Onslow Water Infrastructure Upgrade Project

High-Level Risk Assessment on Constituents (excluding NORMs) of the Residual Saline Stream

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Report

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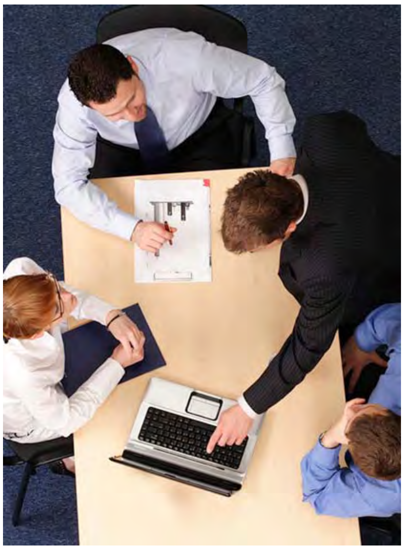
Prepared for:
Chevron Australia Pty Ltd

Prepared by URS Australia Pty Ltd



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ABBREVIATIONS

Abbreviation	Description
ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Average Recurrence Interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BPPH	Benthic Primary Producer Habitat
DIN	dissolved inorganic nitrogen
DIP	dissolved inorganic phosphorous
DON	dissolved organic nitrogen
EPA	Environmental Protection Authority
GL	gigalitres
ha	hectares
kg	kilogram
km	kilometres
m	metre
m^3	cubic metre
m AHD	metres above Australian Height Datum
MDL	Minimum Detection Limits
mg/L	milligrams per litre
N	Nitrogen
$\delta^{15}N$	nitrogen isotope signature
NOAEL	no-observed-adverse-effect level
NTU	Nephelometric Turbidity Units
P	Phosphorous
RSS	Residual Saline Stream
PSU	Practical Salinity Units
TDN	Total dissolved nitrogen
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total phosphorous
w/w	weight per weight
USGS	The United States Geological Survey
RO	reverse osmosis

1 BACKGROUND

1.1 Introduction

Chevron and the Water Corporation are proposing to increase the supply of potable water to the town of Onslow by 2 ML/day. The proposed potable water supply involves the Birdrong Aquifer as a source, with Reverse Osmosis (RO) treatment of the saline groundwater prior to distribution. The RO treatment would produce a Residual Saline Stream (RSS) by-product.

The preferred disposal strategy for the RSS is discharge to Quick Mud Creek in the vicinity of the proposed RO plan downstream of Wheatstone Road. Quick Mud Creek is a tributary of Hooley Creek and is situated within the Ashburton River Delta. Stream flow in Quick Mud Creek is episodic; the watercourse is predominantly dry except during and after episodic stream flow events. Commonly during the dry periods there is natural accumulation of salt, minerals and metals on the low-flow and incised channels of the watercourse and on the supratidal saline flats that span the terrain between Quick Mud Creek and Hooley Creek. As such, the disposed RSS would also accumulate on Quick Mud Creek during dry periods, with subsequent dissolution and mobilisation of accumulated salt, minerals and metals by stream flow events. When the Ashburton River is in flood, its flood waters also commonly (approximate every two years) contribute to the stream flow in Quick Mud Creek and Hooley Creek. The stream flow events are high-energy occurrences typically characterised by fresh water with high sediment and suspended solids loads.

The mobilised RSS would be transported to tidal creeks within the Hooley Creek – Four-Mile Creek tidal estuary and thereafter to the sea. Flow paths for and presence of the RSS constituents in the Hooley Creek – Four-Mile Creek tidal estuary would provide potential temporary interactions with the ecology of the tidal creeks. This ecology includes algal mats and mangrove forest receptors and associated habitats.

There is risk that the RSS disposal and constituents would influence the ecology on flow paths downstream of Quick Mud Creek and in the Hooley Creek – Four-Mile Creek tidal estuary.

The environmental risk assessment associated with the RSS should be read in conjunction with several other reposts under circumstances where additional context is sought. These other reports were also prepared in associated with the Onslow Water Infrastructure Upgrade Project. The additional reports include:

- URS (January 2013) Onslow Water Infrastructure Upgrade Project - Alternative Assessment of Brine Disposal. Reference: WS0 9210 SIF RPT URS 000 00001-000.
- URS (April 2013); Onslow Water Infrastructure Upgrade Project - Definition of Impediments to Residual Saline Stream Disposal. Reference: WS0 9210 SIF RPT URS 000 00002-000.
- URS (January 2014) Onslow Water Infrastructure Upgrade Project - Conceptual design for Injection of the Residual Saline Stream. Reference: WS0 9211 RSK RPT URS 000 00004-000.
- URS (March 2014); Onslow Water Infrastructure Upgrade Project - NORM Risk Assessment at Quick Mud Creek. Reference: WSO 9211 RSK RPT URS 000 00003-000.

1.2 RSS Volumetric and Constituent Specifications

The proposed rate of RSS disposal into Quick Mud Creek is 857 kL/day. This disposal rate is a maximum and assumes the RO plant is operating at its peak. This disposal rate has been limited and optimised through revisions of the RO plant efficiency.

Specifications of the expected RSS constituents are provided in **Table 1-1** (Worley Parsons, 2014). The RSS constituents include:

- Metals (aluminium, barium, copper, lead, nickel, strontium, zinc and others).
- Non-metals (bromide and iodide).
- Metalloid semi-conductors (boron and silica).
- Nutrients (nitrogen and phosphorus).
- Anti-scalant and cleaning agents.

The daily and annual mass of the RSS constituents in Table 1-1 would be about 80 and 29,000 tonnes, respectively.

The RSS specifications also address two scenarios (Scenario1 and Scenario 2) characterised by:

- **Scenario 1:** The nitrogen and phosphorus concentration has been based a total of 11 mg/L of PC191T anti-scalant dosage. The PC191T anti-scalant contains:
  - 6.82 to 9.23 per cent weight/weight (w/w) as P and / or 20.9 to 28.3 per cent w/w as PO_4.
  - Nitrogen content is 1.16 per cent w/w as N from active concentration.
- **Scenario 2:** The nitrogen and phosphorus concentration from anti-scalant dosage has been removed through the use of an alternative anti-scalant product.

In both scenarios, cleaning agents are proposed to be used in three-month campaigns, with discharge for a period of 24-hours during each campaign. The Scenario 2 RSS constituents reflect a focus on limiting nutrient, particularly phosphorous, inputs to the local environment.

1.3 Report Objectives

It was recognised that a number of the RSS constituents may occur in concentrations and or loadings with potentials to provide risks to the existing environments of Quick Mud Creek, the supratidal saline flats and Hooley Creek – Four-Mile Creel tidal estuary. As such, this report objective was to provide a desktop environmental risk assessment that considered the RSS constituents in context to potential for environmental change and or harm to the downstream receiving environments. Note that the environmental risk assessment was solely based on the Scenario 2 RSS constituents.

This environmental risk assessment reviews models of the RSS footprints in the Hooley Creek –Four-Mile Creel tidal estuary in context to potential for environmental risk and harm. This assessment considers worst-case RSS footprints in context to the local and regional hydrology, baseline water quality data, ANZECC & ARMCANZ (2000) guidelines and reference material that provides analogies to relevant case-studies. The risk assessment was informed by mass balance assessments of the RSS constituents in context to selected (0.1, 0.5, 1 and 2-year) periods of accumulation on Quick Mud Creek and subsequent transport and fate downstream of Quick Mud Creek (thus on the supratidal saline flats and in the Hooley Creek – Four-Mile Creek tidal embayment) by low-volumes stream flow events. In this regard it was recognised that the longest periods of RSS constituent accumulation when considered together low-volume stream flow events would provide unlikely worst-case scenarios for the RSS constituent concentrations (source terms) in the stream flow.

It was also recognised for the environmental risk assessment that the Hooley Creek – Four-Mile Creek tidal embayment hosts the habitats of mangroves, mud flats and algal mats that have conservation significance (URS, May 2010). Consequently, these habitats form the focus of the environmental risk assessment.

Table 1-1 RSS Quality Data

RSS Constituents	Units	Scenario 1	Scenario 2
pH		7.78	
Turbidity	NTU	<1	
Dissolved Organic Carbon	mg/L	3.3	
Organic Nitrogen - N		3.3	
Ammonium (as NH_4)		29.5	
Sodium		15,429	
Potassium		484	
Calcium		962	
Magnesium		653	
Copper		0.09	
Lead		0.003	
Nickel		0.057	
Zinc		0.117	
Aluminium		0.017	
Barium		8.7	
Iron		0	
Strontium		28.3	
Manganese		0	
Chloride		26,652	
Bromide		89.6	
Iodide		5	
Nitrogen		0.43[1]	0[2]
Phosphorus		3.38[1]	0.02[2]
Phosphate		4.72[1]	0[2]
Sulphate		17.3	
Bicarbonate		1,940	
Fluoride		3.3	
Sulphur		0.4	
Boron		16.2	
Silica		78.9	
Total Dissolved Solids		46,418	
Citric Acid		114	
Sodium Lauryl Sulphate		2.85	

Notes:

NTU refers to Nephelometric Turbidity Units.

1 The nitrogen and phosphorus concentration has been based a total of 11 mg/L of PC191T anti-scalant dosage as per Scenario 1.

2 The nitrogen and phosphorus concentration from anti-scalant dosage has been removed as per Scenario 2.

2 SETTING CONCEPTUALISATION

The setting conceptualisation has been addressed considering local landforms, observations of baseline range of water qualities and ecology of the tidal creeks. Conceptual aspects of each are discussed below, providing relevant context to the natural environment.

2.1 Landforms

The local setting has been subdivided into five geomorphological landforms. Each landform functions differently in context to the surface water and groundwater environments and also in respect of terrestrial and marine habitats. The five geomorphological units include:

- Ashburton River and immediate Delta.
- Hooley Creek – Four-Mile Creek Tidal Embayment, with predominant habitats that include:
  - Mangroves.
  - High Tide Mud Flats (Bioturbated/Samphire).
  - Algal Mats.
- Supratidal saline flats.
- Quick Mud Creek.
- Dunes Terrain.

Each geomorphological unit is discussed below and shown on **Figure 2.1** to support the conceptualisation of RSS constituent influences, transport and fates downstream of source areas on Quick Mud Creek.

The proposed RSS disposal into Quick Mud Creek and with subsequent mobilisation within the Hooley Creek – Four-Mile Creek tidal estuary would not have a direct influence on the Ashburton River and delta. Notwithstanding, these landforms are discussed because they provide context to the characteristics of the local environments.

2.1.1 Ashburton River and Delta

The catchment of the Ashburton River covers 78,777 km^2. Commonly rainfall is inconsistent and widely variable over the catchment leading to variable stream flow responses after rainfall.

The Ashburton River was initially mapped in 2001 (OzCoasts, Geoscience Australia, 2013) and classified to be predominantly in unmodified condition. The classification included description of a wave-dominated delta that hosted variable landforms and associated habitats. Wave-dominated deltas (OzCoasts, Geoscience Australia, 2013) are typically characterised by:

- Episodic river flows that invade the delta with large volumes of fresh water. The observed (Ruprecht & Ivanescu, 2000) maximum duration of zero flow for the Ashburton River is 14 months. When in flow, the large fresh water volumes tend to temporarily displace the seawater from the delta and flush the local watercourses on the delta. During river flow, salinity in the Ashburton River Delta decreases. At these times, seawater ingress is reduced and the delta becomes temporarily fresh.

- Turbidity is naturally low. Exceptions occur during times of that the river is in flow and within high-energy tidal reaches of the local creeks. At times of stream flow, the turbidity is commonly very high.
- Sediments loads during the episodic flow events tend to be predominantly discharged into the sea. Residence times for stream flow in the delta tend to be short, providing comparatively limited opportunities for the trapping and or processing of both sediment and nutrients within the deltaic landscape.
- Sub-tidal, inter-tidal and supra-tidal habitats are variable, being exposed to transient changes in energy, salinity, sediment load, and turbidity. Typically, there is a low risk of habitat loss linked to sedimentation in these settings.

Generally, stream flow in the Ashburton River is fresh, with salinity about 130 mg/L TDS (Ruprecht & Ivanescu, 2000). The annual flow volumes gauged at Nanutarra Bridge in the period from 1973 to 2008 averaged 840 GL (URS, May 2010). Typically, stream salinity is higher with low flows and lower with high flows. When in flow, however, the Ashburton River mobilises sediment. The turbidity ranges from less than 10 NTU (about 15 mg/L TSS) at low flows of 30 m^3/sec, to 3 300 NTU (about 5 000 mg/L TSS) at a flow rate of around 250 m^3/sec (URS, 2009). The flow-weighted turbidity for Ashburton River is 1,705 NTU and the annual average sediment load has been interpreted to be in the order of 1.3 million tonnes (URS, 2009). This load is widely variable dependent on river flow. The interpreted total annual sediment load in the period from 1973 to 2008 ranged from 450 tonnes (in 2007 during a low flow event) to 13.8 million tonnes (in 1997 during a major flood event).

When in flood, stream flow from the Ashburton River commonly (approximate every two years) contributes to the stream flow in Quick Mud Creek and Hooley Creek. Broad surface water flow characterisations of the Ashburton River and delta (URS, May 2010) indicate that the catchment divides, between the Ashburton River and Hooley Creek are of low topographical relief. During stream flow events typically less frequent than 2-year Average Recurrence Interval (ARI), the Ashburton River spills into the adjoining catchments, forming a broad flood plain within the delta. As such, the Ashburton River affects flood levels and stream flows in Quick Mud Creek and Hooley Creek. For stream flow event ARIs of less than two years, the local catchments function independently, with surface water flow linked with topography.

The characteristics and constituents of the sediments loads transported by the Ashburton River have not been analysed and defined. It was anticipated, however, that the sediment and suspended solids loads would host significant amounts of salt, minerals, metals and nutrients. These constituents would temporarily invade the Ashburton River Delta during periods during and in the short-term after stream flow events.

The Ashburton River Delta is an accretionary sedimentary feature at the mouth of the Ashburton River. Sedimentary accretion is active to the east of the river mouth driven by terrestrial loadings deposited by stream flow events together with littoral sediment transport system and tidal estuarine deposition. The seaward portions of the delta form intertidal habitats. These habitats were surveyed (URS, May 2010) and observed to include fluvial channels and associated tidal creeks and lagoons, extensive mangal forests and high-tide mud flats.

Portions of the sediments loads that invade to delta during and immediately after stream flow events would be intercepted by the mangal forests and contribute to the accretionary process. Other portions would be temporarily available in supporting food webs and nutrient cycles in the intertidal and coastal habitats; these habitats form sinks for dissolved nitrogen, phosphorous and silica (URS, May 2010; after Alongi, 1996). The wide variability in Ashburton River flow volumes and mass of sediment loads indicates robustness in the intertidal habitats responses to temporary short-term episodic changes in salinity, water column turbidity, mineral and metals loadings and nutrient sources.

The Ashburton River Delta has been identified (Semeniuk, 1997) as a mangrove habitat of unique biogeomorphic characteristics of regional significance, with very high conservation values (URS, May 2010). This status is compatible to that provided in Guidance Statement No. 1 (EPA, 2001) and reflects the highest degree of conservation under environmental protection processes.

2.1.2 Quick Mud Creek

The regional Quick Mud Creek watershed covers 1,811 km^2, representing about 2 per cent of the catchment of the Ashburton River. Local reaches of Quick Mud Creek stretch between Wheatstone Road and the crystalliser ponds of Onslow Salt Pty Ltd (URS, November 2012). The local reaches are approximately 5.5 km in length and characterised by a low-flow channel that is about 70 to 80 m in width. The elevation of the low-flow channel ranges from 0.4 to 1.0 m AHD on the reaches downstream of Wheatstone Road, increasing to 1.0 to 1.1 m AHD where barrier bars occur near the outflow from Quick Mud Creek onto the supratidal saline flats (near the Onslow Salt crystalliser ponds). The variations in creek-bed elevations indicate the potential for stream flow on Quick Mud Creek to be attenuated and pool behind barrier bars.

Within the Quick Mud Creek watercourse and clay pans the vegetation is spare and\or absent, except for perimeter samphire. The denuded watercourse and characteristics salt accumulation in the low-flow channel broadly reflect a continuation of the supratidal saline flats landform characteristics. Bounding the watercourse are wide low-relief alluvial plains that contribute to the Ashburton River Delta. The alluvial plains are interspersed with red dunes that form longitudinal dune terrains. Locally, the longitudinal dunes peak at elevations of 11 to 13 m AHD.

Stream flow in Quick Mud Creek is episodic; similar to the Ashburton River flow occurs after localised and\or regional rainfall events. Typically, there are long periods of no flow and short, episodic events of comparatively high flow. During the dry periods there is natural accumulation of salt, minerals and metals on the low-flow and incised channels of Quick Mud Creek and further downstream on the supratidal saline flats. The natural salt accumulation relates to high evaporation potentials that strip water from residual pools after periods of stream flow and discharge saline and hypersaline groundwater from shallow water table settings beneath Quick Mud Creek. In these settings, selected metals can temporarily accumulate in concentrations that exceed ANZECC & ARMCANZ (2000) guideline values.

When in flow, high turbidity and sediment-laden discharge occurs from Quick Mud Creek onto the supratidal saline flats (that form the upper portions of the Hooley Creek – Four-Mile Creek tidal embayment) and subsequently into the tidal creeks. If the regional water shed

(1,811 km^2) was to respond similarly to rainfall when compared to the Ashburton River, then the annual average hydrological characteristics would include:

- Flow volume of about 19 GL.
- Sediment load of about 30,000 tonnes.

These comparisons are significant when considered in context to transport of the RSS constituents from Quick Mud Creek by simulated stream flow volumes of only 1.195 GL derived from 1-year ARI events generated by the immediate catchment area (Refer to **Chapter 3**, **Table 3.3**).

The denuded and salt sink characteristics of the lower reaches of the Quick Mud Creek watercourse provide credibility that this setting is similar to that of the supratidal saline flats and lacks significant habitats and receptors.

2.1.3 Supratidal Saline Flats

Supratidal saline flats tend to be low-gradient, mostly featureless, predominantly dry environments with a varying degree of vertically accreting algal mat colonisation. These settings typically occur above the typical tidal range, but form groundwater discharge zones from the underlying shallow water table. Groundwater discharge occurs by evaporation and seasonally/episodically from seepage fronts. Sediments typically comprise poorly-sorted sandy silts and clays. The high salinity concentrations (surface water and groundwater) in these environments often preclude the growth of higher vegetation and biota. Samphire shrubs occur on perimeter areas at the interface between the saline flats and the dunes hinterland. The supratidal saline flats form habitats for birds during the wet season.

Inundation by stream flow and or highest astronomical tides may occur only for a few days each year. In these settings, evaporation and associated salt accumulation is a significant process. Salt accumulates due to the evaporation of discharging hypersaline groundwater and residual stream flow. Mineral deposits of gypsum and halite are derived from the salt accumulation. These deposits would host inclusions of metals and nutrients predominantly from terrestrial sources. Selected metals can occur in concentrations that exceed ANZECC & ARMCANZ (2000) guideline values. This aspect is not uncommon in hypersaline waters. The comparative enriched concentrations of selected metals may also reflect the natural characteristics of the terrestrial watershed.

Intertidal habitat surveys (URS, May 2010) that extended onto the supratidal saline flats observed an absence of burrowing crabs and other marine invertebrates associated with this landform setting. The denuded and salt sink characteristics of the supratidal saline flats, similar to the lower reaches of Quick Mud Creek provide credibility that this setting lacks significant habitats and receptors.

2.1.4 Hooley Creek – Four-Mile Creek Tidal Estuary

The West Hooley, East Hooley, Middle and Four-Mile creeks form tidal and stream flow watersheds, termed the Hooley Creek – Four-Mile Creek tidal estuary, the within the wider Ashburton River Delta. The tidal creek watercourses are commonly linear to dendritic-shaped incisions within low-gradient, seaward-sloping landforms of intertidal flats, salt flats supratidal saline flats. The Hooley Creek – Four-Mile Creek tidal estuary is an accretionary sedimentary feature aligned along the Hooley, Middle and Four-Mile creeks and associated micro-deltas. Individual tidal creeks are bounded by narrow mangal stands to the hinterland of which occur extensive areas of mud flats and algal mats (URS, May 2010).

Tidal forces control the flow during the majority of the time; commonly there is no fresh water input. Further, the tidal exchange is limited in efficiency and consequently the headwaters of the tidal reaches tend to accumulate salt due to evaporation losses. Tidal flows also generate turbulence and consequently commonly promote comparatively high water column turbidity. The turbidity may preclude or limit the presence of subaquatic benthic macrophytes (seagrasses) and habitat for phytoplankton.

The tidal forces promote perpetual mobilisation, re-suspension and reworking of the sediment fines. Tidal reaches of the creeks tend to intercept and trap the mobilised fine-grained marine and tide-derived suspended and bed-load sediment, promoting accretion and seaward propagation of the estuarine landforms. Mangrove stands and algal mats within the tidal reaches and intertidal flats form the predominant depositional settings for sediment.

Usually, there is no direct connection between the Hooley Creek – Four-Mile Creek tidal estuary and the Ashburton River or the Ashburton River Delta. Connection to the Ashburton River occurs episodically when flows in the river break the banks and invade wider delta areas, including the Hooley Creek – Four-Mile Creek tidal estuary. Such episodic events occur about every two years on average. At these times, the river flows and contributions from the Quick Mud Creek catchment tend to:

- Impose large volumes of fresh water on the delta, including the Hooley Creek – Four-Mile Creek tidal estuary. These large stream flow volumes may flush the watercourse of accumulated salt and temporarily displace the seawater from tidal reaches. Provide significant terrigenous sediment inputs for the duration of the flow event and for a comparatively limited residence time thereafter. The majority of the sediments tend to be fine grained.
- Dramatically increase the turbidity within the tidal estuary for the duration of the flow event and for a comparatively limited residence time thereafter.
- Sediments loads during the episodic flow events tend to be discharged into the sea. Comparatively short residence times limit the trapping and or processing of both sediment and nutrients.

Nutrients within the tidal creek settings are derived from both terrigenous (including pastoral activities) and marine sources. The terrigenous sources are activated only during runoff events. Tidal flows transport and deposit particulate nitrogen and dissolved organic nitrogen onto mangrove stands and intertidal landforms. From the tidal creek settings, nutrient uptake occurs through plant productivity and microbial activity. For example, particulate (sediment-bound) nitrogen may be processed by sediment-dwelling biota (crabs) and or transported to coastal waters in the form of leaf litter and fine particulate matter. Also, dissolved inorganic nitrogen is converted to particulate nitrogen through the activity of phytoplankton and benthic micro-algae and other sediment-dwelling organisms. Phytoplankton and micro-algae productivity tends to be limited at times of comparatively high turbidity (and associated low light penetration).

Similarly to the Ashburton River, the natural sediment and suspended solids loads in the stream flow from Quick Mud Creek (and Holey Creek) would host significant amounts of salt, minerals, metals and nutrients. These constituents would temporarily invade the Hooley Creek – Four-Mile Creek tidal embayment and associated intertidal habitats, contributing to accretionary processes and also supporting food webs and nutrient cycles. The likely wide variability in Quick Mud Creek flows, together with episodic confluence with flows from the Ashburton River, and mass of sediment loads indicates robustness in the intertidal Hooley Creek – Four-Mile Creek tidal embayment habitats responses to temporary short-term episodic changes in salinity, water column turbidity, mineral and metals loadings and nutrient sources.

The intertidal habitats of the Hooley Creek – Four-Mile Creek tidal embayment were surveyed in 2010 (URS, May 2010). This survey indicated the habitats in the tidal estuary progress landward from fluvial channels and associated tidal creeks and lagoons – mangroves – samphire and bioturbated high-tide mud flats – algal mat covered high-tide mud flats to supratidal saline flats. The Hooley Creek – Four-Mile Creek tidal estuary has been classified (URS, May 2010) by Guidance Statement No. 1 (EPA, 2001) as a Guideline 4 setting, with an operational objective to limit impacts to mangrove habitats and ecological function to the minimum practical level.

The survey of the Hooley Creek – Four-Mile Creek tidal embayment (URS, May 2010) indicated the mangrove forests were comparatively poorly developed, with low mangal speciation and overall moderate conservation significance. The conservation significance was based on diversity and primary/secondary productivity, including:

- Diversity: Low (species richness and genetic diversity) to moderate (ecosystem diversity) conservation significance in terms of biodiversity. In particular:
  - The species diversity was low and restricted with the exception of mud-flat crab assemblages. The setting was poorly represented in respect of molluscs and barnacle habitats and presence. The conservation significance in regard to species diversity was considered low to very low.
  - Species endemism provided no special local conservation significance, being representative of the Pilbara coast.
  - No evidence of genetic diversity.
  - Ecosystem diversity of low to moderate conservation significance given the biogeomorphic setting is not uncommon and representative of the Pilbara coast.
- Primary and secondary productivity: High conservation significance linked to high to very high rates of productivity. The survey (URS, May 2010) indicates the Hooley Creek – Four-Mile Creek tidal embayment is characterised by extensive areas (nominally 815 and 637 ha of algal mats and bioturbated mud flats, respectively) that support vast numbers of microphagous and detrivorous crabs with important secondary production rates and associated output of nutrients. Based on estimates (URS, 2010, after Paling and McComb, 1994) the algal mats export 68 kg/ha/annum of nitrogen during tidal inundation and runoff events. This would amount to about 55 tonnes of nitrogen being produced in the tidal embayment each year.

2.2 Baseline Range of Water Qualities

Surface water (URS, 2009, 2010, 2013 and 2014), groundwater (URS 2014) and seawater (MScience 2010 and 2011; URS, 2011) quality monitoring data collected for the Wheatstone Project to date have been collated together with records for the Ashburton River from public domain sources. In particular, these data have been collated to conform to the described landform settings, with a focus on:

- Headwater settings of the Hooley and Quick Mud creeks.
- Supratidal saline flats.
- Hooley Creek – four-Mile Creek tidal estuary.
- Near-shore marine settings.

These data have been used to characterise the baseline terrestrial surface water and tidal estuary marine environments. Comparisons to the ANZECC & ARMCANZ (2000) guidelines for tropical estuaries in Northern Australia are also provided. Baseline data are provided in **Appendix A.**

2.2.1 Discussion on Water Sample Collection

It is recognised that the majority of the water samples were collected in the aftermath of and or unrelated to stream flow events and consequently do not actually represent stream flow influences. Relevant also, is the recognition that the samples predominantly represent water; the understanding of the characteristics and qualities of the large sediment volumes carried in the stream flow is limited. Further, is the understanding that filtering of high sediment loads from water samples has at times presented difficulties and meant that a number of the analytical results included a portion of dissolved particulates (thus soil and water); these data are characterised by comparatively high dissolved metal concentrations.

The described sampling and sample aspects are significant in context to the likely characteristics of RSS footprints in stream flow. Of particular relevance is that the baseline water samples would tend to be skewed towards periods of comparatively quiescent times. Accordingly, the samples would underestimate the water qualities at times of stream flow. Sediment loads would tend to be underestimated and therein the loadings of metals and nutrients as particulates in the water column.

2.2.2 Terrestrial Surface Water Qualities

Summaries of the surface water quality derived from sampling in the headwaters of the Quick Mud and Hooley creeks watersheds and on the supratidal saline flats are provided in **Table 2.1** and **Table 2-2**, respectively. These data are also provided in **Appendix A** (including a figure showing sampling locations). The sampling was opportunistic after rainfall and stream flow events, typically from water pools in incised channels and clay pans.

2.2.3 *Tidal Estuary Water Qualities*

A summary of the surface water quality derived from sampling of the Hooley and Middle tidal creeks is provided in **Table 2.3** and **Appendix A** (including figures showing sampling locations). The sampling was from tidal reaches of the estuary.

Table 2-1 Surface Water Quality in the Headwaters to Quick Mud and Hooley Creeks

Chemistry Group	Analyte	Units	Hooley and Quick Mud Creeks Headwaters Surface Water Quality							
			SW29	SW23	SW47	SW48	SW11	SW12	SW21	SW45
			Apr-11	9/04/2011	15/07/2011	15/07/2011	14/03/2011	14/03/2011	9/04/2011	14/04/2011
Physical	pH (Lab)	pH Units	7.26	7.67	6.78	7.43	7.67	7.53	8.15	6.38
	Total Suspended Solids	mg/L	1,570	5,250	10	250	56	977	10	77,000
	Total Dissolved Solids	mg/L	470	420	46	163	838	430	251	138,000
	Turbidity	NTU	1,840	22,400	64.9	1,780	1.17	2.3	618	213,000
Alkalinity	Bicarbonate Alkalinity ($CaCO_3$)	mg/L	64	93		52	29	29	57	
	Total Alkalinity ($CaCO_3$)		64	93	5	52	29	29	57	
Others	Chloride		8	15	4	29	14	14	28	174,000
	Calcium			<1	<1	2	2	2	2	624
	Magnesium		<1	1	<1	2	2	2	3	12,400
	Potassium		2	3	1	6	5	5	7	3,700
	Sodium		32	42	5	42	20	18	46	94,900
	Sulphate (as SO_4)		<1	6	15	7	4	3	7	10,400
	Copper (Dissolved)		0.051	0.475		0.047	0.034	0.05	0.054	
	Lead (Dissolved)		0.041	0.16		0.014	0.011	0.017	0.048	
	Nickel (Dissolved)		0.04	0.431		0.058	0.03	0.046	0.045	
	Zinc (Dissolved)		0.056	0.619		0.202	0.07	0.18	0.102	

Table 2-2 Surface Water Quality on the Supratidal Saline Flats

Chemistry Group	Analyte	Units	Quick Mud and Hooley Creeks Supratidal Flats Surface Water Quality						
			SW2	SW31	OSW21	SW32	SW41	SW42	SW43
			Jul-12	Apr-11	Jan-14	Apr-11	Apr-11	Apr-11	Apr-11
Physical	pH (Lab)	pH Units	8.09		6.26	7.02	7.25	7.14	7.45
	Total Suspended Solids	mg/L	98		142	344	570	<5	110
	Total Dissolved Solids	mg/L	116,000	16,000	176,000	145,000	47,200	25,200	39,900
Alkalinity	Turbidity	NTU	1.8		20.4		362	0.4	50
	Hydroxide Alkalinity ($CaCO_3$)	mg/L	132	96	10				
	Total Alkalinity ($CaCO_3$)		132	96	10				
Others	Chloride		68,700	71,800	184,000	78,200	42,700	23,600	31,800
	Calcium		1,600	1,840	987	2,520	733	424	696
	Magnesium		4,830	3,880	5,940	4,100	1,960	1,170	2,210
	Potassium		1,670	1,360	2,160				
	Sodium		37,700	34,900	92,300	42,800	22,800	12,800	17,800
	Sulphate (as SO_4)		11,200	5,210	6,650	5,510	3,680	2,580	4,240
	Copper (Dissolved)		0.269	0.057	<0.050	0.052	0.066	<0.010	
	Lead (Dissolved)		<0.001	0.04	<0.050	<0.010	0.018	<0.010	
	Nickel (Dissolved)		0.214	0.042	0.05	0.043	0.059	<0.010	
	Zinc (Dissolved)		0.086	0.123	0.321	<0.052	0.687	0.173	
	Ammonia				9.09				
	Total-P				<0.01				
	Dissolved Organic Carbon				13				
	Nitrate				0.04				
	Nitrite				0.02				

Table 2-3 **Hooley and Middle Creeks Estuarine Water Qualities**

Chemistry Group	Analyte	Units	Hooley and Middle Creeks Estuarine Water Quality						
			SW1	SW17	SW18	A1 to A4	A5 to A8	A9 to A10	OSW21 to OSW23
			Feb-10	Mar-11	Mar-11	2010/2011	2010/2011	2010/2011	February-14
Physical	pH (Lab)	pH Units	8.27	7.94	8.02				7.95 – 8.18
	Total Suspended Solids	mg/L	142	32	52	6 - 20	8 - 18	5 - 11	22 - 30
	Total Dissolved Solids	mg/L	43,400	47,300	42,200	36,100 - 49,000	39,200 - 61,400	36,700 - 48,000	44,600 – 47,900
	Turbidity	NTU		15.8	9.8				
Alkalinity	Bicarbonate Alkalinity ($CaCO_3$)	mg/L	118	112	109				122 – 128
	Total Alkalinity ($CaCO_3$)		118	112	109				122 - 128
Others	Chloride		21,900	25,900	22,900				23,100 – 25,000
	Calcium		494	505	460				517 - 557
	Magnesium		1,690	1720	1,570				2,080 – 2,300
	Potassium		625	607	544				757 - 820
	Sodium		12,100	14,500	13,300				13,400 – 14,200
	Sulphate (as SO_4)		3,520	3,050	3,400				3,250 – 3,400
	Ferrous Iron					<0.002 - 0.007	<0.002 - 0.004	<0.002	0.040 – 0.068
	Aluminium (Dissolved)					<0.01	<0.01	<0.01	0.029 – 0.070
	Copper (Dissolved)		0.015	0.012	0.012	<0.001	<0.001 - 0.027	<0.001	<0.002
	Lead (Dissolved)		<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.0004
	Nickel (Dissolved)		0.017	0.009	0.008	<0.004	<0.004	<0.004	<0.001
	Zinc (Dissolved)		<0.052	<0.005	<0.05	<0.002 - 0.002	<0.002 - 0.021	<0.002 - 0.003	<0.010
	Ammonia					<0.003 - 0.051	<0.003 - 0.066	<0.003 - 0.005	0.08 – 0.09
	Ortho-P					<0.002 - 0.006	<0.002 - 0.003	<0.002 - 0.003	
	Total-P					0.006 - 0.025	0.006 - 0.019	0.009 - 0.011	<0.02
	Total-N					0.10 - 0.29	0.09 - 0.280	0.140 - 0.170	<0.2 – 0.5
	Chlorophyll a					0.0004 - 0.0019	0.0004 - 0.0019	0.0008 - 0.0015	

2.2.4 *Baseline Salinity and Turbidity*

Table 2-4 presents a summary of the indicative baseline concentrations for the salinity and turbidity based on multi-annual data collection from the headwaters of the Quick Mud and Hooley creek watersheds, the supratidal saline flats and clay pans (subject to salt accumulation) and tidal reaches of the Hooley and Middle creeks.

Table 2-4 Indicative Baseline Surface Water Salinity and Turbidity

Parameter	Description	Setting			
		Catchment Headwaters[1]	Supratidal Saline Flats[2]	Tidal Creeks[3]	Nearshore Marine
Salinity (mg/L)	Observed Range	50 – 138,000	16,000 - 176,000	36,100 – 61,400	37,700 – 39,500
	Typical Range	200 – 800	40,000 - 150,000	Approx. 40,000	
Turbidity (NTU)	Observed Range	1 – 213,000	1 - 360	2 - 209	6 - 17
	Typical Range	50 – 2,000	20 - 50	Less than 16	

Notes:

1 Hooley and Quick Mud creeks in local settings.

2 Immediate hinterlands to the Hooley Creek – Four-Mile Creek tidal estuary.

3 Hooley Creek – Four-Mile Creek tidal estuary.

2.2.5 *Baseline Dissolved Metals, Non-Metals, Nutrients and Inorganics*

Table 2.5 provides a collation of the available baseline water quality data in context to constituents of the RSS including selected metals, non-metals, nutrients and inorganic analytes. The tabulated data are aligned with seawater (MScience, 2010 and 2011), the tidal reaches of the Hooley and Middle creeks (URS, 2011) and opportunistic surface water from the Quick Mud and Hooley creek watersheds. These data provide broad baseline perspectives from proposed RSS sources areas on Quick Mud Creek and for transport and fates within and the local tidal creeks and near-shore ocean settings.

The data in **Table 2.4** and **Table 2.5** provide important contexts, including:

- Strong contrasts in the ranges of salinity and turbidity, though particularly within terrestrial settings. The contrast is diminished within the tidal creeks though there remains evident of salt accumulation by evaporation.

- Natural salt accumulation associated with the supratidal saline flats but also evident in clay pans and incised low-flow channels higher in the local catchments.

- Presence of comparatively high turbidity in all waters, though samples from the catchment headwaters tend to be characterised by turbidity up to two orders of magnitude higher than that in the tidal creeks. Recent turbidity data from gauged surface water occurrences on the supratidal saline flats settings ranges up to 2,500 NTU, thus of similar magnitude to those data from the catchment headwaters.

- Strong contrasts in the range of analyte concentrations. The data from discrete settings show ranges in selected analyte concentrations that exceed an order of magnitude.

- The contrasts in analyte concentrations progressively diminish (**Table 2.5)** in the transition the terrestrial to tidal creek to near-shore oceanic settings. This aspect reflects the progressive dilution and mixing in the tidal and marine settings.

- The qualities of the opportunistic surface water samples are comparatively poor. The worst-case quality include:

  - Copper - with upper-bound terrestrial source concentrations of 0.475 mg/L exceeding the tidal creek and seawater concentrations by up to one and three orders of magnitude, respectively. The measured upper-bound copper concentration in samples of low-turbidity was 0.269 mg/L.
  - Lead, nickel and zinc - with upper-bound terrestrial source concentrations of typically exceeding the upper-bound tidal creek and seawater concentrations by one order of magnitude. The measured upper-bound nickel, lead and zinc copper concentration in samples of low-turbidity was 0.214, <0.01 and 0.096 mg/L, respectively.
  - The presence of nitrogen sources, with measured Quick Mud Creek concentration (January 2014) of about 9 mg/L. It was anticipated that these sources would be predominantly related to cattle on local pastoral leases.

Table 2-5 Baseline Surface Water Quality Ranges for Metals, Non-metals, Nutrients and Inorganic Constituents

Analyte	Units	Analyte Concentrations				
		ANZECC & ARMCANZ Guidelines	Onslow and Typical Seawater	Hooley and Middle Tidal Creeks (2010 – 2011)	Opportunistic Surface Water (2010 – 2012)	Upper-Bound Tidal Creek Baseline Conditions
Dissolved Metals						
Barium	mg/L		0.021	0.014 – 0.020		0.021
Aluminium			0.008 – 0.020	0.029 – 0.070		0.020
Copper		0.0013	0.0005	<0.001 – 0.027	<0.01 – 0.475	0.027
Lead		0.0044	0.005	<0.0004	<0.001 – 0.16	0.005
Nickel		0.07	0.0025 – 0.0035	<0.001	<0.01 – 0.431	0.0035
Zinc		0.015	0.004 – 0.039	<0.002 – 0.021	<0.05 – 0.69	0.021
Non-Metals						
Bromide	mg/L		67.3	99.4 - 105		105
Iodide			0.064	<0.1		0.064
Fluoride			1.3	1.3 – 1.4		1.4
Boron			4.45	6.01 – 6.27		6.27
Silica			2.9	<2.0		10.64 (Ashburton)
Strontium			8.1	9.22 – 10.1		10.1
Nutrients						
Ammonium/Ammonia	mg/L	0.015	0.003 – 0.058	0.003 – 0.09	9.09	0.066 – 0.09
Total-N		0.250	0.124 – 0.150	0.090 – 0.5		0.150 – 0.25
Total-P		0.020	0.007 – 0.010	0.006 – 0.025	<0.01	0.01 – 0.025
Chlorophyll *a*		0.002	0.0005 – 0.0007	0.0004 – 0.002		0.002
Inorganics						
pH (Lab)	pH	7.0 – 8.5	8.0 – 8.2	7.95 – 8.18	6.26 – 8.15	6.3 – 8.2
TDS	mg/L		37,700 – 39,500	36,100 – 61,400	46 – 176,000	61,400
Turbidity	NTU	1 - 20	6 - 17	2 - 209	2 – 22,400	Greater than 2,000
Notes:						
The upper-bound baseline concentrations for metals were aligned with the maximum results from low-turbidity opportunistic water samples (**Chapter 2.2.5**).						

2.2.6 *Baseline Water Quality Summary*

The baseline evidence suggests that the local habitats of Ashburton River Delta, including Quick Mud and Hooley creek watersheds are characterised by wide variations in salinity and turbidity. The variations in baseline salinity and turbidity are linked to the infrequent and episodic occurrences of stream flow within a high-evaporation environment and also to both tidal and storm stressors. Salinity and turbidity measured during the period February to April 2009 in surface waters and clay pans within the Ashburton River Delta (Biota, 2010) ranged from:

- Salinity: 30 to 347,000 mg/L TDS in opportunistic can clay pan samples within the Hooley and Quick Mud and Hooley creek watersheds. The presence of crystalline salt crusts within the clay pans and on low-flow channels of the watercourses is not uncommon.
- Turbidity: less than 1 to greater than 5,999 NTU (about 9,000 mg/L TSS). Notably, turbidity in clay pans subject to tidal influences (CWP13, CWP14) was comparatively low between 0 to 348 NTU (about 0 to 520 mg/L TSS). Conversely, the fresh water clay pans within the Quick Mud Creek and Hooley Creek watersheds (CWP01, CWP02, CWP07, CWP08, CWP11, CWP12 and CWP21) were typically highly turbid, greater than 5,999 NTU.

At times after significant flow events the surface water environments may remain turbid for up to a month or two. Measurements of turbidity in surface waters of the Ashburton River Delta ranged from <10 to 6,000 NTU over a six week period from 5 March 2009 to 17 April 2009.

Based on the baseline evidence, it is reconciled that:

- The surface water salinity varies widely dependent on the occurrence and frequency of significant stream flow events. At times during and in the short-term after flow events, the surface water salinity increase due to evaporation losses; clay pans and incisions in low-flow channels become salt sinks wherein crystalline salt crusts are common. In these settings, metals and nutrients would naturally accumulate.
- The surface water salinity and turbidity varies widely dependent on the occurrence and frequency of significant stream flow events. At times during and in the short-term after flow events, the surface water is turbid. Conversely, in the periods between flow events, the surface water environment is comparatively quiescent and characterised by low turbidity.
- The high turbidity in the stream flows events would provide natural sources of metals and nutrients; sources of nutrients related to pastoral activities (cattle) would also be expected. The predominant forms of these sources would be particulate, with metals and nutrients tending to be bound in minerals and as colloids attached to soil particles that are suspended in the water column. The stream flow would transmit these sources to the tidal creeks and into the ocean.
- The local habitats have robustness in exposures to and potential impacts from sediment (and associated metals and nutrients) in stream flow and tidal reaches of the local watercourse.
- Residence times for stream flow (and associated salinity and turbidity) in the Ashburton River Delta and tidal creeks are limited.

2.3 Tidal Creek Productivity and Nutrient Cycles

The intertidal habits and conservation values of the Ashburton River Delta and Hooley Creek-Four-Mile Creek tidal estuary were broadly described in **Chapter 2.1.1** and **Chapter 2.1.1.** Outlined below is a summary that provides further context for these habitats in regards to primary production and nutrient cycles by mangroves, phytoplankton and benthic microalgae, other trophic processes and eutrophication.

2.3.1 Mangroves

Mangrove habitats are characterised as Benthic Primary Producer Habitats (BPPH).

Mangroves inhabit the tidal creeks of the Hooley Creek – Four-Mile Creel tidal estuary. Mangroves have comparatively slow growth compared to most marine plants; they are understood to predominantly draw nutrients from interstitial pore water (soil water), not the water column. Mangrove species distribution is directly related to salinity. In the Pilbara, the presence of dwarf mangroves is aligned with high seawater salinity distributions and these settings inhibit nutrient uptake. Mangrove creeks typically have naturally high nutrient and particulate concentrations.

The United States Geological Survey (USGS, 2004) has shown that mangrove forests may be characterised by several limiting nutrients and the limiting nutrients may vary spatially. For example, fringe, transition and dwarf mangrove stands were characterised by different production sources for nitrogen and phosphate:

- Fringe mangroves – taller trees growing along the shorelines – were nitrogen limited. This fits to the conceptual model that coastal waters are commonly nitrogen limited. Therefore, increases to nitrogen loads and concentrations would have potential to stimulate increased rates of primary production. That said mangroves in pristine fringe settings have higher nitrogen concentrations than found in the transition and dwarf trees.
- Transition trees – mid-reach settings – were co-limited in nitrogen and phosphorous.
- Dwarf trees – hinterland areas of increased salinity and less tidal forcing - were phosphate limited.

The hydrodynamics of the tidal creeks is significant. In tide-dominated coastal systems such as Hooley Creek, strong tidal currents cause fine sediment to re-suspend. Commonly, therefore, the tide-dominated waterways and macro-tidal wave-dominated waterways are generally turbid. Tidal flows also mobilise and transport the available nitrogen and influence residence times of both natural and anthropic (pertaining to human activities including pastoral activities and cattle) nutrient sources. Nitrogen is variable within mangrove forests due to influences of tides, pastoral activity sources and species adaptation.

Light attenuation caused by suspended sediment is a major control on phytoplankton production and biomass. Strong tidal currents (mean tidal range >2 m) also mix the water column and reduce the residence time of algae in the photic zone. Consequently, nutrient concentrations have potential to accumulate in the water column; naturally elevated concentrations of nitrogen may be experienced in the mangrove and algal mat zones.

2.3.2 *Primary Productivity and Other Trophic Processes*

The predominant sources of primary production in mangal assemblages on the Pilbara coast (URS, May 2010) include:

- Mangrove plants – with production of large quantities of organic detritus.
- Microphytobenthos (cyanobacteria layers) of high-tide mud flats that produce and fix nitrogen in the substrate.
- Micro-epiflora and bacteria on mangal trees.
- Planktonic micro-flora in the water column.

These sources provide the intertidal habitats with high organic contents and enable these habitats to support high rates of microbial activity and dense populations of grazing and detrital-feeding invertebrate and fishes. The predominant biomass activity occurs in the assimilation of organic materials and production of organic carbon and nutrients by surface-dwelling and burrowing grazers and detritivores.

Upstream of the mangal settings, the mud flat areas (bioturbated mud flats and algal mats) are burrowed by ocypodid and sesarmid crabs. These burrows maintain favourable geochemical conditions in the substrate, in part due to the feeding on detrital materials gathered from the mud flats surfaces, with subsequent assimilation and redistribution of organic materials. Both the bioturbated mud flats and algal mats are considered as BPPH.

Typically, under natural conditions, primary productivity (by plants, algae and cyanobacteria) is understood to be limited by nitrogen availability. A conceptual model (URS, May 2010) of the nutrient cycle in algal mat and mangal habitats includes the following components:

- Algal mat cyanobacteria fix nitrogen from the atmosphere and make it biologically available in the form of ammonia.
- The ammonia is exported from the algal mat settings at times of by tidal inundation, stream flow and sheet flow derived from incident rainfall.
- Recycling of the nitrogen in microbial processes within the water and sediment columns.
- Uptake of comparatively minor portions of the available nitrogen by plant (mangal) roots.
- Consumption and excretion of microbial flora by herbivores.
- Consumption and excretion of herbivores by carnivores.
- Nitrification (conversion to nitrate) and denitrification (conversion to nitrogen gas) of the excrements.

2.3.3 Eutrophication

Eutrophication is enrichment of water columns and water bodies by nutrients, especially nitrogen and phosphorous. The presence of the nutrients typically promotes increased algal growth. As the algae subsequently die and decompose, the organic carbon content competes with the available dissolved oxygen, leading to oxygen depletion.

Changes in the nutrient balance may produce complex effects on the ecosystem; there may be stimulation of growth but these may be off-set by destabilising influences.

3 PREDICTED RSS TRANSPORT AND FATES

The disposed RSS and associated constituents would accumulate, temporarily at least, in the low-flow channel of Quick Mud Creek. At times after rainfall when there is stream flow in Quick Mud Creek, the RSS constituents would be transported further downstream to the supratidal saline flats and subsequently to the tidal estuary associated with the Hooley, Eastern and Four-Mile creeks. The major stream flow paths appear to terminate in the East Hooley Creek during low-flow events. For the large stream flow events, the low-relief supratidal saline flats promote sheet flows that terminate within the West Hooley Creek, East Hooley Creek and Middle Creek.

The stream flow dilution and seawater mixing characteristics were derived from hydrological and hydrodynamic tidal models developed to characterise the transport and fates of the disposed RSS (URS, March 2014). Importantly, these models were applied to estimate low-flow volumes derived from only local reaches of Quick Mud Creek and Hooley Creek; seeking worst-case scenarios for the transport and fates of the RSS solutions.

3.1 Quick Mud Creek

3.1.1 Evaporation-Concentration Influences

It was anticipated that the RSS would accumulate on the low-flow channel of Quick Mud Creek during the extended periods where the creek bed is dry. During these periods, the salts within the RSS would concentrate under the influences of water loss by evaporation and crystalline salt precipitates would progressively accumulate. The thicknesses of accumulated RSS constituent salt on Quick Mud Creek would be dependent on several factors, including:

- The RSS disposal rate (857 kL/day).
- Area of the low-flow channel.
- The salt bulk density (1.154 kg/m^3).
- Frequency of stream flow events in Quick Mud Creek.
- The magnitudes of stream flow volumes in Quick Mud Creek.

A MIKE21 grid-version model with fixed evaporation loss rates was used to estimate the RSS footprint on Quick Mud Creek. Model predictions indicated the RSS would invade a surface area of about 32 ha, with typical solute volume of about 50 ML. Given the RSS volumes and salt contents, and assuming a pool area of about 32 ha, the thicknesses of the accumulated salt crust would be:

- 1-year period – 0.24 m.
- 2-year period – 0.49 m.
- 3-year period – 0.73 m.

3.1.2 Dissolution and Mobilisation of Salts by Stream Flow

The influence of local stream flow in Quick Mud Creek on the dissolution and mobilisation of the RSS constituent salt was investigated using a MIKE FLOOD HD model. In these investigations it was recognised that comparatively shallow rainfall depths would limit associated stream flow and consequently also limit the discharge of the RSS constituent salt to areas downstream from Quick Mud Creek. Further, the incised topography of Quick Mud Creek, including presence of barrier bars, also enables attenuation of low-volume stream flows within the low-flow channel.

The stream flow volumes for selected design storm events used to characterise the transport of the RSS from Quick Mud Creek are summarised in **Table 3-1**. The two lower stream flow rates in **Table 3-1** show discharge fates that do not reach the Hooley Creek – Four-Mile Creek tidal embayment.

Table 3-1 Predicted Discharge Volumes in Quick Mud Creek

Stream Flow (m^3/s over 24 hours)	24-Hour Flow Volume (GL)	Fate of the Discharge
1	0.086	Quick Mud Creek storage is full but the discharge does not propagate further downstream.
2	0.173	Quick Mud Creek storage is full. The flood propagates further downstream to the supratidal saline flats.
5	0.432	The discharge propagates downstream and reaches the sea through western and eastern Hooley Creek.
10	0.864	The flood propagates further downstream and reaches the sea through Hooley Creek.

3.2 Supratidal Saline Flats

Once the stream flow in Quick Mud Creek propagates onto the supratidal saline flats it mixes with direct rainfall and runoff from the Hooley Creek tributaries. The rainfall and stream flow mixing potentials were predicted using a TUFLOW “rainfall on grid model”. Given the MIKE FLOOD HD model indicated attenuation of stream flow both in Quick Mud Creek and on the supratidal saline flats, the TUFLOW simulations were based on consecutive rainfall events; the consecutive events enabled runoff generated on Quick Mud Creek to traverse the supratidal saline flats and discharge into the local tidal creeks. In these simulations, an initial 1-year ARI event predominantly fills the clay pans and reaches where the low-flow channel is incised, with the subsequent rainfall shedding as stream flow. Thereafter, the simulated events represented 1-, 2-, 5- and 10-year average recurrence interval (ARI) design rainfall storms, respectively.

The predicted direct rainfall and stream flow contributions that influence the RSS source terms at the headwaters of the tidal creeks are provided in **Table 3-2**. From these predictions, the total outflows (1.20, 1.37, 3.98 and 11.81 GL respectively for consecutive 1 + 1, 1 + 2, 1 + 5 and 1 + 10-year ARI events) characterise the source volumes for inflows to the headwaters of the tidal creeks.

Table 3-2 Predicted Direct Rainfall and Stream Flow Contributions to the Tidal Creeks

Event ARI (years)	Stream Flow Contributions (GL)							
	Inflows to Supratidal Saline			Flows on the Supratidal Saline	Outflows to Tidal Creeks			
	Quick Mud	Hooley Creek	Total		West Hooley	East Hooley	Middle	Total
1 + 1	0.11	0.10	0.21	0.98	0.68	0.34	0.18	1.195
1 + 2	0.13	0.29	0.42	0.95	0.68	0.43	0.26	1.373
1 + 5	3.06	0.64	3.70	0.28	1.61	1.19	1.18	3.978
1 + 10	11.79	1.38	13.17	(1.35)	4.54	2.87	4.40	11.814

3.3 Hooley Creek – Four-Mile Creek Tidal Embayment

The fate of the RSS delivered by stream flow to the Hooley Creek – Four-Mile Creek tidal embayment would be dependent on the mixing and transport processes enabled by tidal forces.

A MIKE21HD(FM) hydrodynamic model was developed to predict the transport of the RSS within the Hooley Creek – Four-Mile Creek tidal embayment for the selected ARI stream flow source volumes. In this model, the RSS source volumes derived from TUFLOW were applied at a uniform quality (100 Practical Salinity Units (PSU)) to the East Hooley Creek throughout the designated stream flow periods. The MIKE21HD(FM) hydrodynamic model findings in terms of the durations for the RSS mixing with and dilution by seawater in the tidal embayment are summarised in **Table 3-3**. The predictions indicate that 100-fold dilution of the source volumes would typically occur within one month of the stream flow event.

Table 3-3 TUFLOW RSS Source Transport Predictions and Interpolations

Scenario	TUFLOW Outflow Volume (GL)	Time of Source Dilution from 100 PSU (days)		
		To 50 PSU	To 2 PSU	To 1 PSU
1+1 (250-hour) LT	1.195	10	24	26
1+2 (250-hour) LT	1.373	11	24	26
1+5 (250-hour) LT	3.978	12	25	27
1+10 (250-hour) LT	11.814	13	25	28

Notes:

The LT suffix to each scenario indicates the simulated initial RSS discharge into the tidal estuary occurred during neap tides, with associated smaller seawater volumes in the tidal estuary.

3.4 Discussion

Comparisons between the simulated (**Table 3.3**) and annual average flow volumes derived from the entire Quick Mud Creek and Ashburton River catchments provides relevant context to the lower-bound magnitudes of the simulated stream flow volumes. For example:

- Simulated local catchment response: 1.195 GL.
- Estimated annual average flow volume from entire Quick Mud Creek watershed: 19 GL.
- Ashburton River annual average flow: 840 GL.

The simulated responses may represent only about 6 per cent of typical annual flows on Quick Mud Creek. Similarly, they represent less than 0.2 per cent of the annual average Ashburton River flow volumes.

These comparisons indicate the simulated stream flow volumes represent worst-case scenarios with respect to the dissolution, transport and dilution of the RSS prior to entering the tidal reaches of Hooley Creek. Larger stream flow volumes from Quick Mud Creek alone would substantially dilute the RSS source terms.

The sediment-laden stream flow may also potentially influence the transport mechanisms of the accumulated RSS salts.

4 CHARACTERISTICS OF THE RSS CONSTITUENT FOOTPRINTS

The characteristics of the RSS constituent footprints have been estimated based on the transport and fate mechanisms outlined in **Chapter 3**. Note that the RSS source terms have been derived Scenario 2 where the nitrogen and phosphorus concentrations have been predominantly removed (**Chapter 1.2** and **Table 1-1**) from the anti-scalant dosage. The estimates follow mass balance principles based on the RSS source terms in Quick Mud Creek (**Table 1-1**) to describe the potential RSS source terms in locations at the headwaters of the tidal reaches of East Hooley Creek.

The estimated RSS constituent source terms in the tidal creek settings are shown in **Table 4-1** and **Table 4-2** for stream flow events at times up to 1-year and a 2-year period of RSS salt accumulation on Quick Mud Creek. Also provided in **Table 4-1** and **Table 4-2** are comparisons to interpretations of the local upper-bound baseline qualities (referred from **Table 4-2**) together with guideline values derived from ANZECC & ARMCANZ (2000) for estuarine waters in the tropics of Western Australia. The up to 1-year and 2-year RSS residence times on Quick Mud Creek broadly reflect the maximum periods of zero flow (14 months) and maximum duration of below average flow (28 months) on the Ashburton River (Ruprecht & Ivanescu, 2000). The concentrations are estimated based on a 1 + 1-year ARI stream flow event derived from the local Quick Mud and Hooley creek watersheds that delivers 1.2 GL to the headwaters of the East Hooley tidal creek. This event provides the least dilution compared to 1 + 2-, 1 + 5- and 1 + 10-year ARI events and consequently highest concentration RSS footprints. Note that the 1.2 GL stream flow volume at the headwater of the tidal creeks is small (700 times less) compared to the 840 GL annual averaged gauged flows (1973 to 2008) on the Ashburton River at Nanutarra Bridge. The calculated 1-year and 2-year RSS accumulated salt loads are about 14,500 and 29,000 tonnes, respectively. These loads are about 90 times less than the interpreted (URS, 2009) annual average sediment load for the Ashburton River of 1.3 million tonnes (URS, 2009). The comparative differences in flow volumes and salt/sediment loads reflect that the RSS is providing additional source terms.

Importantly, in **Table 4-1** and **Table 4-2,** the outlined least-dilution scenario concentrations reflect mass balances that assume all the crystalline mineral salts would dissolve in the stream flow and subsequently be transported downstream in solution. In reality and as predicted in geochemical modelling (**Chapter 5**), several crystalline minerals produced by the evaporation-concentration of the RSS constituents would have low solubility. It is unlikely therefore that these minerals would dissolve; they would be transported as insoluble particulates with likely tendency to be adsorbed onto suspended sediment particles. The soluble fraction of these elements may be significantly lower than shown.

Based on the information presented in **Table 4-1** and **Table 4.2** it is evident that:

- For RSS accumulation periods up to one year, the analyte concentrations in source terms to the tidal Hooley Creek are predominantly less than the observed upper-bound baseline concentrations. Exceptions occur for barium, iodide and silica which exceed the range of local concentrations. It was also recognised that both the opportunistic surface water baseline and RSS constituent sources of nitrogen were high compared to concentrations in the tidal creeks and local seawater.
- For RSS accumulation over a 2-year period, the metals copper, nickel and zinc together with Total phosphorous fall within the observed upper-bound baseline range. The baseline concentration range is exceeded by the metal barium, non-metals iodide, boron, silica and strontium and, nitrogen-based nutrients.

Table 4-1 RSS Source Terms to the Tidal Hooley Creek – Up to 1-Year RSS Accumulation

Analyte	Units	Analyte Concentrations					Maximum Dilution Period to Baseline (days)
		ANZECC & ARMCANZ	Upper-Bound Tidal Creek Baseline Conditions	0.1-year RSS Constituent Accumulation	0.5-year RSS Constituent Accumulation	1-year RSS Constituent Accumulation	
Dissolved Metals							
Barium	mg/L		0.021	0.227	1.135	2.269	18
Aluminium			0.020	0.0005	0.002	0.005	
Copper		0.0013	0.027 – 0.269	0.002	0.012	0.023	7
Lead		0.0044	0.005 – 0.01	0.0001	0.0005	0.001	
Nickel		0.07	0.0035 - 0.214	0.001	0.007	0.015	
Zinc		0.015	0.039 - 0.096	0.003	0.015	0.031	8
Non-Metals							
Bromide	mg/L		105	2.34	11.69	23.37	
Iodide			0.064	0.13	0.65	1.30	10
Fluoride			1.4	0.09	0.43	0.86	
Boron			6.27	0.42	2.11	4.23	6
Silica			10.64 (Ashburton)	2.06	10.29	20.58	9
Strontium			10.1	0.74	3.69	7.38	6
Nutrients							
Ammonium/Ammonia	mg/L	0.015	0.066 – 9.09	0.77	3.85	7.70	14
Total-N		0.250	0.150 – 9.09	0.86	4.28	8.56	14
Total-P		0.020	0.01 – 0.025	0.001	0.003	0.005	10
Chlorophyll *a*		0.002	0.002				
Inorganics							
pH (Lab)	pH	7.0 – 8.5	6.3 – 8.2				
TDS	mg/L		61,400	1,211	6,054	12,108	
Turbidity	NTU	1 - 20	Greater than 2,000				
Cleaning Agents							
Citric acid[1]	mg/L			0.04	0.16	0.33	18
Sodium Lauryl Sulfate[1]				0.001	0.004	0.01	18
Notes:							
The light red shading reflects concentrations above the upper-bound baseline range.							

Table 4-2 RSS Source Terms to the Tidal Hooley Creek - 2-Year RSS Accumulation

Analyte	Units	Analyte Concentrations			Mass of 2-year RSS Constituent Accumulation (tonnes)	Maximum Dilution Period to Baseline (days)
		ANZECC & ARMCANZ	Upper-Bound Tidal Creek Baseline Conditions	2-year RSS Constituent Accumulation		
Dissolved Metals						
Barium	mg/L		0.021	4.539	5	35
Aluminium			0.020	0.009	0.01	
Copper		0.0013	0.027 – 0.269	0.047	0.06	14
Lead		0.0044	0.005 – 0.01	0.002	0.002	
Nickel		0.07	0.0035 - 0.214	0.030	0.04	
Zinc		0.015	0.039 - 0.096	0.061	0.07	15
Non-Metals						
Bromide	mg/L		105	46.74	56	
Iodide			0.064	2.61	3	20
Fluoride			1.4	1.72	2	
Boron			6.27	8.45	10	12
Silica			10.64 (Ashburton)	41.16	49	17
Strontium			10.1	14.76	18	12
Nutrients						
Ammonium/Ammonia	mg/L	0.015	0.066 – 9.09	15.39	18	28
Total-N		0.250	0.150 – 9.09	17.11	2	28
Total-P		0.020	0.01 – 0.025	0.010	0.01	20
Chlorophyll *a*		0.002	0.002			
Inorganics						
pH (Lab)	pH	7.0 – 8.5	6.3 – 8.2			
TDS	mg/L		61,400	24,216	29,059	
Turbidity	NTU	1 - 20	Greater than 2,000			
Cleaning Agents						
Citric acid[1]	mg/L			0.65	1	35
Sodium Lauryl Sulfate[1]				0.02	0.020	35
Notes:						
The light red shading reflects concentrations above the upper-bound baseline range.						

5 CONCEPTUAL MODELS FOR POTENTIAL RISK ASPECTS

The RSS constituent source terms indicate a propensity for potential changes in salinity and the presence of selected metals, non-metals and nutrients above indicative baseline concentrations and marine guideline values. Relevant aspects for these potential source terms in relation to the possible environmental risks to the Hooley Creek – Four-Mile Creek tidal embayment are outlined below, specifically including:

- Salinity.
- Solubility.
- Metals.
- Non-metals.
- Nutrients.
- Cleaning agents.

5.1 Salinity

The salinity distribution within Hooley Creek reflects the influx of fresh water from stream flow. Stream flow is episodic and infrequent. Large influxes of stream flow may substantially lower the salinity in inshore areas. Salinity also fluctuates with the penetration of tidal flows and, with mixing of fresh water and marine water by wind and currents. High evaporation rates coupled with low stream flow lead to hyper-salinity in the tidal reaches and headwaters of Hooley Creek. Under these conditions, the estuarine water is commonly of higher salinity than seawater.

Most aquatic organisms function optimally within a narrow range of salinity. Consequently, changing salinity distributions can affect the local ecology. When salinity changes, an organism may lose the ability to regulate its internal ion concentration and therefore enter a state of increased stress.

The nature of the longitudinal salinity gradient (and the position of certain isohalines) is an important factor in the successful recruitment of larva and juvenile fish. Widely-varying salinity settings tend to form low-abundance and low-diversity ecosystems populated by euryhaline species. Such species are adaptable to a broad range of ionic concentrations.

Salinity also influences the types of species that can occur in algal bloom, and on the activity of nitrifying and denitrifying bacteria. For example, sediment underlying freshwater can retain more exchangeable ammonium than sediment underlying saline water. Further, high metals concentrations may enter solution as salinity (and water hardness) increases because calcium and magnesium ions compete for binding sites on clay-organic particle surfaces, and this can interfere with the complexation and adsorption of metals. Increasing salinity, however, may also result in a reduction in dissolved metal concentrations because the clay-organic particles form flocculants with high settling rates which remove the attached metals from the water column.

5.2 Solubility

The solubility is the primary factor to evaluate the bioavailability of the constituents in the environment. Equilibrium geochemical modelling was performed to assess the aqueous species and saturated minerals that may be present in the RSS before disposal to Quick Mud Creek. Note that the RSS chemistry reflects earlier indicative qualities (Worley Parsons, September and November 2013) which slightly differ from the data presented in **Table 1-1**. In the equilibrium modelling, evaporation was simulated by incrementally removing water from the disposed RSS until it was desiccated (more than 99 per cent of the water removed), where the only water remaining was present in hydrated minerals that may have precipitated.

The results of the RSS speciation modelling are summarised in **Table 5-1**, including the predominant aqueous species and the minerals that are predicted to be near or at saturation (saturation index [SI] greater than -0.1).

Table 5-1 Predominant Aqueous Species and Saturated Minerals in the RSS before Disposal

Parameter	Concentration (M)	Predominant Aqueous Species	Saturated Minerals (SI > -0.1)
Cl	5.42E-01	Cl^-, NaCl	-----
Na	4.84E-01	Na^+, NaCl, $NaHCO_3$	-----
C(4)	2.26E-02	HCO_3^-, $NaHCO_3$	-----
Ca	1.98E-02	Ca^{2+}, $CaCl^+$	Calcite, Dolomite
Mg	1.63E-02	Mg^{2+}, $MgCl^+$	Magnesite
K	8.83E-03	K^+, KCl	-----
Si	2.02E-03	H_4SiO_4, NaH_3SiO_4	Chalcedony
B	9.56E-04	BOH_3, $B(OH)_4^-$	-----
N(3)	9.00E-04	NH_4^+, NH_3	-----
Br	8.67E-04	Br^-	-----
Sr	2.24E-04	Sr^{2+}, $SrCl^+$	Strontianite
N(5)	1.77E-04	NO_3^-, $NaNO_3$	-----
S(6)	1.29E-04	SO_4^{2-}, $NaSO_4^-$	-----
F	1.25E-04	F^-, MgF^+	Fluorite
Ba	4.52E-05	Ba^{2+}	Barite
Fe(3)	4.44E-05	$FeCO_3OH$	Ferrihydrite
I	2.36E-05	I^-	-----
Mn	9.41E-06	$MnCO_3$	-----
Fe(2)	1.09E-08	$FeCO_3$	-----
Ra	7.59E-13	Ra^{2+}, $RaCl^+$, $RaCl_2$	-----

As evaporation proceeds, mineral salts are precipitated when they become concentrated to the extent that they exceed their solubility product constant.

Most salts begin to precipitate just before the solution is evaporated to dryness. Halite (NaCl) is most abundant precipitated mineral phase, but it does not begin to precipitate until more than 90 per cent of the water has evaporated. Magnesite ($MgCO_3$), calcite ($CaCO_3$), and chalcedony (SiO_2) are the next most abundant precipitated mineral phases. These minerals begin precipitating when approximately 10 per cent or less water has evaporated. In addition, fluorite (CaF_2), barite ($BaSO_4$), ferrihydrite [$Fe(OH)_3$] and strontianite ($SrCO_3$) also precipitate, but the amounts are small. Barite may co-precipitated with radium [$(Ba, Ra)SO_4$]. Rosenburg et al. (2013) noted radium co-precipitation with barite in evaporation ponds at a desalination plant in Israel.

The mineral precipitates would not account for all ions of the individual elements. As shown in **Table 5-1**, there are aqueous species of these elements that remain soluble. For example, both sodium fluoride and strontium chloride are common compounds in seawater. Further, bromide, iodide, boron and nitrogen would tend to remain in aqueous or soluble speciation.

Once magnesite, calcite, chalcedony, fluorite, barite, ferrihydrite and strontianite are precipitated, they may not readily dissolve during stream flow events because of low solubility. Therefore, these minerals would tend to transported as colloidal particulates. In this form, the barium, fluoride, silica and strontium would tend to have residence times linked to the stream flow duration and be predominantly transported out to sea with limited opportunity for bioavailability.

5.3 Metals

Metals, such as copper, zinc and chromium typically occur at low concentrations in water, are essential for life and are called micronutrients or trace elements. Metals and metalloids are released to soils and the hydrologic cycle during physical and chemical weathering of igneous and metamorphic rocks. The background concentrations are mainly controlled by the geologic characteristics of the watershed.

Metals are partitioned amongst soluble phases, suspended and bottom sediments and biota in aquatic systems. The major pathways of metal partitioning include adsorption, complexation, precipitation and biological uptake. Adsorption is usually the predominant process because metals have strong affinities for iron and manganese oxyhydroxides, particulate organic matter, and to lesser extents clay minerals. Consequently, metals tend to accumulate in bottom sediments. The soluble phase represents the principal source of bio-available metals.

The dissolved metal fraction is favoured under conditions of low pH, low particulate loads and high concentrations of dissolved organic matter. More metals may also enter solution as water hardness increases, because cations (especially Ca^{2+} and Mg^{2+}) also compete with metals for binding sites. Increasing salinity, however, usually results in reduced dissolved metal concentrations because clay-organic particles form flocculants with a high settling velocity. High pH and *Eh* and elevated particulate organic matter concentrations favour metal partitioning to sediment or to suspended particulates if hydraulic energy is high enough.

For barium, it is recognised that it tends to form insoluble sulphates and carbonates. Human studies identified a no-observed-adverse-effect level (NOAEL) of 0.21 mg barium/kg/day (www.pesticideinfo.org.rense.com/general21/tox.htm). This mass is equivalent to 7.0 mg/L. Barium is not typically recognised as a carcinogen and it does not tend to bio-accumulate (US EPA, 2004).

5.4 Non-Metals

The non-metals boron, iodide, silica and strontium occur in the RSS constituent footprints at concentrations above baseline. Information on the toxicology of these non-metals was sourced from the USEPA Integrated Risk Information System (IRIS); (http:/www.epa.gov/IRIS/subst/0010.htm).

Boron: Similar in characteristics to silica and carbon. Found only as oxides, known as borates, which are essential plant nutrients. Borates have low toxicity to humans and mammals (similar to table salt; USEPA, 2004). They are more toxic to arthropods. The US Drinking Water Equivalent Level is 7 mg/L.

Iodide: Iodide is an essential trace element for life and important for the synthesis of thyroid hormones (Linus Pauling Institute, Oregon State University (http://lpi.oregonstate.edu/infocenter/minerals/iodine/). Table salt is commonly iodised; 1 gram of iodised salt contains 0.077 mg of iodide. Iodide is also used in the treatment of fibrocystic breast conditions, with ingestion of 3 to 7 mg/day for a 60 kg person. High doses of iodine may stimulation of the thyroid gland, causing thyroid enlargement (goiter). Prolonged intakes of more than (18 mg/day) have been found to increase the incidence of goiter. The tolerable upper level (Food and Nutrition Board of the Institute of Medicine, US) of intake (from food and formula) iodide ranges from 0.2 to 1.1 mg/day for children to adults.

Silica: Is not a toxic component in normal cases. Intake is not limited.

Strontium: Occurs naturally only in compounds with other elements. The human body absorbs strontium as if it were calcium. Studies indicate a lack of undesirable side-effects; there is a long history of medical research regarding potential health benefits. The reference dose for chronic oral exposure is 0.6 mg/kg per day. The US Drinking Water Equivalent Level is 21 mg/L.

5.5 Nutrients

5.5.1 Overview

The nutrients nitrogen (N) and phosphorus (P) are building blocks for plant and animal growth. Silicon and several metals are also often classified as nutrients. In circumstances where the nutrient concentrations exceed the natural capacities for adsorption and or assimilation, there may be growth of aquatic flora and bacteria that deplete the dissolved oxygen available in the water column. These circumstances, termed eutrophication, may be harmful to the natural ecology.

Total nitrogen (TN) is a measure of all forms of dissolved and particulate nitrogen present within the water column. Nitrogen occurs as inorganic and organic species, both in dissolved and particulate forms. Inorganic nitrogen is found in oxidised (*e.g.* nitrate (NO_3) and nitrite (NO_2)) and reduced (ammonia (NH_4+NH_3) and dinitrogen gas (N_2)) states depending on pH; for seawater approximately 95 per cent of ammonia is in the cationic form ammonium (NH_4^+). Ammonium is the form of nitrogen taken up most readily by phytoplankton. Total dissolved nitrogen (TDN) consists of dissolved inorganic nitrogen (DIN) and dissolved organic nitrogen (DON), and is readily available for plant uptake. Particulate nitrogen can be found in suspension or in the sediment.

Total phosphorous (TP) is a measure of all the various forms of phosphorus (dissolved and particulate) found within the water column. Particulate phosphorus is present in the remains of plants and animals, in minerals and adsorbed onto iron oxyhydroxides on mineral surfaces; it occurs in suspension or in the sediment. The adsorption and desorption of phosphate from mineral surfaces forms a buffering mechanism that regulates dissolved phosphate concentrations in rivers and estuaries.

5.5.2 Mangrove Responses to Nutrient Enrichment

Mangroves have been recognised as a nutrient sink and historically used as a natural filter for wastewater discharge. There is evidence, however, of nutrients as a change factor in northern Australian mangrove forests through research of aquaculture (prawn farm) and water treatment (sewage) treatment activities. Both activities provide nutrient sources disposed to tidal creeks. Findings by McKinnon et. al., (2002a and 2002b) showed that the nutrient enriched footprint linked to prawn farm effluent was limited by high primary production rates coupled to sedimentation and tidal dilution. At times of nutrient-enrichment, there was an increase in phytoplankton and bacteria within the tidal creek. These communities graze within the water column, assimilating the nutrients. This assimilation initially promotes re-packaging as zooplankton and bottom-associated invertebrates and subsequently forms food for a wide range of grazers, including fish. Local-scale changes to a tidal creek setting linked to nutrient-enriched effluents (McKinnon et. al, 2002a) included:

- Elevated concentrations of:
  - Particulate nitrogen.
  - Chlorophyll *a*.
  - Suspended solids.
- Increased rates of primary production by the phytoplankton biomass. The increased production rates were correlated to available nitrogen, phosphorous, organic carbon, chlorophyll *a* and total suspended solids.
- Increased bacteria production, similar to but at a smaller scale compared to the phytoplankton production.
- Production of phytoplankton and bacteria in the water column stripping the additional nutrient concentrations and supporting feeding responses nanoflagellates, protozoans, planktonic crustaceans, benthic epifauna, nekton and fish. These communities graze within the water column, assimilating and processing the nutrients. The conceptual model of the grazing on nutrients in tidal creeks (McKinnon et. al., 2002b; **Plate 5-1**) showed that the growth of the phytoplankton and bacteria biomass lead to other trophic processes, including grazing by fish, that supported the assimilation and dissipation of the available nutrients. This model shows the distributions of microzooplankton and mesozooplankton change in response to limiting nutrients (amongst other factors). For example, phytoplankton and benthic microalgae primary production rates (and Chlorophyll *a* concentrations) increase (Burford et. al., 2012) in response to enriched nitrogen concentrations. The primary production of benthic microalgae is subordinate to that of the phytoplankton. In the tropics, high seawater temperatures support comparatively higher rates of bio-geochemical processes. There is potential for reduced primary production

under circumstances where the seawater temperatures are lower and light availability is diminished.

A conceptual model (McKinnon et. al., 2002b) of the grazing on nutrients in tidal creeks showed that the growth of the phytoplankton and bacteria biomass lead to other trophic processes, including grazing by fish, that supported the assimilation and dissipation of the available nutrients. Experiments measured the grazing of the total microzooplankton community (heterotrophic nanoflagellates, bacteria protozoans and planktonic crustaceans) and considered the role of planktivore fish communities within the nutrient-enriched footprint. These experiments (McKinnon et. al., 2002b) included:

- The distributions of microzooplankton and mesozooplankton change in response to physicochemical characteristics, including stream flow, turbidity, light penetration of the water column degree of eutrophication and limiting nutrients. There was likely a natural balance between phytoplankton and microzooplankton communities.
- Episodic stream flow events flushed the majority of the mesozooplankton from the tidal creeks.
- Dissolved inorganic nitrogen and nutrient enriched macro-particulates enter the tidal creek wherein the water column ecology assimilates the influxes by a feeding response. The water column ecology includes:
    - Heterotrophic nanoflagellates.
    - Bacteria protozoans – Aloricate Ciliates; a major component of the marine heterotrophic nanoplankton.
    - Planktonic crustaceans – Copepodids.
    - Planktonic crustacean larvae – Nauplii.
    - Benthic epifauna – organisms found on the bed of the tidal creek.
    - Nekton - free-swimming organisms, including mud sifters, benthic carnivores, piscivores (fish-eating) and planktivores (plankton-eating).
    - Filter feeding by fish within nutrient-enriched footprints. The fish may alternate between particulate feeding on zooplankton and filter feeding. The filter feeding was limited to direct assimilation of particulates from the water column, resulting in rapid reductions in concentration.
- Fish predation was recognised as a major trophic sink for nutrients, by direct ingestion of macro-particulates and micro-crustaceans.

- Tidal forces distribute and ameliorate the nutrient enriched effluents my mixing with nutrient-limited natural phytoplankton and bacteria communities.
- The light climate in the tidal water column influences the productivity of the phytoplankton and bacteria. High turbidity light climates limit primary productivity.
- The presence of cumulative natural and pastoral activity sources masks the influence of individual nutrient source enrichments.

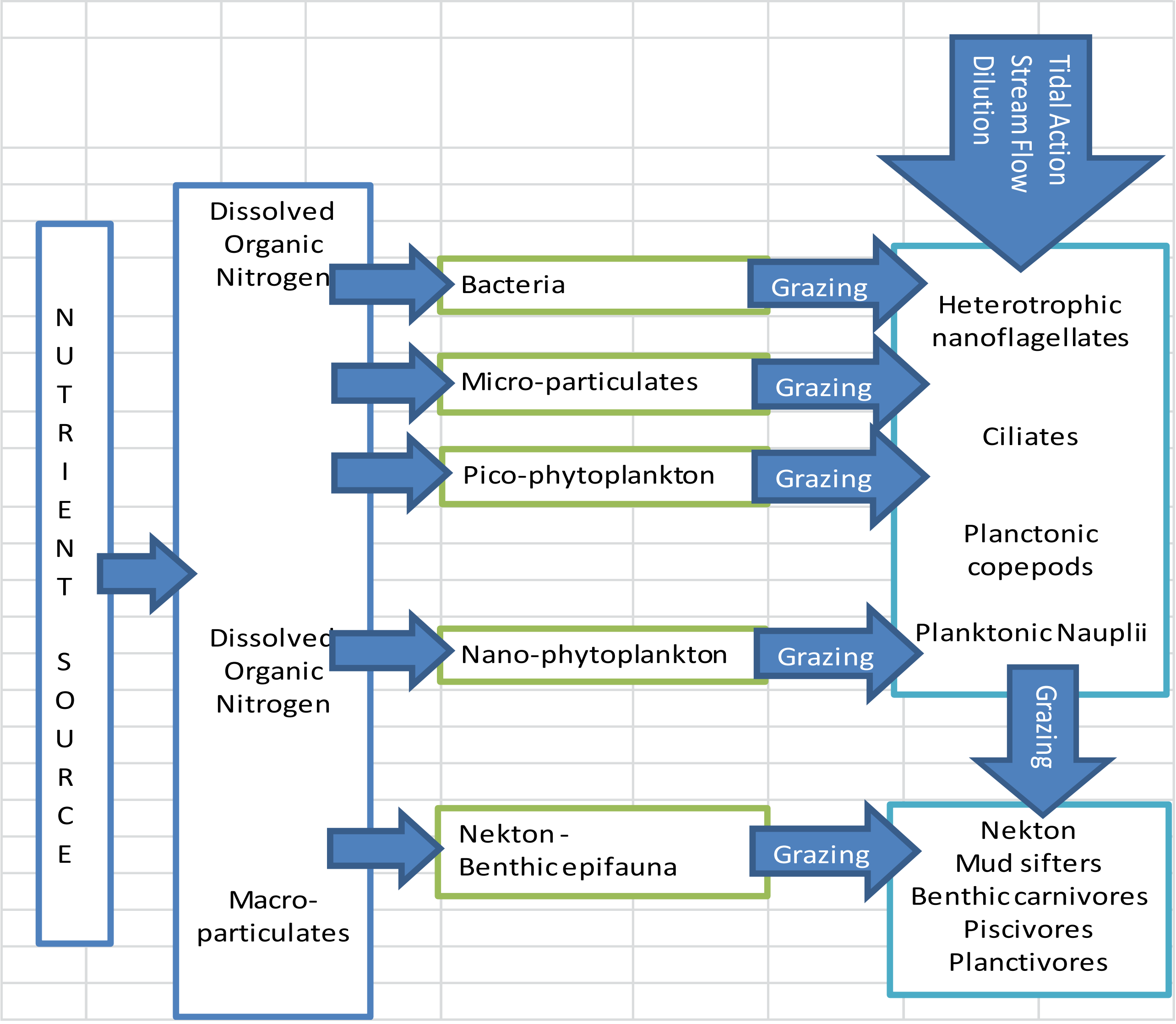

Plate 5-1 Conceptual Tidal Creek Grazing Ecology (after McKinnon et. al., 2002b)

It was recognised (Burford et. al., 2003) that changes in water quality alone were unable to define potential ecological changes linked to discharge of nutrient-enriched effluents. A range of process measurements and bio-indicators together with physicochemical water quality data (Costanzo et. al., 2004) were used to refine the understanding of effects from nutrient enriched shrimp farm effluent. The sampling of the water column in tidal creeks included ammonium and chlorophyll *a* concentrations, phytoplankton assays, nitrogen isotope ($\delta^{15}N$) signatures of mangroves and macroalgae, a phytoplankton light response index and a phytoplankton nutrient response index. The bio-indicators showed the tidal creeks assimilated the nutrients but there were measurable local ecological changes due to nutrient-enriched effluence discharge. Further, was the recognition of uncertainty regarding the assimilation capacity of the tidal creeks and understanding that if this capacity was diminished in the future then the observed tidal creek responses would not be sustained. Under these circumstances, there would be increased potential for detrimental outcomes. The bio-indicator changes (Costanzo et. al., 2004) occurred predominantly within the tidal creeks, but were observed to propagate beyond the mouths of the creeks.

The findings included:

- Ammonium was the predominant nutrient species.
- Filterable reactive phosphorous was at or below detection limit concentrations.
- Phytoplankton biomass assays were sensitive to the aggregate nutrient loads, indicating nutrient co-limitation. Phytoplankton responses to nitrogen in the effluent plume were limited; as there were high ambient concentrations. Dissolved inorganic nitrogen (DIN) to dissolved inorganic phosphorous (DIP) ratios increased from less than 45 to greater than 150 at times of effluent release. A large phosphorous response, indicating phosphorous limitation, as shown by DIN to DIP ratios greater than 150.
- Baseline chlorophyll *a* concentrations in the range 0.5 to 1.0 µg/L increased to between 2.5 to 5.5 µg/L at times of effluent release.
- Mangrove and macroalgae $\delta^{15}N$ signatures were higher in the effluent footprint, steadily decreasing downstream in the tidal creek. The mangroves typically had higher average $\delta^{15}N$ signatures compared to the macroalgae. In the nearby adjoining tidal creeks, the mangrove $\delta^{15}N$ signatures were higher at the mouth, indicating hydrodynamic forces transmitted the effluent.
- There was a predominant nitrogen and phosphorous limitation to the phytoplankton light response index and a phytoplankton nutrient response index. A lack of light was found to influence (limit) growth of phytoplankton.
- Progressive improvements in the physicochemical water column quality downstream in the tidal creeks.
- Other factors including lack of micro-nutrients, temperature, salinity, light and competition for nutrients inhibited the growth of phytoplankton.

Recent research (Fabzi et. al., 2013) regarding the fate of nutrients from shrimp pond effluents showed increased foliar nitrogen concentrations. The monitoring of spatial variations in foliar nitrogen was used to characterise nutrient availability to mangroves and associated environmental change. Potentials for environmental change were identified (Naidoo, 2009 and Lovelock et. al., 2009) based on the understanding that increased nitrogen availability stimulated shoot growth rather than root growth. This aspect was considered to potentially lessen the resilience of mangroves to environmental stressors. The findings by Fabzi et. al. (2013) included that the mangrove foliar nitrogen signatures were higher closer to the shrimp ponds and progressively declined downstream on the tidal creeks.

The evidence from the case-studies on nutrient enrichment from prawn farm effluents indicates that the mangal habitat biomass assimilates and redistributes the available nitrogen loads. A reasonable context in this regard is also provided in that the algal mats are not nitrogen limited, being are able to fix nitrogen from the air and produce and export an estimated 68 kg/ha/annum of nitrogen. Given the algal mats in the Hooley Creek – Four-Mile Creel tidal estuary cover 815 ha, the estimated annual nitrogen production would be 55 tonnes.

5.5.3 Phosphorous Enrichment

Phosphorous-free anti-scaling agents are proposed to be used in the RO plant and consequently report to the RSS as per Scenario 2 described in **Chapter 1.2**. Reference data in regard to their characteristics and potential for environmental harm are provided in **Appendix B.**

Scenario 2 would impose limited changes in phosphorus concentrations, with a marginal (6.2 kg/annum) increase in annual loadings. Phosphorus would continue to be and or become the limiting nutrient. If phosphorus is already limiting there would be negligible potential for additional growth. If phosphorous is not already limiting there may be some additional growth up to the point where it becomes limiting.

5.6 Cleaning Agents

The cleaning agents are citric acid and sodium lauryl sulphate. Both would be additives to the RSS for one day every quarter, thus a total of eight days over a two-year period. Reference data in regard to their characteristics and potential for environmental harm are provided in **Appendix C.**

A research paper (Karlaganis G., January 2001; **Appendix C**) provides the background to the environmental fate of acid citric in the environment. Due to its physicochemical characteristics the agent is highly soluble and mobile in the environment and will partition to the aquatic environment. Citric acid is, however, rapidly degraded in surface waters and in soil. Citric acid is of low acute toxicity to freshwater fish, daphnia, and algae and also to the few marine species tested. Based on the available data, citric acid is not judged to be a substance that presents a hazard to the environment.

Sodium lauryl sulfate is a detergent surfactant. It is commonly used as a cleansing agent in toothpastes, shampoos, bubble baths, shaving creams; any application in which viscosity and foam characteristics are of importance. Coatings may also be applied to fresh citrus fruit and it is used as a food additive. The USEPA secondary drinking water guideline (http://water.epa.gov/drink/contaminants/index.cfm) for foaming agents states a guideline of 0.5 mg/L.

6 DESKTOP ENVIRONMENTAL RISK ASSESSMENT

6.1 Formalities

The environmental risk assessment is described below. This risk assessment was based on the Scenario 2 (**Chapter 1.2, Table 1-1**) specifications of the RSS constituents. In this scenario the nitrogen and phosphorus concentrations from anti-scalant dosage have been limited.

The environmental risk assessment has been guided by a number of discrete aspects intended to enable differentiation of the potential environment risk associated with individual elements and or RSS constituents. These aspects would vary from one stream flow event to another, with consequent changes to environmental risks. As shown, the low-volume stream flow events after considerable RSS residence time on Quick Mud Creek provide the least dilutions and potentials for greater change. The stream flow volumes used to dilute the RSS source terms from Quick Mud Creek reflect flows only from the local watersheds. The reality is that on average there would be stream flow contributions from the wider Quick Mud Creek catchment areas and also from the Ashburton River typically on a biennial basis. In this regard it was recognised that the longest periods of RSS constituent accumulation when considered together low-volume stream flow events would provide unlikely worst-case scenarios for the RSS constituent concentrations (source terms) in the stream flow. Additional conservatism is provided in aligning the risk assessment solely to the baseline concentrations of analytes observed in the tidal creeks and near-shore seawater. It is noteworthy that these baseline data reflect quiescent times, not periods of stream flow.

Further, the environmental risk assessment is predominantly focussed on receiving environments within the Hooley Creek - Four-Mile Creek tidal embayment. It is within this setting that intertidal habitats of moderate conservation significance occur (refer to **Chapter 2.1.4**). The denuded and saline lower reaches of the Quick Mud Creek and the supratidal saline flats form areas which lack significant habitats and receptors.

6.2 Hooley Creek – Four-Mile Creek tidal embayment

The environmental comparative risk assessment broadly informs the level of harm to the identified receptors located within the Hooley Creek – Four-Mile Creek tidal embayment. The receptors include mangrove forests on the tidal creeks and associated ecosystems understanding these may be subject to change under the influences of the RSS footprints. The desktop environmental risk assessment is based on the understanding that metal, non-metal, nutrient and cleaning agent concentrations and loadings in the RSS footprint may contribute to toxicity and or eutrophication risks in the tidal creeks.

An objective approach has been used to guide this risk assessment. The intention was to guide attention to aspects that may warrant further attention understanding that the baseline environmental setting is widely variable and the bio-availability of the RSS constituents would likely be constrained by the episodic nature of stream flow events and associated high turbidity and varied salinity inputs. For each of these environmental risk aspects, there are several contexts to be considered in characterising the likely environmental risks. These contexts include:

- The local tidal creeks a characterised by a wide range of transient and episodic stream flow events with associated suspended sediment (and associated salt, minerals, metals and nutrients) loadings in stream flow and tidal reaches of the local watercourses. These constituents would temporarily invade the tidal creek habitats during periods during and in the short-term after stream flow events. The wide variability in stream flow volumes and mass of sediment loads indicates robustness in the intertidal habitats responses to temporary short-term episodic changes in salinity, water column turbidity, mineral and metals loadings and nutrient sources.

- The RSS constituent footprint would only be manifest within the tidal creeks at times of stream flow. There is expectation that typically there would be stream flow at least once each year. It would only be during comparatively rare periods of low rainfall that stream flow might have a 2-year recurrence interval.

- The risk assessment was informed by low-volumes stream flow events. The stream flow volumes used to dilute the RSS source terms from Quick Mud Creek reflect flows only from the local watersheds. The assessed risks would be reduced under circumstances of larger stream flow volumes, with associated mixing, dissolution, dilution and transport of the RSS constituents. Such circumstances would be usual rather than exceptional. For example:

  - The annual flow volumes gauged at Nanutarra Bridge in the period from 1973 to 2008 averaged 840 GL (URS, May 2010).
  - If the regional Quick Mud Creek water shed responds similarly to the Ashburton River, then the annual average flow volume would be 19 GL.
  - The stream flow volume (generated by the immediate catchment areas) used in context to RSS constituent source terms for the Hooley Creek - Four-Mile Creek tidal estuary was only 1.195 GL derived from 1-year ARI events (Refer to **Chapter 3**, **Table 3.3**).

- The baseline water quality for the local terrestrial watersheds, tidal creeks and near-shore marine settings do not reflect periods of stream flow. These data were interpreted to be representative of comparatively quiescent times in the aftermath of stream flow events. Under these circumstances the observed water qualities would tend to host comparatively low concentrations and loadings of metals and nutrients. Of particular relevance is that the stream flow is highly turbid with suspended sediment, particulates and organic matter. Relevant context is that:

  - The flow-weighted turbidity for Ashburton River is 1,705 NTU and the annual average sediment load has been interpreted to be in the order of 1.3 million tonnes (URS, 2009).
  - If the regional Quick Mud Creek water shed (1,811 km^2) responds similarly to the Ashburton River, then the annual average sediment load would be about 30,000 tonnes.
  - The RSS constituents would provide additional loadings.
  - The RSS constituent loadings for the most part are expected to be insubstantial (about two orders of magnitude less) compared to those from the Ashburton River

and Quick Mud Creek. The calculated 1-year and 2-year RSS accumulated salt loads are about 14,500 and 29,000 tonnes, respectively.

It is expected that the high turbidity would provide episodic source terms (both natural and introduced by pastoral activity) to the tidal creeks with comparatively significant contents of salt, minerals, metals and nutrients derived from the local watershed. The high-turbidity stream flow events would mobilise and transport both dissolved and particulate metals and nutrient concentrations and loads.

- The residence times of the RSS constituents in the tidal reaches of Hooley Creek would be limited to about one-month duration. During this time the RSS source terms become increasingly dilute by mixing with seawater under the influence of tidal flows.

- During residence times of the RSS constituents in the tidal reaches of Hooley Creek, the water column is of high turbidity. The high turbidity is recognised to impose limitations to light penetration and access by the local ecology to the RSS constituents. Both aspects limit the bio-availability of the RSS-constituents, particularly nitrogen.

- The baseline environment is not pristine. This is evident, at least, in the presence of pastoral activity nitrogen sources on Quick Mud Creek. As such, the RSS constituents would contribute to existing altered baseline loadings and potentials for cumulative changes and or impacts to the environment.

- The RSS constituent annual loading of nitrogen would be about 10 tonnes. Based on estimates (URS, 2010, after Paling and McComb, 1994) the algal mats export 68 kg/ha/annum of nitrogen during tidal inundation and runoff events, natural nitrogen availability would be about 55 tonnes each year. The algal mats would not be the sole natural source of nitrogen.

- Phosphorus would be the limiting nutrient and its limited availability would limit potential for additional growth. Additional phosphorous may promote additional growth up to the point where it becomes limiting.

- For the typical stream flow occurrences, the risk profile (**Table 6-3**) is lower compared to the 2-year period for RSS-constituents accumulation. Notwithstanding, the risk constituents remain the same.

- The RSS constituent footprint would be constrained to the Hooley Creek - Four-Mile Creek tidal estuary. The footprint would not propagate to the Ashburton River and mangrove forests at the river mouth.

These factors are consolidated in **Table 6-1** and include:

- A salt precipitation factor that attempts to characterise propensity for elements to form low-solubility crystalline salts due to evaporation-concentration effects.
- A ratio that broadly defines the order of magnitude of RSS solute concentrations compared to the known baseline concentrations and or guideline values.
- Residence times in the Hooley Creek – Four-Mile Creek tidal embayment. The residence times were derived from the hydrodynamic model predictions, factored to ascertain an annual aspect.

- A bio-availability factor that added differentiation based on a general understanding that bio-availability would be higher for water soluble elements and minerals, rather than colloids, insoluble particulates and sediment.
- A toxicity factor that was intended to differentiate metals, non-metals, nutrients, inorganics and cleaning agents.

As a guide, the risk assessment scores (**Table 6-1**) reflect the normalisation of the predicted RSS source concentrations using the defined factors. As such, a score of 1 would tend to reflect a baseline and or guideline equivalent bio-availability in dissolved forms. Scores greater than 1.2 anticipate increased bio-availability compared to baseline and or guideline concentrations. Scores in the range 1.2 to 2.5 would be comparatively medium risks. Scores above 2.5 would be of comparatively high risk. Based on this score mechanism, the desktop risk assessment of the residual saline stream to the receptors uses a four-level hierarchy described as follows:

- **Scores less than 0.1 - Comparatively Very Low Risk:** Low potentials for bio-accumulation and changes to the local ecology leading to environmental harm. Short-term changes to the constituent concentrations leading to low risks of environmental harm.
- **Scores 0.1 to 1.2 - Comparatively Low Risk:** Approximately baseline equivalents, thus limited potentials for bio-accumulation and changes to the local ecology leading to environmental harm.
- **Scores 1.2 to 2.5 - Comparatively Medium Risk:** Marginally above baseline equivalents, thus moderate potentials for bio-accumulation and changes to the local ecology leading to environmental harm.
- **Scores greater than 2.5 - Comparatively High Risk:** Significantly above baseline equivalents, thus potentials for environmental harm through comparatively high concentrations, increased loads, bio-availability and bio-accumulation. Possible changes to the local ecology (including mangroves) and environmental harm.

The environmental risk assessment is contained in **Table 6-2** and **Table 6-3** for 1-year and 2-year RSS source term scenarios**.** This assessment is recognised as being semi-qualitative and subjective. This reflects the absence of facts to inform the assessment and consequently there is reliance on experience and intuition in deriving reasonable outcomes. Further, the risk assessment captures an outline of comparative risks.

Table 6-1 Desktop Environmental Risk Assessment

Aspect	Descriptions
Salt Precipitation Factor	
Discussion	It was recognised that the minerals elements that preferentially precipitate and form low-solubility minerals would not have the evaporation concentration behaviours predicted by the mass balance (which assumes full solubility). The geochemical modelling predicted that barium, silica, strontium and fluorite would tend to precipitate and form low-solubility minerals in the salt crust on Quick Mud Creek. For these minerals, it was anticipated that the subsequent dissolution of the majority of the salt (halite) by stream flow would be unlikely to be accompanied by barium, silica, strontium and fluorite concentrations that exceed those in seawater. Precipitate solubility factors gave been derived for these elements to follow this theme assuming selected percentages of the predicted worst-case scenario source term would be consumed in precipitated minerals.
0.10	Applied to barium. Based on comparatively low solubility of barium sulphate.
0.50	Applied to silica and strontium, understanding that chalcedony and strontianite have low solubility, but that residual silica and strontium in solution is likely given seawater concentrations.
1.00	Applied to the remainder of the elements assuming ready dissolution.
Ratio to Guidelines/Baseline	
Ratio	The ratio describes the dilution required to bring the predicted worst-case source terms to within the baseline/guideline limit. The source terms applied are based on the predicted worst-case scenario concentration multiplied by the Precipitation Factor then divided by the baseline/guideline limit. The ratio preferentially uses the baseline concentration where information is available.
Residence Times	
Ratio	The ratio calculated from the predicted time for dilution by seawater to baseline/guideline concentrations divided by 365 days.
Bio-Availability Factor	
1 percent of the Ratio to guidelines/baseline	Tends to form precipitates insoluble in water. The precipitates would be transported by stream flow, with short residence times in the tidal estuary. There would be limited associated potentials for trapping and bio-availability of the element. The analytes that would tend to low Solubility Factor - Availability include the metals barium, aluminium, copper and zinc and non-metal silica.
5 percent of the Ratio to guidelines/baseline	Tends to be limited by short residence times in the tidal estuary, high sediment and organic loads in the turbid stream flow and co-dependence with other analytes to enable availability. These analytes include nitrogen and phosphorous and is relevant where phosphorous RSS constituent source term concentrations are less than baseline concentrations. This aspect reflects phosphorous as a limiting nutrient, with this limit in effect also limiting the biological assimilation of nitrogen.
25 percent of the Ratio to guidelines/baseline	Tends to form compounds that would bind with colloids and particulates and thus remain suspended in the water column and or have low to moderate solubility in water. These elements and minerals would be transported by stream flow, with short residence times in the tidal estuary. The high sediment and organic loads in the turbid stream flow would enable binding with particulates and limit potentials for trapping and bio-availability. These analytes include phosphorus/phosphate.
50 percent of the Ratio to guidelines/baseline	Tends to remain in solution and or form soluble precipitates in water. These elements and minerals would be transported by stream flow, and hence potentially bio-available, but with short residence times in the tidal estuary. The high sediment and organic loads in the turbid stream flow would also limit associated potentials for trapping and bio-availability. These analytes include non-metals iodide, boron, and strontium together with ammonium and other forms of nitrogen.
Toxicology Factor	
Factor	This factor attempts to comparatively separate the different analytes based on likely toxicology and or environmental harm potentials when present at concentrations that exceed baseline and guideline values. For example, the metals have been assumed to be of highest potential toxicity and the non-metals the least. Only three factors are used: 100 for highest toxicity, 10 and 1 for lowest toxicity characteristics.
Scores and Comparative Risk Ranking	
Overall	The developed scores range over five orders of magnitude. Accordingly, the scores were assigned a risk ranking that typically spans an order of magnitude. The highest scores reflect the highest potential environmental risks.
Greater than 2.5	Comparatively High Risk.
1.2 to 2.5	Comparatively Medium Risk.
0.1 to 1.2	Comparatively Low Risk.
Less than 0.1	Comparatively Very Low Risk.

Table 6-2 **Comparative Environmental Risk Assessment and Scores – 1-Year RSS Accumulation**

Analyte	Symbol	Units	MDL	ANZECC & ARMCANZ (2000)	Upper-Bound Near-shore Baseline	Upper-Bound Tidal Creeks Baseline	Predicted RSS Source Terms	Comparative Environmental Risk Scoring Matrix						
								Dilution Period to Baseline (days)	Salt Precipitation Factor	Ratio to Guidelines/Baseline	Residence Times	Bio-Availability Factor	Toxicology Factor	Score
Dissolved Metals														
Barium	Ba	mg/L		ID	0.021	0.021	2.269	18	0.10	11	0.05	0.01	30	0.2
Aluminium	Al		0.01	0.055(1)	0.001	0.02	0.005	Not Applicable		Less than ANZECC				
Copper	Cu		0.001	0.0013	0.0009	0.027	0.023	7	1.00	Comparable to Baseline				
Lead	Pb		0.001	0.0044	0.0008	0.005	0.001	Not Applicable		Less than ANZECC				
Nickel	Ni		0.001	0.07	0.0066	0.0035	0.015	Not Applicable	1.00	Less than ANZECC				
Zinc	Zn		0.005	0.015	0.005	0.021	0.031	8	1.00	1.5	0.02	0.01	100	0.03
Non-Metals														
Bromide	Br	mg/L		ID	67.3	105	23.37	Not Applicable		Less than Baseline				
Iodide	I			ID	0.064	0.064	1.3	10	1.00	20	0.03	0.50	1.0	0.3
Fluoride	F			ID	1.3	1.4	0.86	Not Applicable		Less than Baseline				
Boron	Br			0.37(1)	4.45	6.27	4.23	6	1.00	Less than Baseline				
Silica	SiO_2			ID	2.9	10.64	20.58	9	0.50	1	0.02	0.01	1.0	0.0002
Strontium	Sr			ID	8.1	10.1	7.38	6	0.50	Less than Baseline				
Nutrients														
Total-N	TN			0.25	0.28	0.25	8.56	14	1.00	31	0.04	0.05	10.0	0.6
Total-P	TP			0.002	0.05	0.025	0.005	20	1.00	Less than Baseline				
Inorganics														
pH (Lab)	pH	pH	0.01	8.0 to 8.4	39,500	7.85	7.78	Not Applicable	1.00	Comparable to seawater				
TDS	TDS	mg/L	10			61,400	12,108	Not Applicable	1.00	Less than seawater				
Turbidity	NTU	NTU	0.1	1 to 20	17	9.8	<1	Not Applicable	1.00	Less than seawater				
Cleaning Agents														
Citric acid[1]		mg/L		100 (2)	0.145		0.33 (3)	18	1.00	0.001	0.05	1.00	1.0	0.0001
Sodium Lauryl Sulfate[1]				25 (2)			0.01 (3)	18	1.00	0.040	0.05	0.50	1.0	0.001

Notes:
ID = Insufficient data to derive a reliable trigger value.
(1) Derived from freshwater guidelines.

(2) These concentrations are estimated from a literature search. There are no formal guidelines that were found.

(3) Derived understanding that doses are applied for one day every three months, thus the cumulative effect is 8 days during a 2-year period of salt accumulation on Quick Mud Creek

Table 6-3 **Comparative Environmental Risk Assessment and Scores – 2-Year RSS Accumulation**

Analyte	Symbol	Units	MDL	ANZECC & ARMCANZ (2000)	Upper-Bound Near-shore Baseline	Upper-Bound Tidal Creeks Baseline	Predictive RSS Source Terms	Comparative Environmental Risk Scoring Matrix						
								Dilution Period to Baseline (days)	Salt Precipitation Factor	Ratio to Guidelines/Baseline	Residence Times	Bio-Availability Factor	Toxicology Factor	Score
Dissolved Metals														
Barium	Ba	mg/L		ID	0.021	0.021	4.539	35	0.10	22	0.10	0.01	30	0.6
Aluminium	Al		0.01	0.055(1)	0.001	0.02	0.009	Not Applicable		Less than ANZECC				
Copper	Cu		0.001	0.0013	0.0009	0.027	0.047	14	1.00	2	0.04	0.01	100	0.1
Lead	Pb		0.001	0.0044	0.0008	0.005	0.002	Not Applicable		Less than ANZECC				
Nickel	Ni		0.001	0.07	0.0066	0.0035	0.03	Not Applicable		Less than ANZECC				
Zinc	Zn		0.005	0.015	0.005	0.021	0.061	15	1.00	3	0.04	0.01	100	0.12
Non-Metals														
Bromide	Br	mg/L		ID	67.3	105	46.74	Not Applicable		Less than Baseline				
Iodide	I			ID	0.064	0.064	2.61	20	1.00	41	0.05	0.50	1.0	1.1
Fluoride	F			ID	1.3	1.4	1.72	12	1.00	1	0.03	0.50	1.0	0.02
Boron	Br			0.37(1)	4.45	6.27	8.45	12	1.00	1	0.03	0.50	1.0	0.02
Silica	SiO_2			ID	2.9	10.64	41.16	17	0.50	2	0.05	0.01	1.0	0.001
Strontium	Sr			ID	8.1	10.1	14.76	12	0.50	1	0.03	0.50	1.0	0.01
Nutrients														
Total-N	TN			0.25	0.28	0.25	17.11	28	1.00	61	0.08	0.05	10.0	2.3
Total-P	TP			0.002	0.05	0.025	0.01	20	1.00	Less than Baseline				
Inorganics														
pH (Lab)	pH	pH	0.01	8.0 to 8.4		7.85	7.78	Not Applicable	1.00	Comparable to seawater				
TDS	TDS	mg/L	10			42,800	24,216	Not Applicable	1.00	Less than seawater				
Turbidity	NTU	NTU	0.1	1 to 20		9.8	<1	Not Applicable	1.00	Less than seawater				
Cleaning Agents														
Citric acid[1]		mg/L		100 (2)	0.145		0.65 (3)	35	1.00	0.001	0.10	1.00	1.0	0.0001
Sodium Lauryl Sulfate[1]				25 (2)			0.02 (3)	35	1.00	0.040	0.10	0.50	1.0	0.002

Notes:

ID = Insufficient data to derive a reliable trigger value.

(1) Derived from freshwater guidelines.

(2) These concentrations are estimated from a literature search. There are no formal guidelines that were found.

(3) Derived understanding that doses are applied for one day every three months, thus the cumulative effect is 8 days during a 2-year period of salt accumulation on Quick Mud Creek

The scores above 1.2 only occur associated with the 2-year RSS accumulation period and include:

- Total Nitrogen – score – 2.3.

The Total Nitrogen score may be skewed conservatively low given the evidence of existing pastoral activity sources (which would reflect an altered baseline) that would contribute to the concentrations and loadings. The Total Nitrogen score reflects comparatively high RSS constituent source terms and low baseline concentrations. Short-term residence times, propensity for stream-flow events to carry high turbidity and limit light penetration of the water column together with limiting phosphorous concentrations were recognised to off-set the nitrogen risk potentials. Consideration of the large nitrogen loads that might be naturally introduced to the Hooley Creek - Four-Mile Creek tidal estuary from the algal mats and likely typical occurrences of higher volume stream flows would both off-set the risk score. Further, is the evidence from case studies that indicate the intertidal habitats host natural biomass constituents and processes that would adjust to increased nutrient sources (as would occur anyway during stream flow events) and consume, assimilate and redistribute the nutrients.

In this score matrix, iodide also ranks comparatively high with a score of 1.1. The iodide score may, however, be skewed conservatively high given it is not usually recognised as a contaminant and is ingested in table salt.

6.3 Supratidal Saline Flats and Quick Mud Creek

The source terms for the RSS at the headwaters of the supratidal saline flats (**Table 4-2**) are about an order of magnitude higher than at the headwaters of the tidal reaches of Hooley Creek (**Table 4-3**). In the RSS hypersaline pools on the low-flow channel of Quick Mud Creek the source concentrations would be higher again.

The higher source concentrations would potentially reflect higher risk potentials to ecological receptors. The receptors, however, would be potentially limited by environmental settings that naturally accumulate salt. The known receptors would be birds (only present during the wet season; the times of stream flow) and algal mats. Presumably the birds would feed on the phytoplankton, heterotrophic nanoflagellates, aloricate ciliates, copepodids and nauplii within the water column of the tidal creeks.

Algal mats are typically comprised of nitrogen fixing algae. The algal mats are not nitrogen limited, able to source nitrogen from the air. An increase in nitrogen concentrations in the occasional stream flows is therefore unlikely to significantly influence the algal mat growth.

7 DISCUSSION OF ENVIRONMENTAL RISKS

In a pragmatic sense, the identified comparatively medium risk scores provide a pointer to the RSS-constituents with highest potentials to contribute to environmental change and or harm. The focus in terms of potential environmental risk is therefore on nitrogen only.

7.1 Significant Analogies

For the risk assessments there are two significant analogies that require further consideration.in context to understanding the actual environmental risks. These analogies are based on observations from:

- Nutrient-enriched shrimp pond effluents to tidal creeks.
- The Ashburton River stream flow in context to the Ashburton River Delta.

Both of these analogies provide themes that tend to ameliorate the environmental risks associated with the RSS. For example:

- Evidence from nutrient-enriched shrimp ponds effluent disposed into tidal creeks is that there is environmental change linked to alteration of natural nutrient limits. The changes that occur may be temporary in that the existing ecology of phytoplankton and bacteria assimilate the nutrients, and the increased biomass is further assimilated in the grazing by ciliates, Copepodids, Nauplii, benthic epifauna, nekton and fish. Change responses also were evident in foliar nitrogen contents of mangrove trees, indicative of growth linked to changes in nutrients limits. The changes have not been described in context of environmental harm. There is, however, recognition that the capacity for the local ecology to assimilate the nutrients may not be boundless and that the long-term sustainability of the ecosystems under such conditions is not tested. That said, the evidence that algal mat within the Hooley Creek - Four-Mile Creek tidal estuary may produce up to 55 tonnes of nitrogen each year would indicate the intertidal habitats naturally adjust to variable nutrient availability and or have limited access to this nitrogen source. The availability of nutrients from the algal mats would be episodic linked to inundation by tides and shedding of rainfall and runoff from the local catchments.

- The Ashburton River provides a widely variable setting imposing vastly different ranges of stream flow volumes and sediment loads onto the delta environment and ecosystems. Quick Mud Creek and Hooley Creek are sub-catchments of the delta and adjoining coastal plain. The river on average delivers 1.3 million tonnes annual sediment loadings (and associated loadings of metals) to the ecology of the Ashburton River Delta. It is understood that these natural loadings do not pose risks to the ecology of the Ashburton River Delta and consequently would be unlikely to promote significant changes in the ecology of the tidal reaches of Hooley Creek. It is expected that the sediment and 840 GL of stream flow temporarily exposes the Ashburton River Delta to substantial loadings of salt, minerals, metals and nutrients. These loadings may be transported in solution and or in the water column in particulates or colloidal forms.

Given these analogies, the likelihood of adverse environmental risk due to nitrogen is considered to be low. It is considered possible there might be environmental change, at least temporarily linked to flow events. The context that supports this risk assessment is also provided by the evidence on the Ashburton River together with potentially ameliorating factors provided by limited residence times, high turbidity and limited light penetration of the water column and phosphorous being a limiting nutrient. Each of these factors would restrict the local bio-availability of the nitrogen.

The Ashburton River analogy is also relevant to the risk assessment for the metals.

The risk assessments would be informed with improved robustness by quality data collected during stream flow events. These data would ideally include sampling and analysis of the stream flow together with suspended soils and particulates.

8 CONCLUSIONS

A desktop comparative risk assessment has been used to interpret potential environment risks to the Hooley Creek – Four-Mile Creek tidal embayment that might arise from worst-case scenarios for the disposal of RSS. This risk assessment was based on the Scenario 2 specifications of the RSS constituents. In this scenario the nitrogen and phosphorus concentrations from anti-scalant dosage have been limited. The worst-case scenario couples a 2-year period of RSS constituent accumulation with low-volume stream flow events generated only from local watersheds. Typically it would be expected that several stream flow events might occur each year, with contributions from the wider Quick Mud Creek catchment areas and also from the Ashburton River typically on a biennial basis. As a guide, the stream flow volumes used to inform the RSS source terms to tidal reaches of Hooley Creek were:

- At least an order of magnitude lower than approximations of annual average flows from the broader Quick Mud Creek catchment.
- Less than 0.2 per cent of annual average flow volumes on the Ashburton River.

Additional conservatism is provided in aligning the risk assessment solely to the baseline concentrations of analytes observed in the tidal creeks and near-shore seawater during quiescent times. It is noteworthy that these baseline data do not reflect periods of stream flow during which the Hooley Creek – Four-Mile Creek tidal embayment would commonly receive high turbidity and sediment laden fresh runoff. It was anticipated that the baseline data would significantly underestimate the salt, mineral, metals and nutrient loadings that would occur in the stream flow and invade the intertidal habitats.

Further, the environmental risk assessment was focussed on receiving environments within the Hooley Creek - Four-Mile Creek tidal embayment. It is within this setting that intertidal habitats of moderate conservation significance occur (refer to **Chapter 2.1.4**). The denuded and saline lower reaches of the Quick Mud Creek and the supratidal saline flats form areas which lack significant habitats and receptors.

A number of discrete aspects (salt precipitation, magnitude of concentrations above baseline/guideline values, residence times, bio-availability and toxicity) were applied in attempts to rationalise and differentiate potential risks. The findings of the Hooley Creek – Four-Mile Creek tidal embayment environmental risk assessment included:

- There is strong contrast between the risk scores for the 1-year and 2-year RSS constituent accumulation source terms. This contrast reflects the risk assessment sensitivity to the period of accumulation for the RSS constituents and the stream flow volumes that form the source terms. The application of reduced RSS accumulation and higher stream flow volumes in the risk assessment would lower the risk scores.
- There was about four orders of magnitude difference across the range of the scores.
- The majority of the comparative risk scores are less than 1.2 and assessed as very low and low environment risks.
- The medium environmental risk scores included:
  - Total Nitrogen – score 2.3 under the worst-case 2-year RSS constituent accumulation source terms.
- The iodide score of 1.1 was comparatively high but considered to be skewed conservatively high given it is not usually recognised as a contaminant and is ingested in table salt.

- There were no high-risk scores.

The Total Nitrogen score reflects comparatively high RSS constituent source terms and low baseline concentrations; this score does not reflect the evidence of existing pastoral activity sources that would contribute to the concentrations and loadings.

Short-term residence times, propensity for stream-flow events to carry high turbidity and limit light penetration of the water column together with limiting phosphorous concentrations were recognised to off-set the nitrogen risk potentials. Consideration of the large nitrogen loads that might be naturally introduced to the Hooley Creek - Four-Mile Creek tidal estuary from the algal mats and likely typical occurrences of higher volume stream flows would both off-set the risk score. Further, is the evidence from case studies that indicate the intertidal habitats host natural biomass constituents and processes that would adjust to increased nutrient sources (as would occur anyway during stream flow events) and consume, assimilate and redistribute the nutrients. Overall based on the compiled evidence the likelihood of adverse environmental impacts and or risk due to the RSS constituent nitrogen was considered to be low. Evidence from nutrient-enriched shrimp pond effluents to tidal creeks and the flow characteristics of the Ashburton River supports this risk assessment. Both provide analogies that indicate the likelihood of ameliorating factors provided by limited residence times, high turbidity and limited light penetration of the water column. Each of these factors would restrict the local bio-availability of the nitrogen. It is considered possible, however, that there might be environmental change, at least temporarily linked to flow events and availability of limiting nutrients.

The metals barium, copper and zinc were ranked with low-risk scores. The worst-case scenario source terms for these metals exceed the ANZECC & ARMCANZ (2000) guidelines and or observed baseline concentrations. It was anticipated that risks from these metals would be ameliorated by low solubility, high turbidity of the stream flow events and limited residence times. The Ashburton River analogy would also ameliorate potential risks associated with metal concentrations and loadings. The supporting context is provided in that on average the river transports 1.3 million tonnes of sediment (and associated loadings of metals) to the ecology of the Ashburton River Delta and evidently does not pose risks to the ecology of the Ashburton River Delta. Consequently similar circumstances associated with tidal reaches of Hooley Creek would be unlikely to promote significant changes in the local ecology.

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Figures

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Client

CHEVRON AUSTRALIA PTY LTD

URS

Project

Desktop Risk Assessment on Constituents (excluding NORMs) of the Residual Saline Stream

Title

Local Geomorphological Landforms

Drawn: RNM
Approved: IB
Date: 18/03/2014
Job No.: 42908178
File No.: 42908178_001.mxd
Figure: 2.1
Rev. A
A3

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APPENDIX A BASELINE DATABASE FOR RSS CONSTITUENTS IN THE PROJECT AREA

Client - Mat	WATER			Sample Type:	REG	REG	REG	REG	REG	REG	REG	REG
Workgroup:	EP1401718			ALS Sample number:	EP1401718001	EP1401718002	EP1401718003	EP1401718004	EP1401718005	EP1401718006	EP1401718007	EP1401718008
Project nam	GW & SW Monitoring			Sample date:	28/02/2014	28/02/2014	28/02/2014	28/02/2014	28/02/2014	28/02/2014	28/02/2014	28/02/2014
				Client sample ID (Primary):	OWS21_280214	OWS22_280214	OWS23_280214	QAQC01_280214	QAQC02_280214	QAQC03_280214	QAQC04_280214	QAQC05-TRIP BLANK
				Client sample ID (Secondary):								
				Sample Site:								
				Purchase Order:	42908272	42908272	42908272	42908272	42908272	42908272	42908272	42908272
Analyte grou	CAS Number	Units	LOR									
EA005P: pH by PC Titrator												
pH Value		pH Unit	0.01		7.95	8.02	8.18	8.23				
EA015: Total Dissolved Solids												
Total Dissolved Solids @180°C		mg/L	10		47900	45200	44600	45700				
EA025: Suspended Solids												
Suspended Solids (SS)		mg/L	5		23	30	22	33				
EA165: CO2 - Free and Total												
Free Carbon	85540-96-1	mg/L	1		3	2	2	2				
Total Carbor	85540-96-1	mg/L	1		116	110	111	123				
ED009: Anions												
Bromide	24959-67-9	mg/L	0.01		102	105	99.4	103				
Iodide	20461-54-5	mg/L	0.01		<0.100	<0.100	<0.100	<0.100				
ED037P: Alkalinity by PC Titrator												
Hydroxide A	DMO-210-001	mg/L	1		<1	<1	<1	<1				
Carbonate A	3812-32-6	mg/L	1		<1	<1	<1	<1				
Bicarbonate	71-52-3	mg/L	1		128	122	124	138				
Total Alkalinity as CaCO3		mg/L	1		128	122	124	138				
ED040F: Dissolved Major Anions												
Sulfur as S	63705-05-5	mg/L	1		1420	1530	1400	1360				
Silicon as Si	14464-46-1	mg/L	0.1		<2.0	<2.0	<2.0	<2.0				
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA												
Sulfate as S	14808-79-8	mg/L	1		3360	3400	3250	3410				
ED045G: Chloride Discrete analyser												
Chloride	16887-00-6	mg/L	1		25000	23800	23100	23600				
ED093F: Dissolved Major Cations												
Calcium	7440-70-2	mg/L	1		557	542	517	489				
Magnesium	7439-95-4	mg/L	1		2080	2300	2140	2090				
Sodium	7440-23-5	mg/L	1		14200	14000	13400	12900				
Potassium	7/09/7440	mg/L	1		757	820	759	748				

Client - Matı	WATER			Sample Type:	REG	REG	REG	REG	REG	REG	REG	REG
Workgroup:	EP1401718			ALS Sample number:	EP1401718001	EP1401718002	EP1401718003	EP1401718004	EP1401718005	EP1401718006	EP1401718007	EP1401718008
Project nam	GW & SW Monitoring			Sample date:	28/02/2014	28/02/2014	28/02/2014	28/02/2014	28/02/2014	28/02/2014	28/02/2014	28/02/2014
				Client sample ID (Primary):	OWS21_280214	OWS22_280214	OWS23_280214	QAQC01_280214	QAQC02_280214	QAQC03_280214	QAQC04_280214	QAQC05-TRIP BLANK
				Client sample ID (Secondary):								
				Sample Site:								
				Purchase Order:	42908272	42908272	42908272	42908272	42908272	42908272	42908272	42908272
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS												
Aluminium	7429-90-5	µg/L	5		29	70	47	35				
Iron	7439-89-6	µg/L	5		68	51	40	39				
Barium	7440-39-3	µg/L	1		20	14	14	13				
Boron	7440-42-8	µg/L	100		6210	6270	6010	5940				
Copper	7440-50-8	µg/L	1		<2	<2	<2	<2				
Lead	7439-92-1	µg/L	0.2		<0.4	<0.4	<0.4	<0.4				
Manganese	7439-96-5	µg/L	0.5		14.7	5.1	5.7	4.6				
Nickel	7440-02-0	µg/L	0.5		<1.0	<1.0	<1.0	<1.0				
Strontium	7440-24-6	µg/L	10		10100	9250	9220	9400				
Zinc	7440-66-6	µg/L	5		<10	<10	<10	<10				
EG094T: Total metals in Fresh water by ORC-ICPMS												
Aluminium	7429-90-5	µg/L	5						<5	8	<5	
Iron	7439-89-6	µg/L	2						<2	10	<2	
Barium	7440-39-3	µg/L	0.5						<0.5	<0.5	<0.5	
Boron	7440-42-8	µg/L	5						<5	<5	<5	
Copper	7440-50-8	µg/L	0.5						<0.5	<0.5	<0.5	
Lead	7439-92-1	µg/L	0.1						<0.1	<0.1	<0.1	
Manganese	7439-96-5	µg/L	0.5						<0.5	<0.5	<0.5	
Nickel	7440-02-0	µg/L	0.5						<0.5	<0.5	<0.5	
Strontium	7440-24-6	µg/L	1						<1	<1	<1	
Zinc	7440-66-6	µg/L	1						1	6	<1	
EK040P: Fluoride by PC Titrator												
Fluoride	16984-48-8	mg/L	0.1		1.3	1.4	1.3	1.4				
EK055G: Ammonia as N by Discrete Analyser												
Ammonia as	7664-41-7	mg/L	0.01		0.09	0.08	0.08	0.05				
EK060G:Organic Nitrogen as N (TKN-NH3) By Discrete Analyser												
Organic Nitrogen as N		mg/L	0.1		<0.2	0.5	0.3	<0.2				
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser												
Total Kjeldahl Nitrogen as N		mg/L	0.1		<0.2	0.6	0.4	<0.2				
EK067G: Total Phosphorus as P by Discrete Analyser												
Total Phosphorus as P		mg/L	0.01		<0.02	<0.02	<0.02	<0.02				
EP002: Dissolved Organic Carbon (DOC)												
Dissolved Organic Carbon		mg/L	1		14	5	8	10				

Table 4-1 Ashburton River Delta and Hooley Creek - Nutrient and TSS Laboratory Analysis

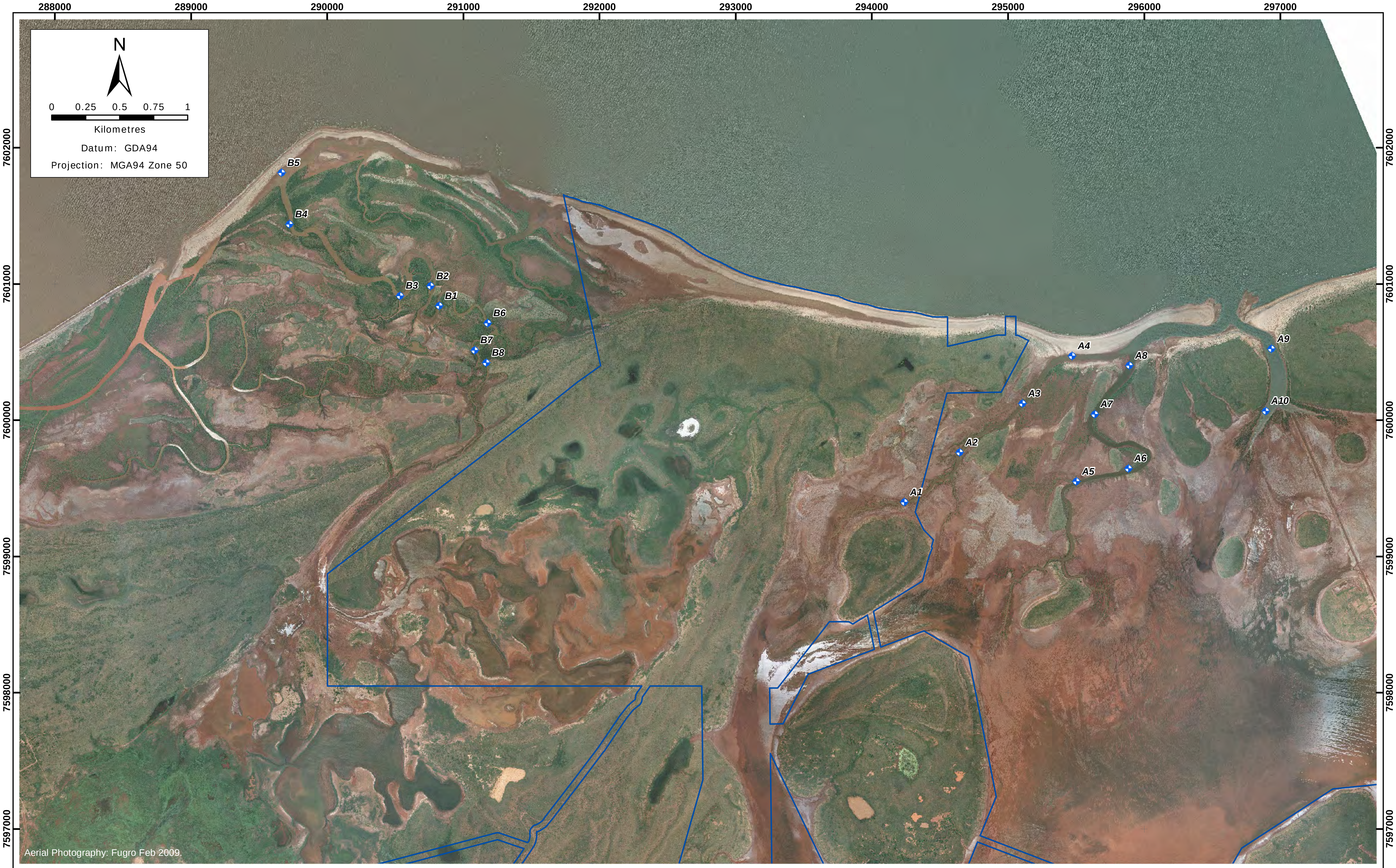
Sample Site	METHOD	2000	4100	2100	4700	2700	2540D	2540E	3000	3000
	ANALYTE	AMMONIA	ORTHO-P	NO3+NO2	TOTAL-P	TOTAL-N	TSS	% LOSS ON	CHLORO-PHYLL'a'	PHAEOPHYTIN 'a'
	Unit	µg.N/L	µg.P/L	µg.N/L	µg.P/L	µg.N/L	mg/L	IGNITION	µg/L	µg/L
	LOR	<6	<4	<4	<10	<100	<2	AT 550°C	<0.2	<0.4
	Sampling Date									
A1	1/09/2010	5	2	<2	14	160	15	23	1.0	<0.2
	6/11/2010	14	6	5	20	200	16	31	0.5	<0.4
	13/03/2011	13	4	9	25	290	19	23	1.9	0.5
A2	1/09/2010	7	<2	<2	11	150	13	28	0.9	0.3
	6/11/2010	9	<4	<4	10	200	11	33	1.0	<0.4
	13/03/2011	51	3	10	20	260	16	26	1	0.2
A3	1/09/2010	<3	<2	<2	6	100	7	21	0.5	<0.2
	6/11/2010	9	<4	<4	<10	200	7	33	0.4	<0.4
	13/03/2011	27	<2	12	17	240	12	32	1.6	0.4
A4	1/09/2010	<3	2	<2	7	90	6	23	0.4	<0.2
	6/11/2010	45	<4	16	<10	200	7	32	0.5	<0.4
	13/03/2011	23	2	12	17	220	20	25	1.5	0.4
A5	1/09/2010	6	<2	<2	7	90	10	21	0.9	<0.2
	6/11/2010	12	<4	<4	10	200	10	38	0.7	<0.4
	13/03/2011	28	3	16	19	280	18	36	1.9	0.6
A6	1/09/2010	<3	2	<2	6	90	11	23	0.7	<0.2
	6/11/2010	66	<4	<4	<10	200	9	25	0.5	<0.4
	13/03/2011	29	2	19	17	270	14	27	1.2	0.6
A7	1/09/2010	<3	<2	<2	10	120	11	25	0.4	<0.2
	6/11/2010	Inaccessible due to weather.								
	13/03/2011	4	<2	4	11	150	9	18	1.8	0.3
A8	1/09/2010	<3	2	<2	5	90	8	18	0.4	<0.2
	6/11/2010	Inaccessible due to weather.								
	13/03/2011	<3	<2	4	13	140	8	26	2	0.4
A9	1/09/2010	<3	3	<2	10	120	13	20	0.5	<0.2
	6/11/2010	Inaccessible due to weather.								
	13/03/2011	5	<2	7	11	160	5	19	1.7	0.4
A10	1/09/2010	<3	<2	<2	9	170	11	22	0.8	<0.2
	6/11/2010	Inaccessible due to weather.								
	13/03/2011	4	<2	6	10	140	6	32	1.5	0.2
B1	2/09/2010	9	4	3	14	180	34	17	1.3	<0.2
	11/11/2010	12	<4	<4	10	200	12	24	1.3	<0.4
	12/03/2011	15	5	11	19	200	22	23	2.7	0.4
B2	2/09/2010	<3	3	<2	19	170	33	20	1.7	<0.2
	11/11/2010	11	5	<4	20	300	24	21	1.4	<0.4
	12/03/2011	14	3	9	17	190	21	30	2.8	0.6
B3	2/09/2010	9	3	2	13	150	18	23	2.4	0.2
	11/11/2010	9	<4	<4	10	100	-	-	1.7	<0.4
	12/03/2011	12	3	8	17	180	21	18	4.1	0.6
B4	2/09/2010	<3	<2	<2	12	120	25	26	3	<0.2

4 Estuarine Monitoring

Sample Site	METHOD	2000	4100	2100	4700	2700	2540D	2540E	3000	3000
	ANALYTE	AMMONIA	ORTHO-P	NO3+NO2	TOTAL-P	TOTAL-N	TSS	% LOSS ON	CHLORO-PHYLL'a'	PHAEOPHYTIN 'a'
	Unit	µg.N/L	µg.P/L	µg.N/L	µg.P/L	µg.N/L	mg/L	IGNITION	µg/L	µg/L
	LOR	<6	<4	<4	<10	<100	<2	AT 550°C	<0.2	<0.4
	Sampling Date									
	11/11/2010	12	<4	6	20	100	-	-	1.0	<0.4
	12/03/2011	16	3	9	20	160	41	23	3.5	1.1
B5	2/09/2010	<3	<2	<2	12	120	18	19	2.2	<0.2
	11/11/2010	10	<4	<4	10	<100	-	-	1.1	<0.4
	12/03/2011	18	2	9	24	190	58	24	4.4	1.2
B6	2/09/2010	Unable to sample due to insufficient tidal height.								
	11/11/2010	9	<4	<4	20	200	11	20	1.0	<0.4
	12/03/2011	11	4	12	20	210	18	16	2.9	0.8
B7	2/09/2010	Unable to sample due to insufficient tidal height.								
	11/11/2010	9	5	<4	20	200	19	27	1.1	<0.4
	12/03/2011	15	5	13	18	180	28	30	1.5	0.7
B8	2/09/2010	Unable to sample due to insufficient tidal height.								
	11/11/2010	9	5	<4	20	200	26	20	1.1	<0.4
	12/03/2011	30	5	26	25	240	22	21	1.8	0.7

Table 4-2 Ashburton River Delta and Hooley Creek – Dissolved Metals Analysis

Sample Site	**Method**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP001**	**ICP006**
	Metal	**Al**	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Pb**	**S**	**Se**	**V**	**Zn**	**Total Ext Hg**
	Unit	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
	LOR	**<0.01**	**<0.02**	**<0.0006**	**<0.001**	**<0.001**	**<0.002**	**<0.5**	**<0.0002**	**<0.004**	**<5**	**<0.004**	**<0.01**	**<5**	**<0.02**	**<0.002**	**<0.002**	**<0.0001**
	Sampling Date																	
A1	1/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	0.003	1800	0.028	0.01	14000	<0.004	<0.01	1200	<0.02	<0.001	<0.002	<0.0001
	6/11/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	0.004	2000	0.014	0.014	15000	<0.004	<0.01	1300	<0.02	<0.002	<0.002	<0.0001
	13/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	0.007	1700	0.028	0.013	14000	<0.004	<0.01	1200	<0.02	0.002	<0.002	<0.0001
A2	1/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1600	0.02	0.011	12000	<0.004	<0.01	1100	<0.02	<0.001	<0.002	<0.0001
	6/11/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	0.003	1800	0.0051	0.011	13000	<0.004	<0.01	1200	<0.02	<0.002	0.002	<0.0001
	13/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	0.006	1700	0.022	0.013	14000	<0.004	<0.01	1200	<0.02	0.002	<0.002	<0.0001
A3	1/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1300	0.0023	0.009	10000	<0.004	<0.01	900	<0.02	<0.001	<0.002	<0.0001
	6/11/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1700	0.0037	0.011	12000	<0.004	<0.01	1100	<0.02	<0.002	<0.002	<0.0001
	13/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	0.003	1600	0.019	0.012	13000	<0.004	<0.01	1100	<0.02	0.002	<0.002	<0.0001
A4	1/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1400	0.0014	0.01	11000	<0.004	<0.01	950	<0.02	<0.001	<0.002	<0.0001
	6/11/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1700	0.0039	0.011	13000	<0.004	<0.01	1100	<0.02	<0.002	<0.002	<0.0001
	13/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	0.003	1600	0.012	0.011	13000	<0.004	<0.01	1100	<0.02	0.002	<0.002	<0.0001
A5	1/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1500	0.016	0.011	12000	<0.004	<0.01	1000	<0.02	<0.001	<0.002	<0.0001
	6/11/2010	<0.01	<0.02	<0.0006	<0.001	0.027	<0.002	1700	0.0039	0.011	12000	<0.004	<0.01	1100	<0.02	<0.002	0.021	<0.0001
	13/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	0.005	1700	0.016	0.012	14000	<0.004	<0.01	1200	<0.02	0.002	<0.002	<0.0001
A6	1/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1500	0.0055	0.01	11000	<0.004	<0.01	990	<0.02	<0.001	<0.002	<0.0001
	6/11/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1600	0.0028	0.01	12000	<0.004	<0.01	1100	<0.02	<0.002	<0.002	<0.0001
	13/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	0.004	1600	0.014	0.012	14000	<0.004	<0.01	1100	<0.02	0.002	<0.002	<0.0001
A7	1/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1400	0.002	0.009	11000	<0.004	<0.01	970	<0.02	<0.001	<0.002	<0.0001
	6/11/2010	Inaccessible due to weather.																
	13/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1400	0.0029	0.011	11000	<0.004	<0.01	960	<0.02	0.002	<0.002	<0.0001
A8	1/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1300	0.0016	0.009	11000	<0.004	<0.01	940	<0.02	<0.001	<0.002	<0.0001
	6/11/2010	Inaccessible due to weather.																
	13/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1300	0.0016	0.01	11000	<0.004	<0.01	920	<0.02	0.002	<0.002	<0.0001
A9	1/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1400	0.002	0.01	11000	<0.004	<0.01	980	<0.02	<0.001	0.003	<0.0001
	6/11/2010	Inaccessible due to weather.																
	13/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1200	0.0009	0.011	11000	<0.004	<0.01	880	<0.02	0.002	<0.002	<0.0001
A10	1/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1500	0.0051	0.01	12000	<0.004	<0.01	1000	<0.02	<0.001	<0.002	<0.0001
	6/11/2010	Inaccessible due to weather.																
	13/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1300	0.0026	0.011	11000	<0.004	<0.01	940	<0.02	0.002	<0.002	<0.0001
B1	2/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	0.004	1700	0.13	0.008	14000	<0.004	<0.01	1200	<0.02	<0.001	<0.002	<0.0001
	11/11/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1400	0.015	0.009	12000	<0.004	<0.01	970	<0.02	<0.002	<0.002	<0.0001
	12/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	0.002	1300	0.06	0.011	11000	<0.004	<0.01	940	<0.02	0.001	<0.002	<0.0001
B2	2/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	0.005	1600	0.12	0.009	13000	<0.004	<0.01	1100	<0.02	<0.001	<0.002	<0.0001
	11/11/2010	0.54	<0.02	<0.0006	<0.001	<0.001	0.49	1500	0.042	0.009	12000	<0.004	<0.01	1100	<0.02	<0.002	0.003	<0.0001
	12/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	0.002	1300	0.049	0.011	10000	<0.004	<0.01	900	<0.02	0.001	<0.002	<0.0001
B3	2/09/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	0.003	1500	0.072	0.008	12000	<0.004	<0.01	1000	<0.02	<0.001	<0.002	<0.0001
	11/11/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1400	0.008	0.01	11000	<0.004	<0.01	1000	<0.02	<0.002	<0.002	<0.0001
	12/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1200	0.017	0.011	10000	<0.004	<0.01	890	<0.02	0.002	<0.002	<0.0001
B4	2/09/2010	0.01	<0.02	<0.0006	<0.001	<0.001	0.002	1400	0.032	0.009	12000	<0.004	<0.01	1000	<0.02	<0.001	<0.002	<0.0001
	11/11/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1400	0.0048	0.01	11000	<0.004	<0.01	970	<0.02	<0.002	<0.002	<0.0001
	12/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1200	0.0011	0.011	11000	<0.004	<0.01	900	<0.02	0.003	<0.002	<0.0001
B5	2/09/2010	0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1400	0.017	0.01	11000	<0.004	<0.01	970	<0.02	<0.001	<0.002	<0.0001
	11/11/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1400	0.0059	0.01	11000	<0.004	<0.01	970	<0.02	<0.002	<0.002	<0.0001
	12/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1200	0.0007	0.011	10000	<0.004	<0.01	880	<0.02	0.002	<0.002	<0.0001
B6	2/09/2010	Unable to sample due to insufficient tidal height.																
	11/11/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1600	0.02	0.01	13000	<0.004	<0.01	1100	<0.02	<0.002	<0.002	<0.0001
	12/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1300	0.056	0.012	11000	<0.004	<0.01	930	<0.02	0.001	<0.002	<0.0001
B7	2/09/2010	Unable to sample due to insufficient tidal height.																
	11/11/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1600	0.025	0.01	13000	<0.004	<0.01	1100	<0.02	<0.002	<0.002	<0.0001
	12/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	0.002	1400	0.083	0.011	11000	<0.004	<0.01	960	<0.02	<0.001	<0.002	<0.0001
B8	2/09/2010	Unable to sample due to insufficient tidal height.																
	11/11/2010	<0.01	<0.02	<0.0006	<0.001	<0.001	0.003	1600	0.028	0.009	13000	<0.004	<0.01	1100	<0.02	<0.002	<0.002	<0.0001
	12/03/2011	<0.01	<0.02	<0.0006	<0.001	<0.001	<0.002	1400	0.083	0.011	11000	<0.004	<0.01	980	<0.02	<0.001	<0.002	<0.0001



Legend

- ◆ Water Quality Sites
- ▭ Indicative Terrestrial Project Area

Client
CHEVRON AUSTRALIA PTY LTD

Project
Wheatstone Project
Terrestrial And Estuarine
Water monitoring Report

Title
Estuarine Water
Sample Locations

Drawn: MR
Approved: AMcT
Date: 20/12/2010
Job No.: 42907466
File No.: 42907466-SW-014.mxd
Appendix C
Rev. A
A3

T:\Jobs\42907466\Surface_Water\MXD\42907466-SW-014.mxd

Figure 1. Sampling sites for metals, nutrients and hydrocarbons

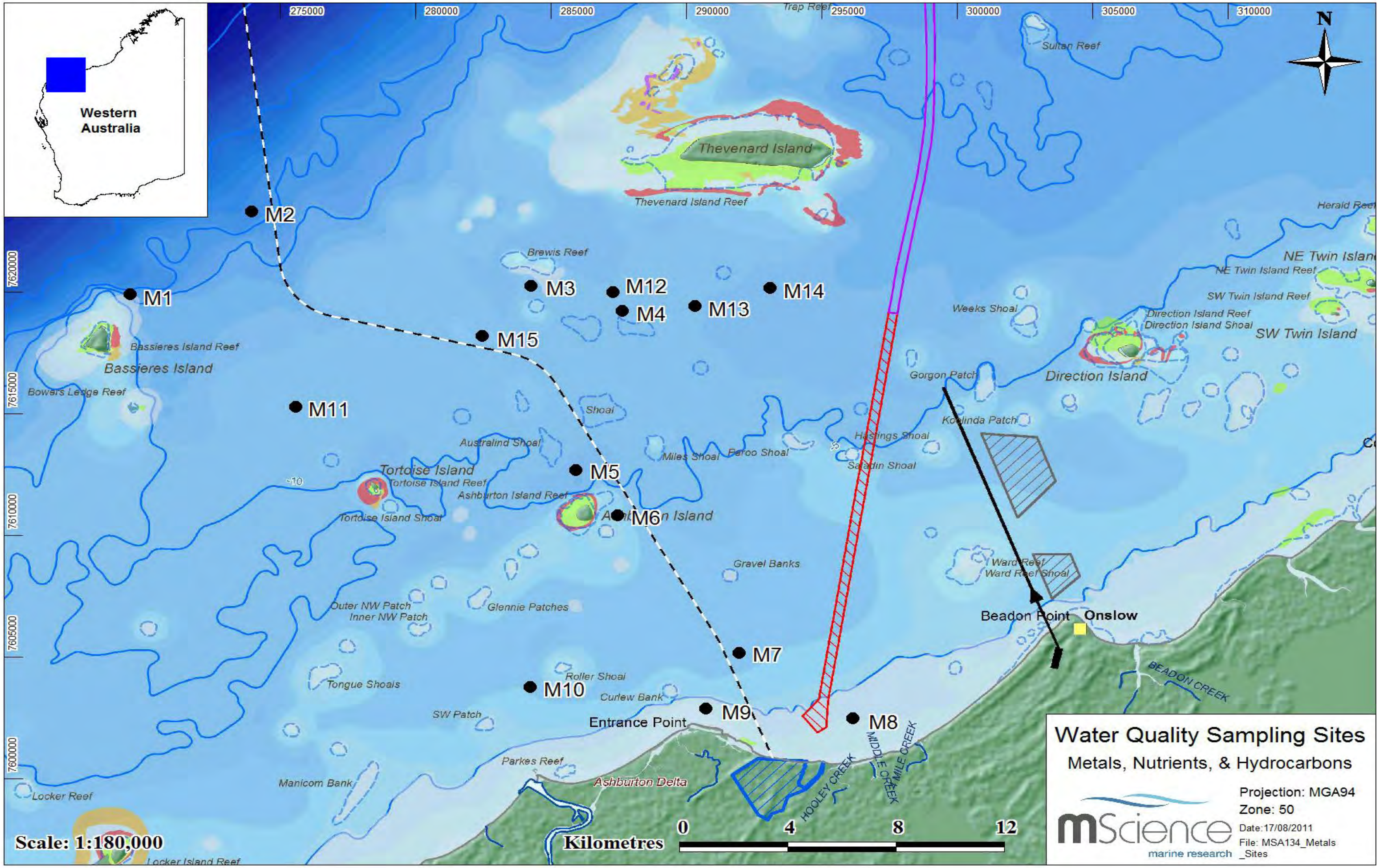


Table 4. Statistical summary of nutrients (µg/l)*

Date	Statistic	Total Nitrogen	Nitrate+Nitrite	Ammonia	Total Phosphorus	OrthoP (FRP)	Chlorophyll a
Guidelines - marine water**		100	8	10	15	5	1.4
Dec-2008	Mean	156.9	30.5	4.8	11.9	2.6	0.36
	Median	**130.0**	**10.0**	4.7	9.7	2.7	0.30
	80th percentile	180.0	62.0	5.7	16.3	3.0	0.50
Mar-2009	Mean	172.6	12.6	5.2	11.6	3.0	1.08
	Median	**173.3**	5.0	4.3	11.7	3.0	0.90
	80th percentile	196.7	17.0	9.7	12.7	4.0	1.50
Mar-2010	Mean	149.4	2.1	3.6	7.9	1.6	0.62
	Median	**135.0**	1.0	1.5	8.0	1.0	0.60
	80th percentile	180.0	3.0	5.0	9.0	3.0	0.60
Aug-2010	Mean	136.3	1.4	2.4	9.9	3.6	0.20
	Median	**135.0**	1.0	1.5	9.0	3.0	0.20
	80th percentile	155.0	1.0	4.0	10.0	3.0	0.20
Nov-2010	Mean	112.3	1.5	2.3	6.1	1.5	0.37
	Median	**115.0**	1.0	1.5	7.0	1.0	0.30
	80th percentile	135.0	1.0	1.5	8.0	2.0	0.50
Mar-2011	Mean	105.7	3.5	3.9	9.1	1.6	0.73
	Median	**100.0**	3.0	2.3	9.0	1.0	0.60
	80th percentile	120.0	5.0	7.0	10.0	2.0	0.85
Jun-2011	Mean	91.0	1.6	2.2	9.5	1.6	0.54
	Median	90.0	1.0	1.5	9.0	1.0	0.50
	80th percentile	100.0	2.5	2.8	10.0	2.0	0.65
All dates	Mean	124.0	5.1	3.2	9.0	2.1	0.51
	Median	**120.0**	1.0	1.5	9.0	2.0	0.50
	80th percentile	150.0	4.0	5.0	10.0	3.0	0.70

*Where individual analyses were below the reporting limit, a value of 50% of the reporting limit was used to calculate statistics.

** National guideline triggers for slight-moderately disturbed systems (ANZECC & ARMCANZ 2000). Numbers in bold red indicate medians that exceed the ANZECC & ARMCANZ guidelines.

Table 5. Statistical summary of metals in marine waters (µg/l)*

Date	Statistic	Al	As	Cd	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn	Hg
Guidelines - marine water**		0.5***	6.8***	0.7**	Cr(III) 27.4 Cr (VI) 4.4**	1.3**		80***	23***	7**	4.4**	6***	100**	15**	0.1**
Reporting limit		<10	<10/20	<0.6	<1	<1	<2	<0.2	<4	<4	<10	<20	<1/<2	<5/<2	<0.1
Dec-2008	Mean	9.4	5.0	0.30	0.50	0.50	4.9	1.0	3.7	2.0	5.0	10.0	0.5	42.2	0.05
	Median	5.0	5.0	0.30	0.50	0.50	1.0	0.8	5.0	2.0	5.0	10.0	0.5	38.7	0.05
	95th percentile	**23.3**	5.0	0.30	0.50	0.50	21.7	2.6	5.3	2.0	**5.0**	**10.0**	0.5	**94.0**	0.05
Mar-2009	Mean	8.6	5.0	0.30	0.50	0.50	2.2	1.0	8.8	2.0	5.0	10.0	0.5	17.6	0.05
	Median	5.0	5.0	0.30	0.50	0.50	2.0	0.4	9.0	2.0	5.0	10.0	0.5	12.0	0.05
	95th percentile	**36.7**	5.0	0.30	0.50	0.50	4.4	4.2	10.3	2.0	**5.0**	**10.0**	0.5	**49.0**	0.05
Mar-2010	Mean	10.0	10.0	0.30	0.50	0.50	1.7	1.0	9.7	2.0	5.0	10.0	0.5	1.1	0.05
	Median	7.5	10.0	0.30	0.50	0.50	1.0	1.2	10.0	2.0	5.0	10.0	0.5	1.0	0.05
	95th percentile	**25.0**	**10.0**	0.30	0.50	0.50	7.5	1.8	10.0	2.0	**5.0**	**10.0**	0.5	1.5	0.05
Aug-2010	Mean	13.0	10.0	0.30	0.50	0.63	1.5	0.6	10.2	2.0	5.0	10.0	0.5	1.0	0.05
	Median	5.0	10.0	0.30	0.50	0.50	1.0	0.5	10.0	2.0	5.0	10.0	0.5	1.0	0.05
	95th percentile	**50.0**	**10.0**	0.30	0.50	1.00	4.0	1.2	11.0	2.0	**5.0**	**10.0**	0.5	1.0	0.05
Nov-2010	Mean	5.2	10.0	0.30	1.45	0.50	9.6	1.1	10.3	2.0	5.0	10.0	1.0	1.0	0.05
	Median	5.0	10.0	0.30	2.00	0.50	11.0	1.2	10.0	2.0	5.0	10.0	1.0	1.0	0.05
	95th percentile	**5.0**	**10.0**	0.30	2.00	0.50	15.0	1.6	11.0	2.0	**5.0**	**10.0**	1.0	1.0	0.05
Mar-2011	Mean	5.0	10.0	0.30	0.50	0.50	1.0	0.9	9.7	3.5	5.0	10.0	1.9	1.0	0.05
	Median	5.0	10.0	0.30	0.50	0.50	1.0	0.9	10.0	3.5	5.0	10.0	2.0	1.0	0.05

Date	Statistic	Al	As	Cd	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn	Hg
	95th percentile	5.0	**10.0**	0.30	0.50	0.50	1.0	2.3	10.0	3.5	**5.0**	**10.0**	3.0	1.0	0.05
Jun-2011	Mean	5.0	10.0	0.30	1.90	0.50	13.7	0.8	11.5	3.5	5.0	10.0	1.0	1.0	0.05
	Median	5.0	10.0	0.30	0.50	0.50	6.5	0.1	11.0	3.5	5.0	10.0	1.0	1.0	0.05
	95th percentile	**5.0**	**10.0**	0.30	5.00	0.50	39.0	4.0	12.0	3.5	**5.0**	**10.0**	1.0	1.0	0.05
All dates	Mean	7.7	9.2	0.30	0.92	0.52	5.4	0.9	9.7	2.5	5.0	10.0	0.9	5.6	0.05
	Median	5.0	10.0	0.30	0.50	0.50	1.0	0.8	10.0	2.0	5.0	10.0	1.0	1.0	0.05
	95th percentile	**20.0**	**10.0**	0.30	3.00	0.50	26.0	2.4	12.0	3.5	**5.0**	**10.0**	2.0	**38.7**	0.05

* All dissolved metals except Hg (Hg measured as total), when measured value was less than reporting limit, a value of 50% of the reporting limit was used to calculate statistics.

** National guideline triggers for slight-moderately disturbed systems (ANZECC & ARMCANZ 2000; Wenziker et al. 2006)

*** Low reliability values guidelines

Numbers in bold red indicate medians that exceed the ANZECC & ARMCANZ guidelines.

APPENDIX B – NUTRIENTS, METALS AND HYDROCARBONS

Table 8. Nutrients in marine water (µg/l)

Parameters	Level	Ammonia	Ortho -P	NO3+NO2	Total P	Total N	Chlorophyll 'a'
Reporting limit		<3	<2	<2	<5	<50	<0.1
Guidelines - marine water**		1-11		2-8	15	100	0.7-1.4
Site	Location						
Samples collected December 14, 2008							
M1	Surface	6.3	3.3	10	9.7	96.7	0.5
M1	Bottom	4.3	3.3	6	9.7	130	0.5
M2	Surface	4.7	3	5.3	9	106.7	0.3
M2	Bottom	3.7	2.7	5.7	9.7	120	0.4
M3	Surface	5.7	2	3.3	9.7	130	0.5
M4	Surface	3	2	4	9.3	123.3	0.4
M5	Surface	3	2	6.3	9.3	103.3	0.3
M5	Bottom	4.3	2.7	12.7	11	140	0.2
M6	Surface	7.7	3	170	18	343.3	0.3
M7	Surface	5.7	2.7	14.7	13	173.3	0.3
M8	Surface	4.3	2.7	62	16.3	180	0.3
M9	Surface	5	2	82.7	16.3	256.7	0.4
M10	Surface	4.7	2.7	13.7	13.7	136.7	0.3
Samples collected March 28, 2009							
M1	Surface	9.7	4	5	11.7	173.3	0.9
M1	Bottom	<3	4	3	12.7	130	1
M2	Surface	4.3	3	4.7	11.7	136.7	1.6
M2	Bottom	<3	3.3	2	13.3	153.3	0.8
M3	Surface	5.3	3.3	2.5	11.7	146.7	0.5
M4	Surface	10.7	5	68.7	11.3	180	1.5
M5	Surface	3	2	3.3	9.3	140	0.9
M5	Bottom	8.8	2	6.7	12	166.7	0.9
M6	Surface	<3	2	4	10.7	173.3	1.4
M7	Surface	5	3	30	10	183.3	1.5
M8	Surface	11	3.3	6	12.3	246.7	0.8
M9	Surface	<3	2	10.7	13	196.7	1.5
M10	Surface	4	2.3	17	10.7	216.7	0.8
Samples collected March 21, 2010							
M1	Surface	<3	3	<2	9	90	0.6
M1	Bottom	<3	3	<2	9	120	
M2	Surface	<3	4	3	11	150	0.6
M2	Bottom	<3	<2	<2	9	220	
M3	Surface	5	<2	<2	8	120	0.5
M3	Bottom	<3	<2	<2	7	140	
M4	Surface	3	2	2	10	200	0.6
M4	Bottom	<3	<2	3	7	120	
M5	Surface	<3	<2	3	8	130	0.6

Parameters	Level	Ammonia	Ortho -P	NO3+NO2	Total P	Total N	Chlorophyll 'a'
M5	Bottom	<3	<2	<2	6	130	
M6	Surface	<3	<2	<2	6	100	0.6
M6	Bottom	<3	<2	2	7	300	
M7	Surface	<3	<2	<2	6	140	1.2
M7	Bottom	4	<2	2	7	160	
M8	Surface	6	<2	<2	7	120	0.4
M8	Bottom	24	<2	12	8	180	
M9	Surface	<3	<2	<2	9	120	0.5
M9	Bottom	5	3	<2	9	150	
Samples collected August 30/31, 2010							
M1	Surface	<3	3	<2	8	120	0.1
M1	Bottom	5	3	4	9	100	0.2
M2	Surface	4	3	<2	9	100	0.1
M2	Bottom	<3	2	<2	9	150	0.2
M3	Surface	<3	2	<2	9	160	0.2
M3	Bottom	<3	3	<2	8	160	0.2
M4	Surface	<3	3	<2	9	150	0.2
M4	Bottom	<3	3	<2	8	180	0.3
M5	Surface	<3	3	<2	8	220	0.2
M5	Bottom	3	2	<2	9	180	0.1
M6	Surface	8	36	6	42	140	0.2
M6	Bottom	<3	3	<2	7	120	0.2
M7	Surface	<3	<2	<2	8	150	0.2
M7	Bottom	<3	2	<2	10	140	0.2
M8	Surface	<3	2	<2	8	140	0.2
M8	Bottom	<3	<2	<2	9	120	0.2
M9	Surface	<3	2	<2	9	100	0.4
M9	Bottom	<3	<2	<2	10	150	0.6
M10	Surface	4	3	<2	10	130	0.2
M10	Bottom	<3	2	<2	9	120	0.2
M11	Surface	<3	2	<2	10	120	0.1
M11	Bottom	5	3	<2	7	170	0.2
M12	Surface	<3	3	<2	8	140	0.1
M12	Bottom	4	3	3	9	130	0.2
M13	Surface	5	3	<2	10	100	0.2
M13	Bottom	<3	2	<2	8	120	0.2
M14	Surface	<3	3	<2	8	110	0.1
M14	Bottom	<3	3	<2	8	100	0.2
M15	Surface	<3	3	<2	10	130	0.2
M15	Bottom	<3	3	2	10	140	0.2
Samples collected November 7/8/9, 2010							
M1	Surface	<3	4	<2	<5	80	0.3
M1	Bottom	<3	3	<2	5	80	0.3
M2	Surface	<3	3	<2	7	90	0.2
M2	Bottom	<3	3	<2	9	120	0.3

Parameters	Level	Ammonia	Ortho -P	NO3+NO2	Total P	Total N	Chlorophyll 'a'
M3	Surface	<3	<2	<2	8	120	0.3
M3	Bottom	<3	<2	<2	<5	120	0.3
M4	Surface	<3	2	<2	6	150	0.3
M4	Bottom	<3	2	<2	8	130	0.3
M5	Surface	<3	<2	<2	7	100	0.3
M5	Bottom	<3	<2	<2	7	90	0.3
M6	Surface	4	2	5	7	100	0.2
M6	Bottom	<3	<2	<2	5	80	0.3
M7	Surface	<3	<2	<2	<5	80	0.5
M7	Bottom	<3	<2	<2	6	140	0.6
M8	Surface	4	<2	<2	5	100	0.5
M8	Bottom	20	<2	10	<5	160	0.7
M9	Surface	<3	<2	<2	8	140	0.5
M9	Bottom	<3	<2	<2	14	130	0.6
M10	Surface	<3	<2	<2	7	130	0.4
M10	Bottom	3	2	3	<5	80	0.3
M11	Surface	<3	2	<2	7	90	0.2
M11	Bottom	<3	2	<2	6	120	0.3
M12	Surface	<3	2	<2	8	120	0.3
M12	Bottom	<3	<2	<2	5	100	0.3
M13	Surface	<3	<2	<2	7	120	0.5
M13	Bottom	<3	<2	<2	8	140	0.6
M14	Surface	<3	<2	<2	<5	60	0.3
M14	Bottom	<3	<2	<2	8	110	0.6
M15	Surface	<3	<2	<2	<5	80	0.4
M15	Bottom	<3	<2	<2	7	210	0.2
Samples collected March 10/11, 2011							
M1	Surface	<3	4	3	8	90	0.4
M1	Bottom	5	2	9	10	100	0.3
M2	Surface	<3	2	3	9	100	0.6
M2	Bottom	8	3	7	7	100	0.5
M3	Surface	<3	2	2	7	90	0.6
M3	Bottom	<3	<2	<2	10	110	0.8
M4	Surface	<3	<2	3	9	110	0.5
M4	Bottom	<3	3	<2	11	100	0.5
M5	Surface	5	2	4	7	80	0.4
M5	Bottom	6	2	4	9	100	0.5
M6	Surface	5	<2	5	10	100	0.4
M6	Bottom	4	2	6	9	100	0.5
M7	Surface	3	<2	3	9	110	0.8
M7	Bottom	5	<2	2	9	120	0.7
M8	Surface	<3	<2	3	10	130	1.5
M8	Bottom	<3	<2	3	11	140	1.7
M9	Surface	<3	<2	3	7	90	1.5
M9	Bottom	<3	<2	2	10	120	1.4

Parameters	Level	Ammonia	Ortho -P	NO3+NO2	Total P	Total N	Chlorophyll 'a'
M10	Surface	8	<2	5	9	120	0.8
M10	Bottom	9	2	4	9	110	0.7
M11	Surface	<3	<2	<2	10	100	1.1
M11	Bottom	<3	<2	<2	8	100	0.5
M12	Surface	<3	<2	8	10	130	0.5
M12	Bottom	5	<2	3	10	100	0.6
M13	Surface	<3	<2	<2	9	110	0.7
M13	Bottom	<3	<2	<2	9	120	0.9
M14	Surface	4	2	3	10	100	0.8
M14	Bottom	9	3	3	10	100	0.7
M15	Surface	9	2	5	7	80	0.5
M15	Bottom	10	2	5	10	110	0.5
Samples collected June 15-18, 2011							
M1	Surface	<3	2	<2	9	80	0.3
M1	Bottom	<3	3	<2	8	70	0.3
M2	Surface	<3	3	<2	9	90	0.5
M2	Bottom	<3	3	<2	10	90	0.5
M3	Surface	<3	2	<2	8	90	0.3
M3	Bottom	<3	<2	<2	8	80	0.5
M4	Surface	<3	<2	<2	7	90	0.5
M4	Bottom	<3	<2	<2	8	90	0.5
M5	Surface	<3	<2	<2	7	80	0.3
M5	Bottom	<3	<2	<2	9	80	0.3
M6	Surface	4	<2	4	8	80	0.2
M6	Bottom	<3	<2	2	8	90	0.2
M7	Surface	4	2	<2	9	100	0.6
M7	Bottom	<3	<2	<2	9	90	0.7
M8	Surface	<3	<2	<2	10	100	1.8
M8	Bottom	4	<2	5	10	120	0.6
M9	Surface	10	7	4	18	130	1.3
M9	Bottom	<3	<2	2	18	130	1.1
M10	Surface	4	<2	3	10	100	0.5
M10	Bottom	<3	<2	<2	11	90	0.5
M11	Surface	4	2	3	9	80	0.2
M11	Bottom	<3	<2	3	10	100	0.7
M12	Surface	<3	<2	<2	8	80	0.3
M12	Bottom	<3	<2	<2	10	90	0.5
M13	Surface	<3	3	<2	10	120	1
M13	Bottom	<3	<2	<2	8	80	0.5
M14	Surface	<3	<2	<2	9	70	0.3
M14	Bottom	<3	<2	<2	8	80	0.3
M15	Surface	<3	<2	<2	9	80	0.3
M15	Bottom	<3	<2	<2	9	80	0.5

Table 9. Metals in marine waters (µg/l)

Parameters		Al	As	Cd	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn	Hg
Reporting limit		<10*	<10/<20*	<0.6*	<1*	<1*	<2*	<0.2*	<4*	<4*	<10*	<20*	<1*/<2	<5/<2*	<0.1*
Guidelines - marine water		0.5**	6.8**	0.7	31.8	1.3		80**	23**	7	4.4	6**	100	15	
Site	Location														
Samples collected December 14, 2008															
M1	Surface	13.3	<10	<0.6	<1	<1	21.7	0.8	<4	<4	<10	<20	<1	42.7	<0.1
M1	Bottom	23.3	<10	<0.6	<1	<1	15.3	0.8	<4	<4	<10	<20	<1	49.0	<0.1
M2	Surface	<10	<10	<0.6	<1	<1	6.7	0.5	<4	<4	<10	<20	<1	26.7	<0.1
M2	Bottom	16.7	<10	<0.6	<1	<1	6.3	0.6	<4	<4	<10	<20	<1	49.0	<0.1
M3	Surface	13.3	<10	<0.6	<1	<1	2.7	0.6	<4	<4	<10	<20	<1	21.3	<0.1
M4	Surface	15.0	<10	<0.6	<1	<1	4.0	0.7	<4	<4	<10	<20	<1	34.3	<0.1
M5	Surface	<10	<10	<0.6	<1	<1	<2	0.8	5.3	<4	<10	<20	<1	38.7	<0.1
M5	Bottom	<10	<10	<0.6	<1	<1	<2	0.8	5.0	<4	<10	<20	<1	57.7	<0.1
M6	Surface	<10	<10	<0.6	<1	<1	<2	0.8	5.0	<4	<10	<20	<1	94.0	<0.1
M7	Surface	<10	<10	<0.6	<1	<1	<2	1.3	5.3	<4	<10	<20	<1	44.7	<0.1
M8	Surface	<10	<10	<0.6	<1	<1	<2	1.3	5.3	<4	<10	<20	<1	14.3	<0.1
M9	Surface	<10	<10	<0.6	<1	<1	<2	2.6	5.3	<4	<10	<20	<1	38.0	<0.1
M10	Surface	<10	<10	<0.6	<1	<1	<2	1.6	5.3	<4	<10	<20	<1	38.3	<0.1
Samples collected March 28, 2009															
M1	Surface	<10	<10	<0.6	<1	<1	2.3	0.5	8.3	<4	<10	<20	<1	11.3	<0.1
M1	Bottom	<10	<10	<0.6	<1	<1	2.7	0.3	6.3	<4	<10	<20	<1	15.7	<0.1
M2	Surface	<10	<10	<0.6	<1	<1	<2	0.4	6.7	<4	<10	<20	<1	25.0	<0.1
M2	Bottom	<10	<10	<0.6	<1	<1	4.4	0.4	8.7	<4	<10	<20	<1	12.0	<0.1
M3	Surface	<10	<10	<0.6	<1	<1	<2	0.4	9.7	<4	<10	<20	<1	10.3	<0.1
M4	Surface	<10	<10	<0.6	<1	<1	<2	0.4	9.0	<4	<10	<20	<1	39.3	<0.1
M5	Surface	<10	<10	<0.6	<1	<1	<2	0.3	9.3	<4	<10	<20	<1	6.3	<0.1
M5	Bottom	15.0	<10	<0.6	<1	<1	2.0	0.3	10.3	<4	<10	<20	<1	7.7	<0.1
M6	Surface	10.0	<10	<0.6	<1	<1	<2	0.5	9.3	<4	<10	<20	<1	18.0	<0.1

Parameters		Al	As	Cd	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn	Hg
M7	Surface	<10	<10	<0.6	<1	<1	3.3	1.5	8.7	<4	<10	<20	<1	49.0	<0.1
M8	Surface	36.7	<10	<0.6	<1	<1	4.0	4.2	9.0	<4	<10	<20	<1	12.7	<0.1
M9	Surface	<10	<10	<0.6	<1	<1	2.0	2.4	10.0	<4	<10	<20	<1	11.0	<0.1
M10	Surface	<10	<10	<0.6	<1	<1	2.7	1.2	8.7	<4	<10	<20	<1	10.3	<0.1
Samples collected March 21, 2010															
M1	Surface	<10	<20	<0.6	<1	<1	<2	0.3	9	<4	<10	<20	<1	<2	<0.1
M1	Bottom	10	<20	<0.6	<1	<1	<2	0.3	10	<4	<10	<20	<1	<2	<0.1
M2	Surface	<10	<20	<0.6	<1	<1	13	0.6	9	<4	<10	<20	<1	<2	<0.1
M2	Bottom	10	<20	<0.6	<1	<1	<2	0.5	10	<4	<10	<20	<1	<2	<0.1
M3	Surface	<10	<20	<0.6	<1	<1	<2	0.6	9	<4	<10	<20	<1	<2	<0.1
M3	Bottom	<10	<20	<0.6	<1	<1	<2	0.5	10	<4	<10	<20	<1	<2	<0.1
M4	Surface	10	<20	<0.6	<1	<1	<2	0.6	10	<4	<10	<20	<1	<2	<0.1
M4	Bottom	<10	<20	<0.6	<1	<1	<2	0.9	9	<4	<10	<20	<1	<2	<0.1
M5	Surface	<10	<20	<0.6	<1	<1	<2	1	10	<4	<10	<20	<1	<2	<0.1
M5	Bottom	<10	<20	<0.6	<1	<1	2	1.3	10	<4	<10	<20	<1	<2	<0.1
M6	Surface	10	<20	<0.6	<1	<1	<2	1.2	9	<4	<10	<20	<1	<2	<0.1
M6	Bottom	20	<20	<0.6	<1	<1	<2	1.3	10	<4	<10	<20	<1	<2	<0.1
M7	Surface	20	<20	<0.6	<1	<1	<2	1.5	10	<4	<10	<20	<1	<2	<0.1
M7	Bottom	<10	<20	<0.6	<1	<1	<2	1.3	10	<4	<10	<20	<1	<2	<0.1
M8	Surface	20	<20	<0.6	<1	<1	<2	1.5	10	<4	<10	<20	<1	<2	<0.1
M8	Bottom	10	<20	<0.6	<1	<1	<2	1.7	10	<4	<10	<20	<1	2	<0.1
M9	Surface	10	<20	<0.6	<1	<1	<2	1.1	10	<4	<10	<20	<1	<2	<0.1
M9	Bottom	30	<20	<0.6	<1	<1	<2	1.4	10	<4	<10	<20	<1	<2	<0.1
M10	Surface	<10	<20	<0.6	<1	<1	<2	1.8	9	<4	<10	<20	<1	<2	<0.1
M10	Bottom	<10	<20	<0.6	<1	<1	<2	1.5	10	<4	<10	<20	<1	<2	<0.1
Samples collected August 30/31															
M1	Surface	20	<20	<0.6	<1	1	<2	0.3	10	<4	<10	<20	<1	<2	<0.1
M1	Bottom	70	<20	<0.6	<1	<1	5	0.4	10	<4	<10	<20	<1	<2	<0.1

Parameters		Al	As	Cd	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn	Hg
M2	Surface	30	<20	<0.6	<1	<1	3	0.2	10	<4	<10	<20	<1	<2	<0.1
M2	Bottom	50	<20	<0.6	<1	<1	4	0.3	10	<4	<10	<20	<1	<2	<0.1
M3	Surface	40	<20	<0.6	<1	<1	4	0.3	11	<4	<10	<20	<1	<2	<0.1
M3	Bottom	20	<20	<0.6	<1	<1	<2	0.2	11	<4	<10	<20	<1	<2	<0.1
M4	Surface	20	<20	<0.6	<1	<1	<2	0.3	10	<4	<10	<20	<1	<2	<0.1
M4	Bottom	10	<20	<0.6	<1	<1	<2	0.4	10	<4	<10	<20	<1	<2	<0.1
M5	Surface	10	<20	<0.6	<1	<1	<2	0.5	11	<4	<10	<20	<1	<2	<0.1
M5	Bottom	<10	<20	<0.6	<1	<1	<2	0.5	9	<4	<10	<20	<1	<2	<0.1
M6	Surface	20	<20	<0.6	<1	4	2	1	11	<4	<10	<20	<1	<2	<0.1
M6	Bottom	<10	<20	<0.6	<1	<1	<2	0.6	10	<4	<10	<20	<1	<2	<0.1
M7	Surface	<10	<20	<0.6	<1	<1	<2	0.9	10	<4	<10	<20	<1	<2	<0.1
M7	Bottom	<10	<20	<0.6	<1	<1	<2	0.9	10	<4	<10	<20	<1	<2	<0.1
M8	Surface	<10	<20	<0.6	<1	<1	<2	1.1	10	<4	<10	<20	<1	<2	<0.1
M8	Bottom	<10	<20	<0.6	<1	<1	<2	1.1	10	<4	<10	<20	<1	<2	<0.1
M9	Surface	<10	<20	<0.6	<1	<1	<2	1.2	10	<4	<10	<20	<1	<2	<0.1
M9	Bottom	<10	<20	<0.6	<1	<1	<2	1.4	11	<4	<10	<20	<1	<2	<0.1
M10	Surface	<10	<20	<0.6	<1	<1	<2	0.8	10	<4	<10	<20	<1	<2	<0.1
M10	Bottom	<10	<20	<0.6	<1	<1	<2	0.8	10	<4	<10	<20	<1	<2	<0.1
M11	Surface	<10	<20	<0.6	<1	<1	<2	0.3	11	<4	<10	<20	<1	<2	<0.1
M11	Bottom	<10	<20	<0.6	<1	<1	<2	0.4	10	<4	<10	<20	<1	<2	<0.1
M12	Surface	<10	<20	<0.6	<1	<1	<2	0.3	10	<4	<10	<20	<1	<2	<0.1
M12	Bottom	<10	<20	<0.6	<1	<1	2	0.5	10	<4	<10	<20	<1	<2	<0.1
M13	Surface	<10	<20	<0.6	<1	<1	<2	0.8	10	<4	<10	<20	<1	<2	<0.1
M13	Bottom	<10	<20	<0.6	<1	<1	<2	0.7	11	<4	<10	<20	<1	<2	<0.1
M14	Surface	<10	<20	<0.6	<1	<1	<2	0.6	10	<4	<10	<20	<1	<2	<0.1
M14	Bottom	<10	<20	<0.6	<1	<1	<2	0.6	10	<4	<10	<20	<1	<2	<0.1
M15	Surface	<10	<20	<0.6	<1	<1	<2	0.4	11	<4	<10	<20	<1	<2	<0.1
M15	Bottom	<10	<20	<0.6	<1	<1	<2	0.5	10	<4	<10	<20	<1	4	<0.1

Parameters		Al	As	Cd	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn	Hg
Samples collected November 7/8/9															
M1	Surface	<10	<20	<0.6	2	<1	14	0.4	10	<4	<10	<20	<2	<2	<0.1
M1	Bottom	<10	<20	<0.6	2	<1	14	0.4	10	<4	<10	<20	<2	<2	<0.1
M2	Surface	<10	<20	<0.6	1	<1	7	0.3	10	<4	<10	<20	<2	<2	<0.1
M2	Bottom	<10	<20	<0.6	2	<1	12	0.4	10	<4	<10	<20	<2	<2	<0.1
M3	Surface	<10	<20	<0.6	1	<1	11	0.9	11	<4	<10	<20	<2	<2	<0.1
M3	Bottom	<10	<20	<0.6	1	<1	11	0.9	10	<4	<10	<20	<2	<2	<0.1
M4	Surface	<10	<20	<0.6	2	<1	11	0.9	11	<4	<10	<20	<2	<2	<0.1
M4	Bottom	<10	<20	<0.6	1	<1	11	0.8	11	<4	<10	<20	<2	<2	<0.1
M5	Surface	<10	<20	<0.6	3	<1	9	1.6	11	<4	<10	<20	<2	<2	<0.1
M5	Bottom	<10	<20	<0.6	2	<1	15	1.5	10	<4	<10	<20	<2	<2	<0.1
M6	Surface	<10	<20	<0.6	2	<1	16	1.5	10	<4	<10	<20	<2	<2	<0.1
M6	Bottom	<10	<20	<0.6	2	<1	11	1.4	10	<4	<10	<20	<2	<2	<0.1
M7	Surface	<10	<20	<0.6	<1	<1	4	1.4	10	<4	<10	<20	<2	<2	<0.1
M7	Bottom	<10	<20	<0.6	2	<1	15	1.5	10	<4	<10	<20	<2	<2	<0.1
M8	Surface	<10	<20	<0.6	2	<1	11	1.2	10	<4	<10	<20	<2	<2	<0.1
M8	Bottom	<10	<20	<0.6	2	<1	7	1.2	11	<4	<10	<20	<2	<2	<0.1
M9	Surface	<10	<20	<0.6	<1	<1	4	0.9	10	<4	<10	<20	<2	<2	<0.1
M9	Bottom	<10	<20	<0.6	2	<1	5	1.3	11	<4	<10	<20	<2	<2	<0.1
M10	Surface	<10	<20	<0.6	<1	<1	6	1.6	11	<4	<10	<20	<2	<2	<0.1
M10	Bottom	<10	<20	<0.6	2	<1	10	1.6	10	<4	<10	<20	<2	<2	<0.1
M11	Surface	<10	<20	<0.6	<1	<1	4	0.8	10	<4	<10	<20	<2	<2	<0.1
M11	Bottom	<10	<20	<0.6	2	<1	14	1	10	<4	<10	<20	<2	<2	<0.1
M12	Surface	<10	<20	<0.6	1	<1	11	1.4	10	<4	<10	<20	<2	<2	<0.1
M12	Bottom	<10	<20	<0.6	2	<1	15	1.3	10	<4	<10	<20	<2	<2	<0.1
M13	Surface	<10	<20	<0.6	1	<1	7	1.7	10	<4	<10	<20	<2	<2	<0.1
M13	Bottom	<10	<20	<0.6	2	<1	12	1.4	10	<4	<10	<20	<2	<2	<0.1
M14	Surface	<10	<20	<0.6	1	<1	8	0.7	10	<4	<10	<20	<2	<2	<0.1

Parameters		Al	As	Cd	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn	Hg
M14	Bottom	10	<20	<0.6	<1	<1	8	0.7	10	<4	<10	<20	<2	<2	<0.1
M15	Surface	<10	<20	<0.6	<1	<1	2	1.1	11	<4	<10	<20	<2	<2	<0.1
M15	Bottom	<10	<20	<0.6	<1	<1	2	1	10	<4	<10	<20	<2	<2	<0.1
Samples collected March 10/11															
M1	Surface	<10	<20	<0.6	<1	<1	<2	0.3	9	<7	<10	<20	<2	<2	<0.1
M1	Bottom	<10	<20	<0.6	<1	<1	<2	0.3	9	<7	<10	<20	<2	<2	<0.1
M2	Surface	<10	<20	<0.6	<1	<1	<2	0.3	9	<7	<10	<20	<2	<2	<0.1
M2	Bottom	<10	<20	<0.6	<1	<1	<2	0.3	10	<7	<10	<20	<2	<2	<0.1
M3	Surface	<10	<20	<0.6	<1	<1	<2	0.4	9	<7	<10	<20	<2	<2	<0.1
M3	Bottom	<10	<20	<0.6	<1	<1	<2	0.4	10	<7	<10	<20	<2	<2	<0.1
M4	Surface	<10	<20	<0.6	<1	<1	<2	0.7	9	<7	<10	<20	2	<2	<0.1
M4	Bottom	<10	<20	<0.6	<1	<1	<2	0.6	9	<7	<10	<20	2	<2	<0.1
M5	Surface	<10	<20	<0.6	<1	<1	<2	0.8	9	<7	<10	<20	2	<2	<0.1
M5	Bottom	<10	<20	<0.6	<1	<1	<2	0.9	10	<7	<10	<20	2	<2	<0.1
M6	Surface	<10	<20	<0.6	<1	<1	<2	0.8	10	<7	<10	<20	2	<2	<0.1
M6	Bottom	<10	<20	<0.6	<1	<1	<2	0.8	10	<7	<10	<20	2	<2	<0.1
M7	Surface	<10	<20	<0.6	<1	<1	<2	1.3	10	<7	<10	<20	2	<2	<0.1
M7	Bottom	<10	<20	<0.6	<1	<1	<2	1.3	10	<7	<10	<20	2	<2	<0.1
M8	Surface	<10	<20	<0.6	<1	<1	<2	1.9	10	<7	<10	<20	2	<2	<0.1
M8	Bottom	<10	<20	<0.6	<1	<1	<2	1.8	10	<7	<10	<20	2	<2	<0.1
M9	Surface	<10	<20	<0.6	<1	<1	<2	2.4	10	<7	<10	<20	2	<2	<0.1
M9	Bottom	<10	<20	<0.6	<1	<1	<2	2.3	10	<7	<10	<20	2	<2	<0.1
M10	Surface	<10	<20	<0.6	<1	<1	<2	1.7	10	<7	<10	<20	2	<2	<0.1
M10	Bottom	<10	<20	<0.6	<1	<1	<2	0.9	10	<7	<10	<20	2	<2	<0.1
M11	Surface	<10	<20	<0.6	<1	<1	<2	0.4	10	<7	<10	<20	<2	<2	<0.1
M11	Bottom	<10	<20	<0.6	<1	<1	<2	0.3	10	<7	<10	<20	2	<2	<0.1
M12	Surface	<10	<20	<0.6	<1	<1	<2	0.7	10	<7	<10	<20	3	<2	<0.1
M12	Bottom	<10	<20	<0.6	<1	<1	<2	0.7	10	<7	<10	<20	2	<2	<0.1

Parameters		Al	As	Cd	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn	Hg
M13	Surface	<10	<20	<0.6	<1	<1	<2	1	10	<7	<10	<20	3	<2	<0.1
M13	Bottom	<10	<20	<0.6	<1	<1	<2	1	10	<7	<10	<20	2	<2	<0.1
M14	Surface	<10	<20	<0.6	<1	<1	<2	1	10	<7	<10	<20	2	<2	<0.1
M14	Bottom	<10	<20	<0.6	<1	<1	<2	1.1	10	<7	<10	<20	2	<2	<0.1
M15	Surface	<10	<20	<0.6	<1	<1	<2	0.9	10	<7	<10	<20	3	<2	<0.1
M15	Bottom	<10	<20	<0.6	<1	<1	<2	0.9	9	<7	<10	<20	3	<2	<0.1
Samples collected June 15-18, 2011															
M1	Surface	<10	<20	<0.6	<1	<1	7	<0.2	11	<7	<10	<20	<2	<2	<1
M1	Bottom	<10	<20	<0.6	<1	<1	6	<0.2	11	<7	<10	<20	<2	7	<1
M2	Surface	<10	<20	<0.6	1	<1	10	<0.2	11	<7	<10	<20	<2	<2	<1
M2	Bottom	<10	<20	<0.6	<1	<1	6	<0.2	11	<7	<10	<20	<2	<2	<1
M3	Surface	<10	<20	<0.6	4	<1	32	<0.2	11	<7	<10	<20	<2	<2	<1
M3	Bottom	<10	<20	<0.6	4	<1	30	<0.2	11	<7	<10	<20	<2	<2	<1
M4	Surface	<10	<20	<0.6	3	<1	26	<0.2	11	<7	<10	<20	<2	<2	<1
M4	Bottom	<10	<20	<0.6	3	<1	22	<0.2	12	<7	<10	<20	<2	<2	<1
M5	Surface	<10	<20	<0.6	5	<1	38	3	11	<7	<10	<20	<2	<2	<1
M5	Bottom	<10	<20	<0.6	1	<1	8	<0.2	11	<7	<10	<20	<2	<2	<1
M6	Surface	<10	<20	<0.6	5	<1	42	4	12	<7	<10	<20	<2	<2	<1
M6	Bottom	<10	<20	<0.6	5	<1	39	4	12	<7	<10	<20	<2	<2	<1
M7	Surface	<10	<20	<0.6	<1	<1	<2	2	12	<7	<10	<20	<2	<2	<1
M7	Bottom	<10	<20	<0.6	<1	<1	<2	<0.2	12	<7	<10	<20	<2	<2	<1
M8	Surface	<10	<20	<0.6	<1	<1	<2	<0.2	13	<7	<10	<20	<2	<2	<1
M8	Bottom	<10	<20	<0.6	<1	<1	<2	<0.2	12	<7	<10	<20	<2	<2	<1
M9	Surface	<10	<20	<0.6	<1	<1	<2	<0.2	12	<7	<10	<20	<2	<2	<1
M9	Bottom	<10	<20	<0.6	<1	<1	<2	<0.2	11	<7	<10	<20	<2	<2	<1
M10	Surface	<10	<20	<0.6	<1	<1	<2	<0.2	12	<7	<10	<20	<2	<2	<1
M10	Bottom	<10	<20	<0.6	<1	<1	<2	<0.2	11	<7	<10	<20	<2	<2	<1
M11	Surface	<10	<20	<0.6	<1	<1	<2	<0.2	12	<7	<10	<20	<2	<2	<1

Parameters		Al	As	Cd	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn	Hg
M11	Bottom	<10	<20	<0.6	<1	<1	<2	<0.2	11	<7	<10	<20	<2	<2	<1
M12	Surface	<10	<20	<0.6	5	<1	36	<0.2	11	<7	<10	<20	<2	<2	<1
M12	Bottom	<10	<20	<0.6	4	<1	28	<0.2	11	<7	<10	<20	<2	<2	<1
M13	Surface	<10	<20	<0.6	<1	<1	<2	3	11	<7	<10	<20	<2	<2	<1
M13	Bottom	<10	<20	<0.6	<1	<1	<2	<0.2	12	<7	<10	<20	<2	<2	<1
M14	Surface	<10	<20	<0.6	<1	<1	4	<0.2	12	<7	<10	<20	<2	<2	<1
M14	Bottom	<10	<20	<0.6	3	<1	26	4	12	<7	<10	<20	<2	<2	<1
M15	Surface	<10	<20	<0.6	2	<1	14	<0.2	11	<7	<10	<20	<2	<2	<1
M15	Bottom	<10	<20	<0.6	4	<1	26	3	11	<7	<10	<20	<2	<2	<1

Table 2. Background nutrients around the proposed nearshore outfall (µg/l)

Date	Statistic	Total Nitrogen	Nitrate+Nitrite	Ammonia	Total Phosphorus	OrthoP (FRP)
Guidelines - marine water*		100	2-8	1-10	15	5
Reporting limit		50	5	5	10	2
Aug-2010	Mean	158.0	9.1	15.5	5.0	3.2
	Median	155.0	9.7	12.8	5.0	3.0
	80th percentile	170.0	12.7	27.0	5.0	3.8
	95th percentile	180.0	15.2	37.7	5.0	4.0
Nov-2010	Mean	102.0	11.1	32.0	5.0	1.4
	Median	110.0	13.3	34.5	5.0	1.0
	80th percentile	122.5	16.1	40.5	5.0	2.0
	95th percentile	125.0	18.0	40.5	5.0	2.0
Mar-2011	Mean	237.7	6.7	105.7	7.5	1.0
	Median	225.0	5.0	94.0	7.5	1.0
	80th percentile	259.9	9.3	133.0	10.0	1.0
	95th percentile	275.0	9.8	138.5	12.5	1.0
June-2011	Mean	84.5	9.0	14.1	11.0	2.8
	Median	35.3	10.3	12.5	7.5	2.5
	80th percentile	161.8	10.5	18.0	16.3	4.0
	95th percentile	225.8	10.8	19.5	22.5	4.0
All dates	Mean	145.6	9.0	41.8	7.1	2.1
	Median	147.5	9.3	24.9	5.0	2.0
	80th percentile	225.0	12.0	84.3	7.5	3.3
	95th percentile	259.9	16.6	133.0	17.5	4.0

* ANZECC & ARMCANZ (2000) default trigger values for inshore tropical marine waters

** Reporting Limit - The lowest amount of an analyte in a sample that can be quantitatively determined with method used

3.2 Metal toxicants

Table 3. Background metals around the proposed nearshore outfall (µg/l)*

Date	Statistic	Ag	Al	As	Cd	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn	Hg
Guidelines - marine water**		0.8/1.8	0.5***	As (III) 2.3 As (IV) 4.5***	0.7/14	Cr(III) 7.7/49 Cr (VI) 0.14/20	0.3/3		80***	23***	7/200	2.2/6.6	Se (IV) 3 Se (VI) 3 ***	50/160	7/23	0.1/0.7
Reporting limit		100/10	10	20/0.4	0.6	1	1	2	0.2	4	4/7	10	20/0.5	1/2	5/2	0.1
Aug-2010	Mean	<100	<10	<20.0	<0.6	<1	<1	1.4	0.8	10.0	<4	<10	<20	0.50	8.8	0.05
	Median	<100	<10	<20.0	<0.6	<1	<1	1.0	0.8	10.0	<4	<10	<20	0.50	8.0	0.05
	95th percentile	<100	<10	<20.0	<0.6	<1	<1	3.0	1.0	10.5	<4	<10	<20	0.50	12.5	0.05
Nov-2010	Mean	<10	<10	<20.0	<0.6	<1	<1	1.0	0.7	9.0	<4	<10	<20	1.00	1.0	0.03
	Median	<10	<10	<20.0	<0.6	<1	<1	1.0	0.7	9.0	<4	<10	<20	1.00	1.0	0.03
	95th percentile	<10	<10	<20.0	<0.6	<1	<1	1.0	0.7	9.5	<4	<10	<20	1.00	1.0	0.03
Mar-2011	Mean	<10	<10	1.0	<0.6	<1	<1	1.4	1.0	9.8	<7	<10	<0.5	1.90	2.9	0.05
	Median	<10	<10	1.0	<0.6	<1	<1	1.0	0.6	10.0	<7	<10	<0.5	2.00	2.0	0.05
	95th percentile	<10	<10	1.1	<0.6	<1	<1	2.5	2.3	10.0	<7	<10	<0.5	2.00	7.5	0.06
June-2011	Mean	<10	<10	1.0	<0.6	<1	<1	1.0	0.1	10.0	<7	<10	<0.5	1.00	2.9	0.03
	Median	<10	<10	1.0	<0.6	<1	<1	1.0	0.1	10.0	<7	<10	<0.5	1.00	1.0	0.03
	95th percentile	<10	<10	1.0	<0.6	<1	<1	1.0	0.1	10.5	<7	<10	<0.5	1.00	9.5	0.03
All dates	Mean	<10	<10	5.5	<0.6	<1	<1	1.2	0.6	9.7	<7	<10	<20	1.10	3.9	0.04
	Median	<10	<10	5.6	<0.6	<1	<1	1.0	0.6	9.8	<7	<10	<20	1.00	1.8	0.03
	95th percentile	<10	<10	10.0	<0.6	<1	<1	2.8	1.7	10.5	<7	<10	<20	2.00	12.0	0.06

* All dissolved metals, when the measured value was less than the reporting limit; a value of 50% of the reporting limit was used to calculate statistics. If all measured values were less than the reporting limit, no statistics were calculated.

** National guideline triggers for 99% (High LEP)/ 90% (Moderate LEP) species protection (ANZECC & ARMCANZ 2000; Wenziker et al. 2006).

*** Low reliability guidelines values.

3.3 Physical stressors

Physical stressors around the proposed nearshore outfall site are summarised in Table 4.

Ministerial Statement 873 (Environmental Protection Authority 2011) indicates that physical and chemical parameters trigger values are to be based on 95th percentile of natural background (for Moderate LEP) and 80th percentile of natural background (for High LEP). Table 4 provides an indication of the variation in these physical parameters – these provide the basis for development of preliminary triggers. However, most of these parameters (particularly turbidity, temperature and salinity [shown as TDS]) can change sharply over short periods of time. It is recommended these triggers be based on a combination of long term statistics (as shown in Table 4) and real-time comparative Reference sites. Only by using this combination will the program be able to address both the relationship between natural and discharge parameters together with an assessment of potential impact.

Table 4. Physical stressors around the proposed nearshore outfall (units as shown)

Date	*Statistic*	*pH*	*Turbidity (NTU)*	*Temperature (°C)*	*Total Dissolved Solids (g/l)**
Guidelines - marine water**		Moderate LEP between 5th – 95th percentile of natural background High LEP between 20th – 80th percentile of natural background			
Reporting Limit					10
Aug-2010	Mean	8.2	1.6	22.8	39.5
	Median	8.2	2.4	22.8	39.5
	5th percentile	8.2	0.0	22.7	39.4
	20th percentile	8.2	0.4	22.7	39.4
	80th percentile	8.2	2.4	22.8	39.5
	95th percentile	8.2	2.5	22.8	39.6
Nov-2010	Mean	8.2	5.7	26.4	38.5
	Median	8.2	5.6	26.5	38.5
	5th percentile	8.2	4.0	26.2	38.3
	20th percentile	8.2	4.7	26.3	38.4
	80th percentile	8.2	6.8	26.5	38.6
	95th percentile	8.2	7.3	26.5	38.7
Mar-2011	Mean	8.1	5.4	29.9	34.9
	Median	8.1	5.6	29.9	35.0
	5th percentile	8.0	3.6	29.9	34.5
	20th percentile	8.1	4.0	29.9	34.5
	80th percentile	8.1	6.8	30.0	35.3
	95th percentile	8.1	7.3	30.0	35.5
June-2011	Mean	8.0	12.0	19.4	37.9
	Median	8.0	10.7	19.4	38.0
	5th percentile	7.9	5.4	19.2	37.5
	20th percentile	8.0	7.9	19.3	37.5
	80th percentile	8.1	16.9	19.5	38.3
	95th percentile	8.1	21.5	19.5	38.5

Date	Statistic	pH	Turbidity (NTU)	Temperature (^{o}C)	Total Dissolved Solids (g/l)*
Summer	Mean			28.2	
Nov/Mar	Median			28.2	
	5th percentile			26.2	
	20th percentile			26.4	
	80th percentile			29.9	
	95th percentile			30.0	
Winter	Mean			21.1	
Aug/June	Median			21.1	
	5th percentile			19.2	
	20th percentile			19.4	
	80th percentile			22.8	
	95th percentile			22.8	
All dates	Mean	8.1	6.2	24.6	37.7
	Median	8.1	5.5	24.5	38.4
	5th percentile	8.0	0.4	19.3	34.5
	20th percentile	8.0	2.4	19.5	35.3
	80th percentile	8.2	8.9	29.9	39.4
	95th percentile	8.2	16.9	30.0	39.5

* Salinity is usually expressed in parts per thousand (ppt) (g/kg), TDS is expressed in g/l and is therefore an overestimate of salinity expressed as ppt. Salinity (in ppt) was not measured in this program.

** Guideline methods as specified in Ministerial Statement 873.

3.4 Other contaminants

Physical stressors around the proposed nearshore outfall site are summarised in Table 5.

Oil and grease was rarely detectable and median concentration always below 5 mg/l. The slightly higher levels at some times would indicate that it would be appropriate to use the 95th percentile as a trigger level for Moderate LEP and the 80th percentile as the trigger level for the area of High LEP.

The test for free chlorine was not sensitive enough to detect if chlorine concentrations approached the low reliability ANZECC & ARMCANC guideline value. Under such circumstances a more sensitive method combined with comparison to Reference sites would be advised.

Total coliforms measured were well below guideline values for recreational water use.

Figure 1. Location of sites for collection of water samples

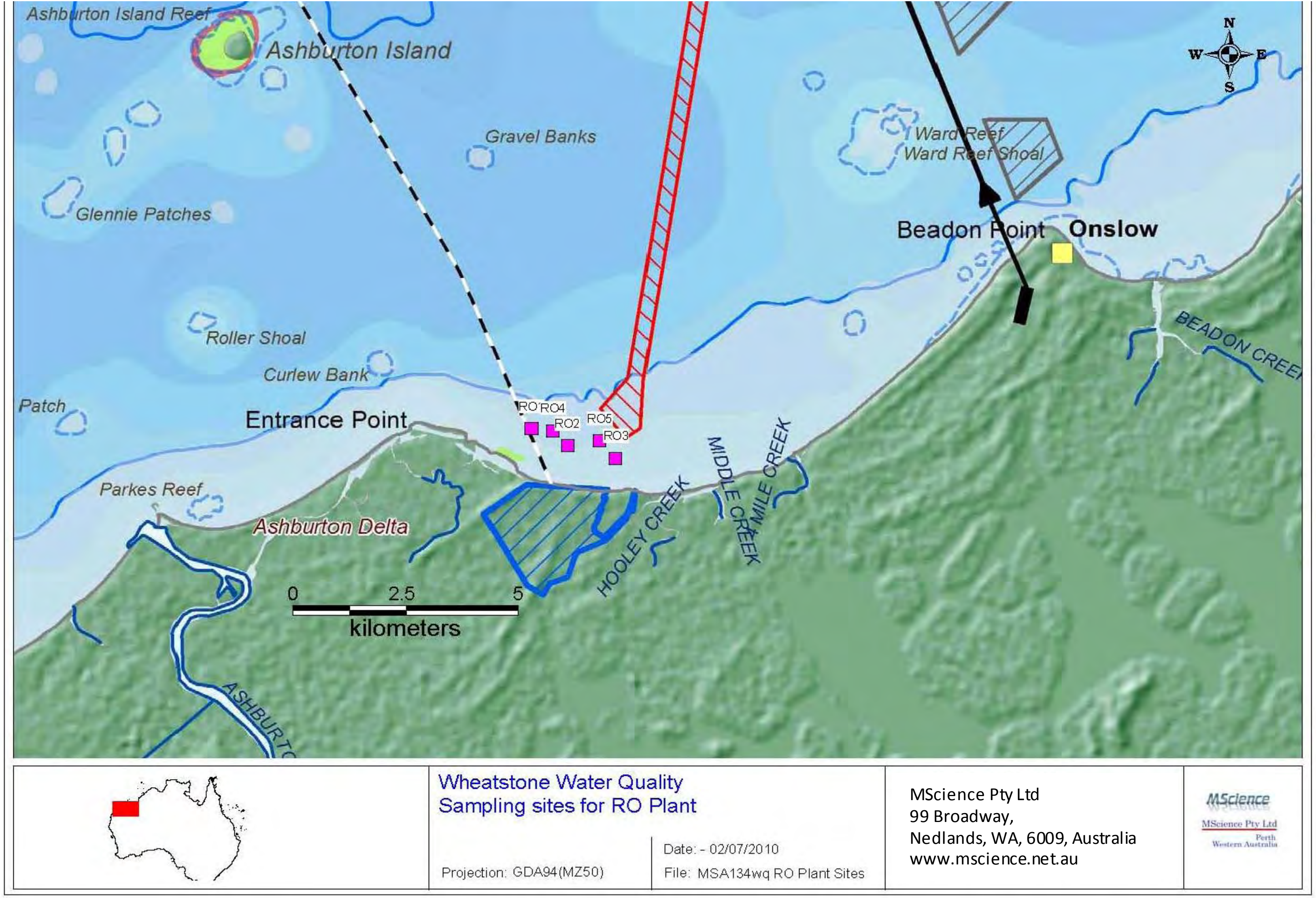
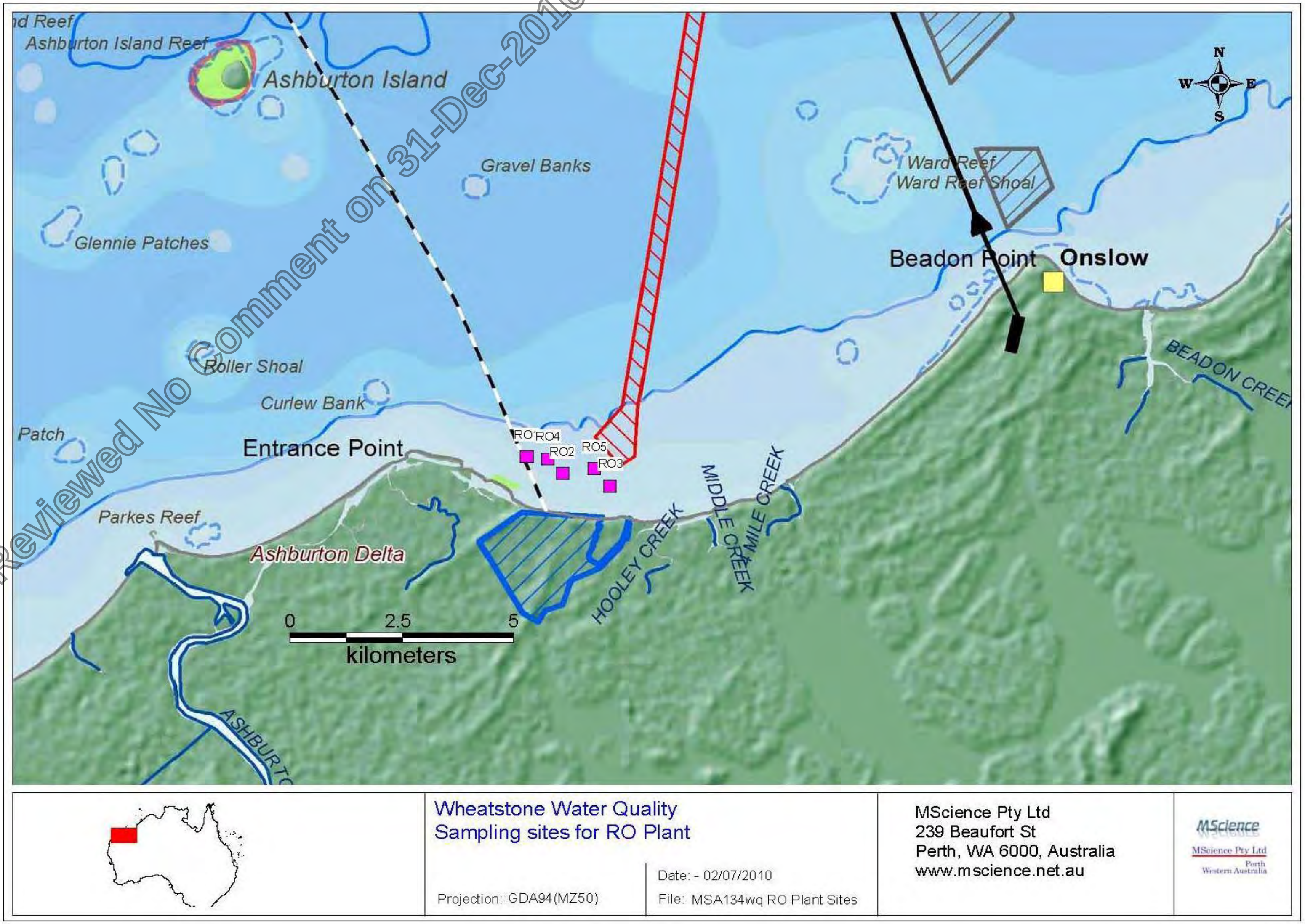


Figure 1. Sites for collection of water samples



ANALYTICAL REPORT

WORLD RECOGNISED ACCREDITATION

CLIENT DETAILS

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Project	**MSA134 RO Plant Sites**
Order Number	**134-2**
Samples	11

LABORATORY DETAILS

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SGS Reference	PE053769 R1
Report Number	0000010103
Date Reported	25 Nov 2010

COMMENTS

The document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. NATA accredited laboratory 2562(898).

Samples RO1/1, RO1/3, RO2/1, RO2/3, RO3/1, RO3/3, RO4/1, RO4/3. RO5/1, RO5/3 and ROSpare were diluted due to high conductivity for metals. Hence the LORs were raised for these samples.
Total Nitrogen and Total Phosphorus detection limits raised due to matrix interferences.

This report cancels and supersedes the report No.PE053769 dated 18 November 2010 issued by SGS Environmental Services due to amendments made to the mercury reporting units and ammonia results.

SIGNATORIES

Jeremy Truong Inorganics Co-ordinator	Kurt Blackman Inorganic Team Leader - Soils	Said Hirad Laboratory Manager

		Sample Number	PE053769.001	PE053769.002	PE053769.003	PE053769.004	PE053769.005
		Sample Matrix	Water	Water	Water	Water	Water
		Sample Date	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00
		Sample Name	RO1/1	RO1/3	RO2/1	RO2/3	RO3/1
Parameter	**Units**	**LOR**					
pH in water Method: AN101							
pH	No unit	-	7.8	8.0	8.1	8.2	8.2
Conductivity and TDS by Calculation - Water Method: AN106							
Conductivity	µS/cm	2	56000	55000	55000	55000	56000
Total Dissolved Solids (TDS) in water Method: AN113							
Total Dissolved Solids Dried at 180°C	mg/L	10	38600	38000	38500	38500	38000
Colour by Discrete Analyser Method: AN285							
Colour (True)	Hazen	1	<1	<1	<1	<1	<1
Total and Volatile Suspended Solids (TSS / VSS) Method: AN114							
Total Suspended Solids Dried at 105°C	mg/L	5	11	15	14	15	14
Volatile Suspended Solids Ignited at 550°C	mg/L	5	<5	<5	<5	<5	<5
Alkalinity Method: AN135							
Bicarbonate Alkalinity as HCO_3	mg/L	5	150	140	150	150	1400
Carbonate Alkalinity as CO_3	mg/L	1	<1	<1	<1	<1	<1
Total Alkalinity as $CaCO_3$	mg/L	5	120	120	120	130	1100
Chloride by Discrete Analyser in Water Method: AN274							
Chloride	mg/L	1	21000	21000	21000	21000	21000
Sulphate in water Method: AN275							
Sulphate	mg/L	1	3000	3000	3000	3100	3000
Chlorine Free and Total DPD Method: AN144							
Free Chlorine by DPD Colourimetric	mg/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Acidity and Free CO2 Method: AN140							
Free CO_2 by titration as mg CO_2/L	mg CO2/L	5	<5	<5	<5	<5	<5
Fluoride by Ion Selective Electrode in Water Method: AN141							
Fluoride by ISE	mg/L	0.1	1.0	1.0	1.0	1.0	1.0
Total Cyanide in water Method: AN077/AN154							
Total Cyanide	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Weak Acid Dissociable Cyanide Method: AN078/AN154							
Weak Acid Dissociable Cyanide	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hydrogen Sulphide Method: AN513							
Hydrogen Sulphide, H_2S	mg/L	0.15	<0.15	<0.15	<0.15	<0.15	<0.15

		Sample Number	PE053769.001	PE053769.002	PE053769.003	PE053769.004	PE053769.005
		Sample Matrix	Water	Water	Water	Water	Water
		Sample Date	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00
		Sample Name	RO1/1	RO1/3	RO2/1	RO2/3	RO3/1
Parameter	**Units**	**LOR**					
Reactive Silica by FIA Method: AN259							
Reactive Silica, SiO_2	mg/L	0.022	0.23	0.21	0.23	0.25	0.24
Forms of Carbon Method: AN190							
Total Organic Carbon	mg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Metals in Water (Dissolved) by ICPOES Method: AN321							
Calcium, Ca	mg/L	0.2	430	430	450	450	460
Iron, Fe	mg/L	0.02	<0.20↑	<0.20↑	<0.20↑	<0.20↑	<0.20↑
Magnesium, Mg	mg/L	0.1	1300	1400	1400	1400	1400
Potassium, K	mg/L	0.1	500	500	540	550	550
Silica, Soluble	mg/L	0.05	<0.50↑	<0.50↑	<0.50↑	<0.50↑	<0.50↑
Sodium, Na	mg/L	0.5	11000	11000	11000	11000	12000
Hardness by Calculation	mg CaCO3/L	5	6500	6600	7000	6900	7000
Mercury (dissolved) in Water Method: AN311							
Mercury	mg/L	0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Mercury (total) in Water Method: AN311							
Mercury	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Total Nitrogen by Persulphate Digestion FIA Method: AN268							
Total Nitrogen (Persulphate Digestion)	mg/L	0.05	<0.50↑	<0.50↑	<0.50↑	<0.50↑	<0.50↑
Total Phosphorus by Persulphate Digestion FIA in Water Method: AN269							
Total Phosphorus (Persulphate Digestion)	mg/L	0.01	<0.10↑	<0.10↑	<0.10↑	<0.10↑	<0.10↑
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258							
Nitrate, NO_3 as NO_3	mg/L	0.05	0.09	<0.05	0.09	<0.05	<0.05
Nitrite, NO_2 as NO_2	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Low Level Ammonia Nitrogen by FIA Method: AN261							
Ammonia Nitrogen, NH_3 as N	mg/L	0.005	0.058	<0.005	0.026	0.055	0.026
Filterable Reactive Phosphorus (FRP) Method: AN278							
Filterable Reactive Phosphorus	mg/L	0.002	<0.002	<0.002	0.003	<0.002	<0.002
Methylene Blue Active Substances (MBAS) in Water Method: AN192							
Anionic Surfactants as MBAS (Calculated as LAS MW	mg/L	0.05	1.3	1.4	1.4	1.4	1.3
Total Phenolics in Water Method: AN194							
Total Phenols	mg/L	0.005	0.005	<0.005	0.007	<0.005	<0.005
Oil and Grease in Water Method: AN185							
Oil and Grease	mg/L	5	<5	<5	<5	6	<5

		Sample Number	PE053769.001	PE053769.002	PE053769.003	PE053769.004	PE053769.005
		Sample Matrix	Water	Water	Water	Water	Water
		Sample Date	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00
		Sample Name	RO1/1	RO1/3	RO2/1	RO2/3	RO3/1
Parameter	Units	LOR					
Calculation of Anion-Cation Balance (SAR Calc) Method: AN121							
Anion-Cation Balance	%	-100	-3	-2	0	0	-1
Sum of Ions*	mg/L	-	37200	37200	37800	37900	39000

		Sample Number	PE053769.006	PE053769.007	PE053769.008	PE053769.009	PE053769.010
		Sample Matrix	Water	Water	Water	Water	Water
		Sample Date	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00
		Sample Name	RO3/3	RO4/1	RO4/3	RO5/1	RO5/3
Parameter	Units	LOR					
pH in water Method: AN101							
pH	No unit	-	8.2	8.2	8.2	8.2	8.2
Conductivity and TDS by Calculation - Water Method: AN106							
Conductivity	µS/cm	2	55000	57000	56000	56000	56000
Total Dissolved Solids (TDS) in water Method: AN113							
Total Dissolved Solids Dried at 180°C	mg/L	10	39300	38100	38800	38400	38400
Colour by Discrete Analyser Method: AN285							
Colour (True)	Hazen	1	<1	<1	<1	<1	<1
Total and Volatile Suspended Solids (TSS / VSS) Method: AN114							
Total Suspended Solids Dried at 105°C	mg/L	5	15	31	<5	20	11
Volatile Suspended Solids Ignited at 550°C	mg/L	5	<5	<5	<5	<5	<5
Alkalinity Method: AN135							
Bicarbonate Alkalinity as HCO_3	mg/L	5	150	140	140	150	150
Carbonate Alkalinity as CO_3	mg/L	1	<1	<1	<1	<1	<1
Total Alkalinity as $CaCO_3$	mg/L	5	120	120	120	120	120
Chloride by Discrete Analyser in Water Method: AN274							
Chloride	mg/L	1	21000	20000	20000	21000	20000
Sulphate in water Method: AN275							
Sulphate	mg/L	1	3000	3000	3000	3000	3000
Chlorine Free and Total DPD Method: AN144							
Free Chlorine by DPD Colourimetric	mg/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Acidity and Free CO2 Method: AN140							
Free CO_2 by titration as mg CO_2/L	mg CO2/L	5	<5	<5	<5	<5	<5
Fluoride by Ion Selective Electrode in Water Method: AN141							
Fluoride by ISE	mg/L	0.1	1.0	1.0	1.0	1.0	1.0

		Sample Number	PE053769.006	PE053769.007	PE053769.008	PE053769.009	PE053769.010
		Sample Matrix	Water	Water	Water	Water	Water
		Sample Date	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00
		Sample Name	RO3/3	RO4/1	RO4/3	RO5/1	RO5/3
Parameter	Units	LOR					

Total Cyanide in water Method: AN077/AN154

Total Cyanide	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Weak Acid Dissociable Cyanide Method: AN078/AN154

Weak Acid Dissociable Cyanide	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Hydrogen Sulphide Method: AN513

Hydrogen Sulphide, H_2S	mg/L	0.15	<0.15	<0.15	<0.15	<0.15	<0.15

Reactive Silica by FIA Method: AN259

Reactive Silica, SiO_2	mg/L	0.022	0.24	0.24	0.24	0.23	0.23

Forms of Carbon Method: AN190

Total Organic Carbon	mg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Metals in Water (Dissolved) by ICPOES Method: AN321

Calcium, Ca	mg/L	0.2	440	440	450	430	460
Iron, Fe	mg/L	0.02	<0.20↑	<0.20↑	<0.20↑	<0.20↑	<0.20↑
Magnesium, Mg	mg/L	0.1	1400	1400	1400	1400	1400
Potassium, K	mg/L	0.1	550	530	560	520	560
Silica, Soluble	mg/L	0.05	<0.50↑	<0.50↑	<0.50↑	<0.50↑	<0.50↑
Sodium, Na	mg/L	0.5	11000	11000	12000	11000	12000
Hardness by Calculation	mg CaCO3/L	5	6900	6800	7000	6700	7100

Mercury (dissolved) in Water Method: AN311

Mercury	mg/L	0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005

Mercury (total) in Water Method: AN311

Mercury	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005

Total Nitrogen by Persulphate Digestion FIA Method: AN268

Total Nitrogen (Persulphate Digestion)	mg/L	0.05	<0.50↑	<0.50↑	<0.50↑	<0.50↑	<0.50↑

Total Phosphorus by Persulphate Digestion FIA in Water Method: AN269

Total Phosphorus (Persulphate Digestion)	mg/L	0.01	<0.10↑	<0.10↑	<0.10↑	<0.10↑	<0.10↑

Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258

Nitrate, NO_3 as NO_3	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	0.08
Nitrite, NO_2 as NO_2	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Low Level Ammonia Nitrogen by FIA Method: AN261

Ammonia Nitrogen, NH_3 as N	mg/L	0.005	<0.005	0.030	0.039	0.054	0.027

Filterable Reactive Phosphorus (FRP) Method: AN278

Filterable Reactive Phosphorus	mg/L	0.002	<0.002	<0.002	<0.002	0.002	0.002

Parameter	Units	LOR					
		Sample Number	PE053769.006	PE053769.007	PE053769.008	PE053769.009	PE053769.010
		Sample Matrix	Water	Water	Water	Water	Water
		Sample Date	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00	10/11/10 9:00
		Sample Name	RO3/3	RO4/1	RO4/3	RO5/1	RO5/3

Methylene Blue Active Substances (MBAS) in Water Method: AN192

Anionic Surfactants as MBAS (Calculated as LAS MW	mg/L	0.05	1.5	1.4	1.3	1.3	1.4

Total Phenolics in Water Method: AN194

Total Phenols	mg/L	0.005	0.007	<0.005	<0.005	0.008	<0.005

Oil and Grease in Water Method: AN185

Oil and Grease	mg/L	5	<5	<5	<5	7	<5

Calculation of Anion-Cation Balance (SAR Calc) Method: AN121

Anion-Cation Balance	%	-100	0	0	1	-2	3
Sum of Ions*	mg/L	-	37600	37200	37500	37300	37200

Parameter	Units	LOR	
		Sample Number	PE053769.011
		Sample Matrix	Water
		Sample Date	10/11/10 9:00
		Sample Name	ROSpare

pH in water Method: AN101

pH	No unit	-	8.2

Conductivity and TDS by Calculation - Water Method: AN106

Conductivity	µS/cm	2	56000

Total Dissolved Solids (TDS) in water Method: AN113

Total Dissolved Solids Dried at 180°C	mg/L	10	39500

Colour by Discrete Analyser Method: AN285

Colour (True)	Hazen	1	<1

Total and Volatile Suspended Solids (TSS / VSS) Method: AN114

Total Suspended Solids Dried at 105°C	mg/L	5	<5
Volatile Suspended Solids Ignited at 550°C	mg/L	5	<5

Alkalinity Method: AN135

Bicarbonate Alkalinity as HCO_3	mg/L	5	150
Carbonate Alkalinity as CO_3	mg/L	1	<1
Total Alkalinity as $CaCO_3$	mg/L	5	120

Chloride by Discrete Analyser in Water Method: AN274

Chloride	mg/L	1	21000

Sulphate in water Method: AN275

Sulphate	mg/L	1	3000

Chlorine Free and Total DPD Method: AN144

Free Chlorine by DPD Colourimetric	mg/L	0.1	<0.1

Marine and Freshwater Research Laboratory Environmental Science

Telephone: (08) 9360 2907 Facsimile: (08) 9360 6613

NATA

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MURDOCH UNIVERSITY
PERTH, WESTERN AUSTRALIA

WATER QUALITY DATA

Contact: Heidi Mielke
Customer: SGS Environmental
Address: 10 Reid Road, Newburn WA 6105

Date of Issue: 7/12/2010
Date Received: 11/11/2010
Our Reference: MIS10-33
Your Reference: PE053769A

METHOD SAMPLE CODE	Sampling Date	ICP001 Ag mg/L	ICP001 Al mg/L	ICP001 As mg/L	ICP001 B mg/L	ICP001 Ba mg/L	ICP001 Be mg/L	ICP001 Cd mg/L	ICP001 Cr mg/L	ICP001 Cu mg/L	ICP001 Fe mg/L
Reporting Limit		**<0.01**	**<0.01**	**<0.02**	**<0.06**	**<0.0004**	**<0.0001**	**<0.0006**	**<0.001**	**<0.001**	**<0.002**
File		**10111501**	**10111501**	**10111501**	**10111801**	**10111501**	**10111501**	**10111501**	**10111501**	**10111501**	**10111501**
PE053769A-1	10/11/2010	<0.01	<0.01	<0.02	5.0	0.0060	<0.0001	<0.0006	<0.001	<0.001	<0.002
PE053769A-2	10/11/2010	<0.01	<0.01	<0.02	5.0	0.0062	<0.0001	<0.0006	<0.001	<0.001	<0.002
PE053769A-3	10/11/2010	<0.01	<0.01	<0.02	5.0	0.0062	<0.0001	<0.0006	<0.001	<0.001	<0.002
PE053769A-4	10/11/2010	<0.01	<0.01	<0.02	5.1	0.0060	<0.0001	<0.0006	<0.001	<0.001	<0.002
PE053769A-5	10/11/2010	<0.01	<0.01	<0.02	5.1	0.0060	<0.0001	<0.0006	<0.001	<0.001	<0.002
PE053769A-6	10/11/2010	<0.01	<0.01	<0.02	5.1	0.0059	<0.0001	<0.0006	<0.001	<0.001	<0.002
PE053769A-7	10/11/2010	<0.01	<0.01	<0.02	4.9	0.0061	<0.0001	<0.0006	<0.001	<0.001	<0.002
PE053769A-8	10/11/2010	<0.01	<0.01	<0.02	5.1	0.0062	<0.0001	<0.0006	<0.001	<0.001	<0.002
PE053769A-9	10/11/2010	<0.01	<0.01	<0.02	5.1	0.0059	<0.0001	<0.0006	<0.001	<0.001	<0.002
PE053769A-10	10/11/2010	<0.01	<0.01	<0.02	5.1	0.0059	<0.0001	<0.0006	<0.001	<0.001	<0.002
PE053769A-11	10/11/2010	<0.01	<0.01	<0.02	5.0	0.0060	<0.0001	<0.0006	<0.001	<0.001	<0.002

Signatory:

Date: 7/12/2010

Marine and Freshwater
Research Laboratory
Environmental Science

Telephone: (08) 9360 2907 Facsimile: (08) 9360 6613

NATA
Accreditation Number: 10603
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MURDOCH
UNIVERSITY
PERTH, WESTERN AUSTRALIA

WATER QUALITY DATA

Contact: Heidi Mielke
Customer: SGS Environmental
Address: 10 Reid Road, Newburn WA 6105

Date of Issue: 7/12/2010
Date Received: 11/11/2010
Our Reference: MIS10-33
Your Reference: PE053769A

METHOD SAMPLE CODE	Sampling Date	ICP001 Mn mg/L	ICP001 Mo mg/L	ICP001 Ni mg/L	ICP001 Pb mg/L	ICP001 S mg/L	ICP001 Sb mg/L	ICP001 Se mg/L	ICP001 Sr mg/L	ICP001 V mg/L	ICP001 Zn mg/L
Reporting Limit		<0.0002	<0.004	<0.004	<0.01	<5	<0.02	<0.02	<0.01	<0.002	<0.002
File		10111501	10111501	10111501	10111501	10111801	10111501	10111501	10111801	10111501	10111501
PE053769A-1	10/11/2010	0.0006	0.009	<0.004	<0.01	940	<0.02	<0.02	8.2	<0.002	<0.002
PE053769A-2	10/11/2010	0.0006	0.009	<0.004	<0.01	950	<0.02	<0.02	8.3	<0.002	<0.002
PE053769A-3	10/11/2010	0.0007	0.009	<0.004	<0.01	930	<0.02	<0.02	8.2	<0.002	<0.002
PE053769A-4	10/11/2010	0.0007	0.010	<0.004	<0.01	930	<0.02	<0.02	8.3	<0.002	<0.002
PE053769A-5	10/11/2010	0.0006	0.009	<0.004	<0.01	970	<0.02	<0.02	8.1	<0.002	<0.002
PE053769A-6	10/11/2010	0.0007	0.009	<0.004	<0.01	930	<0.02	<0.02	8.0	<0.002	<0.002
PE053769A-7	10/11/2010	0.0007	0.009	<0.004	<0.01	940	<0.02	<0.02	8.1	<0.002	<0.002
PE053769A-8	10/11/2010	0.0006	0.009	<0.004	<0.01	950	<0.02	<0.02	8.1	<0.002	<0.002
PE053769A-9	10/11/2010	0.0007	0.008	<0.004	<0.01	960	<0.02	<0.02	8.3	<0.002	<0.002
PE053769A-10	10/11/2010	0.0006	0.009	<0.004	<0.01	960	<0.02	<0.02	8.3	<0.002	<0.002
PE053769A-11	10/11/2010	0.0008	0.009	<0.004	<0.01	970	<0.02	<0.02	8.1	<0.002	0.015

Signatory:

Date: 7/12/2010

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

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ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EP1400686**	Page	: 1 of 4
Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: CATHERINE COCKBURN	Contact	: Shuk Hui Li
Address	: Supplier ID number - 1179447 LEVEL 4 226 ADELAIDE TERRACE PERTH WA, AUSTRALIA 6000	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: catherine.cockburn@urs.com	E-mail	: ShukHui.Li@alsglobal.com
Telephone	: +61 08 9326 0100	Telephone	: 08 9209 7655
Facsimile	: +61 08 9326 0296	Facsimile	: 08 9209 7600
Project	: Wheatstone Groundwater Surface water Monitoring	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: 42908272		
C-O-C number	: ----	Date Samples Received	: 31-JAN-2014
Sampler	: P.H.	Issue Date	: 07-FEB-2014
Site	: ----		
		No. of samples received	: 1
Quote number	: EP/464/12 V4	No. of samples analysed	: 1

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Metals Instrument Chemist	Perth Inorganics
Chas Tucker	Senior Inorganic Chemist	Perth Inorganics
Efua Wilson	Metals Chemist	Perth Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EA016: Calculated TDS is determined from Electrical conductivity using a conversion factor of 0.65.**
- **EG020: Metals LOR for particular sample(s) raised due to high TDS content**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**OSW21_300114**	----	----	----	----
			Client sampling date / time	30-JAN-2014 09:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP1400686-001**	**----**	**----**	**----**	**----**
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**6.26**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**270000**	----	----	----	----
EA016: Non Marine - Estimated TDS Salinity								
Total Dissolved Solids (Calc.)	----	1	mg/L	**176000**	----	----	----	----
EA025: Suspended Solids								
Suspended Solids (SS)	----	5	mg/L	**142**	----	----	----	----
EA045: Turbidity								
Turbidity	----	0.1	NTU	**20.4**	----	----	----	----
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	**26900**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**10**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**10**	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**6650**	----	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**184000**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**987**	----	----	----	----
Magnesium	7439-95-4	1	mg/L	**5940**	----	----	----	----
Sodium	7440-23-5	1	mg/L	**92300**	----	----	----	----
Potassium	7440-09-7	1	mg/L	**2160**	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.50	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.050	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0058**	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.050	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.050	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.050**	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.050	----	----	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**OSW21_300114**	----	----	----	----
			Client sampling date / time	30-JAN-2014 09:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP1400686-001**	**----**	**----**	**----**	**----**
EG020F: Dissolved Metals by ICP-MS - Continued								
Zinc	7440-66-6	0.005	mg/L	**0.321**	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**12.2**	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	----	----	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**9.09**	----	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	----	0.01	mg/L	**0.02**	----	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	**0.04**	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.06**	----	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	<0.01	----	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**5330**	----	----	----	----
Total Cations	----	0.01	meq/L	**4610**	----	----	----	----
Ionic Balance	----	0.01	%	**7.27**	----	----	----	----
EP002: Dissolved Organic Carbon (DOC)								
Dissolved Organic Carbon	----	1	mg/L	**13**	----	----	----	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	**14**	----	----	----	----

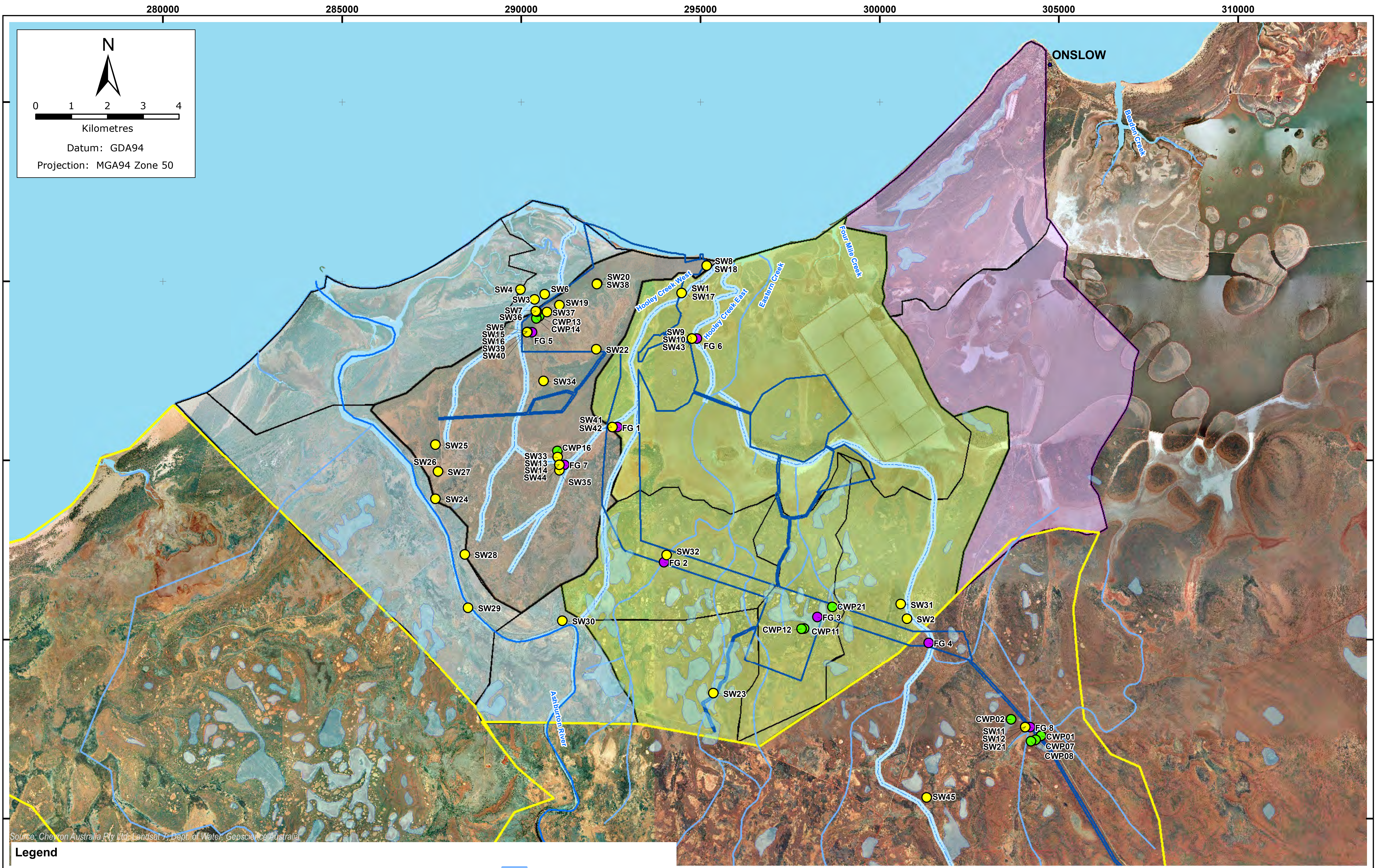
Table 3-3 Surface Water Quality Laboratory Analysis

Site No.	Field No.	Sample Date	pH Value	Total Dissolved Solids @ 180ºC	Suspended Solids	Turbidity	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Sulphate as SO4 -2	Cl	Ca	Mg	Na	K	As	Cd	Cr	Cu	Ni	Pb	Zn	Hg	Total Anions	Total Cations
			pH	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L
																	0.001	**0.0001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.005**	**0.0001**		
SW1		18-Feb-10	8.27	43400	142	-	<1	<1	118	118	3520	21900	494	1690	12100	625	<0.01	<0.001	<0.01	0.015	0.017	<0.01	<0.052	<0.0001	693	706
SW2		21-Feb-10	6.71	347000	553	-	<1	<1	202	202	3190	181000	2850	29600	62800	9900	<0.021	<0.0021	<0.021	0.108	0.039	<.021	<.105	<0.0001	5190	5560
SW3		20-Feb-10	7.78	64600	-	-	<1	<1	169	169	4560	29000	705	2130	16700	854	<0.01	<0.01	0.013	0.012	0.013	<.01	0.11	<0.0001	916	958
SW4		10-Jul-10	7.84	64600	-	-	Only a limited water quality suite was conducted on surface water samples during this time (as per scope)																			
SW5		14-Jul-10	7.97	73300	-	13.8																				
SW6		15-Nov-10	7.69	64400	150	15																				
SW7		16-Nov-10	7.99	114000	548	4.3																				
SW8		17-Nov-10	8.04	55200	523	1.9																				
SW9		24-Jan-11	7.9	68200	660	-																				
SW10		24-Jan-11	-	97000	68	-																				
SW11		14-Mar-11	7.67	838	56	1170	<1	<1	29	29	4	14	2	2	20	5	0.003	0.0002	0.047	0.034	0.03	0.011	0.07	<0.0001	1.05	1.31
SW12		14-Mar-11	7.53	430	977	2300	<1	<1	29	29	3	14	2	2	18	5	0.004	0.0001	0.062	0.05	0.046	0.017	0.18	<0.0001	1.03	1.18
SW13		14-Mar-11	7.08	102	36	18.3	<1	<1	8	8	6	17	2	1	12	2	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.026	<0.0001	0.77	0.77
SW14		14-Mar-11	7.15	80	8	7.4	<1	<1	15	15	6	25	1	2	15	1	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.286	<0.0001	1.11	0.88
SW15		13-Mar-11	7.4	4260	22	8.8	<1	<1	23	23	259	2120	55	138	1170	50	<0.001	<0.0001	0.002	0.002	0.003	<0.001	0.167	<0.0001	65.6	66.3
SW16		13-Mar-11	-	-	-	4.4	-	-	-	-	-	-	-	-	-	-	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.443	<0.0001	-	-
SW17		13-Mar-11	7.94	47300	32	15.8	<1	<1	112	112	3050	25900	505	1720	14500	607	<0.001	<0.0001	<0.001	0.012	0.009	<0.001	<0.005	<0.0001	796	816
SW18		13-Mar-11	8.02	42200	52	9.8	<1	<1	109	109	3400	22900	460	1570	13300	544	<0.001	<0.0001	<0.001	0.012	0.008	<0.001	<0.005	<0.0001	719	744
SW19		13-Mar-11	8.12	4900	26	24.1	<1	<1	106	106	631	1700	248	164	970	36	0.004	<0.0001	<0.001	0.006	0.003	<0.001	<0.005	<0.0001	63.4	68.9
SW20		13-Mar-11	8.1	662	28	185	<1	<1	95	95	9	158	4	11	111	15	0.006	<0.0001	0.012	0.012	0.009	0.002	0.015	<0.0001	6.55	6.29
SW21		09-Apr-11	8.15	251	10	678	<1	<1	57	57	7	28	2	3	46	7	0.004	0.0001	0.06	0.054	0.045	0.018	0.102	<0.0001	2.07	2.54
SW22		09-Apr-11	8.19	89600	395	2.7	<1	<1	124	124	10600	46800	1930	3150	25300	1320	<0.010	<0.0010	<0.010	0.046	<0.010	<0.010	0.097	0.0002	1540	1490
SW23		10-Apr-11	7.67	420	5250	22400	<1	<1	93	93	6	15	<1	1	42	3	0.01	0.0011	0.225	0.475	0.431	0.16	0.619	<0.0001	2.4	2.02
SW24		10-Apr-11	7.11	194	80	219	<1	<1	37	37	18	43	9	4	36	6	0.002	<0.0001	0.016	0.016	0.011	0.004	0.067	<0.0001	2.34	2.53
SW25		10-Apr-11	7.1	110	28	29.8	<1	<1	45	45	3	9	9	2	13	6	<0.001	<0.0001	0.003	0.006	0.002	<0.001	0.006	<0.0001	1.2	1.34
SW26		10-Apr-11	6.6	86	80	63.9	<1	<1	15	15	2	9	1	<1	11	4	<0.001	0.0002	0.006	0.009	0.005	0.002	0.073	<0.0001	0.59	0.67
SW27		10-Apr-11	7.39	162	260	335	<1	<1	41	41	3	12	6	2	19	5	0.002	<0.0001	0.017	0.016	0.012	0.004	0.02	<0.0001	1.23	1.38
SW28		10-Apr-11	6.78	377	335	669	<1	<1	17	17	1	6	<1	<1	12	3	0.002	<0.0001	0.03	0.027	0.023	0.008	0.058	<0.0001	0.53	0.62

3 Surface Water Monitoring

Site No.	Field No.	Sample Date	pH Value	Total Dissolved Solids @ 180ºC	Suspended Solids	Turbidity	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Sulphate as SO4 -2	Cl	Ca	Mg	Na	K	As	Cd	Cr	Cu	Ni	Pb	Zn	Hg	Total Anions	Total Cations
			pH	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L
SW29		10-Apr-11	7.26	470	1570	1840	<1	<1	64	64	<1	8	2	<1	32	2	0.003	0.0003	0.041	0.051	0.04	0.014	0.056	<0.0001	1.5	1.53
SW30		10-Apr-11	7.19	1620	990	3460	<1	<1	47	47	4	8	2	1	24	3	0.005	0.0003	0.083	0.103	0.093	0.038	0.141	<0.0001	1.25	1.29
SW31		14-Apr-11	7.75	116000	352	-	<1	<1	96	96	5210	71800	1840	3880	34900	1360	<0.010	0.0012	0.012	0.057	0.042	0.04	0.123	<0.0001	2140	1960
SW32		14-Apr-11	7.02	145000	344	-	<1	<1	21	21	5510	78200	2520	4100	42800	827	<0.010	0.005	<0.010	0.052	0.043	<0.010	<0.052	<0.0001	2320	2340
SW33		14-Apr-11	8.42	7950	300	-	<1	5	132	138	16	101	6	6	127	6	<0.010	<0.0010	0.27	0.229	0.21	0.1	0.319	<0.0001	5.94	6.5
SW34		14-Apr-11	8.28	75000	84	-	<1	<1	106	106	7350	34200	1040	2080	16400	835	<0.010	<0.0010	<0.010	0.043	0.017	<0.010	<0.052	<0.0001	1120	958
SW35		15-Apr-11	7.71	44600	64	39.6	<1	<1	121	121	4030	26500	819	1860	15200	657	<0.010	<0.0010	<0.010	0.017	0.014	<0.010	<0.052	<0.0001	834	871
SW36		15-Apr-11	7.94	41200	94	-	<1	<1	120	120	3630	20100	627	1380	11200	504	<0.010	<0.0010	<0.010	0.012	<0.010	<0.010	<0.052	<0.0001	645	646
SW37		15-Apr-11	8.1	420	24	32.5	<1	<1	78	78	23	118	10	11	84	9	0.004	<0.0001	0.006	0.005	0.008	<0.001	0.051	<0.0001	5.36	5.28
SW38		15-Apr-11	8.01	6250	<5	1.5	<1	<1	44	44	2560	5440	705	438	2720	99	0.005	<0.0001	0.001	0.013	0.004	<0.001	0.012	<0.0001	208	192
SW39		15-Apr-11	7.27	-	-	1.5	<1	<1	12	12	22	83	6	6	48	4	-	-	-	-	-	-	-	-	3.04	3.03
SW40		15-Apr-11	7.18	-	-	11.5	<1	<1	7	7	6	21	2	1	13	2	-	-	-	-	-	-	-	-	0.86	0.8
SW41		16-Apr-11	7.25	47200	570	362	<1	<1	60	60	3680	42700	733	1960	22800	791	<0.010	<0.0010	0.067	0.066	0.059	0.018	0.687	<0.0001	1280	1210
SW42		16-Apr-11	7.14	25200	<5	0.4	<1	<1	26	26	2580	23600	424	1170	12800	465	<0.010	<0.0010	<0.010	<0.010	<0.010	<0.010	0.173	<0.0001	720	689
SW43		16-Apr-11	7.45	39900	110	50	<1	<1	82	82	4240	31800	696	2210	17800	812	-	-	-	-	-	-	-	-	986	1010
SW44		14-Apr-11	8.06	735	1440	40	<1	<1	75	75	13	30	8	5	28	10	-	-	-	-	-	-	-	-	2.59	2.27
SW45		14-Apr-11	6.38	138000	77000	213000	<1	<1	743	743	10400	174000	624	12400	94900	3700	-	-	-	-	-	-	-	-	5140	5280

- In some instances there is insufficient water to sample all parameters



Source: Chevron Australia Pty Ltd; Landsat 7; Dept. of Water; Geoscience Australia

Legend

- ● Towns
- ▭ Claypans
- ▭ Indicative Terrestrial Project Area
- ● Surface Water Opportunistic Sampling Location
- ● Claypan Location
- ● Flow Gauge Location
- ╌ Palaeochannels (URS, 2009)
- — Major Watercourses
- — Minor Watercourses
- ▭ Ashburton Delta
- ▭ Southwest Catchment
- ▭ Hooley Creek Catchment
- ▭ Northeast Catchment
- ▭ Local Sub-catchments
- ▭ Ashburton River Sub-catchments

Client **CHEVRON AUSTRALIA PTY LTD**	Project Wheatstone Project Terrestrial And Estuarine Water Monitoring Report		Title Surface Water, Claypan and Flow Gauge Locations
URS	Drawn: MR/CJT/RNM	Approved: RM	Date: 10/05/2011
	Job No.: 42907466	File No.: 42907466-SW-016_RD.mxd	Appendix B
			Rev. D
			A3

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APPENDIX B REFERENCE DATA ON ANTI-SCALING AGENTS

Anti-scalant PermaTreat PC-191T; a phosphonate thus with risks of eutrophic conditions and algal blooms.														
The nitrogen and phosphorus concentration has been based a total of 11 mg/L of PC191T anti-scalant dosage. The anti-scalant contains:														
• 6.82% - 9.23% w/w as ‘P’ and / or 20.9% - 28.3% w/w as ‘PO4’ (worst case has been used in table above)														
• Nitrogen content is 1.16% w/w as ‘N’ from active concentration														
• Toxological Asessment - low toxicity to aquatic life, including: not calssified as harmful to aquatic invertebrates; not classified as harmful to fish; not harmful to birds; not harmful to mammals; low potential fro bioaccumulation; active substances shown to be slowly biodegradable, though not considered readily biodegradable.														
Anti-scalant PermaTreat PC-161T; a phosphate-free antiscalant.														
Chemical names Maleic Acid and Polycarboxylic acid polymer.														
• Toxological Asessment - no toxicity studies have been completed on this product. Mobility and bioaccumulation potentials have been estimated using a funacity model; the results suggest that 30 to 50 pecent would have fates in the water column and 50 to 70 percent would accumulate in sedient. The sediment fraction is not expeted to bioaccumulate. The potential environmental hazard is low though organic portions are expected tpo be poorly biodegradable.														

APPENDIX C REFERENCE DATA ON CLEANING AGENTS

Chemical Name: Sodium lauryl sulfate (SLS) - RN: 151-21-3

Sodium lauryl sulfate (SLS) is a detergent surfactant commonly used as a cleansing agent in all sorts of personal care products. It appears in toothpastes, shampoos, bubble baths, shaving creams -- any product that requires suds. Sodium lauryl sulfate is useful in a wide variety of personal care applications in which viscosity building and foam characteristics are of importance. Because of its low salt content, this product is particularly useful in formulations that are sensitive to high levels of sodium chloride. It is compatible with alkanolamides and amphoterics so that maximum optimization of foam and viscosity characteristics can be reached in the finished product.

Sodium lauryl sulfate is:

Used in shampoos, hand soaps, hair dyes, bath products, shaving creams and medicated ointments.

Used in hand dishwashing detergents; used in many cleaning compounds.

Used in electrophoretic separation and molecular weight estimation of proteins; wetting agent, detergent.

Used in the preparation of blood samples.

Used as a cleansing agent in cosmetics.

Used as a whipping aid in dried egg products.

Used in the characterization of quaternary ammonium compounds.

Used in the preparation of samples for dietary fiber content.

Food additive (emulsifier and thickener).

Used in the electroplating industry, particularly nickel and zinc; as an emulsifier, wetting agent and adjuvant in insecticides; as an emulsifier and penetrant in varnish and paint remover; in the formulation of injection-molded explosives; anti-foaming agent in solid rocket propellants; as a model surfactant and reference toxicant in aquatic and mammalian toxicological testing.

Hazardous Decomposition:

When heated to decomposition it emits toxic fumes of (sulfur oxides and sodium oxides). since it is used as an additive in milk, when milk is boiled, we inhale the poisonous gases that are emitted in industries at our home at our convenience. This also results in slow death. This type of adulteration is done in major cities, where everything is business and life is past and the Health administrations are corrupt. Please note the hazards which these poisonous gases can induce on a baby. This explains why the mortality rate is on a high in metropolitan cities compared to the rural and native villages and towns.

FDA Requirements:

Coatings may be applied to fresh citrus fruit for protection of the fruit in accordance with the following conditions: (a) the coating is applied in the minimum amount required to accomplish the intended effect and (b) the coating may be formulated from /sodium lauryl sulfate/ ... used in the minimum quantity required to accomplish the intended effect. Limitation: complying with 172.822. As a film former.

The food additive sodium lauryl sulfate may be safely used in food in accordance with the following conditions: (a)the additive meets the following specifications: 1. It is a mixture of sodium alkyl sulfates consisting chiefly of sodium lauryl sulfate and 2. it has a minimum content of 90% sodium alkyl sulfates. It is used or intended for use: 1. As an emulsifier in or with egg whites whereby the additive does not exceed the following limits: egg white solids, 1000 ppm; frozen egg whites, 125 ppm; and liquid egg whites, 125 ppm. 2. As a whipping agent at a level not to exceed 0.5% by weight of gelatine used in the preparation of marshmallows. 3. As a surfactant in fumaric acid-acidulated dry beverage base whereby the additive does not exceed 25 ppm of the finished beverage and such beverage base in not for use in a food for which a standard of identity established under section 401 of the Act precludes such use. As a surfactant in fumaric acid-acidulated fruit juice drinks whereby the additive does not exceed 25 ppm of the finished fruit juice drink and it is not used in a fruit juice drink for which a standard of identity established under section 401 of the Act precludes such use. 4. As a wetting agent at a level not to exceed 10 ppm in the partition of high and low melting fractions of crude vegetable oils and animal fats, provided that the partition step is followed by a conventional refining process that includes alkali neutralization and deodorization of the fats and oils.

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