigate effects of dust generation.
BPPM01	708349, 8615189	Respirable dust ($PM_{2.5}$)	High risk areas where a rapid identification of dust events / elevated dust levels will trigger timely management response to mitigate effects of dust generation.
BPDD01 to BPDD13 and PADD01	708265, 8611892	Dust deposition	Dust deposition stations distributed around the site boundary to monitor the rate deposition of dust in the vicinity of vegetation, especially adjacent to mangrove communities. PADD01 has been included to measure dust deposition within the vicinity of Palmerston for the benefit of identifying potential amenity impacts to third-party property.

7.3.3 Detailed Description of the Sampling Methods

The two methods of dust sampling used in this monitoring program are described in more detail below:

Continuous Sampling and Analysis of PM_{10} and $PM_{2.5}$

Since the commencement of the monitoring program, the continuous sampling and analysis of PM_{10} was undertaken using DustTrack analysers manufactured by TSI and supplied by Eco Environmental Inc. This analyser is a type of nephelometer which automatically measures and records real-time airborne PM_{10} concentrations using the principle of forward laser light scatter. All of these analysers, with the exception of that at PAPM01, were replaced by E-Sampler analysers at the site during the first week of October 2012. An additional E-Sampler analyser measuring $PM_{2.5}$ was also installed at

BPPM01. The E-Sampler is manufactured by Met One Inc. and operates using the same principle as the DustTrack analyser and produces equivalent results. The DustTrack analysers were selected as an interim measure (hired units) because they were able to be rapidly deployed at the beginning of the program during the dry season (not cyclone rated). The E-samplers were identified as a more permanent monitoring station (purchased) and which have proven to be more robust.

The equipment calibration certificates are provided in **Appendix V** (DustTrack) and **Appendix W** (E-Samplers).

The data recorded by the analysers were downloaded from each unit remotely using a combination of radio telemetry and a central modem. Data were downloaded twice a week and stored in the URS central project database. The downloaded data were received in CSV file format, which is compatible with Microsoft Excel and most spreadsheet programs. The results are presented as particulate weight per unit volume in micro grams per cubic metre (µg/m^3).

SMS/Email alerts are now issued to the JKC Site Environmental Advisors and other key personnel when concentrations reflect those that have the potential to exceed the daily 24-hour mean NEPM standard. The alert trigger level applied to Blaydin Point and Palmerston was initially set at 250 µg/m^3 in October 2012 but was reduced to 200 µg/m^3 on 26 February 2013. The trigger level was lowered to provide an earlier warning that the 24-hour mean criteria may be exceeded under the current conditions. As an additional measure, the web portal also has a daily running mean, which shows what the mean concentration is between midnight and the time the web portal is accessed. It is advisable that this value is accessed from the portal when SMS/Email alerts are triggered. The change in trigger level is annotated on the time concentration charts discussed in **Section 7.4.1.1**.

Dust Deposition

Dust deposition sampling, described in the EIMP was undertaken using the methodology described in AS3580.10.1. This involved the installation of dust deposition gauges in locations surrounding the Project site. The locations were chosen to represent the ambient conditions at the Mangrove communities and residential dwellings on the edge of the City of Palmerston. Sampling media deployed at each gauge consisted of one 4.0 L glass dust deposition bottle (nominal volume) and a 150 ± 10 mm diameter glass funnel. The funnel is supported firmly in the neck of the dust deposition bottle by a plastic stopper with a groove or outlet pipe to allow water overflow under excessive rainfall conditions. Dust deposition bottles are pre-conditioned with approximately 20 mL of Copper Sulphate ($CuSO_4$) solution which acts as a fungicide and does not affect the dust sample results.

7.4 Results

7.4.1 Respirable Dust (PM_{10} and $PM_{2.5}$)

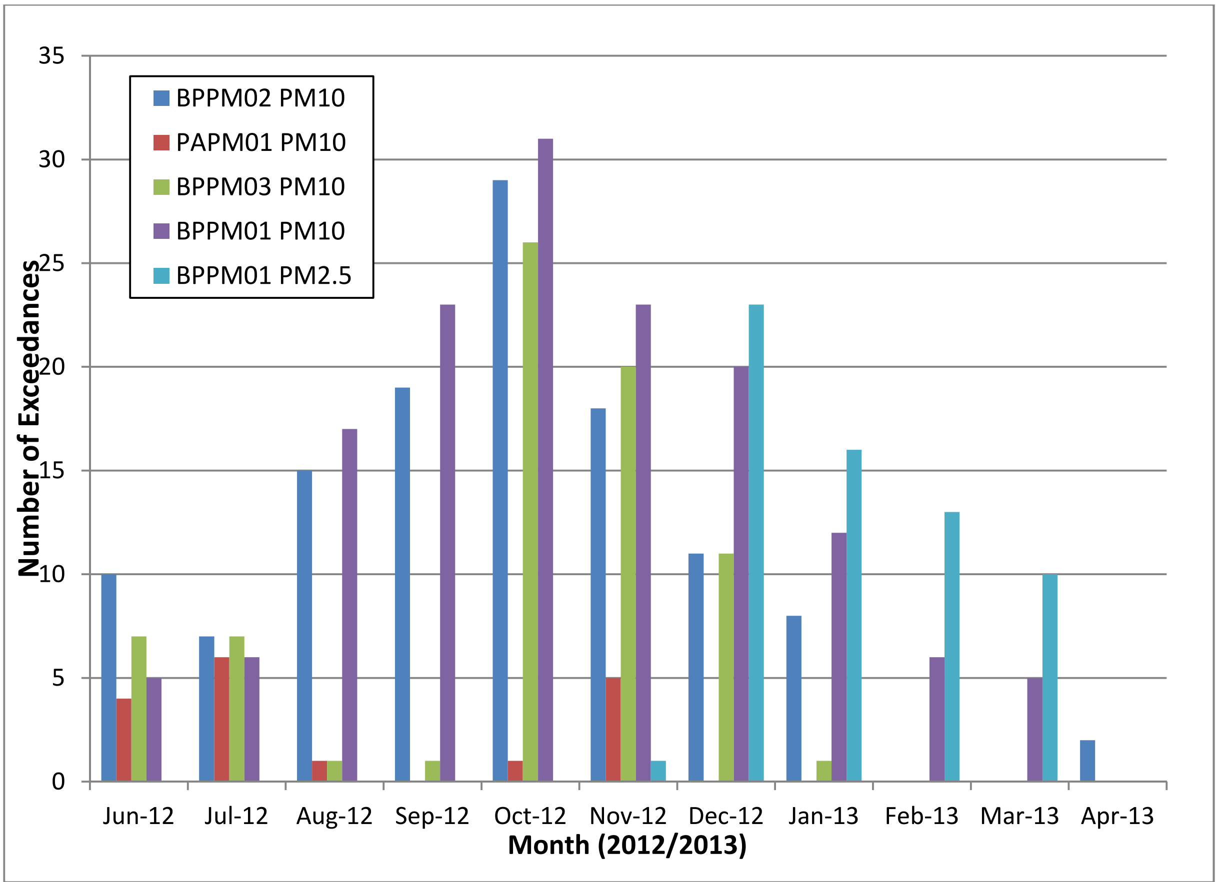
This section presents the respirable dust results as recorded by the E-sampler and DustTrack analysers. The data are presented as continuous concentration plots for each monitoring station across the 10 months of monitoring (**Chart D1** to **Chart D5**). The continuous data has also been processed to identify the occurrence of exceedances of the adjusted alert trigger values.

7 Air Quality (Dust)

The continuous plots (**Chart D1** to **Chart D5**) show the relative peaks or dust events as they have occurred throughout the monitoring program for each of the monitoring stations. No dust related complaints were received during this monitoring period.

The 24-hour mean values for PM_{10} from each of the continuous analyser sites are compared against the 50 µg/m^3, while the $PM_{2.5}$ concentrations are compared against the advisory standard of 25 µg/m^3 as outlined in the EIMP. **Chart 7-1** provides a graphical summary of the number of exceedances of the EIMP air quality criterion by month, June 2012 to April 2013.

Chart 7-1 Exceedances of the EIMP Criterion between 1 June 2012 and 12 April 2013



The data show that each of the monitoring stations has experienced dust events that have led to this EIMP criterion being exceeded. The number of exceedances appears to peak for three of the four stations (BPPM01-PM_{10}, BPPM02-PM_{10} and BPPM03-PM_{10}) in October 2012, then progressively decreasing in number to April 2013. The fourth monitoring station (PAPM01-PM_{10}) is located near residential areas in Palmerston and has recorded exceedances during five of the 10-month monitoring program to date. No trends on the number of exceedances recorded at Palmerston appears discernible from the data presented here. It should be noted that the $PM_{2.5}$ measured at station BPPM01 commenced in October 2012. Further examination on the source of dust is presented in the discussion section of this dust report.

7 Air Quality (Dust)

The highest number of exceedances for PM_{10} was 148, recorded at monitoring station BPPM01, located in the central eastern part of Blaydin Point. At the same location, the $PM_{2.5}$ sampler recorded 63 exceedances of its relevant standard.

The second highest number of exceedances of 119 were recorded at monitoring station BPPM02, located at the north-western part of the site, while monitoring station BPPM03 recorded the third highest number of exceedances of 74 during the same monitoring period.

The least number of exceedances of the respirable dust air quality criteria was 17 recorded by monitoring station PAPM01, located at the south-western boundary of the Palmerston residential area. Put into perspective, the air quality criterion for respirable dust is applicable to 24-hour mean concentrations and is applicable to urban environments and human receptors. Within these urban environments, five exceedances per year are permissible. While there are exceedances at each monitoring location on Blaydin Point, there are no residential receptors being exposed to such concentrations. The closest residential receptors are those in Palmerston, located approximately 4 km to the north east of the site. The influence of the dust to Palmerston is further examined in the discussion section of this report.

7.4.2 Analytical Results (Dust Deposition)

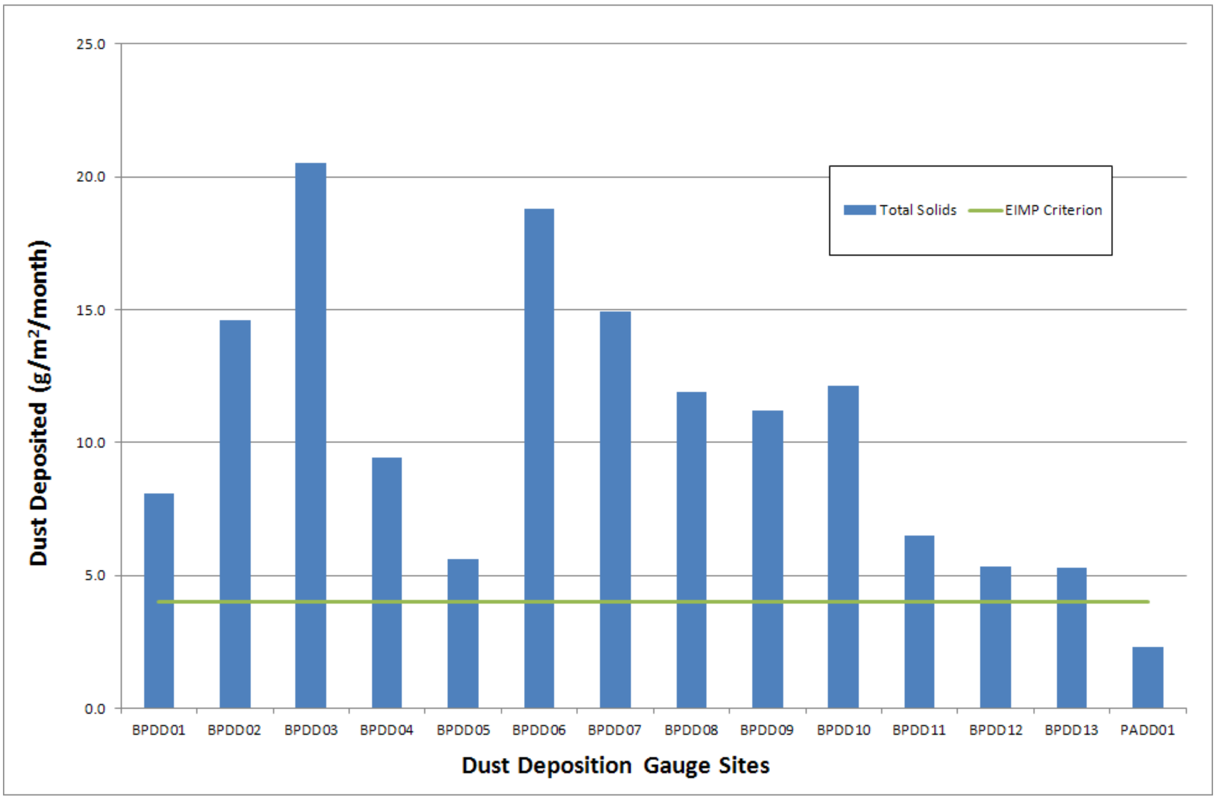
Dust deposition gauges are located at 13 monitoring locations across the site, and one is co-located with the continuous analyser adjacent to Palmerston as shown in **Figure D1**. The results are compared against an annual average of 4 g/m^2/month (applicable where no baseline level is recorded) as defined in the EIMP.

The average dust deposition rates for the period June 2012 to March 2013 are provided in **Chart 7-2**. As deposition gauges are collected and analysed on a monthly basis, the April 2013 dust deposition results have not yet been determined. Laboratory reports are provided in **Appendix Y**. The data are presented as a monthly average based on 10 months of monitoring for total solids and five months of monitoring for insoluble dust. The chart shows that the average dust deposition rate over this period is highest at BPDD03[1] (20.5 g/m^2/month) followed by BPDD06 (18.8 g/m^2/month) and BPDD07 (14.9 g/m^2/month). These values are effectively a running average, as the EIMP criterion is based on 12-months of monitoring, and therefore comparable when the June 2013 become available.

[1] Total solids represent the worst-case scenario of dust deposition. Insoluble solids are presented here to reflect the insoluble fraction within the sample.

7 Air Quality (Dust)

Chart 7-2 Average Dust Deposition (Total Solids) for June 2012 to March 2013 Monitoring Period

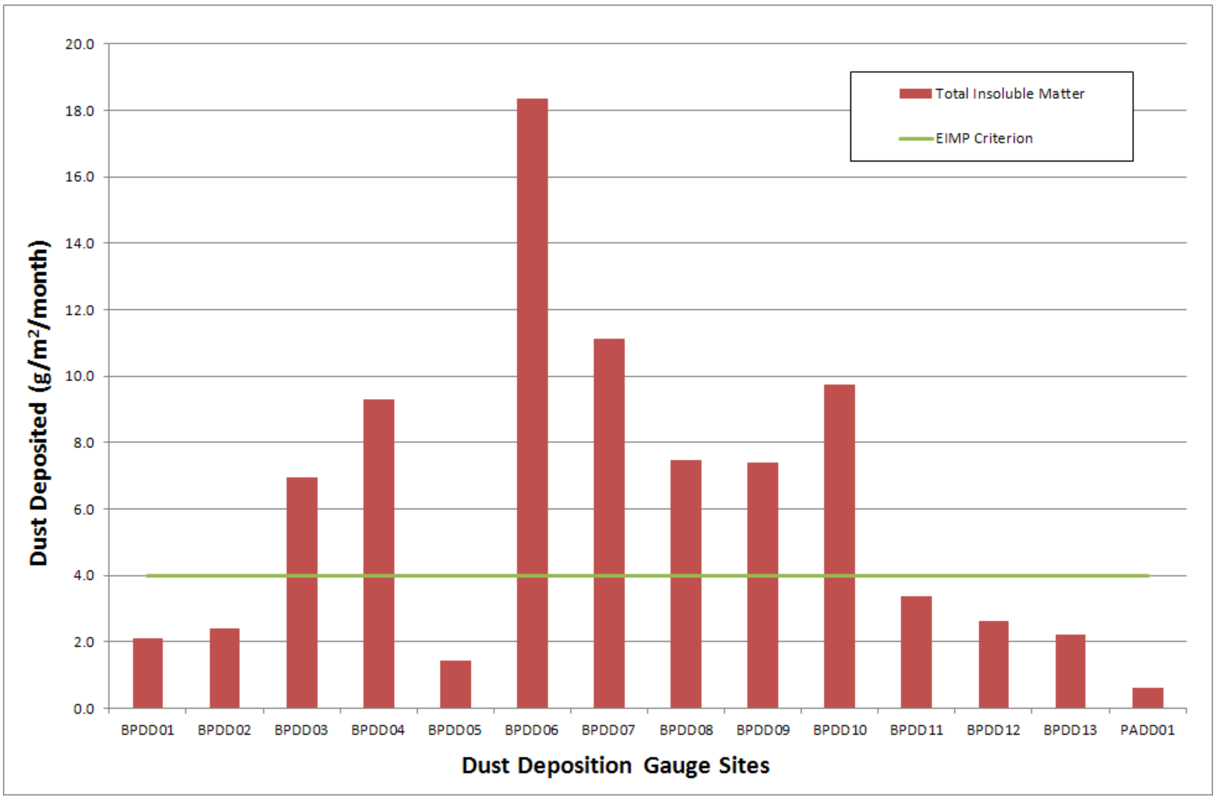


The insoluble fraction of the dust deposited in the sample excludes dissolved salts or other matter that is counted in the total solids sample and presented in **Chart 7-3**. The data collection for insoluble matter commenced in November 2012 and the running average until March 2013 showed monitoring stations BPDD06 (18.4 g/m^2/month), BPDD07 (11.1 g/m^2/month) and BPDD10 (9.8 g/m^2/month) recorded the highest values over this period. It should be noted that the insoluble and total solids have been sampled over different time periods and therefore are not suitable for direct comparison and have therefore been included as separate charts.

Average dust deposition rate was lowest at the Palmeston depostion gauge PADD01 and no exceedance of the EIMP dust deposition criterion was observed.

7 Air Quality (Dust)

Chart 7-3 Average Dust Deposition (Total Insoluble Matter) for November 2012 to March 2013 Monitoring Period



The majority of the average dust deposition rates exceed the EIMP criterion of 4 g/m^2/month at on-site monitoring locations. The data presented here show a running average that is comparable to the EIMP criterion only after a 12-month period.

The sampling location at BPDD03 which recorded the highest average dust deposition rate is located close to and on the western side of the site access road. This station is likely to record vehicle-generated dust deposition, which is influenced by the prevailing south-easterly winds during the dry season months of monitoring (June to October 2012).

Dust deposition occurring at BPDD06 recorded the second highest average deposition rate. BPDD06 is located in the southern section of the main CWA site. This location is therefore likely to experience dust generated in the central area of the construction site, due to activities within the area or simply from open ground through dust suspended from the north-westerly winds, which also significantly contributed to the wind direction during the wet season months of monitoring (November 2012 to March 2013).

The sampling location at BPDD07 which recorded the third highest dust deposition is located in the south-eastern corner of the main CWA site. Similar to BPDD06, this location is also likely to experience dust generated in the central area of the construction site, from dust suspended from the north-westerly winds in the wet season.

7.4.3 Monitoring Data Validation

7.4.3.1 Respirable Dust

Gravimetric analysis was undertaken on each of the E-sampler analysers in accordance with the E-sampler manufacturer's instructions. The purpose was to identify the correlation between the light scatter analyser employed by the E-sampler with an alternative method - the insertion of pre-weighed 47 mm Teflon filters. The laboratory reports are provided in Appendix X. The results of the correlation study identified that the E-samplers are over-reading by a range of between 29% and 269% based on the results of this exercise.

This is the first of the correlation excercises, and the poor correlation is considered in part due to the very low sample masses collected during the monitoring period. During the sampling period, Easter 2013, the site experienced high rainfall and little site activity. As such the recommended mass, according to the manufacturer, of 500 µg was not collected by any of the analysers. The analyser with the poorest correlation only collected 102 µg. Based on this single trial, it is considered too soon to modify the 'gain' on the E-sampler, instead, the next trial will incorporate longer sampling periods to ensure that a greater mass is recorded and with it improved repeatability.

7.4.3.2 Dust Deposition

To assess the reliability of the laboratory analytical results, URS examined the number of tests reported versus that requested, sample handling, preservation and holding times and the use of appropriate laboratory LORs. Our examination indicates that the analytical data can be used as a basis for interpretation subject to the limitations outlined in the Data Validation Reports provided as **Appendix Z**.

7.5 Discussion

7.5.1 Dust sources (Correlation of Data With Site Works)

7.5.1.1 Respirable Dust

This section examines the data recorded over the 10-month monitoring program to date in conjunction with site weather data and the site activities register. With exceedances having already occurred, this interrogation of the data is proposed to identify the direction from which the dust recorded is coming from and what types of activities have led to the exceedances if the dust is coming from within the site boundary.

The provision of the weather station at Blaydin point has allowed for the generation of air quality roses that take into account wind speed and direction in conjunction with the real time dust concentration being recorded by the continuous analysers. For each of the 421 exceedances of the 24-hour mean criteria, recorded over the 10-month period, an air quality rose was produced. The rose was then examined to identify the direction of the main peak relative to the analysers' position on the site. An estimation was also made as to the percentage of the rose that represented dust being recorded that originated from within the site boundary. The 421 dust roses have been included in this report (**Appendix X**).

7 Air Quality (Dust)

Those roses that identified dust was originating from offsite, were removed from the total. The remainder were examined in terms of data supplied in the site activities register for the project so far. Taking account of the direction from which the dust originated during an exceedance, coupled with a spatial and geographical understanding of the activities occurring during such exceedances, this process has derived a ranking of activities that are understood to contribute to the exceedances recorded. The site activities timeline (**Chart 1**) and the site area activity maps of the site (**Figure 1** and **Figure 2**) have been used to inform this assessment. The progressive findings of this process are presented in **Table 7-2, Table 7-3** and **Table 7-4.**

Table 7-2 Dust Source Exceedance Analysis

Filter level	BPPM01-PM_{10}	BPPM01-$PM_{2.5}$	BPPM02-PM_{10}	BPPM03-PM_{10}	PAPM01-PM_{10}
Total number of exceedances	148	63	119	74	17
Exceedances attributed to site activities	119 (80.4%)	59 (93.7%)	114 (95.8%)	60 (81.1%)	0 (0%)

*$PM_{2.5}$ commenced monitoring in October 2012

The data presented in **Table 7-2**, shows that for all but the Palmerston monitoring station, the majority (above 80%) of exceedances recorded attributable to dust originating from site. Taking the site activities register, these exceedances were then matched on a month by month basis to identify the activities occurring in the vicinity of the site when exceedances were recorded. The data from this site activity analysis is presented in **Table 7-3**.

Table 7-3 Dust Source Exceedance Analysis by Month (Dust Identified Sourced from Site)

Month	BPPM01-PM_{10}	BPPM01-$PM_{2.5}$	BPPM02-PM_{10}	BPPM03-PM_{10}	PAPM01-PM_{10}
June (occurrence)	1	N/A	10	2	0
Activity	Site clearance / rockfill		Site clearance / rockfill,	Site clearance / rockfill	-
July (occurrence)	2	N/A	7	5	0
Activity	Site clearance / rockfill		Site clearance / rockfill	Site clearance / rockfill	-
August (occurrence)	10	N/A	15	1	0
Activity	Site clearance / rockfill, operation of batching plant / construction of turkey's nest, test pile installation.		Site clearance, rockfill, operations of batching plant, construction of turkeys nest, test pile installation, geotech drilling area 2, ground improvement works area 2, 4b and area 11	Site clearance, rockfill, operations of batching plant, construction of turkeys nest, test pile installation.	-
September (occurrence)	17	N/A	19	0	0
Activity	Site clearance, rockfill, operation of batching plant, pile testing.		Site clearance, rockfill, operations of batching plant, test pile, ground improvement works area 2, 4b and area 11	N/A	-
October (occurrence)	29	0	29	25	0

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Month	BPPM01-PM_{10}	BPPM01-$PM_{2.5}$	BPPM02-PM_{10}	BPPM03-PM_{10}	PAPM01-PM_{10}
Activity	Site clearance, rockfill, geotech work, cut and fill operations, ground improvement works in area 3A and 3B, removal of topsoil in area 1A and commencement of site access road in area 1A		Site clearance, rockfill, geotech work, cut and fill operations, ground improvement works in area 3A and 3B, area 4b and area 11	Site clearance, rockfill, geotech work, cut and fill operations	-
November (occurrence)	18	1	18	16	0
Activity	Rockfill, geotech work, cut and fill operations, ASS Pad, site access road Area 1a, 3B, 8 and mangrove clearing area 12.		Rockfill, geotech work, cut and fill operations, ASS Pad, ground improvement works area 3B, 4B, 11 and mangrove clearing area 12.	Rockfill, geotech work, cut and fill operations, ASS Pad	-
December (occurrence)	19	19	11	10	0
Activity	Rockfill, geotech work, cut and fill operations, ASS Pad, site access road Area 1a, ground improvement works area 3B, 8 and mangrove clearing area 12.		Rockfill, geotech work, cut and fill operations, ASS Pad, ground improvement works area 3B, 4b, 11 and mangrove clearing area 12.	Rockfill, geotech work, cut and fill operations, ASS Pad	-
January (occurrence)	12	16	3	1	0
Activity	Rockfill, geotech work, cut and fill operations, ASS Pad, ground improvement works area 3B, 8 and rock area 8, general fill Area 8 reinforced concrete pipe installation area 8 mangrove clearing area 12.		Rockfill, geotech work, cut and fill operations, ASS Pad, ground improvement works area 3B, 11, 11c Mangrove clearing area 12.	Rockfill, geotech work, cut and fill operations, ASS Pad	-
February (occurrence)	6	13	0	0	0
Activity	Rockfill, geotech work, cut and fill operations, ASS Pad, ground improvement work area 3B, mangrove clearing area 12, laydown of hardstanding area 3a, SIMOPS road open area 13		-	-	-
March (occurrence)	5	10	0	0	0
Activity	Laydown of hardstanding 3a, ground improvement works 3b, 6, 7, 11C, mangrove clearing area 12, rock and general fill area 8, reinforced concrete pipe installation area 8.		-	-	-
April (occurrence)	0	0	2	0	0
Activity	No activities described were available for April				

Table 7-3 shows that there are some activities listed that were long in duration and had a site wide influence, while others were more localised and only influenced certain monitoring stations. A key finding of the air quality rose examination was that none of the roses, recorded on days of exceedances at Palmerston, identified the particulate matter as originating from site. At a distance of approximately 4 km, no specific site activity was attributed to these exceedances.

Taking the activities occurring near each of the monitoring stations and adding up each of the exceedances that they could have contributed to a ranked list of activities is presented in **Table 7-4**. For clarification, the exceedances occurring for PM_{10} and $PM_{2.5}$ were not combined, but instead the higher value was the number of exceedances used to represent the single monitoring location, BPPM01.

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Table 7-4 Ranked Order of Activities Contributing to 24-Hour Exceedances

Contributing activity	BPPM01	BPPM02	BPPM03	Total
Rockfill	114	112	60	**335**
Geotech work	95	61	52	**208**
Cut and fill operations	84	61	52	**197**
Site clearance	59	80	33	**172**
Ground improvement works in area 3B	105	61	0	**166**
Site access road Area 3b	89	61	0	**150**
ASS Pad	72	32	27	**131**
Mangrove clearing area 12.	76	32	0	**108**
Ground improvement works area 11	0	95	0	**95**
Ground improvement works area 4b	0	92	0	**92**
Operation of batching plant	27	34	1	**62**
Ground improvement works in area 3A	29	29	0	**58**
Site access road Area 1a	37	0	0	**37**
Pile testing.	17	19	0	**36**
Ground improvement works rock area 8	35	0	0	**35**
Ground improvement works area 2	0	34	0	**34**
Removal of topsoil in area 1A	29	0	0	**29**
Commencement of site access road in area 1A	29	0	0	**29**
Construction of turkey's nest	10	15	1	**26**
Test pile installation	10	15	1	**26**
General fill Area 8	26	0	0	**26**
Reinforced concrete pipe installation area 8	26	0	0	**26**
Laydown of hardstanding area 3a,	23	0	0	**23**
Site access road Area 8	18	0	0	**18**
Geotech drilling area 2	0	15	0	**15**
Ground improvement works area 11c	10	3	0	**13**
SIMOPS road open area 13	13	0	0	**13**
Ground improvement works area 6	10	0	0	**10**
Ground improvement works area 7	10	0	0	**10**

It should be noted that whilst **Table 7-4** shows the ranking of the activities that were occurring at the time an exceedance was recorded, the ranking is influenced by the resolution of the activity description. For those activities that were identified as site wide, they have featured in influencing each monitoring station even though on any given day, the specific activity could have been not in the area of the monitoring station. The resolution of the site activity register does not allow for this level of interpretation.

The assessment has not excluded the days where no activity was being undertaken. Typically this is a suitable approach, as open areas of unsealed ground also have the potential to generate dust, simply from appropriate strength winds passing over dry soil. However, when this is combined with instances of bushfires in the region, particularly when these bushfires occur on public holidays, it is not determinable if it is localised wind borne dust or due to a larger event. As a result these have been simply included within the data provided.

7.5.1.2 Dust Deposition

The dust deposition results are influenced on a month by month batch sample. However unlike respirable dust, the air quality criteria is a long term annual mean rather than a short 24-hour mean. As such all activities in the vicinity of the dust deposition gauges will contribute to the annual deposition rate. This section therefore only presents the the geographically relevant activites and does not interrogate the data spatially. **Table 7-5** shows the different areas (**Figure 1** and **Figure 2**) that are immediately adjacent to each of the dust depositing monitoring locations. It is considered that deposited dust is usually contributed by dust generated within a 50 to 100 metre radius of the monitoring station, subject to moisture conditions and speed of wind and type of dust generating source. **Table 7-5** also shows the activities that have occurred in the identified areas listed. Given the proximity these activities are likely to have contributed to the dust deposition of the respective monitoring locations.

Table 7-5 Dust Sampling Locations at Blaydin Point and Palmerston

Monitoring Location IDs	Average Total Solids Exceeding EIMP Criteria	Average Insoluble Matter Exceeding EIMP Criteria	Adjacent Areas	Activities
BPDD01	Yes	No	1B	Intersection works April 2012 to Nov 2012, Mobilisation Apr 2012, Set up of offices Apr 2012
BPDD02	Yes	No	Access Road	Excavation Aug 2012 to Sept 2012
BPDD03	Yes	Yes	1A	Commencement of site access road Jun to Nov 2012
BPDD04	Yes	Yes	8	Ground improvement works Aug 2012 to Jan 2013
BPDD05	Yes	No	1A, 8	Commencement of site access road Jun to Nov 2012, Ground improvement works Aug 2012 to Jan 2013
BPDD06	Yes	Yes	3A, 13	Ground improvement Oct 2012, Laydown of hardstanding Mar 2013, Installation of rebar for outfall lock Feb 2013, SIMOPS road open Mar 2013
BPDD07	Yes	Yes	13	SIMOPS road open Mar 2013
BPDD08	Yes	Yes	3A, 3B	Ground improvement Oct 2012, Laydown of hardstanding Mar 2013, Installation of rebar for outfall lock Feb 2013
BPDD09	Yes	Yes	3A, 3C, 3D, 12, 7	Ground improvement Oct 2012, Laydown of hardstanding Mar 2013, Installation of rebar for outfall lock Feb 2013, Mobile offices construction Nov 2012 to Feb 2013, Soils survey Oct 2012 to Jan 2013, Mangrove Clearing Nov 2012 to Mar 2013, Ground improvement works Mar 2013
BPDD10	Yes	Yes	11B, 12	Mangrove clearing Nov 2012 to Mar 2013
BPDD11	Yes	No	11A	no activities provided for Area 11A
BPDD12	Yes	No	11	Ground improvement works Aug 2012 to Feb 2013
BPDD13	Yes	No	Access Road	Excavation Aug 2012 to Sept 2012
PADD01	No	No	N/A	N/A

7.5.2 Trend Analysis

On examination of the data, the spatial trend suggests a peak in the number of exceedances for both dust parameters across the monitoring stations (excluding Palmerston) during October, then a continuing decrease to April. This correlates generally with the change from the marked dry to wet season in the Northern Territory. Whilst moisture plays its part, the wind direction also changes with the season. The wind roses for the monitoring program are presented in **Chart 7-2**.

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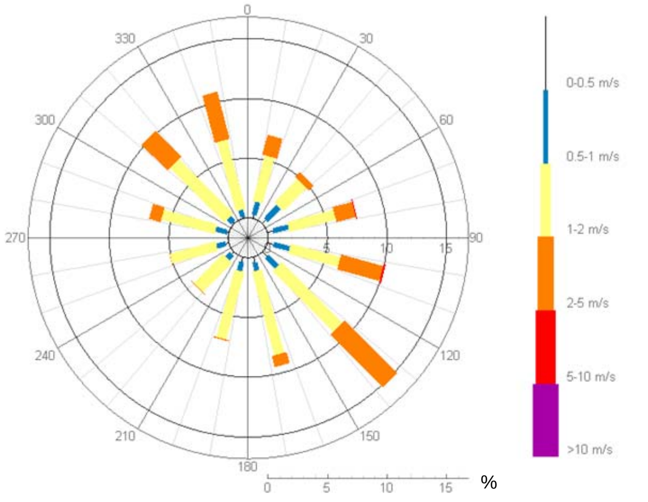
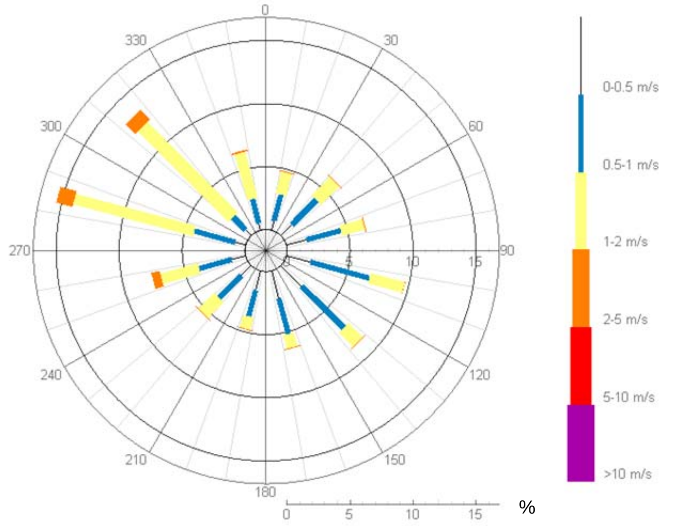
Chart 7-4 Dry Season Wind Rose June 2012 to October 2012



1.3% Calm 97.3% valid data present

Chart 7-5 Wet Season Wind Rose November 2012 to April 2013



5.2% Calm 90.1% valid data present

The wind roses show a noticeable shift in direction from predominantly south east to predominantly north west. Wind speeds recorded show a relative slowing of the winds in during the wet season when compared with the dry. Both the slowing of the winds and the increased moisture in the air and soil all contribute to reducing the number of exceedances recorded over the monitoring period. This weather change is also coupled with the fact that as the project is constructed there is a greater percentage of hard stand areas. With the sealing, vehicles produce less dust and there is a greatly reduced tendancy for wind blown dust to contribute to dust loadings.

7.5.3 Performance against EIMP Criteria

7.5.3.1 Respirable dust

Irrespective of the sources of the dust, the project has recorded 421 exceedances of the EIMP respirable dust criteria, with 352 of those being identified as attributable to onsite activities. One of the purposes of the criteria is to avoid impact of respirable particulate matter on third-party sensitive receptors. Given the absence of residential receptors at Blaydin point and the indication of the analysed data that exceedances at Palmerston are not attributable to site activities of the project, it is considered that no discernible effect on third-party residential receptors has occurred from dust generated over the 10-month monitoring program.

7.5.3.2 Dust deposition

The air qulality criteria applied to dust deposition is primarily applied for amenity protection. This may relate to the protection of third-party property, or alternatively the avoidance of dust plumes as a visible impact. The criteria also acts as a guide to the protection of vegetation that may be susceptible to dust deposition on leaves, leading to a deleterios effect on plants.

The site has mangroves at its borders and the dust deposition guages are placed to monitor the dust rates in relation to the mangrove health monitoring also in place (**Section 6**). To date, it is understood that no adverse effect on mangrove health has been sustained as a result of elevated dust deposition rates in the vicinity.

Regarding impacts to human amenity criteria, to date there have not been any dust related complaints with regards to the work carried out at Blaydin Point. This is primarily due to the site's distance from its nearest residential receptors in Palmerston. No exceedance of the dust deposition criterion has been observed at the Palmerston deposition gauge PADD01, which also recorded the lowest average dust deposition rate.

Airborne Noise

8.1 Scope of Works

The EIMP identifies specific requirements for airborne noise monitoring, noise criteria and potential monitoring locations. Two long-term noise loggers were deployed to continuously measure construction noise levels at Blaydin Point and at Palmerston. These noise loggers have been measuring noise since the initiation of construction activities in June 2012 through to April 2013.

The objective of the airborne noise monitoring is to indicate compliance with the nominated construction noise limits. Each month, the monitoring results are analysed and interpreted to determine whether construction related activities within the CWA site are giving rise to exceedances of the noise limits at sensitive receptors.

This section of the annual report presents:

- Noise criteria;
- Detailed description of the noise monitoring methodology; and
- Discussion of the monitoring results, including a summary of the noise compliance performance, trends analysis and correlation with site works.

8.2 EIMP Performance Criteria

Table 8-1 below summarises the adopted noise limits based on the EIMP.

Table 8-1 Noise Limits

Type of Receptor	Daytime (07:00 – 19:00 hrs.) Noise Limit – $L_{Aeq(12hr)}$	Night-time (19:00 – 07:00 hrs.) Noise Limit – $L_{Aeq(12hr)}$
Residential	55 dB(A)	45 dB(A)
Industrial	70 dB(A)	70 dB(A)

The noise monitoring program was designed to monitoring compliance at the nearest residential receptors. It has been established that when compliance with the noise criteria is achieved at the nearest residential receptor, compliance would also be deemed at surrounding industrial receptors.

8.3 Field Methodology

The approach to noise monitoring is based on the general methodology outlined in the EIMP. The objective of noise management at the site is to minimise the impacts of construction noise on local communities (nearest sensitive receptors), which have been identified as residences in the City of Palmerston.

Noise monitoring has been undertaken to assess compliance with the noise limits listed in **Section 8.2** and in accordance with the following standards and guidelines:

- Australian Standard (AS) 1055.1:1997, Acoustics — Description and measurement of environmental noise;
- AS 2436:2010, Guide to noise and vibration control on construction, maintenance and demolition sites; and
- Noise guidelines for development sites in the Northern Territory (NRETAS 2011).

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Noise measurements have been taken at a height of 1.2 to 1.5 m above ground level (AGL) and more than three meters from any potentially noise reflective surface.

The unattended noise loggers were set to Fast time weighting, A weighting and hourly recording of a number of noise indices. These hourly values are considered to be representative of the noise environment during the preceding hour during which the measurements were taken. The hourly L_{Aeq} values are post processed to calculate the $L_{Aeq(12hr)}$ values for comparison to the noise limits. Results from the noise loggers were downloaded twice a week and compared to the noise limits.

The daytime $L_{Aeq(12hr)}$ noise levels were recorded between 7 am and 7 pm; while the night-time $L_{Aeq(12hr)}$ were recorded between 7 pm the previous day and 7 am on the actual referenced monitoring date.

8.3.1 Monitoring Locations and Rationale

The sampling pattern has been designed to target noise emissions at the Project boundary and at the closest sensitive receptors identified during the environmental impact assessment.

Table 8-2 below summarises the monitoring locations, the measurement parameters and the rationale for monitoring at each location. See **Figure E1** (attached) for an aerial image showing the noise monitoring locations.

Table 8-2 Noise Monitoring Locations

Location IDs	GDA Coordinates	Parameter	Rationale
BPPM01	E 712412, N 8616788	$L_{Aeq(12hr)}$	Monitoring at the site to help manage noise levels on site and also determine if the source of noise complaints is due to construction activities.
PAPM01	E 709437, N 8614389	$L_{Aeq(12hr)}$	Monitoring at the Turf Farm on Catalina Road, Palmerston, to obtain noise data that is representative of the noise environment at the nearest residential receptors in Palmerston. These measurements cannot be directly compared to the noise limits, as the location is not within 15m of or on the boundary of a Noise Sensitive Receptor, however this location is between the site and the closest sensitive receptor.

The chosen monitoring locations differ with those identified in Table 4-11 of the EIMP as permanent noise monitors were not installed at BPAN02 (Nearest industrial receptor) or EAAN01 (East Arm Wharf). The rationale for not including these two monitoring locations is based on a practical interpretation of the noise limits at both types of identified sensitive receptors, residential and industrial. It was stated in **Section 8.2** of this report that should compliance be achieved at the most sensitive residential receptor, then construction noise levels will be such that compliance will also be achieved at the nearest industrial receptor.

8.3.2 Monitoring Period

The ongoing monitoring has been undertaken continuously since 15 June 2012. The noise monitoring period referenced in this report comprises June 2012 through to April 2013. Details of start time, finishing time and disruptions of the monitoring are summarised in **Table 8-3**.

Table 8-3 Noise Monitoring Period

Location IDs	Start Date/Time	Finish Date/Time	Disruptions/Outages
BPPM01	Friday 14 June 2012, 19:00 hrs. CST	Friday 12 April 2013, 19:00 hrs. CST	Data loss occurred at this location during these periods: • Between 10 am on 20/12/2012 and 9 am on 17/01/2013 (23 days). • Between 10 am on 25/02/2013 and 10 am on 01/03/2012 (6 days). Total monitoring time = 273 days
PAPM01	Friday 14 June 2012, 19:00 hrs. CST	Friday 12 April 2013, 19:00 hrs. CST	Data loss occurred at this location during this period: • Between 7 am on 10/04/2013 and 7 pm on 12/04/2013 (2 days). Total monitoring time = 300 days

8.3.3 Monitoring Equipment

The noise monitoring strategy outlined in the EIMP proposed two noise monitoring terminals (NMT) with audio recording and telemetric capabilities. Two temporary noise loggers were deployed and have been used at the monitoring locations whilst issues around the specification for the procurement of the permanent NMTs where resolved. The temporary noise loggers have been used during the entire monitoring period.

The measurements obtained using the temporary noise meters do not entail variation in the measurement methodology. The temporary noise loggers do not have audio recording capabilities and additional analysis of noise data was required to interpret any exceedance of the noise limits.

The noise monitoring equipment comprised:

- At BPPM01:
  - One Acoustic Research Laboratories type 1 EL-315 Logger, serial number 15 004 045, used between commencement of the monitoring period and 14 January 2013;
  - One Acoustic Research Laboratories type 1 EL-315 Logger, serial number 15 299 419, used between 14 January 2013 and the end of the monitoring period;
- At PAPM01: One Acoustic Research Laboratories type 1 EL-315 Logger, serial number 15 299 425, used for the entire monitoring period;
- Acoustic calibrator Pulsar model 105, serial number 6210;
- Standard microphone windshields;
- Solar panels; and
- Analogue modems.

The permanent NMTs have now be procured and will be installed. These NMT will introduce audio recording capabilities as required by the EIMP.

8.4 Field Observations

The $L_{Aeq(12hr)}$ noise levels for locations BPPM01 and PAPM01 have been plotted on individual charts for every month and analysed to asses compliance against the noise limits. **Appendix AA** presents these charts.

The noise levels recorded at the Turf Farm location in Palmerston (PAPM01) are considered to be representative of the noise environment at the nearest residential properties; however, as this location is circa 400 m from these properties and likely to be influenced by activities within the farm, direct comparisons with the noise limits should be made with caution. The levels from the CWA site are provided for reference and should not be directly compared with the noise limits.

The following information is presented in this section:

- A summary of the continuous noise levels over the 302 days of monitoring, in **Section 8.4.1**;
- A summary of the recorded exceedances in **Section 8.4.2**; and
- References to the monitoring data validation in **Section 8.4.3**.

8.4.1 Continuous Monitoring

The results of the continuous noise measurements over the 302 days of monitoring at the CWA Site and Palmerston are presented in **Chart 8-1** and **Chart 8-2** below, respectively. Each chart presents daytime and night-time $L_{Aeq(12hr)}$ noise level lines.

Due to the temporal scale the $L_{Aeq(12hr)}$ individual data readings are hard to distinguish in these charts; however, the visual information these charts provide is useful to determine trends and patterns over the whole monitoring period and allows for comparisons between different months or seasons.

8.4.1.1 CWA Site (BPPM01)

Chart 8-1 shows the $L_{Aeq(12hr)}$ noise levels at the CWA site. Two main features of the noise levels at this site are noted: the overall increase in noise levels and a distinguishable pattern throughout the monitoring period where evenly separated minimums are the $L_{Aeq(12hr)}$ noise levels on Sundays. This noticeable decrease in noise levels on Sundays strongly implies that the dominant noise source on the other days of the week is construction activities. These Sunday falls, while still present, are less evident on the latest months of the monitoring period due to intensified works across the site that implies more general activity, inclusive of Sundays.

Night-time noise levels above 50 dB(A) are sufficiently above the assumed baseline levels of circa $L_{Aeq(12hr)}$ 40 dB (based on Sunday/Monday night levels) that it can be confidently stated that they are not caused by distant anthropogenic noise sources or weather induced noise (e.g. wind and rain). Night-time working at the CWA site, which appears to have occurred on the majority of nights during the monitoring period, is most likely to have generated these elevated noise levels.

The overall increase in noise levels is also evident across the later months, observed from the minimums and maximums in the plot. Minimums are between 45 and 50 dB(A) in 2013, compared to the initial 35-40 dB(A) range in mid-2012.

Night-time and daytime noise levels are in general very similar. Visually, night-time peaks are marginally higher and observed with nearly the same frequency as for daytime. This reveals that, in

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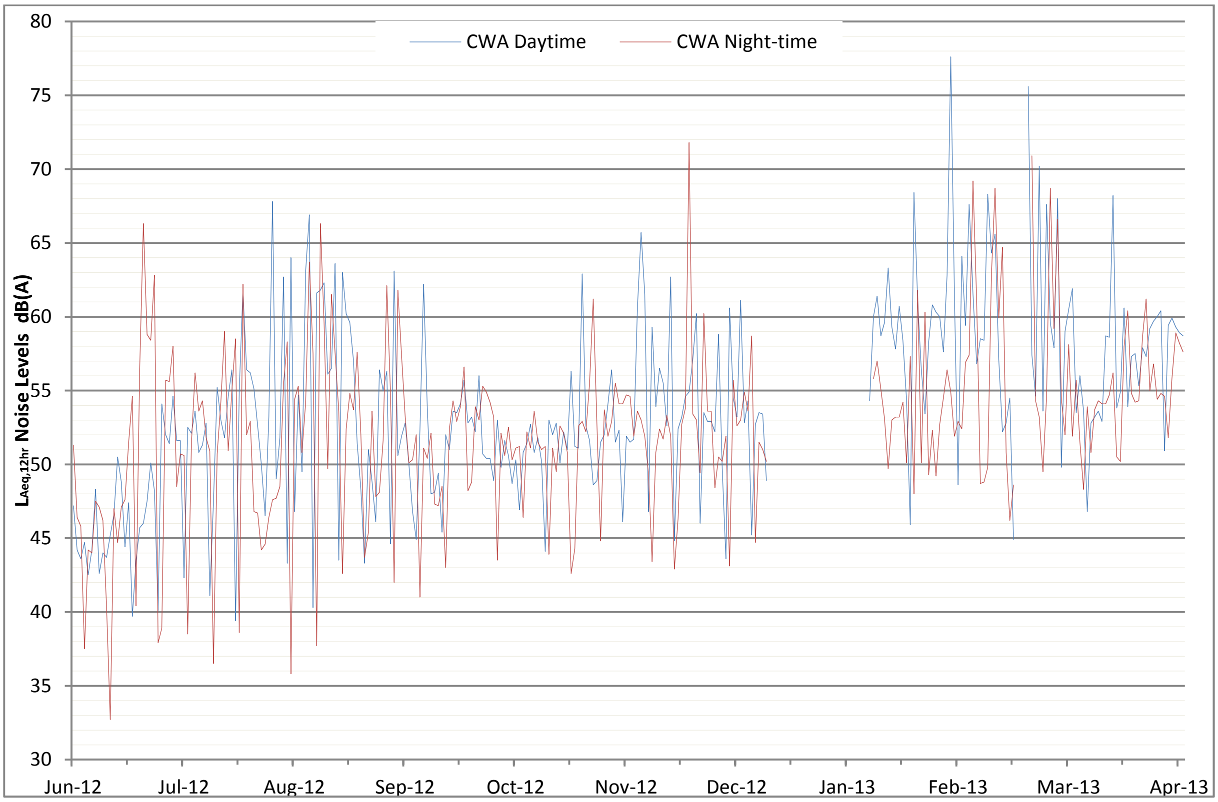
general, the intensity of night-time construction works has been marginally more intense than daytime construction.

Chart 8-1 $L_{Aeq(12hr)}$ Noise Levels at the CWA Site During the Monitoring Period



Equipment failure which occurred between the Christmas/New Year season and mid-January 2013. During this period construction works continued; however, the noise levels in Palmerston decreased and did not show correlation with construction noise levels.

8.4.1.2 *Palmerston (PAPM01)*

Chart 8-2 shows the noise levels in Palmerston. This graph is noticeably different to that of the CWA site. The dynamic range of the noise levels at this location is less variable and, apart from atypical events that occurred between the months of August and September 2012, the levels vary approximately within the same ranges across the entire monitoring period. Minimums are typically around 45 dB(A) and peaks between 60 and 65 dB(A).

The elevated noise events registered between August and September 2012 are not related to construction at the CWA since no correlation was found with the CWA site noise monitor.

A noticeable pattern is repeated where the daytime (blue) peaks clearly dominate the upper end of the graph and the night-time (red) falls dominate the lower end of the plot. This shows a typical residential/sub-urban setting where night-time $L_{Aeq(12hr)}$ noise levels are around 10 dB(A) lower than the daytime levels.

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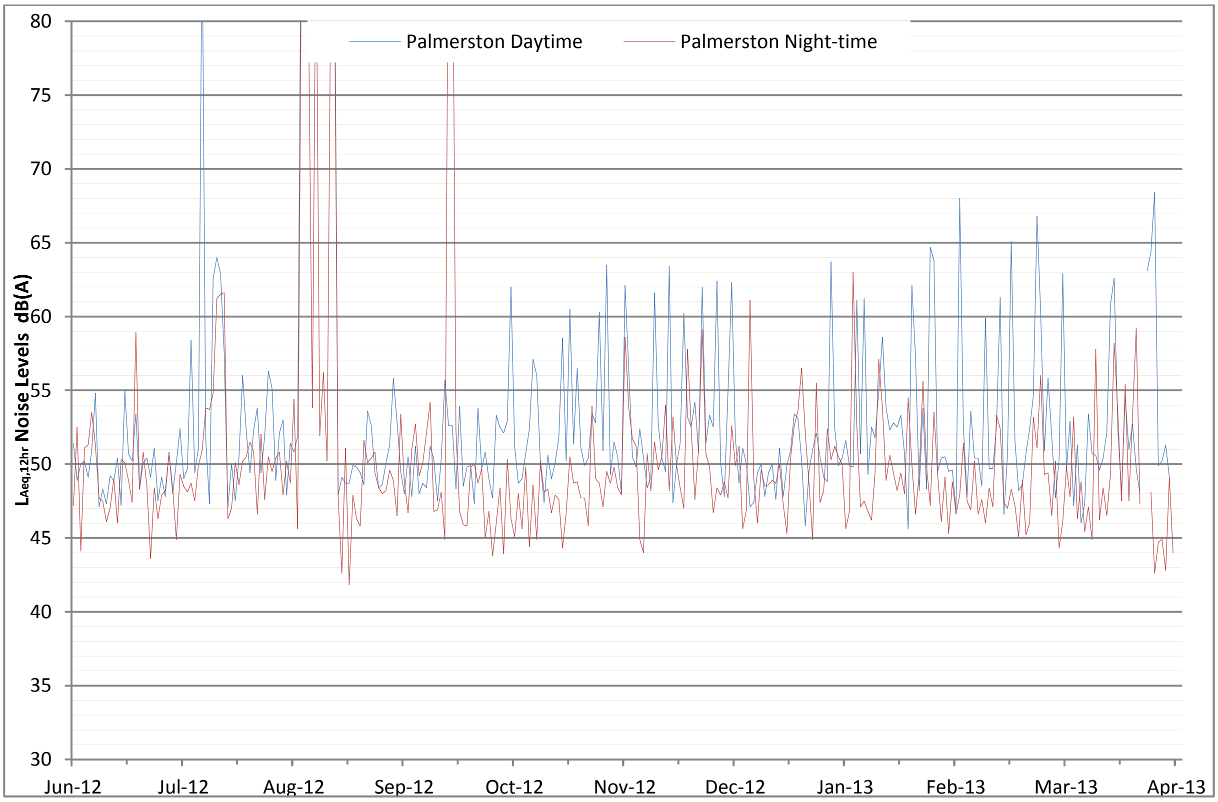
A visual inspection reveals that the night-time $L_{Aeq(12hr)}$ noise limit of 45 dB(A) is typically exceeded throughout the monitoring period; while the daytime noise limit of 55 dB(A) is often exceeded, albeit with less frequency.

Chart 8-2 $L_{Aeq(12hr)}$ Noise Levels at Palmerston During the Monitoring Period



8.4.2 Recorded Exceedances

Table 8-4 below shows a summary of the exceedances during the entire monitoring period. The presented data are derived from measurement results which may include natural sounds, as well as anthropogenic noise. It should also be noted that exceedances at the BPPM01 monitoring location are presented for illustrative purposes only since this is not a noise sensitive receptor, and therefore the noise limits cannot be directly applied.

Table 8-4 Summary of Noise Limit Exceedances for the Monitoring Period

Location IDs	Month	Days Monitored	Number of Monthly Daytime Exceedances	Number of Monthly Night-time Exceedances
BPPM01	Jun-12	16	0	10
	Jul-12	31	2	25
	Aug-12	31	17	26
	Sep-12	30	5	25
	Oct-12	31	3	27
	Nov-12	30	9	27
	Dec-12	20	4	18
	Jan-13	14	12	14
	Feb-13	28	19	25

Location IDs	Month	Days Monitored	Number of Monthly Daytime Exceedances	Number of Monthly Night-time Exceedances
	Mar-13	30	17	30
	Apr-13	12	11	12
PAPM01	Jun-12	16	0	15
	Jul-12	31	7	29
	Aug-12	31	11	28
	Sep-12	30	2	29
	Oct-12	31	6	24
	Nov-12	30	6	28
	Dec-12	31	3	30
	Jan-13	31	6	30
	Feb-13	28	6	26
	Mar-13	31	6	27
	Apr-13	10	3	2

The exceedances of interest are those at Palmerston, being representative of the noise-sensitive receptors. The average exceedance in Palmerston is 6 dB(A) for both daytime and night-time. The exceedances at this location were caused by fluctuations in the natural ambient noise of the Palmerston locality. The typical night-time ambient noise levels in Palmerston are evidently higher than the $L_{Aeq(12hr)}$ noise limit. The large number of night-time exceedances in Palmerston are not related to construction noise at the CWA site.

From the hourly data analysis undertaken every month during the monitoring period, only a few exceedances were observed simultaneously occurring at the CWA site and Palmerston. However, the data analysis does not indicated that exceedances at Palmerston were triggered by construction noise at the CWA site.

8.4.3 Monitoring Data Validation

The noise loggers were field calibrated prior to the commencement of data logging and each month during the site maintenance visits. No significant discrepancies (greater than 0.5 dB) were noted in the initial and monthly measurement reference calibration tests.

The instruments comply with AS IEC 61672.1 – 2004 "Electroacoustics – Sound level meters – Specifications" and AS IEC 60942-2004: "Electroacoustics - Sound Calibrators" and have current calibration certificates traceable to a NATA certified laboratory. See **Appendix BB** for the calibration certificates.

8.5 Discussion

8.5.1 Trend Analysis

This section presents an analysis of the noise data gather between June 2012and April 2013. There is limited availability of noise data previous to June to allow for a comparison against a baseline (i.e. without construction at the site). Therefore, the analysis focuses on the trends in the noise data collected over the eleven months of noise monitoring and assumes a baseline from observations during typical quiet days (e.g. Sundays).

Chart 8-3 and **Chart 8-4** show a smoothed version of the $L_{Aeq(12hr)}$ noise levels for CWA site and Palmerston (as presented in **Chart 8-1** and **Chart 8-2)**, respectively. The numerical smoothing has been done to stress important features in trends and it was mathematically achieved applying a 4^{th} degree polynomial regression to the full noise data set.

Chart 8-3 below shows the trendline of noise levels at the CWA site. The evident and most relevant conclusion from this chart is that the noise emissions generated from the CWA site progressively increased over the eleven months of the monitoring period, peaking between February and March 2013.

Overall, the daytime noise levels stay higher than night-time noise levels. Approximately from December 2012, daytime $L_{Aeq(12hr)}$ typically fluctuate between 55 dB(A) and 60 dB(A) and night-time $L_{Aeq(12hr)}$ fluctuate around the 55 dB(A) level.

Chart 8-3 CWA Site Smoothed Noise Levels

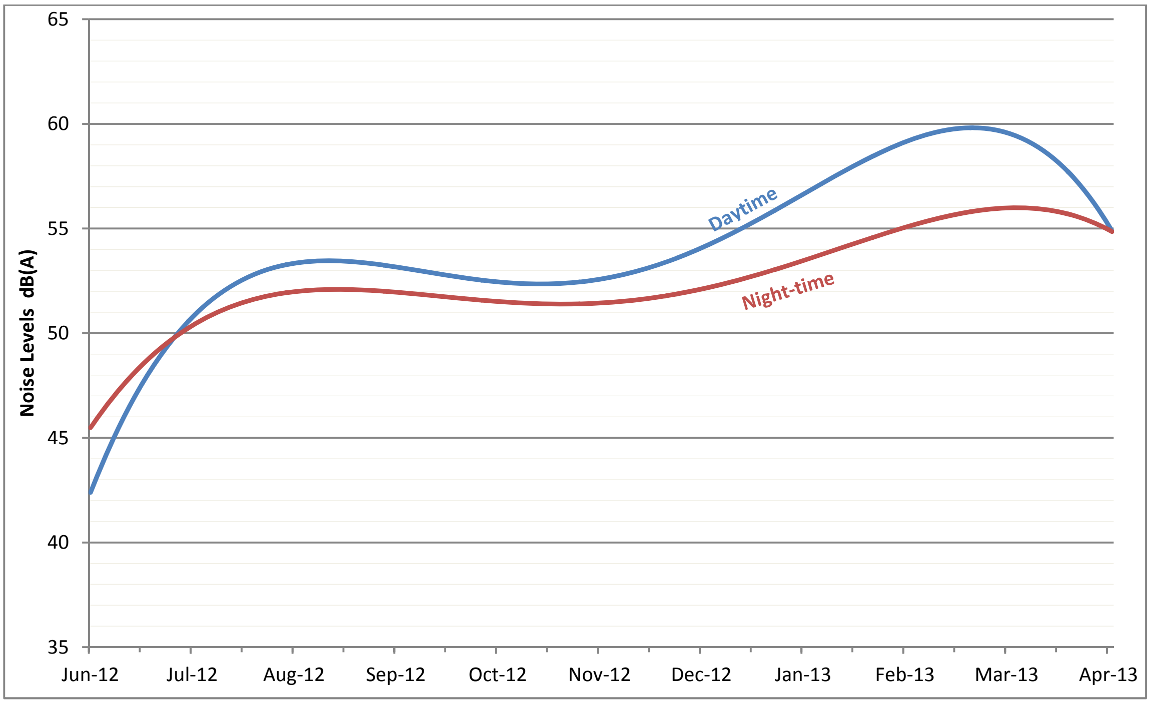


Chart 8-4 presents the trendline of noise levels at Palmerston. The trends show minimal variations of noise levels across the whole monitoring period. This variation is attributed to seasonal variability in ambient noise (i.e. wet season and dry season). From this chart, no correlation is observed with noise levels at the CWA site.

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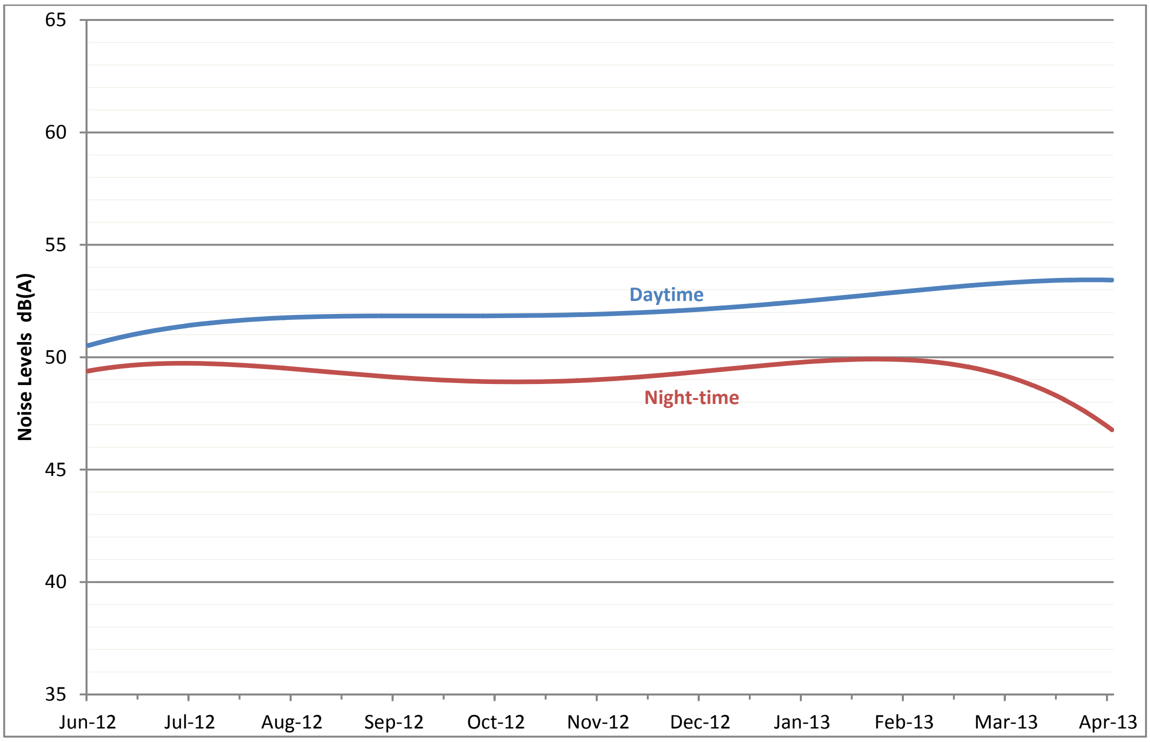
Chart 8-4 Palmerston Smoothed Noise Levels



8.5.2 Performance against EIMP Criteria

Noise emissions from the CWA site have generally complied with the noise limits nominated by the EIMP. A number of noise exceedances were recorded at Palmerston; however, no exceedance is attributed to construction noise at the CWA site.

Few exceedances during the monitoring period were observed simultaneously occurring at the CWA site and Palmerston. However, the data analysis does not indicated that exceedances at Palmerston were triggered by construction noise at the CWA site.

Effectiveness of the Noise Monitoring Methodology

The noise monitoring strategy effectively addressed the monitoring requirements established in the EIMP. Audio recording of events is desirable for future monitoring since it would allow an audio review of events where exceedances at Palmerston are suspected to have been caused by construction activity at the CWA site.

The monitoring locations are effective in capturing the noise emissions at representative locations of the site and sensitive receptors. The CWA site monitoring location (BPPM01) could be improved to capture construction noise from a more spatially centric location towards the north-east end of the site.

Noise Criteria

Currently, the noise levels monitored within the CWA site noise are compared against the same noise limit nominated for the residential sensitive receptors. This comparison provides an indicative log of the noise emissions generated on site, for illustrative purposes.

It is recommended that an estimation of the typical noise reduction between the CWA site boundary and the sensitive receptors be modelled to set “trigger” noise levels at the construction site. This will enable a better control of the noise emissions from site and will assist the contractor in understanding when construction noise levels are at risk of triggering an exceedance at the sensitive receptors. Noise modelling calculations, which can factor in variables such as distance, wind speed and direction, meteorological conditions and topographical screening can determine the noise reduction.

8.5.3 Correlation of Data with Site Works

No correlation between the noise levels at the sensitive receptors in the City of Palmerston and those on the CWA site was observed.

From reviewing the logs it is assumed that activities such as drilling, site clearing, excavations, ground improvement and general vehicle transit would have dominated the noise levels. An activity with high risk of generating elevated noise emissions is piling. “Test piling” was identified between August and September 2012 within the site; however, no changes in noise trends were noticeable from the CWA site noise monitoring data.

Flora and Fauna Monitoring

Section 2.4 of the EIMP details the scope of the EIMP and includes flora and fauna monitoring. **Table 9-1** details the frequency and monitoring methodology of the flora and fauna monitoring program. The flora and fauna management Project objective was to avoid disturbance to flora and fauna outside the approved clearing footprint.

Table 9-1 Environmental Impact Monitoring Program - Flora and Fauna Monitoring

Monitoring Program	Frequency	Monitoring Methodology
Flora and Fauna Monitoring	Following initial clearance of handover area	Visual assessment of clearance against the clearance permit Clearing limits will be collected using DGPS. Monitoring of vegetation health of non-mangrove vegetation communities along the perimeter of the CWA to determine impacts on health. Data will be compared to control site data gathered within the locality.

The flora and fauna monitoring program was undertaken by third parties and as such no analyses are undertaken here. **Sections 9.1** and **9.2** provide an overview of the work undertaken to meet the requirements of the EIMP flora and fauna monitoring only.

9.1 Flora Monitoring

The flora management Project objective was to avoid disturbance to flora outside the approved clearing footprint with the aim of zero incidents of unauthorised clearing and disturbance. The purpose of the vegetation monitoring was to detect changes in the health and composition of vegetation communities through a monitoring program by visual inspection, collection of Global Positioning System (GPS) data and a review of trends through time. Additionally, an assessment of compliance with clearance limits was to be undertaken.

The CEMP states that flora and vegetation surveys of the site were undertaken during the dry season in October 2007 and at the end of the wet season in May 2008. The area approved to be cleared is 362 hectares (ha) and is comprised of an area above the intertidal zone and a small area within the intertidal zone (JKC 2012). The vegetation above the intertidal zone is dominated by Eucalyptus woodland (132.4 ha), Melaleuca communities (73.4 ha) and closed monsoon vine forest (60.7 ha) whilst the area in the intertidal zone is dominated by mangrove communities (JKC 2012).

Progressive post-clearing surveys were undertaken by in 2012 in the months of July, September and November. Surveys were undertaken by licenced surveyors. Maps of each of the surveys are provided at **Appendix CC**.

A survey undertaken in July indicated that 226.0795 ha had been cleared within the approved clearing area and a minor area was cleared outside of the approved boundary (0.2439 ha) (see **Appendix CC** JKC_SITE_MAP_200_A, 31 August 2012).

Surveys undertaken in September and November 2012 show the area cleared at the date of survey, the area cleared and grubbed, the area of Mangrove vegetation cleared and the area of stripped soil.

No final clearing survey was provided to URS for inclusion in this report.

No vegetation health assessment or monitoring records were provided to URS for inclusion in this report.

9.2 Fauna Monitoring

The fauna management Project objective was to avoid disturbance to fauna outside the approved clearing footprint. Additional fauna management objectives listed in the CEMP include avoiding injury/death to native fauna resulting from clearing, vehicle strikes and entrapment. The fauna monitoring methodology is not explicitly stated in the EIMP however the CEMP (JKC 2012) states that the mitigation measure for the fauna management objectives included engaging wildlife handlers during clearing operations to salvage and relocate native animals to areas away from the CWA.

The CEMP states that surveys of terrestrial vertebrate fauna were undertaken during the dry season in late October 2005 and at the end of the wet season in May 2008. In total, 148 vertebrate species were recorded in the fauna survey, including nine species of mammal (of which four were bats), 106 birds, 22 reptiles and 11 frogs (JKC 2012).

Wildlife handlers were present on site and worked ahead of and with clearing machinery during clearing operations conducted in April, May and July 2012. This work was undertaken by specialist consultants in accordance with NT wildlife permits (Permit to Interfere with Protected Fauna, *Territory Parks and Wildlife Conservation Act*). A report was prepared by the consultancy at the conclusion of the staged clearing operation that provided details on native animal relocations, injuries and deaths. All reports are proved in **Appendix DD**. Mammals (including bats), reptiles, birds and amphibians were recorded during the surveys. Mammals and reptiles were relocated where possible. Injured animals were reported and passed to a wildlife carer. Native animal deaths were also recorded.

Pre-clearance fauna load reduction was undertaken by wildlife specialists from 12 to 27 April 2012 during clearing works.

Wildlife spotters / catchers returned to site to relocate or catch injured native animals throughout the clearing conducted between 31 April to 12 May 2012.

Wildlife spotters / catchers returned to site to relocate or catch injured native animals throughout the clearing conducted between 13 July to 1 August 2012.

Additionally the primary sub-contractor gained NT wildlife permits (*Permit to Interfere with Protected Fauna, Territory Parks and Wildlife Conservation Act*) to enable them tocathc and relocate wildlife encounterd on site. The primary sub-consultant maintained a fauna register to detail fauna sightings, injuries and deaths. The register is provided in **Appendix DD**.

Weed Monitoring

Section 2.4 of the EIMP details the scope of the EIMP and includes weed monitoring. **Table 10-1** details the frequency and monitoring methodology of the weed monitoring program. The weed management Project objective was zero introduction and spread of new weeds.

Table 10-1 Environmental Impact Monitoring Program - Weed Monitoring

Monitoring Program	Frequency	Monitoring Methodology
Weed Monitoring	Quarterly	Visual inspection to review onsite weed management efficacy. Weed locations will be captured by DGPS and newly identified weed locations will be incorporated into the weed inventory.

The weed monitoring program was undertaken by third parties and as such no analyses is undertaken here. This section provides an overview of the work undertaken to meet the requirements of the EIMP weed monitoring only.

The purpose of the weed monitoring is to protect the vegetation fringing the site areas. Monitoring of the vegetation was achieved through visual inspection, collection of GPS data and review of trends in health and weed species compositions. Quarterly reports were not provided to URS for inclusion in this report.

A field survey of weeds in terrestrial habitats was conducted by consultant scientists at the site between 1 and 6 March 2012. The survey documented the distribution, diversity and abundance/density of weeds within the Blaydin Point project area and provided GPS records of weed locations. This survey found that the number of weed species had not increased on the site however the distribution of weeds had increased. **Appendix EE** provides a copy of the summary report and the database of weed locations and GPS records.

Weed treatment was undertaken on site by a weed treatment company on 6 – 8 March with follow up control on 21 and 24 April. Aerial application of herbicide to the large stand of Cenchrus (Pennisetum) in the borrow pits occurred on 27 March. **Appendix EE** provides a copy of the report.

A survey was conducted by consultant scientists to reassess the distribution, diversity and abundance/density of weeds within and adjacent to the site and to assess the effectiveness of the weed treatment program on 28, 29 March and 3 April 2013. This survey found that the number of weed species had not increased on the site and that the area of weed occurrence had decreased indicating that weed treatment had been effective to control the spread of weeds off site. **Appendix EE** provides a copy of the report.

Summary of Environmental Observations

Blaydin Point site works conducted between April 2012 and April 2013 consisted primarily of civil works. Based on field observations and laboratory results, the following activities were identified to be the potential influences of environmental disturbance to off-site areas:

- Vegetation clearing;
- Cut and fill;
- Dynamic replacement ground improvement
- Drainage works and AAS treatment areas / hard stands; and
- Road works and facility installation.

These activities are discussed below with regards to monitoring conducted between April 2012 and April 2013.

Vegetation Clearing

Vegetation clearing includes grubbing and mulching, which removes flora, exposing soils beneath. Exposed soils have potential to erode the terrestrial environment and be transported by fallen rainwater to receiving environments such as mangrove communities and surface water bodies. Additionally, the removal of vegetation can increase wind speeds across the exposed surface, potentially increasing dust transport across the terrestrial environment.

Although dissolved solid concentrations increased in surface water samples collected in Darwin Harbour, it could not be concluded these changes can be attributed to on-shore construction works, dredging, or typical seasonal fluctuations associated with the on-set of the rainy season.

TSS analyte would be likely to be impacted during vegetation clearing. TSS levels recorded in Darwin Harbour (**Chart A4**) are shown as higher in June 2012 and in January 2013. January 2013 TSS levels could potentially be linked to the rainfall run-off bringing debris and dirt to the surface water environment. It is not clear at this stage if the vegetation clearing activities (started in June 2012) would have impacted on the June 2012 TSS levels. It is suspected that the tidal processes are dominating the datasets collected.

Mangrove community health and tree condition data indicate that mangroves at the monitoring sites adjacent to the Blaydin Point site have remained in a healthy condition with no evidence of deterioration in mangrove health related to the vegetation clearing activities.

With the onset of wet season rainfall, surface water flows mobilised fine silts along the edge of the project site resulting in thin veneers (1 to 3 mm thickness) being deposited over mangrove muds at a few localised areas (three mangrove monitoring sites). Thin veneers of this thickness present no potential threat to the mangroves and it is expected that the veneers will be re-worked by the suite of invertebrate fauna that inhabit the mangrove substrates (bioturbation processes). The use of mulch banks around the perimeter of the site have formed an effective barrier to sediment contained within surface water from moving into adjacent mangrove areas. In many areas around the site it was evident that fine silts had been deposited on the landward side of the mulch banks with little or no silt deposition occurring on the mangrove or seaward side of the banks.

The vegetation and site clearance activities were occurring at the time when 172 exceedances across three of the four monitoring stations were recorded. This was the fourth most common activity occurring during recorded exceedances. Based on the data collected during the monitoring program, the site clearance activities could not be attributed to exceedances recorded near the sensitive

11 Summary of Environmental Observations

receptors in Palmerston. Vegetation clearing did not raise noise to levels beyond the general trend of noise levels during the first stage of construction activities. The noise sources used during these activities, which in majority would have been excavators, backhoe loaders and dozers, are broadband non-impulsive type of noise sources. These noise sources, spatially spread over the site, were not flagged for triggering any nuisance at noise sensitive receptors (i.e. in Palmerston).

Ongoing impacts to flora and fauna (other than mangrove communities) cannot be assessed based on the records provided by third-parties. Records of vegetation health assessments were not provided to URS for inclusion in this report. Reports of the results of wildlife handlers indicate that several species of mammals, birds, reptiles and amphibians were relocated to alternative habitats, passed to a wildlife carer where they were injured or were reported deceased. Fauna encounters (observations, injuries and deaths have been reported by the primary sub-contractor in a register however no records beyond 27 September 2012 have been entered suggesting that the register may be incomplete.

Pre-clearance and post-clearance weed surveys conducted by third parties state that no new weed species have been introduced to the site and that overall there has been a reduction in the weed speciesd diversity, distribution and abundance on the site as a result of weed management. Ongoing weed management strategies were recommended for NT listed weed species (Gamba grass, Mission grass and Hytis).

Bulk Earthworks

Bulk earthwork activities include removal and relocation of insitu material from high areas to low areas of the site. Bulk earthwork activities have potential to further erode the terrestrial environment, as indicated in association with vegetation clearing. Bulk earthwork activities also have potential increase the amount of vehicular traffic in areas susceptible to erosion. Increased movement of soils around the site and subsequent handling and stockpiling may generate dust. This increased traffic has potential to increase airborne dust and noise. Cut and fill changes surface topography, which can vary ancipated patterns of surface water drainage.

Bulk earthworks undertaken to form the alignment of Area 11A and the ground flare area (Area 12) have modified tidal flows and caused localised ponding impacts to mangroves within and outside of the site boundary. Rehabilitation of these areas is being investigated with emphasis based on restoring the appropriate tidal hydrology and utilising natural mangrove propagule (mangrove seed/seedling) recruitment for re-vegetation and on-going monitoring.

Bulk earthwork activities were occurring at the time when 197 exceedances across three of the four monitoring stations were recorded. This was the third most common activity occurring during recorded exceedances. Based on the data collected during the monitoring program, the site clearance activities could not be attributed to exceedances recorded near the sensitive receptors in Palmerston.While dust coatings on mangrove canopies were observed at some mangrove monitoring sites adjacent to the earthworks in September 2012 there has been was no indication that physiological function of the mangroves had been impaired or the health of the mangroves had deteriorated due to the dust. The dust coatings on mangrove canopies have been of a transient nature determined by the extent of earthworks activity at particular locations and the onset of the wet season. Mangrove monitoring surveys undertaken in December 2012 and March 2013 surveys noted that significant rainfall had washed dust from the canopies and the dust coatings were no longer evident.

11 Summary of Environmental Observations

Surface water samples collected from on-site sediment basins reported concentrations of aluminium above control site concentrations and although dust composition samples were not collected, it may be concluded that the potential exists for air-borne dust to affect receiving surface water bodies. The contribution of noise from earthworks was in general similar to that during the vegetation clearing stage, based on excavators and dozers being the main sources of noise.

Ground Improvement

Ground improvement includes dynamic replacement, stone columns and dynamic consolidation. These activities may affect low-lying estuarine areas, particularly dynamic replacement techniques which have potential trigger ASS and affect the surrounding sediments, mangroves, groundwater and/or surface water receptors. As ground improvement was undertaken between June 2012 and April 2013, and has potential to affect off-site areas. Ground improvement has potential to affect soil permeability, soil porosity, groundwater retention, and surface water flow and infiltration. This is includes but is not limited to dewatering, which has potential to expose or create ASS.

pH would be the analyte showing if the surface water environment have been impacted by ASS. The marine and terrestrial pH dataset do not present any abnormalities that could be due to uncovering ASS locations.

TSS analyte would be likely to be impacted during ground improvements. TSS levels have been detected at higher levels at the BPSW sites compared to the control sites, which could be attributed to higher velocities and water movements typical of the inter-tidal environments. It is therefore not clear at this stage if ground improvements have impacted on TSS levels in Darwin Harbour. It is suspected that the tidal processes are dominating the datasets collected.

With but one exception, impacts to groundwater directly attributable to ground improvement activities are not immediately apparent due to insufficient monitoring data. However, it should be noted that groundwater monitoring bores could not be installed in the areas of the groundwater improvement works prior to commencement of those works. The one exception is monitoring bore BPGW28, where EC increased dramatically between November and December 2012 before decreasing somewhat in January and February 2013. This sharp increase in EC is likely related to drainage issues and subsequent ponding that was noted in the mangrove areas adjacent to Area 11A in November 2012.

Monitoring data collected from mangrove areas located outside of the site boundary indicate that there has been no disturbance to mangrove sediments or any associated deterioration of mangrove health that can be attributed to ground improvement works. Ground level and sediment quality data and observations made at the mangrove monitoring sites showed no change to ground levels or surface sediments that would indicate the formation of mudwaves or other ground disturbance features that could potentially occur from ground improvement works.

There were several instances and areas where ground improvement works were occurring and the influence on the ambient dust concentration was dependent on where the activities were, their duration, the wind direction speed and moisture content. Each of the ground improvement works were occurring when exceedances were recorded by the dust monitoring stations. Ground improvement works at site location area 3B, was the fifth most common activity contributing to respirable ambient dust concentration exceedances. Ground improvement at area 7 was the least common. Refer to Table 7-4 for the full list. Based on the data collected during the monitoring program, the site clearance activities could not be attributed to exceedances recorded near the sensitive receptors in

11 Summary of Environmental Observations

Palmerston.Airborne noise generated from ground improvement activities are difficult to distinguish from other activities that occurred simulataneously on site. The were varied, spatially spread across various areas within the site and ongoing for over ten months, The characteristics of the noise generated by these activities are broadly varied, including broadband type of noise, occasionally impulsive and typically identified as steady over 12 hours of construction. No correlation has been identified between these activities and atypical noise emissions,

Drainage works and ASS Treatment Areas / Hard stands

Mangrove sediment quality data and observations made during wet season monitoring indicate that freshwater surface water flows and seepage is still occurring within the hinterland fringe mangrove zone and there is no evidence that modifications to surface water flows, drainage or seepage within and along the perimeter of the project site has resulted in any changes to mangrove health. This wet season freshwater input which emanates from adjacent terrestrial areas (i.e. the project site) is required for the maintenance of the hinterland fringe mangrove zone (Semeniuk 1983 and 1985). Mangrove community health and tree condition data at monitoring sites located within the hinterland fringe mangrove zone at Blaydin Point show that the mangroves have remained in a healthy condition similar to control sites.

Dust emissions related to drainage related works, and ASS treatment and hardstands are less widespread than the other activities described. Of those activities that fall within this topic, preparation of the the acid sulphate soils pad was most common of these activities that contributed to ambient respirable dust exceedances)131 instances).Construction of the turkey's nest, reinforced concrete pipe installation area 8 were occurring when 26 exceedances were recorded and laydown of hardstanding in area 3a was occurring when 23 exceedances occurred. Based on the data collected during the monitoring program, these site activities could not be attributed to exceedances recorded near the sensitive receptors in Palmerston.

Road Works and Construction of Hard Stand Areas

The installation of permanent and temporary roads has potential to increase erosion and dust issues associated with increased personnel and subsequent traffic on site. Construction of hard stand areas also reduces permeability of surfaces and increases sheet flow which may result in surface water discharge and scour. Road and hard stand installations may include use of potentially contaminating materials including pre-coated fine crushed rock, concrete, bitumen and other hydrocarbons.

Hydrocarbons were not detected in the surface water environment of the Darwin Harbor. Higher turbidity and TSS observed in the BPSW sampling locations compared to the control sites could be attributed to rainfall run-off discharges due to rainfall during the wet season. It is not clear if road works impacted on the surface water environment.

Dust Preparation of site access road 3B. 1A and Area 8 were all in operation when exceedances were recorded by the dust monitoring stations. These are listed in decreasing occurrances, (150, 37, 18 respectively). It should be remembered that the existence of the road is once source from windblown dust, deposited by vehicles, the other is from vehicle exhausts themselves, more specifically from diesel engines. Based on the data collected during the monitoring program, these activities could not be attributed to exceedances recorded near the sensitive receptors in Palmerston.

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Groundwater in the vicinity of the temporary facilities generally reported higher concentrations of dissolved metals and lower pH than other areas of the site; however, the reason(s) for these trends are difficult to quantify given the lack of monitoring data prior to installation of the facilities.

In areas immediately adjacent to major unsealed roadways generally reported higher dust deposition rates.

The above conclusions are to be read in conjunction with limitations detailed in **Section 15** of this report.

12

Suggested EIMP Improvements

The following chapter presents suggested improvements to the current EIMP (Version 6), based on annual monitoring conducted between April 2012 and April 2013, and interpretations of the monitoring contained in this report.

Surface Water

- Additional marine monitoring site mid-way between BPSW27 and CSSW01;
- Four of the existing stations be upgraded to provide continuous measurement of the directly observable analytes. This will provide detailed information on the temporal variation over the tidal, spring-neap and seasonal time scales. Suggested locations include BPSW30, BPSW31, BPSW32 and CSSW02. The analytes that should be measured at these locations are temperature, salinity, turbidity, dissolved oxygen, redox potential and pH. Serie 5 multi-parameter logging probes by OTT are an example of such instruments.

Groundwater

- Install additional data loggers;
- Install planned monitoring bores; and
- A desktop assessment of the potential to identify “reference sites” undertaken by URS and JKC to determine alternative assessment of the site against ANZECC criteria.

Mangrove Community Health, Sediments and Bio-indicators

- Regular surveillance inspections of mangroves around the perimeter of the site to look for evidence of mangrove stress/dieback and ponding (e.g. monthly frequency to be undertaken around low tide during a neap tide phase). This could be aligned with regular perimeter inspections that are undertaken by on-site environmental staff as part of other CEMP related monitoring and management commitments
- Monitoring within mangrove areas affected by ponding impacted to determine the tidal inundation regime once drainage and rehabilitation works are implemented and to assess mangrove seedling recruitment

Air Quality (Dust)

- Revise locations of ambient respirable dust monitoring to more closely reflect sensitive receptor locations after full 12 months of monitoring has been completed.

Airborne Noise

- The CWA site monitoring location (BPPM01) could be improved to capture construction noise from a more spatially centric location towards the north-east end of the site;
- It is recommended that an estimation of the typical noise reduction between the CWA site boundary and the sensitive receptors be modelled to set “trigger” noise levels at the construction site. This will enable a better control of the noise emissions from site and will assist the contractor in understanding when construction noise levels are at risk of triggering an exceedance at the sensitive receptors. Noise modelling calculations, which can factor in variables such as distance, wind speed and direction, meteorological conditions and topographical screening can be used to determine the noise reduction between the site and the receptors.

12 Suggested EIMP Improvements

- For compliance assessment purposes, the noise criteria which is currently applied to the site monitoring results (BPPM01) should be replaced by the calculated trigger noise levels specified in the previous point.

No suggested EIMP improvements to the flora, fauna and weed monitoring is required.

13

Glossary

"A" Frequency Weighting

The method of frequency weighting the electrical signal with a noise measuring instrument to simulate the way the human ear responds to a range of acoustic frequencies. It is based on the 40 phon equal loudness contour. The symbols for the noise parameters often include the letter "A" (e.g. L_{Aeq}) to indicate that frequency weighting has been included in the measurement.

Alkalinity

Alkalinity is a measure of a water sample's ability to neutralise an acid or, in other words, how much acid can be added to the water without causing a significant change in pH. There are three types of alkalinity: carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and hydroxide (OH^-); total alkalinity is the sum of all three.

Ambient Noise

The all-encompassing sound at a site comprising all sources such as industry, traffic, domestic, and natural noises. It does not include a contribution from the noise source under assessment. It is represented as the L_{Aeq} noise level in environmental noise assessment (See also L_{Aeq}).

Background Noise

Background noise is the term used to describe the underlying level of noise present in the ambient noise, measured in the absence of the noise under investigation, when extraneous noise is removed. It is measured statistically as the A-weighted noise level exceeded for ninety per cent of a sample period. This is represented as the L_{A90} noise level.

dB (Decibel)

A unit of sound level measurement. The human ear responds to sound logarithmically rather than linearly, so it is convenient to deal in logarithmic units in expressing sound levels. To avoid a scale which is too compressed, a factor of 10 is introduced, giving rise to the decibel. It is equivalent to 10 times the logarithm (to base 10) of the ratio of a given sound pressure to a reference pressure.

Dissolved Oxygen (DO)

Dissolved oxygen, or DO, is a measure of the amount of oxygen dissolved in water. DO is important to aquatic ecosystems, and can affect the stability of trace metals and organic contaminants.

Duplicate Sample

A duplicate sample is a sample that is collected concurrently from the same location and under the same conditions as the primary sample. When analysed by the same laboratory, comparison of primary and duplicate sample results provides a measure of the precision of those results.

Electrical Conductivity (EC)

Electrical conductivity, or EC, is a measure of a water sample's ability to transmit an electrical current. Water that is high in dissolved salts (ions) such as chlorides, sulphate, carbonates, sodium, calcium,

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magnesium and potassium has a greater ability to transmit electricity. Consequently, EC provides an indirect measure of salinity.

Equipment Rinsate Blank

An equipment rinsate blank, or rinsate blank, is a water sample whose purpose, upon analysis, is to provide evidence of possible cross-contamination between sampling locations due to failure to adequately decontaminate the sampling equipment. The equipment rinsate blank is collected by dispensing analyte-free water over the sampling equipment that is utilised at two or more monitoring locations.

Extraneous Noise

Noise resulting from activities that are not typical of the area. Untypical activities may include construction, and traffic generated by holiday periods and by special events such as concerts or sporting events. Normal daily traffic is not considered to be extraneous.

Field Blank

A field blank is a water sample whose purpose, upon analysis, is to provide evidence of ambient field contamination which may affect analytical results. The field blank is a sample of analyte-free water that is decanted from the laboratory-supplied container into the appropriate sampling container whilst at a sampling location where ambient field contamination is most likely to occur.

Free Field

An environment in which a sound wave may propagate in all directions without obstructions or reflections. Free field noise measurements are carried out outdoors at least 3.5 m from any acoustic reflecting structures other than the ground.

Frequency

Frequency is synonymous to pitch and is measured in units of Hz.

Hardness

Hardness is measure of the amount of multivalent ions, typically calcium and magnesium ions, which are present in water. Hard water is generally not harmful to one’s health but can result precipitation of scale on water heaters and other equipment.

Impulsive Noise

Noise having a high peak of short duration or a sequence of such peaks. Noise from impacts or explosions, e.g., from a pile driver, punch press or gunshot, is called impulsive noise. It is brief and abrupt, and its startling effect causes greater annoyance than would be expected from a simple measurement of the sound pressure level.

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Intermittent Noise

Noise with a level that abruptly drops to the level of or below the background noise several times during the period of observation. The time during which the level remains at a constant value different from that of the ambient being of the order of 1 s or more.

$L_{Aeq(12hr)}$

A-weighted equivalent continuous noise level. This parameter is widely used and is the constant level of noise that would have the same energy content as the varying noise signal being measured. The letter "A" denotes that the A-weighting has been included and "eq" indicates that an equivalent level has been calculated. This is referred to as the ambient noise level. (See Ambient Noise), The 12hr denotes that exponential averaging has been undertaken over 12 hours.

Limit of Reporting (LOR)

The Limit of Reporting, or LOR, is the minimum concentration of a given analyte that can reliably detected by the laboratory.

Low Flow Sampling

Low flow sampling is a method of collecting groundwater samples from a monitoring bore. With this methodology, groundwater is pumped from the screened interval of the bore at rate comparable with that of natural groundwater inflow into the bore. Advantages to low-flow sampling over other methods include lower purge volumes and a lesser degree of sample agitation.

Matrix Spike

A matrix spike is a sample prepared by the laboratory and whose purpose is to verify that the physical properties of the matrix, e.g. water, do not interfere with the analytical results.

Oxygen Reduction Potential (Redox)

Oxygen reduction potential, or redox, is a measure of a water sample's ability to either gain or lose electrons when a new species is introduced. Water having a positive redox value (oxidising conditions) has a tendency to gain electrons from the new species. Conversely, water having a negative redox value (reducing conditions) has a tendency to lose electrons to the new species. Redox reactions can play a significant role in the fate and transport of contaminants within an aquifer.

Perception of Sound

The number of sound pressure variation per second is called the frequency of sound, and is measured in Hertz (Hz). The normal hearing for a healthy young person ranges from approximately 20 Hz to 20 kHz. In terms of sound pressure levels, audible sound ranges from the threshold of hearing at 0 dB to the threshold of pain at 130 dB and over. A change of 1 dB or 2 dB in the level of a sound is difficult for most people to detect, whilst a 3 dB to 5 dB change corresponds to small but noticeable change in loudness. An increase of about 8 – 10 dB is required before the sound subjectively appears to be significantly louder.

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pH

Water pH is a measure of the water's acidity and is equivalent to the negative log hydrogen ion concentration. Water having a pH of 7.00 is considered to be neutral, a pH <7.00 is considered acidic, and a pH > 7.00 is considered to be alkaline.

Relative Percentage Difference (RPD)

Relative Percentage Difference, or RPD, is a measure of precision between two different sets of laboratory analytical results, e.g. between primary and duplicate samples.

Sound Power Level (SWL)

Sound power is the energy radiated from a sound source. This power is essentially independent of the surroundings, while the sound pressure depends on the surroundings (e.g. reflecting surfaces) and distance to the receptor. If the sound power is known, the sound pressure at a point can be calculated. Sound power is also measured in logarithmic units, 0 dB sound power level corresponding to 1 pW (10^{-12} W). The symbol used for sound power level is SWL or Lw, and it is specified in dB.

Sound Pressure Level (SPL)

Sound pressure is the measure of the level or loudness of sound. Like sound power level, it is measured in logarithmic units. The symbol used for sound pressure level is SPL, and it is generally specified in dB. 0 dB is taken as the threshold of human hearing.

Sound Pressure Levels of Some Common Sources

Sound Pressure Level (dB)	Sound Source	Typical Subjective Description
140	Propeller aircraft; artillery fire, gunner's position	
120	Riveter; rock concert, close to speakers; ship's engine room	Intolerable
110	Grinding; sawing	
100	Punch press and wood planers, at operator's position; pneumatic hammer or drilling (at 2 m)	Very noisy
80	Kerbside of busy highway; shouting; Loud radio or TV	
70	Kerbside of busy traffic	Noisy
60	Department store, restaurant, conversational speech	
50	General office	Moderate
40	Private office; Quiet residential area	Quiet
30	Unoccupied theatre; quiet bedroom at night	
20	Unoccupied recording studio; Leaves rustling	Very quiet
10	Hearing threshold, good ears at frequency of maximum sensitivity	
0	Hearing threshold, excellent ears at frequency maximum response	

Static Water Level (SWL)

Static water level, or SWL, is the depth to the groundwater surface in a monitoring bore, as measured from a reference point, typically the top of the bore casing.

Tonality

Noise containing a prominent frequency and characterised by a definite pitch

13 Glossary

Total Dissolved Solids

Total Dissolved Solids, or TDS, is a measure of the combined dissolved content of organic and inorganic substances in a water sample.

Trip Blank

A trip blank is a sample of analyte free water that is placed in the same container as the primary samples, taken to site and transported in the same manner as the primary samples, and delivered to the laboratory for analysis. The purpose of the trip blanks is to assess whether cross-contamination may have occurred between samples between the time of sampling and transport to the laboratory.

Triplicate Sample

A triplicate sample is a sample that is collected concurrently from the same location and under the same conditions as the primary and duplicate samples. Unlike the primary and duplicate samples, however, triplicate samples are analysed by a different laboratory. Comparison of primary and triplicate sample results provides a measure of the precision of the results and of the laboratories as well.

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Limitations

This Report is provided strictly in accordance with and subject to the following limitations:

a) This Report was prepared for **JKC** in accordance with normal prudent practice and by reference to applicable environmental regulatory authority and industry standards, guidelines and assessment criteria in existence at the date of this Report, and any previous site investigation and assessment reports referred to in this Report.
b) This Report has been prepared for the sole benefit of **JKC** and neither the whole nor any part of this Report may be used or relied upon by any party other than **JKC**
c) This Report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by URS for use of any part of this Report in any other context.
d) This Report is based solely on the scope of work agreed between URS and **JKC** and described in section 1.5.1 ("Statement of Scope") of this Report.
e) This Report should be read in conjunction with the Attached Reports. No responsibility is accepted by URS for use of this Report in any other context.
f) This Report is based solely on the investigations and findings contained in the Attached Reports and on the conditions encountered and information reviewed at the time of preparation of each Attached Report.
g) This Report is subject to all limitations and recommendations included in the Attached Reports.
h) Where any Attached Report indicates that information has been provided to URS by third parties, URS has made no independent verification of this information except as expressly stated in the Attached Report.
i) URS has only considered those chemicals specifically referred to in this Report. URS makes no statement or representation as to the existence (or otherwise) of any other chemicals.
j) This Report has been prepared to address on-site contamination issues only (within the context of and limited to the Scope of Work).
k) Investigations undertaken in respect of this Report are limited to the site areas.
l) Investigations undertaken prior to this Report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and contamination may have been identified prior to this Report.
m) Subsurface conditions can vary across a particular site and cannot be exhaustively defined by the investigations carried our prior to this Report. It is unlikely therefore that the results and estimations expressed or used to compile this Report will represent conditions at any location removed from the specific points of sampling.
n) A site which appears to be unaffected by contamination at the time the Attached Reports were prepared may later, due to natural phenomena or human intervention, become contaminated
o) Except as specifically stated above, URS makes no warranty, statement or representation of any kind concerning the suitability of the site for any purpose or the permissibility of any use, development or re-development of the site.
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q) URS makes no determination or recommendation regarding a decision to provide or not to provide financing with respect to the site.
r) The ongoing use of the site and/or the use of the site for any different purpose may require the owner/user to manage and/or remediate site conditions, such as contamination and other conditions, including but not limited to conditions referred to in the Attached Reports.






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