Wheatstone Project

Definition of Impediments to Residual Saline Stream Disposal

1	17-April-2013	Issued for Use	LS	IB	IB
0	16-April-2013	Issued for Use	LS	IB	IB
REV	**DATE**	**DESCRIPTION**	**ORIG**	**CHK**	**APPR**

IP Security	☒ Company Confidential	**Total number of Pages (including Cover sheet):**	**73**

For Contractor Documents	**Contract No**	**Contractor Document No**	**Contractor Rev.**
	C674443	WHST-STU-WA-RPT-0112	**1**

COMPANY DOCUMENT CONTROL NO.	**Project**	**Area**	**Discipline**	**Type**	**Originator**	**Package**	**Sequence-Sht**	**Revision**
	WS0	9210	SIF	RPT	URS	000	00002-000	1

Report

Onslow Water Infrastructure Upgrade Project

Definition of Impediments to Residual Saline Stream Disposal

17 APRIL 2013

Prepared for

Chevron Australia Pty Ltd

124, QV1, 250 St Georges Terrace
Perth WA 6000

42908178

URS

Project Manager:

……
Ludovic Sprauer
Senior Hydrologist

URS Australia Pty Ltd

Level 4, 226 Adelaide Terrace Perth WA 6000 PO Box 6004, East Perth 6892 Australia
T: 61 8 9326 0100 F: 61 8 9326 0296

Principal-In-Charge:

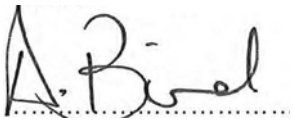
……
Ian Brunner
Senior Principal

Author:

……
Mike Jones
Project Environmental Scientist

……
Ludovic Sprauer
Senior Hydrologist

Reviewer:



……
Ashley Bird
Principal Environmental Scientist

Date: **17 April 2013**
Reference: 42908178/W0751/1
Status: Final

.

Table of Contents

Table of Contents

Table of Contents

Tables

Figures

Appendices

Abbreviations

Abbreviation	Description
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
Chevron	Chevron Australia Pty Ltd
DEC	Department of Environment and Conservation
DoW	Department of Water
DRF	Declared Rare Flora
ERMP	Environmental Review and Management Program
EPA	Environmental Protection Agency
EPBC	Environmental Protection and Biodiversity Conservation Act
FAO	Food and Agriculture Organization
GL	Giga-Litres
ha	hectares
H_2S	Hydrogen sulphide
NORM	Naturally Occurring Radioactive Materials
LiDAR	Light Detection and Ranging
LNG	Liquid Natural Gas
m	metres
mBq/L	Millibecquerels per litre
Mg/L	Milligrams per litre
ML	Mega-Litres
mtpa	Mega tonnes per annum
OEPA	Office of the Environmental Protection Authority
QMC	Quick Mud Creek
RO	Reverse Osmosis
RSS	Residual Saline Stream
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
U.S.A	United States of America
TDS	Total Dissolved Solids
WET	Whole effluent toxicity

Executive Summary

As part of an on-going commitment to the Onslow community, Chevron is undertaking the upgrade of the town potable water infrastructure. One supply option involves the RO treatment of groundwater sourced from the Birdrong Aquifer. The RO treatment produces a Residual Saline Stream (RSS) by-product. Disposal strategies for the RSS were assessed (URS, 2012a) for two sites (Site A and Site B). Subsequently, Chevron has refined the disposal setting to Site B. There are four RSS disposal strategies under consideration and two 'poorer' (RSS3) or 'better' (RSS4) residual saline streams.

The RSS disposal strategies all occur in terrestrial settings and include:

1. Option 1 - Direct discharge to Quick Mud Creek with process option 1 (RSS3).
2. Option 2 - Direct discharge to Quick Mud Creek with process option 2 (RSS4).
3. Options 3 - Discharge by injection into Trealla Limestone with process option 1 (RSS3).
4. Options 4 - Discharge to infiltration basin with process option 1 (RSS3).

The Project is defined as the proposed desalination plant including the disposal infrastructure. The Project area comprises any infrastructure used to dispose the residual saline stream such as proposed pipe discharging into Quick Mud Creek and the footprint of the concentrate on the baseline environment.

The purpose of this study was to define impediments to regulatory approvals for the RSS disposal options, and make recommendations on the least-risk strategy in term of regulatory process. In order to comparatively rank the disposal options, the following methodology was used:

- Review of case studies with analogues to the Project area. A number of relevant case studies were found with equivalent disposal options to the proposed. These case studies have been used to identify key environmental aspects, regulations and guidelines and for any precedents for disposal options.
- Development of an environment aspects register.
- Identification of potential baseline environments, based on literature review. The baseline setting has been informed by review of the Wheatstone project baseline information, DEC and EPA flora and fauna search tools and the *Alternative Assessment of Brine Disposal Report* (URS, 2012).
- Identification of the potential impacts on the baseline environments for the individual RSS disposal options. Development of an impediments ranking assessment. The potential impacts that the RSS disposal option would have on the environment were identified together with the potential associated regulatory impediments. The risk that the impediment may trigger difficulties in the regulatory process has been ascertained using an environmental risk matrix. This matrix is based on the likelihood of the impediments and the consequence of that impediment on the regulatory process (such as triggering referral to the commonwealth government).
- Identification of the least impediment regulatory option. The comparative ranking assessment considers only the risks on a scale from medium to extreme. Some of these key elements would have more influence on the regulatory process. In order to take account of this influence, weighting will be applied to the key elements.

Executive Summary

Discussion on Impediments and Risks

Option 1 – Discharge of RSS3 into Quick Mud Creek

The key regulatory impediments for discharge into Quick Mud Creek are considered as follows:

- Radionuclides accumulation but less relevant if radionuclides are reduced (filter backwash).
- Degradation of ephemeral ecosystems.

Option 2 – Disposal of RSS4 to Quick Mud Creek

Option 2 has similar impacts to Option 1, with lesser accumulation of beta activities radionuclides, however, given lower initial concentrations. The 'better quality' RSS only contains trace radionuclides and significantly mitigates the risk that accumulation by evaporation would exceed appropriate thresholds. That said, the magnitude of the potential changes in radionuclides concentrations and other RSS indicators have not been predicted. Intuitively an order of magnitude change may not be unrealistic.

Option 3 – Discharge by Injection into Trealla Limestone

- Degradation of 2,560 ha of good to excellent condition vegetation.
- Degradation of fauna habitat.
- Degradation of clay-pan fauna habitat.

Option 4 - Discharge to Infiltration Basin

Regulatory risks are considered similar to Option 3 with a smaller extent (1,533 ha).

Recommended RSS Disposal Option

Based on the described assessments, Option 2 - disposal of RSS4 to Quick Mud Creek would provide the least impediments for regulatory approval..

There are a number of credentials that support Option 2:

1. While impacts to receptors exist, they are not considered significant.
2. Provides the least potential impacts to native vegetation.
3. Limits radionuclide accumulation.
4. Avoids impacts to Conservation Significant flora.
5. There are numerous case studies and broadly analogous precedents for approvals to discharge RSS to saline environments subject to periodic and episodic flooding events.
6. Provides the lowest ranked score.

Option 1 is worthy of further consideration and modelling work to determine if radionuclide accumulation will be limited by periodic flushing and geomorphological factors. Option 1 with reduced radionuclides (a simpler process than Option 2) may also be considered to have comparatively low regulatory risk.

1

Introduction

1.1 Background

Chevron has received primary environmental approvals for a 25 mega tonnes per annum Liquid Natural Gas (LNG) processing facility within the Ashburton North Strategic Industrial Area south of Onslow, Western Australia. Early construction activities have been commenced by Bechtel, Chevron's downstream construction contractor. As part of an on-going commitment to the Onslow community, Chevron is undertaking the upgrade of the town potable water infrastructure. One supply option involves the Birdrong Aquifer as a source, with Reverse Osmosis (RO) treatment of the saline groundwater prior to distribution. The RO treatment produces a Residual Saline Stream (RSS) by-product. Disposal strategies for the brine were assessed (URS 2012a) for two sites (Site A and Site B) in the absence of consideration for potential environmental impacts and other impediments to the regulatory process approval. A number of disposal options have been identified, as follows:

1. Surface Water Disposal to Quick Mud Creek.
2. Infiltration Basin.
3. Injection into Trealla Limestone.

The purpose of this study is to identify potential regulatory impediments and environmental risks in regards to these RSS disposal options.

The Project area was assumed to include the areas traversed by any infrastructure used to dispose the RSS, such as the proposed pipe discharging into Quick Mud Creek, and the potential footprints of the RSS on the baseline environment.

1.2 Inland Disposal Options

There are four RSS disposal strategies under consideration. Each refers only to “Site B” (Project area), shown as the proposed desalination plant site on Figure 1-1, and incorporates either a ‘poorer’ (RSS3) or ‘better’ (RSS4) RSS.

The RSS disposal strategies all occur in terrestrial settings and include:

1. Option 1 - Direct discharge to prescribed outlet within Quick Mud Creek with process option 1 (RSS3).
2. Option 2 - Direct discharge to prescribed outlet within Quick Mud Creek with process option 2 (RSS4).
3. Options 3 - Discharge by injection into Trealla Limestone with process option 1 (RSS3).
4. Options 4 - Discharge to infiltration basin with process option 1 (RSS3).

1.3 Objectives of this Study

This study looks to define potential impediments to the selected RSS disposal strategies from a regulatory and environmental risk perspective. The identification of environmental impediments to the RSS discharge is based on:

- Assessments in regards to potential environmental footprints and, risks and potential impediments to regulatory approvals.
- Regulatory guidelines for discharge to ephemeral creek, infiltration to water table and injection into deep aquifer.
- Case studies with similar themes and, where possible, similar discharge chemistry.

1 Introduction

The definition of regulatory process impediments, which refer to other aspects such as monitoring programme implementation and contingency plans, is based on regulatory guidelines and case studies.

2

Residual Saline Stream Characteristics

2.1 Residual Saline Stream Chemistry

The water supply option involves the Birdrong Aquifer as a source, with RO treatment of the saline groundwater prior to distribution. The RO treatment would produce a RSS by-product (Table 2-1). RSS is a concentrate stream that contains a Total Dissolved Solids (TDS) concentration lower than 36,000 milligrams per litre (mg/L) (Kimes, J.K.,1995). Critical RSS parameters are considered to be TDS, temperature, and specific weight (density). The RSS may also contain low amounts of chemicals used during pre-treatment and post-treatment processes.

The constant discharge rate is estimated to be 1.6 ML/day over 80 years with a salinity of 34,685 mg/L. The volume of salt that would be discharged into the environment throughout the life of the Project is estimated to be 16,205,000 tonnes.

RSS quality data are derived for two different process options based on preliminary process selections using an incomplete suite of source water quality data. The RSSs are referred as:

- RSS3 for the “poorer” RSS. A minimal treatment approach where the majority of chemistry parameters from the Birdrong Aquifer remain in the RSS. RSS3 includes iron and radionuclide-rich solutes in the RSS (Blight N., 2012). Radionuclide and iron concentrations could be reduced by specific treatments.
- RSS4 for the “better” RSS. A robust water treatment approach where the majority of potential chemistry parameters are removed prior to the RSS being discharged (Blight N., 2012).

Potential RSS indicators that would be imposed on the local environment include chemicals, soluble metals and radionuclide concentrations. The volume of RSS discharge is the same for both treatment options (1.6 ML/day). Table 2-1 gives the chemical signature of the groundwater and RSS.

2.2 Potential Residual Saline Stream Indicators

The RSS would be characterised by specific signatures which would form indicators of potential changes to the baseline environments. These potential indicators include:

- Presence of chemical constituents.
- Soluble metals concentrations.
- Gross beta emissions.
- Concentrations of strontium.

These aspects are discussed below.

The RSS indicator concentrations would tend to increase along the flow paths on Quick Mud Creek, as residence times on the creek bed increase and evaporation forces provide cumulative influences. This aspect has not been assessed. That is, the magnitude of the potential changes in concentration of these indicators has not been predicted. Intuitively an order of magnitude change may not be unrealistic.

2.2.1 Chemicals

Chemicals are used in pre-treatment, post-treatment and membrane cleaning. The chemicals are chlorine, scale inhibitors and acids, for which there are uncertainties regarding their concentrations and potential environmental impacts (Svenson M. 2005). In this study chemicals used in the pre and post treatment processes have been included in the RSS chemistry estimates; however chemicals associated with the membranes have been excluded.

2 Residual Saline Stream Characteristics

2.2.2 Metals

Only soluble iron is included in the assessment with a concentration varying from 0.5 to 3.7 mg/L for B4 and B3, respectively. Other metals are likely to be present in noticeable concentrations in the Birdrong Aquifer, including arsenic, cadmium, chromium, copper, lead, nickel, zinc and mercury. Further water quality analysis should be undertaken in the Birdrong Aquifer in order to determine the concentrations for the metals in the supply water and hence in the RSS.

2.2.3 Gross Beta

Beta particles are a radiation emitted by radioactive materials including radium-228, strontium-90 and cesium-137. Beta particle radiation can cause both acute and chronic health effects. Chronic health effects result from low-level exposure over a long period (approximately 5 to 30 years). The main chronic health effect from radiation is cancer (State Water Resources Control Board 2008). Threshold values are defined in the USA (see Chapter 4, Table 4-2) for public drinking water.

2.2.4 Strontium

Strontium has moderate mobility in soils and sediments and sorbs moderately to metal oxides and to the surface of clays and other minerals (Watts P. & Howe P., 2006). Naturally produced strontium is not radioactive and exists in four stable isotopic forms. The average concentration of strontium in seawater is approximately 8 mg/L. Strontium is present in nearly all fresh surface water across USA; average concentrations are between 0.3 and 1.5 mg/L. The average occurrence in soil worldwide is approximately 240 mg/kg. Average concentrations in drinking-water in Germany and the USA are reported to be about 0.34 mg/L and 1.1 mg/L. Exposure to low concentrations of stable strontium has not been shown to affect adult health. The only stable strontium compound that may cause cancer is strontium chromate, but this is due to chromium not strontium. The USA Environmental Protection Agency (EPA) has set a limit of 4 mg/L of drinking water (ATSDR, 2004).

2 Residual Saline Stream Characteristics

Table 2-1 Residual Saline Stream and Groundwater Quality Data

Chemistry Parameter	Concentration (mg/L, unless otherwise specified)			
	RSS3[1]	RSS4[1]	Superficial Aquifer[2]	Trealla Limestone[3]
TDS	34,685	34,578	93,100	259,000
Total Alkalinity	584	562	143	126
Calcium	1,167	116	1670	1320
Magnesium	493	58	2,610	7,790
Sodium	11,093	11,093	19,800	46,000
Potassium	472	548	647	1700
Aluminium	0.02	0.02	-	-
Manganese	0.42[3]	0.39	-	-
Iron	3.7[4]	0.52	-	-
Silicon	54	5.8	-	-
Fluoride	2.41	2.41	-	-
Ammonia	1.86	1.71	-	-
Chloride	20,359	20,359	40,800	114,000
Nitrite	0.02	0.02	-	-
Nitrate	0.05	0.05	-	-
Reactive Phosphorus	0.02	0.02	-	-
Radionuclides Gross Beta (mBq/L)	14,750[5]	<1	-	-
Strontium	18	1.8	-	-
Barium	5.5	0.55	-	-

Notes:

1 RSS3 and RSS4 based on preliminary process designs.

2 Laboratory results from monitoring bore E052FG-S sampled by URS on 31 October 2009 (URS 2012b).

3 Laboratory results from monitoring bore E052FG-D sampled by URS on 30 October 2009 (URS 2012b).

4 Iron - 0.52 mg/L if the filter backwash is separated.

5 Radionuclides Gross Beta - 7,375 mBq/L if filter backwash is separated.

2.3 Predicted Residual Saline Stream Disposal Footprints

Modelling has been completed in order to predict the footprint of the disposed RSS for the options of discharge to ephemeral creek, injection into Trealla Limestone and infiltration basin (URS, 2012a). Conclusions of the modelling are described as follows:

- Discharge to ephemeral creek strategy. The discharge point is located within the Terrestrial Assessment Area (TAA) around the floodway on Wheatstone Road. MIKE 21 HD simulations provided predictions of the surface water footprint within Quick Mud Creek. These predictions assumed an absence of storage and through-flow within the water table aquifer; the water balance was driven by potential evaporation losses of 2.88 mm/day. The predicted RSS footprint from disposal of 1,334 kL/day extended 5,100 m downstream of the assumed outlet on Quick Mud Creek. Overall wetted area is about 40 ha. The bed creek was assumed dry in the hydraulic model. Seasonal groundwater discharge, however, occurs in pools that form within the major depressions along Quick Mud Creek (URS, pers. obs.). These pools should be incorporated later on in the hydraulic model to be conservative. Also the evaporation rate is not constant throughout the year and may be refined to average monthly rates in the in the model to reflect seasonal changes.
- The Trealla Limestone was modelled using a transmissivity of 50 m^2/day based on limited available data in the Project area. The injected RSS would mound the water table beneath the sand dunes and displace the local groundwater in storage above the Trealla Limestone. The footprint of the injection impacts ranged up to 2,700 m from the sources for a flow rate of 1,334 kL/day. Overall mounding area is about 2,780 ha. The predicted mounding intersected the ground surface within the local ephemeral creeks, including Quick Mud Creek, and on the perimeters of the sand dunes. The predicted mounding did not propagate to or impact the top of the high dunes. These areas were therefore excluded from the footprint. Therefore, the effective mounding area is about 2,560 ha.
- Infiltration basin simulations indicate that the available storage above the baseline water table is rapidly saturated, with subsequently mounding of the water table and lateral propagation of the infiltrates over a radial distances up to 2,400 m for a flow rate of 1,334 kL/day. Overall mounding area is about 1,730 hectares. Similarly, the high dunes were also excluded from the infiltration basin this footprint, reducing the effective mounding area is about 1,533 ha.

Figure 2-1 summarises the maximum footprints for all three strategies.

3

Information on Impediments to Inland Disposal

3.1 Potential Changes to Baseline Environment

Baseline studies for the Wheatstone Project have been reviewed to ascertain the existing environment for flora and fauna. The Project area, including local reaches of Quick Mud Creek, similarly occur in the Ashburton River Delta were recognised to host compatible vegetation and fauna assemblages as the Wheatstone Project area. Therefore, the results of these baseline studies have been used to give an indication of the baseline conditions within the RSS disposal areas. Site specific studies for the RO plant will be required to confirm the assumed assemblages.

For the surface water and groundwater baseline, site specific work has been undertaken (URS 2012a).

3.1.1 Surface Water

The surface water baseline has been determined in section 8.1.1 of the report *Onslow Water Infrastructure Upgrade Project – Alternative Assessment of Brine Disposal* (URS 2012a). Quick Mud Creek stretches between Wheatstone Road and the crystalliser ponds of Onslow Salt Pty Ltd. It is approximately 5.5 km long with a wide low-flow channel of 70 to 80 m. The creek bed would act as a natural evaporation pond for any RSS discharged to it.

The main characteristics of Quick Mud Creek are:

- The creek is ephemeral and collects runoff from local upstream catchments and/or breakout flows during severe flood from the right bank of the Ashburton River.
- The frequency of floods within Quick Mud Creek is not accurately established in the absence of long-term monitoring data. The floods within Quick Mud Creek originate from cyclone events and localised storms. URS has installed three flow gauges along the Quick Mud Creek and the current dataset shows occurrence of at least one minor flood event a year. Further monitoring is required to fully ascertain the flood frequency. A flush effect (inundation with fresh water) is noted to occur only during major flow events. When major flood events occur in the Project area, the floodway referred to as Floodway 1 on Onslow Road, upstream of Quick Mud Creek, is inundated (Figure 1-1). Main Roads Western Australia possesses a database recording the road closure caused by rainfall events or cyclones (URS 2010b). The database shows seven road closures on floodways along Onslow Road from 2000 to 2009. Floodway 1 seems to have been inundated at least three times over this nine year period. This provides confidence that there is a high potential for Quick Mud Creek to experience a flush effect.
- Quick Mud Creek is not located within the typical tidal embayment, but rare storm surges do inundate the lower and upper reaches of the watercourse.
- The geomorphology of Quick Mud Creek would be acceptable for RSS discharge; this acceptance is enhanced by the common occurrence after rainfall of a few shallow pools within the watercourse downstream of Wheatstone Road. These pools would act to:
  - Store the RSS over a relatively short path. A 2D hydraulic model showed a plume extending about 5 km downstream of Wheatstone Road for a flow rate for 1,334 kL/day (URS, 2012a).
  - Increase the evaporation rate due to shallow water depths varying from 0.1 to 0.6 m.
  - Increase the evaporation rate due to low flow velocities based on the flat slope of Quick Mud Creek (based on LiDAR data supplied by Chevron in 2009).

3 Information on Impediments to Inland Disposal

- Quick Mud Creek water quality is subject to significant variation depending on the climatic events and transient flow conditions, from a hypersaline to a fresh water environment. The likely water quality characteristics are:
  - The creek flows after significant rainfall events. It is likely that fresh water pools are formed during and for the short-term after these events. Thereafter, the pools accumulate salt to become brackish, saline and hypersaline as they progressively evaporate. A TDS concentration of 82,300 mg/L was reported from pools on the creek in April 2011 (URS, 2012a). Salt crusts have also been visible on the bed of the channel (URS personal observations, November 2012).
  - The sediment is composed of siltstones, sand and clay and may contain high concentrations of salts and metals (this assumption would need to be verified by sampling).
  - The creek is a groundwater discharge area at least temporarily after significant rainfall events.

For this report, Quick Mud Creek was assumed to predominantly form a dry, saline and hypersaline environment. The occurrence of fresh low-salinity water was linked to sporadic and episodic rainfall events and associated stream flows. It is possible that temporary freshwater pools in Quick Mud Creek may create temporary niches for fauna. Numerous freshwater pools are visible in the Project area after rainfall events, and this provision might reduce the importance of the pools in Quick Mud Creek.

Two shallow aquifers occur within the Ashburton River Delta setting:

- The unconfined aquifer within the superficial formations of Ashburton River Delta Alluvium; composed of poorly consolidated claystone and minor limestone. The thickness of the superficial formations is approximately 25 m. The measured groundwater salinity varies from 50,000 to 160,000 mg/L TDS. Measured copper concentrations exceed the ANZECC Guidelines for freshwater and marine ecosystems.
- The confined aquifer within the Trealla Limestone is located between the 25 to 60 m below ground level. The measured salinity varies from 156,000 to 220,000 mg/L TDS. Metals such as cadmium, chromium, copper, lead are present in the aquifer at concentrations that exceed the ANZECC Guidelines for freshwater and marine ecosystems detectable concentrations (URS 2012a).

The baseline water table typically occurs at shallow depths of a few metres. On the fringes of sand dunes and beneath low-elevations settings such as Quick Mud Creek, the depths to the water table may be less than 1.0 m. Predictive modelling (URS 2012a) showed that the shallow aquifers provide limited potential for RSS storage. The injection of RSSs was predicted to give rise to mounding of the water table; in local settings the predicted water table mounding expressed on the ground surface.

3.1.2 Flora and Vegetation

A vegetation and flora survey was undertaken by Biota in 2010. This survey included vegetation mapping, though not including the lower reaches of Quick Mud Creek and the entirety of the area to be impacted by the groundwater mounding from injection. The survey indicated the following vegetation sub-associations may be affected by the Project, as shown in Figure 3-1

- Areas of coastal mudflat (tidal creeks; this is a general description, and it should be noted that Quick Mud Creek is not tidal), which feature only very scattered shrubs, mainly of *samphires*

(*Tecticornia spp.*). Unit was found to be of excellent condition, considered of low conservation status (Biota sub association code *mf*).

- Inland sand plains supported *Triodia lanigera* (*hummock grasslands*) with a variable shrub cover dominated by *wattles* (*Acacia spp.*; very good to good condition). Considered of high conservation significance (Biota sub association code *Atete*).
- Clayey plains along the Onslow Road supported *Acacia xiphophylla* (*Snakewood*) tall shrublands (considered of moderate significant) over various *spinifex* species (very good condition; considered of moderate conservation significance) (Biota sub association code *SPmERibEUa*).
  Coastal sand plains supported a general cover of Triodia epactia hummock grasslands with scattered shrubs, mainly *Acacia tetragonophylla* (Kurara), **Prosopis pallida* (*Mesquite*) and **Vachellia farnesiana* (*Mimosa Bush*); these areas were variably invaded by **Cenchrus ciliaris* (*Buffel Grass*). Small areas of outcropping calcrete supported characteristic shrubs, including *Scaevola pulchella* and *Indigofera monophylla* (very good to excellent condition), considered of low conservation significance (Biota unit code *Atete*).

The following vegetation sub-association has been identified in the vicinity:

- The red sand dunes occurring further inland supported tall open shrublands dominated by *Grevillea stenobotrya*, *Crotalaria cunninghamii* (*Green Birdflower*) and *Trichodesma zeylanicum var. grandiflorum* (Camel Bush) over *Triodia epactia* and/or *T. schinzii*; shrublands of *Acacia stellaticeps* over *Triodia epactia* occurred in the dune swales (Biota unit code GsCRcTRzTe). Considered of high conservation significance.

It was considered unlikely that the vegetation sub-associations on the crests and upper-elevation portions of the sand dunes would be impacted by the predicted water table mounding.

3.1.2.1 Groundwater Dependent Communities

None of the vegetation associations encountered in the Wheatstone Project area were identified as being entirely groundwater dependent. The Biota report (2010) states that: *'Of the vegetation sub-associations identified for the Wheatstone study area, none are likely to comprise ecosystems dependent entirely on groundwater.'*

3.1.2.2 EPBC Listed Flora

Biota (2010) indicated only one species listed as 'Vulnerable' under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* had been recorded in the vicinity. This location was remote from the Project area and will not be impacted.

A search of the EPBC Protected Matters Tool (Appendix B) did not indicate any listed threatened ecological communities in the Project area.

3.1.2.3 Declared Rare Flora

A declared rare flora search was reported by Biota (2010). This stated that of the three potential DRF species occurring in the Pilbara, none are likely to occur in vegetation assemblages encountered in this Project area.

3.1.2.4 Priority Flora

A targeted flora study was undertaken (URS, 2011) to identify potential species of priority flora. This report indicated a number of occurrences of *Triumfetta echinata*, a Priority 3 listed flora species, close

to the Project area. It was considered likely that the *Triumfetta echinata* would occur within the footprint of groundwater mounding should RSS be injected or infiltrated. It was also recognised, however, that *Triumfetta echinata* are typically restricted to the higher elevation dune habitats. These habitats were considered unlikely to be impacted by the predicted water table mounding.

It was considered unlikely that priority flora would exist within Quick Mud Creek, but actual occurrence or not in riparian perimeter areas would be dependent on the findings of baseline surveys.

3.1.3 Fauna

3.1.3.1 Troglofauna and Stygofauna

A subterranean fauna assessment was undertaken (Biota, 2010), with the following conclusions:

"No troglofauna have been recorded from the study area during the three phases of field sampling documented in this report. This result is consistent with the nature of the subterranean habitats present in the study area and there appears to be a low likelihood that troglofauna occur in the study area or the immediate surrounds.

Stygofauna have been confirmed as occurring in the study area, but only at low frequency and from just two spatial locations. Two taxa have been collected (the copepod Phyllopodopsyllus thiebaudi and the oligochaete Enchytraeidae sp. 1). Based on confirmed distributional data, there is no risk that P. thiebaudi is restricted to the study area. Given the ecology and distributional patterns of stygal oligochaetes in similar habitats elsewhere in the region (for Enchytraeidae sp. 1), it is unlikely that this taxon is restricted to the study area.

The survey results therefore do not suggest a diverse or significant stygal community occurs in the aquifers beneath the study area. The results from field sampling in the Plant part of the study area, and the similarity of the habitats, suggest there is no requirement for sampling in the SIC and Camp areas. Both the fauna recorded during field surveys, and the nature of the subterranean habitats, suggest a low level of risk that any stygal species would be restricted to the study area."

Based on the survey results it is considered a low likelihood that troglofauna exists in the vicinity of Quick Mud Creek.

It is possible that the groundwater mounding and change in groundwater chemistry may alter potential stygofauna habitats. It was recognised, however, that Quick Mud Creek would form an unlikely habitat given its low elevation, substrate and occurrence of hypersaline groundwater.

3.1.3.2 Potential Short Range Endemic Fauna

Biota (2009) indicated the following conclusions on potential short range endemic fauna (SREs) in the area:

'Despite thorough searching of suitable habitat for invertebrate groups considered to support SRE taxa, no SRE invertebrate fauna were identified within the Project area'.

3 Information on Impediments to Inland Disposal

Further:

'No confirmed Short Range Endemic (SRE) taxa were collected during the Biota (2010b) survey of the overall Wheatstone study area, despite systematic sampling and targeted searches. The only fauna belonging to potential SRE groups collected were two pseudoscorpion taxa, which proved to be known morphotypes with wider regional distributions (Biota 2010b).'

Therefore, it was considered unlikely that the proposed disposal of RSS would impact SREs. A baseline survey of Quick Mud Creek would be required, however, to confirm the presence or absence of SREs.

3.1.3.3 Threatened Fauna

EPBC Listed Fauna

A search of the SEWPaC Protected Matters Tool was undertaken (Appendix B) which indicated the presence of two listed threatened species, the mulgara and northern quoll.

For the mulgara, the Biota (2010) concluded: *The Brush-tailed Mulgara may potentially occur within the Wheatstone study area based on its broader distribution, thought it has never been recorded during previous surveys in the locality"*

For the northern Quoll, the Biota (2010) stated: *This species was also not considered further as none of the core Land Systems in which it occurs in the bioregion are present in the study area (Biota 2009d), and it has never been recorded in previous surveys in the locality."*

DEC Listed Fauna

The DEC maintains a list of fauna which it considered to be rare or threatened, and protected under the Wildlife Conservation Act 1950. With regards to DEC listed fauna, the Biota report (2010) stated:

"The available data indicate a low likelihood of threatened fauna occurring in the Wheatstone area, and a limited listing of Priority fauna."

Therefore, it is considered that the Project will not affect any Threatened Fauna.

3.1.3.4 Clay-Pan/Ephemeral Fauna

A clay-pan ephemeral fauna survey undertaken for the Wheatstone Area, concluded:

"Similarity analysis of the site assemblage data indicate that, sampling effects aside, the Study Area sites contain effectively equivalent suites of invertebrate fauna to those represented in reference sites in the immediate locality. This pattern of equivalent suites of species in similar units appears consistent with landscape-scale processes that occur in the area during flood events. Evidence from Cyclone Dominic and the nature of the topography suggest that under major flood events the aquatic habitats of many of the clay-pans become interconnected through surface flooding.

This presents a scenario of relatively reduced risk of species isolation to individual clay-pans at this local scale, which is consistent with the outcome of the community similarity analysis, the distribution of individual species recorded from Study Area sites, and the findings of this survey in general."

A number of clay-pans are located in the vicinity of the Project which may be impacted by the predicted groundwater mounding. There may be ephemeral fauna present in Quick Mud Creek.

It was considered that the Quick Mud Creek did not conform to the typical ephemeral clay-pan setting and therefore unlikely to form a predominant host for clay-pan/ephemeral fauna. Of note, however, is that a number of clay-pan fauna sites have been identified within the predicted water table mounding footprint for Option 3 and Option 4. Therefore, it would be preferable to acknowledge that clay-pan/ephemeral fauna may exist in the creek until baseline surveys provide definitive data.

3.1.3.5 Migratory Species

Biota described three EPBC Act listed migratory species as observed within the Wheatstone Project area and surrounds, and the EPBC Act database indicated a further ten migratory species may frequent the area. Relevant to the project area, these include:

- Rainbow Bee-eater (*Merops ornatus*).
- Fork-tailed swift (*Apus pacificus*).
- White-bellied Sea Eagle (*haliaeetus leucogaster*).

Biota did not find that these species are dependant or associated with the terrestrial habitats of the area. Therefore, it was considered unlikely that the Project would have impacts on migratory species.

3.1.3.6 Conservation and Natural Heritage Areas

A database search on the DEC website did not indicate any conservation or natural heritage areas.

3.2 Changes Linked to Discharge to Quick Mud Creek

3.2.1 Surface Water

Option 1 and Option 2 may have a number of potential impacts with regards to surface water:

- **Change of hydrology regime** leading to permanent presence of water and pools in the low flow channel.
- **Change of geomorphology** leading to increase of bed sedimentation.
- **Change in water/sediment quality** leading to increased salinization and potential bioaccumulation of metals and radionuclides.

Salt accumulation and deposition is expected to occur over periods of dry conditions. The rate of salt deposition was estimated as 0.03 m per annum (URS 2012a); this was considered to be a minimal rate. Fresh water flooding through Quick Mud Creek was expected to dissolve the salt crust and ultimately the accumulated salt would be transported to the ocean.

3.2.2 Groundwater

Option 1 and Option 2 may have a number of potential impacts with regards to groundwater:

- **Change in groundwater levels** leading water table mounding beneath the watercourse.
- **Change in aquifer hydraulic parameters** potentially influencing the transient RSS footprint.
- **Change in groundwater quality** with increased salinization, metals and radionuclide accumulation.

3.2.3 Flora and Vegetation

Option 1 and Option 2 were interpreted to provide a limited interface, if any with flora and vegetation. The Quick Mud Creek watercourse was observed to be a barren expanse.

3.2.4 Fauna

The disposal of RSS by discharge into Quick Mud Creek is likely to have the following impact:

- Changes to the water and soil chemistry, may have impacts on clay-pan/ephemeral fauna. By converting the lower reaches of Quick Mud Creek into a permanent watercourse, the RSS would increase the available water and influence its transient quality compared to baseline. Seasonal and or episodic flushing during periods of rainfall generated stream flow would tend to temporarily remove or dilute the signatures of the RSS.

3.3 Changes Linked to Injection into Trealla Limestone

3.3.1 Groundwater

Option 3 may have a number of potential impacts with regards to groundwater:

- **Change in groundwater levels** leading water table mounding over an extensive area (2,780 ha).
- **Change in aquifer hydraulic parameters** potentially influencing the transient RSS footprint.
- **Change in groundwater quality** with increased salinization, metals and radionuclide accumulation.

3.3.2 Surface Water

Option 3 may be limited on potential impacts with regards to surface water:

- Change in flow regime is considered as limited. The mounding of groundwater reaching the ground surface is evaporated and not converted into flow.

3.3.3 Flora and Vegetation

- **Changes to the hydrological regime** through groundwater mounding. This has the potential to waterlog root systems changing the environment for flora and vegetation and, may either degrade or kill vegetation units.
- **Changes to the water/soil chemistry** from the RSS discharge. This has the potential to impact flora through root uptake and subsequent bioaccumulation.
- **Clearing of vegetation** for the construction of injection equipment.

The predicted footprint from water table mounding covered significant areas. In order to estimate the associated potential impact to flora and vegetation it was assumed that the water table mounding would not impose on the dune crests and surrounds of comparatively high elevation. It was considered likely, therefore, that the groundwater mounding would impact 2,560 ha of vegetation. In general terms, the impacts would be predominant in areas of groundwater discharge, thus within the ephemeral creeks, intra-dune swales and on breaks in the slopes between the sand dunes and riparian zones. These impact areas may be significantly less than the predicted footprint of 2,560 ha.

3.4 Changes Linked to Discharge to Infiltration Basin

3.4.1 Groundwater

Option 4 may have a number of potential impacts with regards to groundwater:

- **Change in groundwater levels** leading water table mounding over an extensive area (1,533 ha).
- **Change in aquifer hydraulic parameters** potentially influencing the transient RSS footprint.
- **Change in groundwater quality** with increased salinization, metals and radionuclide accumulation.

3.4.2 Surface Water

Option 4 may be very limited of potential impacts with regards to surface water:

- Change in flow regime is considered as limited. The mounding of groundwater reaching the ground surface is likely to be evaporated and not converted into flow.

3.4.3 Flora and Vegetation

- **Changes to the hydrological regime** through groundwater mounding. This has the potential to waterlog root systems changing the environment for flora and vegetation and, may either degrade or kill vegetation units.
- **Changes to the water/soil chemistry** from the RSS discharge. This has the potential to impact flora through root uptake and subsequent bioaccumulation.
- **Clearing of vegetation** for the construction of the pipeline and outfall.

The predicted footprint from water table mounding covered significant areas. In order to estimate the associated potential impact to flora and vegetation it was assumed that the water table mounding would not impose on the dune crests and surrounds of comparatively high elevation. It was considered likely, therefore, that the groundwater mounding would impact 1,533 ha of vegetation. In general terms, the impacts would be predominant in areas of groundwater discharge, thus within the ephemeral creeks, intra-dune swales and on breaks in the slopes between the sand dunes and riparian zones. These impact areas may be significantly less than the predicted footprint of 1,533 ha.

3.5 Regulatory Legislation and Guidelines

There are a number of key pieces of environmental legislation and guidelines surrounding the disposal of saline water and brines to the environment, as shown in Appendix A.

4

Case Studies

The following is discussion on case studies considered relevant to the saline and or brine disposal. Where possible case studies have been identified in Australia, however, it was found that the Project area is unique and consequently, case studies were source from other countries. The case studies either consider similar issues to the Project, or release to similar environments.

A summary of the selected case studies is provided in Table 4-1 together with the analogous aspects to the Project.

Table 4-1 Summary of Case Studies and Analogies to the Project

Case Study	Setting	Analogous Aspects
Discharge to Surface Waters		
Guidelines for discharge to salt lakes/playas	Goldfields, WA	Disposal of saline and hypersaline groundwater to playas.
White Flag Lake	Kuduna Gold Mine, WA	
Discharge to Lake Lefroy	St Ives Gold Mine, WA	
Bitterns disposal to Middle Creek tidal embayment	Onslow Salt, Ashburton River Delta, WA	Disposal of bitterns to a marine setting downstream of the Project area.
Regulations for discharge to surface water in the USA	USA Mainland	48 per cent of desalination facilities in the USA dispose of brines to surface water environments.
Injection into Deep Aquifers		
Injection of brines into confined aquifers	Florida, USA	Use of injection to dispose of brines, though the settings lack compatibility with the Project area.
Injection of saline groundwater into confined aquifers to limit environmental impacts	Christmas Creek Mine, WA	
Guidelines for injection of brines from coal seam gas	DERM	
Infiltration Basins		
Infiltration of brines within Tamala Limestone	Water Corporation, Denham, WA	Use of infiltration to disposal of brines
Infiltration of bitters in a sealing basin and associated channel	Shark Bay Salt Joint Venture, Useless Loop, WA	

4 Case Studies

4.1 Discharge to Surface Water

4.1.1 Guidelines for Discharges to Salt Lakes in the Goldfields

Sixteen lakes are or have been used to dispose saline groundwater from mining projects in the Goldfields. The DoW has designed a framework for the consideration of the cumulative impacts of groundwater disposal to salt lakes in the Goldfields of Western Australia (Outback Ecology Services, 2009). The purpose of the framework was to present risk matrices for the disposal of saline and hypersaline groundwater to salt lakes or playas.

The degree of similarity between the disposal of saline groundwater to playas and Option 1 and Option 2 is high. The context is to discharge saline water to saline water bodies with irregular and or episodic fresh water flooding events. The major difference is the high level of endemism of aquatic fauna in the salt lakes (Halse 2001; Hebert *et al*., 2000 & Remegio *et al*., 2001).

Salt lakes are considered as wetlands. The following physical descriptors were fundamental mechanisms of a wetland (Department of Environmental Protection, 1998):

- Hydro-period.
- Salt load.
- Salt concentration.
- Ionic composition.
- pH.
- Pollutants.
- Nutrients.
- Sediment.

Groundwater discharge sites generally contain higher concentrations of salts, nutrients and certain metals in both water and sediments compared to natural lakes.

It was concluded that if the above characteristics of a wetland were not significantly changed by groundwater discharge then the biological processes and existing uses of the wetlands would also be protected (Coleman M., 2003).

4.1.1.1 Key Issues

Key issues associated with groundwater discharge to salt lakes were found to be:

- Aquatic biota including algae, invertebrates and water birds can be affected by groundwater discharge (Timms, 2005). This is relevant to Option 1 and Option 2.
- Biodiversity tends to be lower at groundwater discharge sites (Outback Ecology, 2008a). This aspect was attributed to unfavourable conditions such as high flow rates, erosion and extreme salinity. In addition a salt crust can form in the immediate vicinity of the discharge outfall as a result of the evaporation of discharge groundwater. Thick salt crusts in conjunction with excessive salinity concentrations may prevent or limit the natural occurrence of breeding cycles triggered by fresh water inundation (Campagna 2007; Timms 2005).

4 Case Studies

4.1.1.2 Risk Management Approach

Three matrices were proposed by an ecological consultancy commissioned by DoW in order to determine the level of acceptance of the discharge (Outback Ecology Services, 2009):

1. A matrix which indicates cumulative percentage of lake impacted, including:
   - Lake size score.
   - Unique physical score conditions.
   - Unique biological score conditions.
   - Water regime score.
   - Water/bed quality.
   - Biota.
2. A matrix which determines the characteristics of the dewatering discharge and site location, including (Outback Ecology Services, 2009):
   - Cumulative discharge volume in ML/year.
   - Proximity to other discharges.
   - Salinity of discharge in mg/L.
   - Concentrations of metals.
   - Discharge site (open playa, creek-line opening, and embayment).
3. A matrix which calculates the risk, from low risk to high risk, of the dewatering discharge operations to the particular salt lake.

The key point of this framework document (Outback Ecology Services, 2009) was that the groundwater discharge was assessed against the baseline characteristics.

4.1.2 Kuduna Gold Mine – Groundwater Discharge to White Flag Lake

Kuduna Gold Mine is located 25 km northwest of Kalgoorlie and included open pit and underground developments for which dewatering is required. The abstracted groundwater is hypersaline and discharged to the saline White Flag Lake. Key project information has been obtained from the DEC Works Licence Approval dated January 2011.

4.1.2.1 Relevant Regulatory Controls

The groundwater discharge is controlled through the following:

- **Part IV Environmental Protection Act 1986, Environmental Impact.** An amendment to the mine dewatering discharge to White Flag Lake was referred to the EPA. On consideration the EPA did not formally asses the project but expected the developers and relevant agencies to ensure that outcomes would be environmentally acceptable.
- **Part V Environmental Project Act 1986, Environmental Management:** The site was assessed under prescribed premises under Category 06: Mine Dewatering, a premise on which groundwater was abstracted and discharged into the environmental to allow mining of ore. This action required a discharge licence, for which the DEC provided approval for 12,000,000 m^3 to be disposed per annum to White Flag Lake.

4 Case Studies

4.1.2.2 Key Issues

The DEC has identified a number of key issues around discharging hypersaline groundwater, as described below.

- **Prevention of erosion at the discharge point.** High velocity discharge will encourage entrainment of sediment and erosion of the lakebed. With the application of suitable engineering controls, however, the risk is considered minimal, and monitoring is considered an appropriate regulatory requirement.
- **Ensuring fringing areas of the lake are not significantly affected by inundation or salt spray from hypersaline water discharge**. Increasing water availability and residence time in the lake has the potential to cause death of fringing vegetation. Vegetation may also be impacted via increase in salt-laden winds from hypersaline waters and via increased salt load inhibiting the germination of new- plants.
- **Increase in salt load, change in hydro-period and increase in salinity during episodic rainfall** events which may affect the breeding cycle of biota.

4.1.2.3 Management of Key Issues

- **Works Approval for construction of discharge point**. Discharge point was constructed under a DEC works approval that required Kuduna to '*construct the discharge spillway releasing mine dewater to White Flag Lake to ensure minimal erosion and scouring impacts and reduce the likelihood of ponding in White Flag Lake*'.
- **Monitoring Condition to ensure the spillway is functioning correctly.** Should adverse effects be identified then the licensee will be given the opportunity to implement a management approach to minimise adverse effects. A licence amendment would be incorporated should the licensee fail to manage adverse effects. The licence may be modified with particular reference to reducing or modifying discharge quantities or quality should an adverse effect continue.
- **Monitoring of White Flag Lake.** Flora and fauna monitoring is undertaken at White Flag Lake and the fringing environment and sediment chemistry. The licensee is required to report monitoring on an annual basis. Monitoring has not shown any adverse environmental impacts related directly to dewatering discharge to White Flag Lake over the 10 year monitoring period to date. The DEC has recommended using NWQMS (ANZ Guidelines 2000) trigger values for metals in discharge waters. However, the DEC acknowledges that guideline values should be set higher due to the temporary nature of water within ephemeral hypersaline waterways.

4.1.3 St. Ives Gold Mine – Lake Lefroy

The St. Ives Gold Mine is located on Lake Lefroy, south of Kalgoorlie. Lake Lefroy is an elongated playa which is dry for much of the year and, characterised with a thick halite salt crust and no freshwater phase. The riparian zone and playas and clay-pans that surround Lake Lefroy are considered important in terms of providing habitat for aquatic biota and supporting ecological function of the area. The reviewed document was the Report and Recommendations of the Environmental Protection Authority (2011) on expansion plans for the gold mining operations, including the diverting of groundwater from pit dewatering (30 GL per annum) to the playa.

4 Case Studies

4.1.3.1 Relevant Regulatory Controls

The outcomes of the EPA recommendations are that the proposed expansion plans and discharge would be acceptable, and should be approved with appropriate conditions. The project would be controlled through the following regulatory controls:

- **Part IV Environmental Protection Act 1986, Environmental Impact.** A level of assessment of PER was set for the project by the EPA. The project was given approval subject to conditions in 2000.
- **Wildlife Conservation Act 1950.** Licence to handle and remove native fauna from construction areas.
- **Part V of the Environmental Protection Act 1986.** Various Works Approvals and an operating Licence are required for construction and operation of the St Ives Gold Mine. This includes a discharge licence.
- **Rights in Water and Irrigation Act 1914** – licence for abstraction (dewatering).

4.1.3.2 Key Issues

- **Inundation of the riparian zone and the playas and clays with hypersaline water as a result of dewatering discharge.** The area to be disturbed does not contain any Threatened Ecological Communities or Declared Rare Flora, and the EPA did not consider that the loss of the riparian vegetation from inundation would significantly impact on the ecological function of the lake. The area disturbed only represents a small portion of the total riparian zone of Lake Lefroy.
- **Increased disturbance of the lake bed** contributing to a high than natural rise in water levels in the lake during flooding following a large rainfall event.
- **Build-up of metals associated with the dewatering discharge.** The dewatering discharge will increase salinity and metal concentrations on the lake surface. The main area of impact would be to the surface of the playa where it was assumed that the metals would be immobilised in the sediment.

4.1.3.3 Management of Key Issues

The EPA has set the following conditions to manage potential impacts to the environment:

- **Development of a monitoring program**, particularly to monitor any impacts on the riparian zone of Lake Lefroy and the playas and clay pans that are adjacent to the lake.
- **Monitoring the area of inundation of the lake** following large rainfall events.
- **Using data collected during monitoring** to verify the predicted area of impact from the surface water model developed by the proponent.

The EPA concluded that: "*Given the limited aquatic biota on Lake Lefroy due to the hypersaline conditions, the availability of riparian zone and playa and clay pan habitat outside the modelled area of inundation and the proponent's proposed management actions, the EPA considers that the surface water discharge is unlikely to significantly impact on the biological diversity and ecological integrity of Lake Lefroy and its surrounds."*

4.1.4 Onslow Salt Bitterns Disposal

Onslow Salt Pty Ltd operates just 6 km downstream of the Project area. For Works Approval, Onslow Salt submitted a proposal to EPA in 1995. One of the activities assessed by the EPA was the

discharge of bitterns through a channel. The activity was referred as 'Condition 14' Onslow Salt Pty Ltd (1995) and described as following: *Discharge of bitterns into Middle Creek shall occur only on outgoing tides, or into the ocean via an appropriate outfall channel, whichever is the most environmentally acceptable to the Environmental Protection Authority. Condition 14 requires Onslow Salt to limit the discharge of bitterns (a dense, highly saline fluid) into Middle Creek to outgoing tides only. The rationale behind this condition was to limit the opportunity for bitterns to be discharged into the root zone of the mangroves, which would create a severe risk to their health. It is accepted that there would be some loss of bottom dwelling animal from the tidal creek because bittern can be lethal to some animals. Onslow Salt proposed to discharge bitterns via a channel, which has a base below the root zone of the mangroves, at half-tide or higher into Middle Creek. The volume of bitterns to be discharged was estimated in 1991 to be 7,000 kL/day*.

The EPA considered a case study in Western Australia to assess the potential impacts of the bitterns. This case study was the Cargill Salt bitterns discharge monitoring programme at Port Hedland. The key points from the associated technical reports were:

- **Bitterns can be lethal to juvenile fish and prawns.**
- **Bitterns can result in lower abundance and diversity of benthic animals** in the tidal creeks.
- **Bitterns can be lethal to mangroves** if prolonged contact occurs.
- With high density, most of the bitterns remain as a concentrated stream in the deepest parts of the discharge channel and creeks for distances of about 2 km and for periods of at least one lunar tidal cycle.

The discharge of bitterns by Onslow Salt Pty Ltd was approved by EPA and is still active in 2012.

4.1.5 Regulation in the USA

In 2009, approximately 48 per cent of desalination facilities in the USA disposed of their brines to surface waters (Hoepner and Lattemann, 2002) including discharge to perennial creeks and within the tidal influence zone. Other disposal options include deep well injection, land application and evaporation ponds. The discharge water RSS3 and RSS4 would not be considered as 'brine' in the USA legislation as the TDS is below 36,000 mg/L.

The USA legislation discharge to surface waters is framed on demonstration of acceptable brine chemistry (such as pH, Total Suspended Solids, TDS and different individual chemical concentrations such as for metals and NORM). The concentration limits are assessed based upon the nature, use of receiving water body, toxicity to human and aquatic toxicity. Also required is an effluent toxicity test (WET test) where different organisms common to the receiving environment are exposed to the brine during a time period and demonstrate survival. WET tests undertaken for a project in Florida failed due to excessive calcium and fluoride levels (Mickley, 2001).

The main impediments with the surface water disposal are:

- Contaminants present in raw water.
- Imbalance in essential ions.
- Low dissolved oxygen, high H_2S, etc.
- Toxicity of additives.
- Low pH (due to acid addition).
- Different salinity than receiving water.

4 Case Studies

4.2 Injection into Deep Aquifers

4.2.1 Experiences in Florida, USA

In Florida there are at least 70 deep injection well systems (Kimes J.K., 1995); although regulations prohibit well injections to groundwater which can be used as drinking water. Permissions to use deep well injections have been found to require the monitoring of well integrity and water quality in nearby monitoring wells. The TDS of injected brines is about 36,000 mg/L which is similar to the B3 and B4 brines.

The majority of injection wells are isolated from the overlying aquifer by an aquitard, reflecting the main concern with deep well injection being the contamination of overlying drinking water aquifers due to well leakage. This would not be the case for the Project where the Trealla Limestone is not isolated from the water table by an aquitard; the groundwater quality is also poor and unsuited for beneficial use.

4.2.2 Christmas Creek Water Management Scheme Environmental Review

The Christmas Creek Mine is located in the Pilbara region of Western Australia, approximately 111 km north of Newman. The Christmas Creek Water Management Scheme involves the injection of abstracted groundwater (both saline and brackish) to limit potential impacts on the Fortescue Marsh. The Environmental Review and Management Plan (ERMP) was submitted in May 2011, and was approved by the EPA in August 2011. Groundwater injection (up to 42.5 GL/annum) was expected to create significant mounding of the water table.

4.2.2.1 Relevant Regulatory Controls

- The proposal was referred and approved under Part IV of the “Environmental Protection Act 1986”.

4.2.2.2 Relevant Key Issues

- Contamination of groundwater quality due to mounding.
- Interference with natural surface water flow regimes.
- Direct clearing of vegetation for infrastructure.
- Indirect disturbance of vegetation caused by:
  - Groundwater mounding from injection.
  - Saline water from leaking pipeline.
- Loss of terrestrial fauna habitat and/or disruption of terrestrial fauna linkages from clearing activities or changes to surface water availability.
- Loss or disturbance of stygofauna or troglofauna habitat.
- Fauna entrapment or drowning and temporary interference with movement from trenching for the installation of pipelines or ponds.
- Increase in surface water ponding on migratory birds (in Fortescue Marsh).

4.2.2.3 Management of Key Issues

The EPA set a number of conditions in order to manage key issues, including:

- Complete a compliance assessment plan.
- Ensure that construction of the infrastructure and implementation does not cause the loss of Declared Rare Flora, Priority 1 Flora and Priority 2 Flora unless otherwise approved.
- Undertaken targeted surveys of the area proposed for water conveyance infrastructure.
- Ensure that groundwater mounding does not result in groundwater level rising within 2 metres of the surface. Undertake groundwater monitoring.
- Ensure that there is no mortality of keystone plant species or significant changes in habitat characteristics attributable to the project.
- Prepare a Vegetation Health Monitoring and Management Plan.

4.2.3 Department of Environment and Resources Management (DERM) Guidelines

The DERM (Queensland) has developed and published management strategies for brine from Coal Seam Gas water treatment in the Guideline for Preparing an Environmental Management Plan for Coal Seam Gas activities. This guideline provides a hierarchy for determining management options such as injection of brine. The injection of brine is the preferred strategy if:

- The single geological unit is not regionally consistent and extensive.
- The Formation is isolated above and below by an aquitard within the hydraulic impact zone.
- The aquifer does or could not supply water for potable, agricultural, industrial and commercial purposes.

4.3 Infiltration Basin

There are very few examples in Australia or around the world of brine or bittern discharge through infiltration basins and the associated recharge of the local aquifers.

4.3.1 Infiltration Ponds for Desalination Reject Water in Denham

An existing desalinisation plant in Denham (Rockwater, 2011) disposes its brine via an infiltration basin into the Tamala Limestone; with over flow onto the ground. The volume infiltrated is 170 kL/day which is significantly lower than the rate being considered by this study - 1,600 kL/day. The main concerns associated with this are:

- **Potential impact on local water table in term of quantity** without specifying the potential associated issues.
- **Potential impact on stygofauna.**

The impact of the proposed brine was considered very low with no significant increase of the local water table and no impact on stygofauna.

4.3.2 Construction Crystallizer Ponds, Useless Loop, Shark Bay

In 1999 the Shark Bay Salt Joint Venture proposed a project to construct additional crystalliser ponds in Shark Bay. The bittern disposal was proposed to be through infiltration.

Bitterns have been disposed of by either using sealed ponds or by discharge into the highly saline groundwater through the floor of an existing channel within the salt works. The EPA commented that this method is acceptable. A commitment from the proponent to monitor the change in water quality, especially within the nearby marine environment, was asked for by the EPA. The main concern was the **change in sea water quality in the Shark Bay Heritage Property** through direct discharge of infiltration through the ground. No mention is made about potential impact on the vegetation or fauna resulting from the sealing ponds.

4.4 Water Quality Guidelines

4.4.1 ANZECC

For the Wheatstone Project's environmental approval, potential impacts on groundwater quality were assessed based on baseline quality data and, water and salt balances (EIA/ERMP, 2010). The ANZECC guidelines (2000) were referenced for the surface water and groundwater quality assessments.

4.4.1.1 Surface Water

Two samples were collected in the Project area during Cyclone Carlos in February 2011. Analytical results were compared to ANZECC National Guidelines for Fresh and Marine Water Quality (2000). The majority of concentrations for metals, turbidity, salinity and major ions exceeded the guidelines values for the corresponding environment (URS, 2011e).

The data collected from the majority of sites during 2010 to 2011 sampling events (URS, 2011e) suggested the surface water was generally saline to hypersaline, near neutral to slightly alkaline and as sodium chloride type. The majority of metal concentrations analysed in the surface water naturally occur above the ANZEEC trigger values (95 per cent protection level) for marine water (ANZEEC/ARMCANZ, 2000).

Opportunistic surface water samples collected in June 2011 after recent rainfall exhibited parameter concentrations associated with freshwater, although theses flows dissipated within approximately 24 hours.

4.4.1.1 Groundwater

The ANZECC default trigger values for salinity in slightly disturbed ecosystems in tropical Australia, including North Western Australia have been deemed not appropriate due to the hypersaline nature of the groundwater. Provisional trigger values of 139,700 to 143,000 mg/L TDS have been suggested for the water table zone where the brine is expected to interact with the local groundwater (URS 2011e). The relatively low TDS concentrations around 34,500 mg/L for the RSS3 and RSS4 brines should not be an environmental impediment in terms of contamination of the groundwater. Also the majority of the baseline values for metals, turbidity, salinity, major ions exceeded the guidelines values.

4 Case Studies

4.4.2 Radionuclides

4.4.2.1 USA Guidelines

The USA Environmental Protection Agency (EPA) has set standards for radioactive substances in public drinking water supplies (Howard County Health Department, 2005). The standards, shown in Table 4-2, define the maximum permissible level of contaminant legally allowed in water, taking into account the public health risk, available treatment technology and costs of treatment.

Table 4-2 USA EPA Standards for Radioactive Substances in Drinking Water

Contaminant	Primary Type of Radiation	Radioactivity (Bq/L)			
		RSS3	RSS3 with separated filter backwash	RSS4	USA EPA Standard
Gross Beta	Beta Particles	14.75	7.375	<1	18.43

4.4.2.2 URS Experience

In December 2012, personal communications with an URS expert in nuclear decommissioning and radioactive waste in the United Kingdom revealed the following experience: *The anticipated gross beta 15 Bq/L activity of the discharge waters would not in itself be a problem for discharge. Based on experience I wouldn't anticipate there to be much effect on animals or plants. The issue which will require consideration is the fact that change in Eh and pH of the brines as they are discharged will lead to the precipitation of the Naturally Occurring Radioactive Material (NORM; which are natural materials containing radioactive elements) bearing minerals.*

In regards to the assumed project life of 80 years, the NORM accumulations would be considered as an impediment although the absolute value rate seems low in term of the USA EPA guidelines.

4.4.3 Strontium

In Australia, the permissible concentration of strontium has not been prescribed for drinking water or receiving environments. Natural strontium is non-radio-active. The human body contains approximately 4.6 ppm strontium and its specific function has not been established. It is absorbed simply because of its similarity to calcium. Consumption of food and water containing high calcium overcomes the problem. The proposed strontium concentration in RSS3 is 18 mg/L. There is uncertainty on accumulation of strontium during the evaporation process if discharged to Quick Mud Creek in open air. Onslow Salt Pty Ltd evaporates large volumes of seawater just downstream of the Project area with an initial 8 mg/L (seawater) concentration of strontium.

The accumulation of strontium has not been pointed out yet as an impediment by the regulators during Onslow Salt Pty Ltd operations. Therefore, it is not recognised as an impediment to the regulatory process.

5

Assessments of Impediments and Risks

5.1 Screening and Selection of Disposal Options

When considering the RSS disposal options the over-arching objective is to ensure that the long-term management of brine occurs in a safe, environmentally friendly and socially responsible manner.

In order to ascertain the potential impediments that the RSS disposal options pose towards the Project's regulatory approvals process, two major components have been assessed:

1. A register of environmental aspects has been compiled. The environmental aspects have been derived from case studies, literature review and professional experience.
2. Identification of potential impediments that are not environmental or technical risks but linked to the core of the regulatory process.

The impacts that RSS disposal may have on an environmental aspect have been identified, along with the regulatory impediment that may be triggered. The risk that the impediment may be triggered has been ascertained using an Environmental Risk Matrix table, which is based on the likelihood of the impact occurring and the consequence of that impact on the regulatory process (such as triggering referral to the Commonwealth Government). The Risk Matrix table has been developed from the Wheatstone Draft EIS/ERMP, which is based on the criteria as set out by EPA in 2009. The Environmental Risk Matrix table is shown in Table 5-1

Criteria defined below are most likely to constitute certain degrees of impediment:

- The perception of the public or the regulators regarding best practice in terms of RSS disposal. For instance, injection into safe geological formations is a preferred strategy in Australia.
- The abundance and relevance of case studies to support the option strategies. In Australia, the EPA gives importance to precedence provided by existing or similar cases in order to assess proposals.
- The existence of contingency options. This are required as a fall back should the results of a monitoring programme, required by the EPA or DEC, demonstrate the occurrence of unacceptable impacts.
- The complexity and duration of environmental studies required to define the baseline environment.

5 Assessments of Impediments and Risks

Table 5-1 Environmental Risk Matrix

		Consequence Category					
		6	5	4	3	2	1
		Negligible	Minor	Moderate	Major	Massive	Catastrophic
Likelihood Category	1. Almost Certain	Low	Medium	High	Extreme	Extreme	Extreme
	2. Likely	Low	Low	Medium	High	Extreme	Extreme
	3. Possible	Low	Low	Low	Medium	High	Extreme
	4. Unlikely	Very Low	Very Low	Low	Low	Medium	High
	5. Remote	Very Low	Very Low	Very Low	Low	Low	Medium

Extreme Risk	Modification of proposal will be required for approval. Detailed discussion and agreement with EPA and DSEWPaC or other government departments on proposed studies required. Likely to have significant environmental effects which will trigger referral to EPA and possibly DSEWPaC. Unlikely to be environmentally acceptable to regulators. Would pose a regulatory impediment to the Project.
High Risk	Detailed discussion and agreement with EPA and DSEWPaC required. Likely to have significant environmental effects which would trigger referral to EPA. Likely to pose a regulatory impediment to the project.
Medium	Detailed discussion and agreement with EPA required.
Low Risk	Unlikely to pose regulatory impediment to project. May require further study based on confidence of literature review.
Very Low Risk	Unlikely to pose regulatory impediment to the Project.

5 Assessments of Impediments and Risks

5.1 Impediment and Risk Assessment

A register of likely environmental aspects and potential impacts has been compiled and is shown in Appendix C. The register incorporates the entire range of potential risks. It was anticipated that only the higher risk aspects would form significant potential regulatory impediments. These have been identified, based on the literature review, case studies and professional experience, in Table 5-2 and carried through the impediment and risk assessment. Subsequently, each of these higher risk potential impediments has been comparatively assessed (Table 5-3) for each RSS disposal option.

Table 5-2 Matrix of Significant Environmental Aspects and Potential Change

Impediment Aspect	Potential Change
Surface Water Quality	Radionuclides accumulation.
Groundwater Quality	Radionuclides accumulation.
Fauna Habitats	Groundwater mounding and change in chemistry of water and sediments reducing quality/quantity of habitat.
Clay-pan Fauna	Increased water flow and change in chemistry of water and sediments reducing quality/quantity of habitat.
Vegetation and Flora	Change in water levels/chemistry may have adverse impact on native vegetation: 0 ha for Option 1 and Option 2; 2,560 ha for Option 3; and 1,533 ha for Option 4.

5.2 Ranking of Residual Saline Stream Disposal Options

The overall objective is to comparatively rank the predominant impediments to regulatory approvals and subsequently identify the RSS disposal option with least associated risk. The environmental risk impediments defined in Table 5-3 have been comparatively ranked to identify the preferred option for the RSS disposal, taking into account all assumptions and uncertainties described throughout the report.

The comparative ranking assessment considers only the risks on a scale from medium to extreme as indicated in Table 5-3. A number of these key elements would influence the regulatory process more than others. In order to take account of this influence, relative weightings were assessed for these key elements. Each of the environmental risk impediments in Table 5-3 has been scored from 0 to 100 assuming that the highest score is 100. High scores stand for strong impediments or negative aspects in terms of regulatory approval. Low scores represent lesser impediments to the regulatory process.

The developed ranking is described as follows:

- Extreme regulatory risk rank is 100.
- High regulatory risk rank is 75 to <100.
- Medium regulatory risk rank is 50 to <75.
- Low to very low risk ranks are 0 to <50.

5 Assessments of Impediments and Risks

The maximum total weighting expressed is 100 per cent. The key elements and respective relative weightings are described in Table 5-4. The results of this assessment in the form of a semi-quantitative score and ranking matrix are provided in Table 5-5 which represents a transparent and logical comparative assessment of the discrete options. The weighted scores for each impediment and each option is calculate in the table based on the above assumptions. The weighted scores are summed in the weighted ranking. Low scores show low impediment risk. High scores show high risk impediments. For scores higher than 60 to 70, the regulatory process is expected to be complex and uncertain.

5 Assessments of Impediments and Risks

Table 5-3 Potential Environmental Impediments

Key Aspects	Receptor	Potential Impact	Regulatory Risk	Option 1 'Discharge to Creek' RSS3 with Radionuclides	Option 1 'Discharge to Creek' RSS3 with reduced amount of Radionuclides	Option 2 'Discharge to Creek' RSS4	Option 3 'Injection to Aquifer' RSS3 with Radionuclides	Option 4 'Infiltration Basin' RSS3 with Radionuclides
				Risk of Impediment				
Surface Water Quality	Water Sediment	Radionuclides Accumulation	Acceptable as long it is not creating harm to the environment	High	Medium	Very low	Medium	Medium
Groundwater Quality	Water Sediment	Radionuclides Accumulation	Acceptable as long it is not creating harm to the environment	High	Medium	Very low	Medium	Medium
Fauna	Fauna Habitat	Groundwater mounding and change in chemistry of water and sediments reducing quality/quantity of habitat	Significant impacts may be unacceptable	Medium	Medium	Medium	High	High
	Clay-pan Fauna	Increased water flow and change in chemistry of water and sediments reducing quality/quantity of habitat	Unacceptable impact to clay-pan fauna	Low	Low	Low	Medium	Medium
Vegetation and Flora	Good to excellent native vegetation	Change in water levels/chemistry may have adverse impact on native vegetation: 0 ha for Option 1 and Option 2; 2,560 ha for Option 3; and 1,533 ha for Option 4	Unacceptable impact on good to excellent native vegetation. Offsets for impacts to potentially good to excellent vegetation	Low	Low	Low	Extreme	High
	Priority Flora	Adverse impact on priority ecological flora	DEC would consider impact to Priority Fauna unacceptable	Low	Low	Low	Extreme	Extreme

5 Assessments of Impediments and Risks

Table 5-4 Assessment of Key Impediments and Weighting

Key Aspects	Receptor	Major Concerns	Weight (per cent)	Justification
Surface Water Quality	Water/Sediment	Radionuclides Accumulation	25	Accumulation of radionuclides may be a serious impediment.
Groundwater Quality	Water/Sediment	Radionuclides Accumulation	25	Accumulation of radionuclides may be a serious impediment.
Fauna	Fauna Habitat	Groundwater mounding and change in chemistry of water and sediments reducing quality/quantity of habitat	5	This aspect is not as important as the fauna habits are not considered significant.
	Clay-pan Fauna	Increased water flow and change in chemistry of water and sediments reducing quality/quantity of habitat	10	This is a relatively high impediment in the Goldfields.
Vegetation and Flora	Good to excellent native vegetation	Change in water levels/chemistry may have adverse impact on native vegetation: 0 ha for Option 1 and Option 2; 2,781 ha for Option 3; and 1,727 ha for Option 4	10	Destruction of good to excellent quality native vegetation is a medium impediment.
Listed Flora and Fauna	Priority Flora and fauna	Adverse impact on priority ecological flora	25	Destruction of priority flora is a major impediment as mentioned in many of the case studies.
Total			**100**	

5 Assessments of Impediments and Risks

Table 5-5 Comparatively Weighted Regulatory Impediments Assessment

Key Aspects	Weighted Aspects	Receptor	Potential Impact	Weighted Scores and Comparative Ranking				
				Option 1 Discharge to Creek		Option 2	Option 3	Option 4
				RSS3 with Radionuclides	RSS3 with Reduced Radionuclides	Discharge to Creek	Injection to Aquifer	Infiltration Basin
Surface Water Quality	25	Water/Sediment	Radionuclides Accumulation	19	12	0	13	13
Groundwater Quality	25	Water/Sediment	Radionuclides Accumulation	19	12	0	13	13
Fauna	5	Fauna Habitat	Groundwater mounding and change in chemistry of water and sediments reducing quality/quantity of habitat	12	12	12	4	4
	10	Clay-pan Fauna	Increased water flow and change in chemistry of water and sediments reducing quality/quantity of habitat	0	0	0	5	5
Vegetation and Flora	10	Good to excellent native vegetation	Change in water levels/chemistry may have adverse impact on native vegetation: 0 ha for Option 1 and Option 2; 2,560 ha for Option 3; and 1,533 ha for Option 4	0	0	0	10	8
	25	Priority Flora	Adverse impact on priority ecological flora	0	0	0	25	25
Weighted Ranking	**100**			**50**	**36**	**12**	**70**	**68**

5 Assessments of Impediments and Risks

The comparatively weighted regulatory impediments assessment indicates there is:

- Strong contrast between the options that provide disposal into Quick Mud Creek and those that involve infiltration and injection.
- Further strong contrast between the options that exclude and include the presence of radionuclides in the disposal to Quick Mud Creek.

As defined by the comparative ranking assessment, the least impediment risk RSS disposal strategy is Option 2 ‘discharge to creek’ with ‘clean’ RSS4. This option has limited impediments because RSS4 has low concentrations for all parameters and with disposal onto the bed of the watercourse would not impact riparian or sand dune vegetation. The process to achieved RSS4 is, however, comparatively complex.

Option1 ‘discharge to creek’ with RSS3 with reduced radionuclide concentration is second ranked. Under this option, the radionuclide activity in RSS3 is actually below the USA EPA standard for drinking water. The other parameters, such as calcium and magnesium that form signatures of RSS3, are not defined as impediment as their local occurrences in the natural environment are at high concentrations. Therefore, this option would also be considered comparatively low risk in terms of regulatory process and may actually be preferred given the additional treatment requirements associated with RSS4. It was recognised, however, that the RSS3 radionuclide stream would increase in concentration within the environment of Quick Mud Creek where evaporation losses would drive accumulation effects. The concentrated stream would likely exceed the USA EPA guidelines for drinking water but may not pose significant environmental risk due to the likely frequent occurrence of stream flow flushing events. These aspects are worthy of further consideration.

In conclusion, the preferred option is Option 2 ‘discharge to creek’ with RSS4 that has radionuclides removed as part of the process.. Option 1,’ discharge to creek’ with RSS3, may have added support if it can be demonstrated that the accumulation of beta activity typically does not exceed environmental thresholds.

6

Conclusions

6.1 Conclusions on Impediments and Risks

The application of a risk-based approach has been used to define the impediments associated with each RSS disposal option. The ranked impediments assessments identify the predominant environmental risks linked to each RSS disposal option. These aspects are outlined below.

Until site specific baseline surveys are undertaken for the Project area, there is uncertainty as to whether a number of regulatory processes will be triggered or if potential impacts may be acceptable to both Chevron and the regulators.

6.1.1 Option 1 – Discharge of RSS3 into Quick Mud Creek

The key regulatory impediment for discharge into Quick Mud Creek was considered as:

- Radionuclides accumulation in the surface water and local groundwater. This impediment becomes a medium risk if the radionuclide concentrations are reduced by specific process.
- Degradation of clay-pan/ephemeral ecosystems.

Radionuclide Accumulation

Based on received advice it was considered unlikely that the anticipated radionuclide activity in the initial disposed RSS would have a significant effect on animals and plants. It was considered likely, however, that the radionuclide activity may increase over time as salts accumulate (forming crusts) due to evaporation. Flushing by irregular and episodic stream flow events would mitigate this risk, transporting the accumulated salts into the ocean. In real terms the radionuclide accumulation was considered unlikely to result in adverse environment effects, but may lead to concentrations reaching level which may be deemed unacceptable to the regulators. The reduction of concentrations of radionuclides in RSS3 would mitigate the impediment risk. In summary, the concentrated stream would likely exceed the USA EPA guidelines for drinking water but may not pose significant environmental risk due to the likely frequent occurrence of stream flow flushing events. These aspects are worthy of further consideration, inclusive of predictive assessments of the accumulation that would occur on flow paths within Quick Mud Creek.

Degradation of Ephemeral Ecosystems

In the absence of baseline studies for Quick Mud Creek, it was assumed that local ephemeral ecosystems may exist.

There are clay-pan fauna habitats in the local setting area which may be impacted by the mounding of the water table. Impacts are likely to include permanent inundation of and change to the water quality within the clay-pan habitats. In the absence of site specific information, this aspect was considered a medium risk impediment.

6.1.2 Option 2 – Disposal of RSS4 to Quick Mud Creek

Option 2 has similar impacts to Option 1, with the exception of accumulation of radionuclides. The ‘better quality’ RSS only contains traces of radionuclides and significantly mitigates the risk that the radionuclide accumulation by evaporation from Quick Mud Creek would exceed appropriate environmental thresholds.

6.1.3 Option 3 – Discharge by Injection into Trealla Limestone

- Degradation of 2,560 ha of good to excellent condition vegetation.
- Degradation of fauna habitat.
- Degradation of clay-pan fauna habitat.

Degradation of Good to Excellent Condition Vegetation

Predictive assessments have shown that injection of RSS into the Trealla Limestone would likely cause mounding of the water table, with the potential to affect 2,560 ha of good to excellent condition vegetation. Considering the amount of native vegetation to be impacted, this is considered a regulatory impediment to the Project.

Degradation of Fauna Habitat

The degradation of the native vegetation would tend to lead to degradation of fauna habitat. Removal of 2560 ha of potential fauna habitat is likely to be an impediment to the regulatory process that may require environmental conditions.

Degradation of Clay-pan Fauna Habitats

There are clay-pan fauna habitats in the local setting area which may be impacted by the mounding of the water table. Impacts are likely to include permanent inundation of and change to the water quality within the clay-pan habitats. In the absence of site specific information, this aspect was considered a medium risk impediment.

6.1.4 Option 4 - Discharge to Infiltration Basin

Regulatory risks are considered similar to Option 3 although the predicted area of impact (1,533 ha) would be smaller.

6.2 Recommended Residual Saline Stream Disposal Option

Based on the described assessments, Option 2 - disposal of RSS4 to Quick Mud Creek would provide the least risk impediments for regulatory approval. There are a number of credentials that support Option 2:

1. While impacts to receptors exist, they are not considered significant.
2. Provides the least potential impacts to native vegetation.
3. Limits radionuclide accumulation.
4. Avoids impacts to “rare flora:” Conservation Significant Flora.
5. There are numerous case studies and broadly analogous precedents for approvals to discharge RSS to saline environments subject to periodic and episodic flooding events.
6. Provides the lowest ranked score.

Option 1 is worthy of further consideration to determine the impact of radionuclide accumulation and which concentrations will be limited by periodic flushing and geomorphological factors. If the extent and effects of radionuclide accumulation can be shown to be minimal Option 1 may also be considered to have comparatively low regulatory risk.

7

References

Agency for Toxic Substances and Disease Registry (2004) – Toxicological Profile for strontium, Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australian and New Zealand (ANZEEC & ARMCANZ) (2000) – *An introduction to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality*.

Biota (2010a) – *Wheatstone Project Terrestrial Fauna Survey.* Prepared for URS and Chevron.

Biota (2010b) – *A Vegetation and Flora Survey of the Wheatstone Study Area, near Onslow*. Prepared for URS on behalf of Chevron.

Biota (2010c) – *Wheatstone Project Claypan Ephemeral Fauna Survey.* Prepared for Chevron and URS.

Biota (2010d) – *Wheatstone Project Subterranean Fauna Assessment*. Prepared for URS and Chevron.

Biota (2010e) – *Wheatstone Project Flora and Fauna Assessment Addendum.* Prepared for URS and Chevron.

Blight N. (2012) – *Brine Chemistry for URS CTR 4, Brine Disposal Environmental Risk Assessment*, prepared for Chevron, unpublished memorandum.

Chevron (2010). – *Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Wheatstone Project. Volume II.*

Coleman M. (2003) – *Salt Lakes in the Western Australia Landscape, a discussion paper prepared for the Department of Environmental Protection*, March 2003.

DEC (2011). *Licence Approval. Environmental Project Act 1986 – licence 7323/1998/11. Kundana Gold Pty Ltd.*

EPA. (2008). *Environmental Guidance for Planning and Development.*

EPA. (2010). *Gold Mining Developments on Lake Lefroy – Beyond 2010. St. Ives Gold Mining Company Pty Ltd.*

Fortescue Metals Group. (2011) *Christmas Creek Water Management Scheme. Environmental Review.*

Kimes, J.K. (1995) – *The Regulation of Concentrate Disposal in Florida*, Desalination 102.

Howard Country Health Department (2005) – *Radionuclides and Your Well Water: A Homeowner's Guide, prepared by Bureau of Environmental Health*, September 2005.

Mohamed A.M.O, Maraqa M., Handdhaly J. Al (2005) – *Impact of land disposal of reject brine from desalination plants on soil and groundwater,* accepted 21 February 2005.

Onslow Salt Pty Ltd (1995) – *Onslow Solar Salt Project, Proposed changes to Environmental Conditions, Report and Recommendations of the Environmental Protection Authority*, Bulletin 776.

Outback Ecology Services (2009) – *Development of Framework for Assessing the Cumulative Impacts of Dewatering Discharge to Salt Lakes in the Goldfields of Western Australia.* prepared for DoW and funded by Rangelands NRM, January 2009.

7 References

Rockwater (2011) - *Hydrogeological Investigation of Infiltration Basins for Desalination reject water-Denham, pp. Unpublished report prepared for Water Corporation.*

Santos Ltd (2008) – GLNG Upstream Brine Management Strategy, 2008.

Scott J., Paduan J., Roberts P, Schlenk D., Weis J. (2012) – *Management of Brine Discharges to Coastal Water, Recommendations of a science Advisory Panel, technical report 694.*

Shark Bay Salt Joint Venture (1999) – *Construction of additional crystallizer ponds, Useless Loop, Shark Bay, Report and recommendations of the environmental Protection Authority*, March 1999.

State Water Resources Control Board, *Division of Water Quality, GAMA Program (2008) – Groundwater Information Sheet, Radionuclides*, August 2008

Svenson M. (2005) – *Desalination and the Environment: Options and Considerations for brine disposal in inland and coastal locations*, Department of Biometry and Engineering, 2005.

Tanji K., Kielen, N. (2004) – *Agricultural Drainage Water Management in Arid and Semi-Arid area, FAO Irrigation and Drainage,* Paper 61.

Younos T. (205) – *Environmental Issues of Desalination*, Universities Council on Water Resources, Journal of Contemporary Water Research & Education, Issue 132, Pages 11-18, December 2005.

URS (2011) – *Wheatstone Project. Targeted Flora Survey Report,* prepared for Chevron Australia, 2011, unpublished report.

URS (2012a) – *Onslow Water Infrastructure Upgrade Project, Alternative Assessment of Brine Report*, November 2012, prepared for Chevron Australia, October 2010, unpublished report.

URS (2012b) – *Wheatstone Downstream Project, Flood Modelling and Access Road Design*, Prepared for Chevron Australia, December 2010, unpublished report.

URS (2010c) – *Onslow Salt Joint Flood Study*, prepared for Chevron, unpublished report.

URS (2001d) – *Granny Deeps Water Resources Prefeasibility Study – Disposal of Hypersaline Water*, prepared for Barrick Granny Smith Pty Ltd, unpublished report.

URS (2011e) – *Wheatstone Project, Groundwater and Surface Water Monitoring 2010-2011*, *Interpretive Report*, September 2011.

Watts P., Howe P. (2006) – Strontium and Strontium Compounds, prepared for World Health Organisation.

Figures

N
W E
S

0 1 2 4 6 8 Kilometers

Scale at A3: 1:88,833

Coordinate System: GDA 1994 MGA Zone 50

Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

EIS Terrestrial Assessment Area
Quick Mud Creek
Site B
Major Road
Minor Road
Track
Major Watercourses
Minor Watercourses

Chevron

ONSLOW WATER INFRASTRUCTURE UPGRADE PROJECT
DEFINITION OF IMPEDIMENTS TO RESIDUAL SALINE STREAM DISPOSAL

SITE B
PROPOSED DESALINATION PLANT

URS

INTRODUCTION

File No: **42908178-WG-033.mxd** Drawn: **LS** Approved: **IB** Date: **2/4/2013**

Figure: **1-1**

Rev. **A** A3

Option 1 - Discharge to Creek Poorer RSS

40 hectares

Option 2 - Discharge to Creek Cleaner RSS

40 hectares

Option 3 - Injection into Trealla

2560 hectares

Option 4 - Infiltration Basin

1533 hectares

ONSLOW ROAD

TWITCHIN ROAD

296000 298000 300000 302000 304000 306000 308000

7594000 7592000 7590000 7588000

N W E S

Assumed Footprints for RSS Disposal
Proposed Desalination Plant Location
Major Road
Minor Road
Track

-0.06 - 1.1
1.2 - 2.5
2.6 - 3.8
3.9 - 5.1
5.2 - 6.3
6.4 - 7.5
7.6 - 8.8
8.9 - 10
11 - 12
13 - 14
15 - 16
17 - 18
19 - 21
22 - 24
25 - 31

Scale at A3: 1:70,000
Coordinate System: GDA 1994 MGA Zone 50
Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Chevron

ONSLOW WATER INFRASTRUCTURE UPGRADE PROJECT
DEFINITION OF IMPEDIMENTS TO RESIDUAL SALINE STREAM DISPOSAL

ASSUMED AND EXPECTED IMPACT FOOTPRINTS FROM GROUNDWATER MOUNDING OVER 80 YEARS FLOW RATE 1,334 KL/D

URS

BRINE CHARACTERISTICS

File No: **42908178-WG-032.mxd** Drawn: **LS** Approved: **IB** Date: **2/4/2013**

Figure: **2-1** Rev. **A** A3

296000 298000 300000 302000 304000 306000 308000

7596000 7594000 7592000 7590000 7588000

Quick Mud Creek

ONSLOW ROAD

TWITCHIN ROAD

Site B

Legend

Vegetation Mapping (Bicta, 2009)

- Indicative Terrestrial Project Area
- Wheatstone Threatened Flora
  - *Abutilon uncinatum* ms.
  - *Atriplex flabelliformis*
  - *Eleocharis papillosa*
  - *Eremophila forrestii* subsp. *viridis*
  - *Triumfetta echinata*
- Undescribed
  - *Abutilon* sp.
  - *Aenictophyton* aff. *reconditum* (Onslow)

C1, C2, C3, C3 / C2, C3 / CP1, C4, CD1, CD2, CP1, CP2, CP3, CP4, CP5 / CP4, CS1, CS1 / CP1, CS1 / CS2, CS2, CS3, CS4, CS4 / CP1, CS4 / CS1, CS5, CS6, D1, D2, D3, D4, H1, ID1, ID2, ID3, ID4, IS1, IS2, T1, T2

Expected Vegetation Damage Footprint for Injection

Expected Vegetation Damage Footprint for Infiltration

N W E S

0 0.25 0.5 1 1.5 2

Scale at A3: 1:40,000 Kilometers

Coordinate System: GDA 1994 MGA Zone 50

Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Chevron

ONSLOW WATER INFRASTRUCTURE UPGRADE PROJECT
DEFINITION OF IMPEDIMENTS TO RESIDUAL SALINE STREAM DISPOSAL

WHEATSTONE PROJECT AND PREVIOUSLY RECORDED TARGETED FLORA LOCATIONS

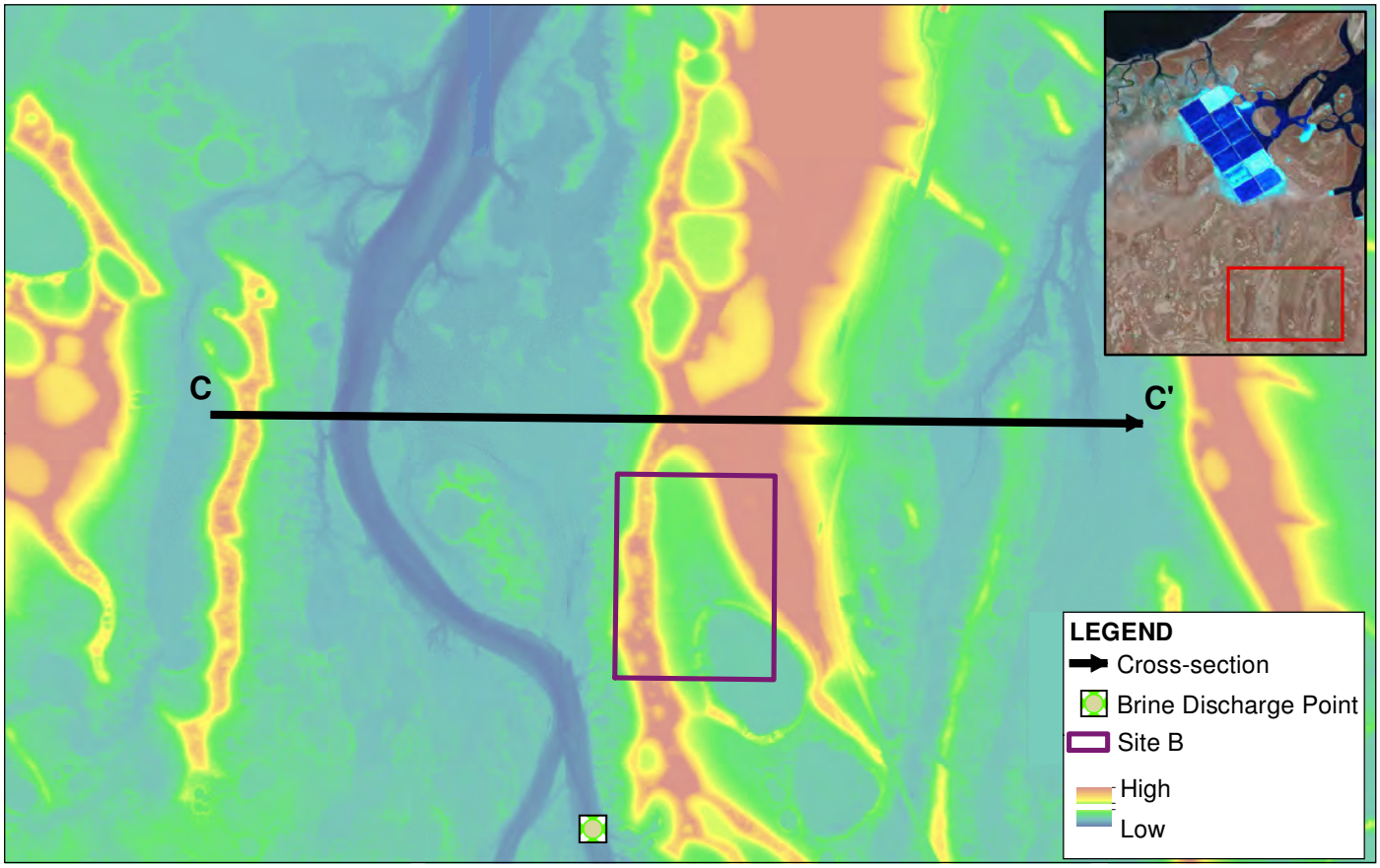
URS

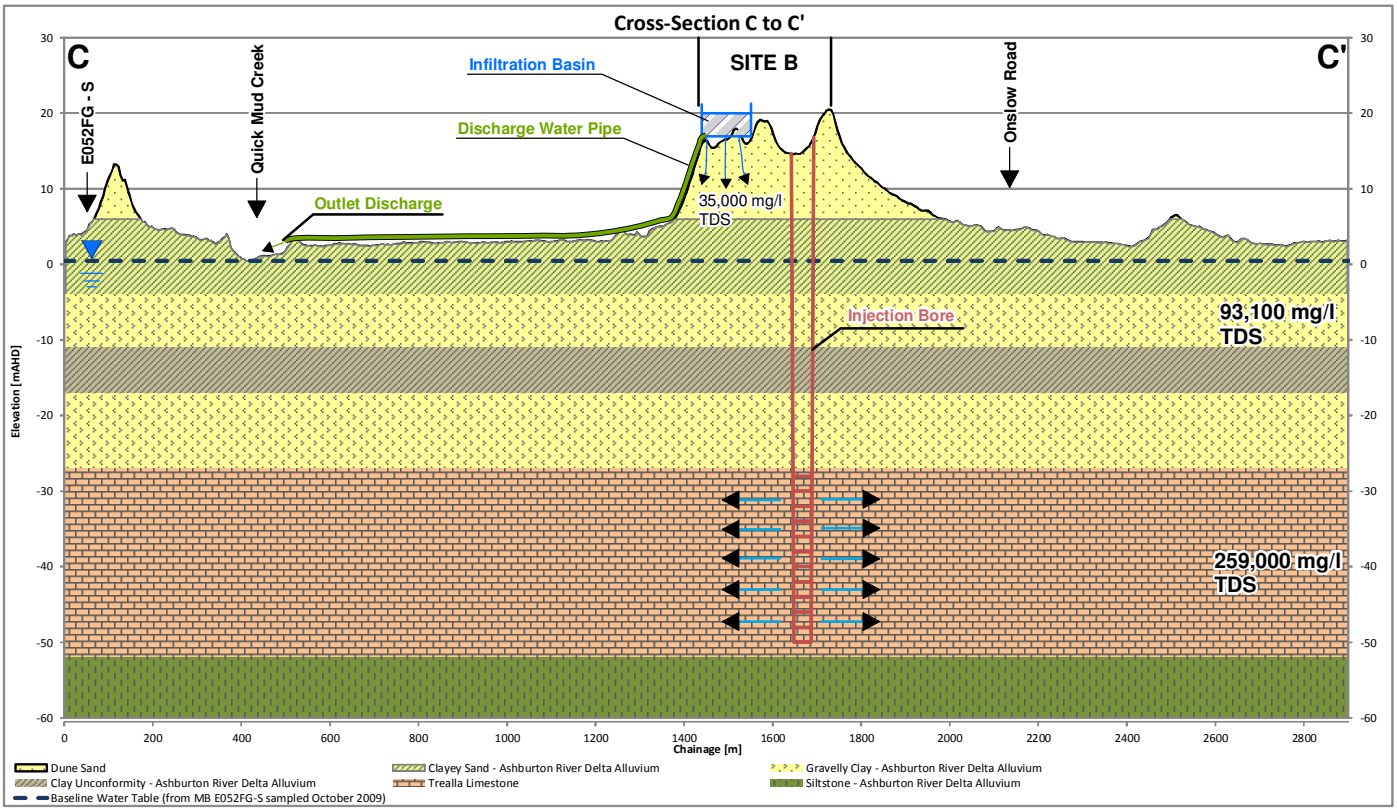
BASELINE

File No: **42908178-WG-035.mxd** Drawn: **LS** Approved: **IB** Date: **2/4/2013**

Figure: **3-1**

Rev. **A** A3





N
W E
S

Scale: 1:25,000

0 500 1,000 Meters

Coordinate System: GCS GDA 1994

Source: Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Chevron

ONSLOW WATER INFRASTRUCTURE UPGRADE PROJECT
DEFINITION OF IMPEDIMENTS TO
RESIDUAL SALINE STREAM DISPOSAL

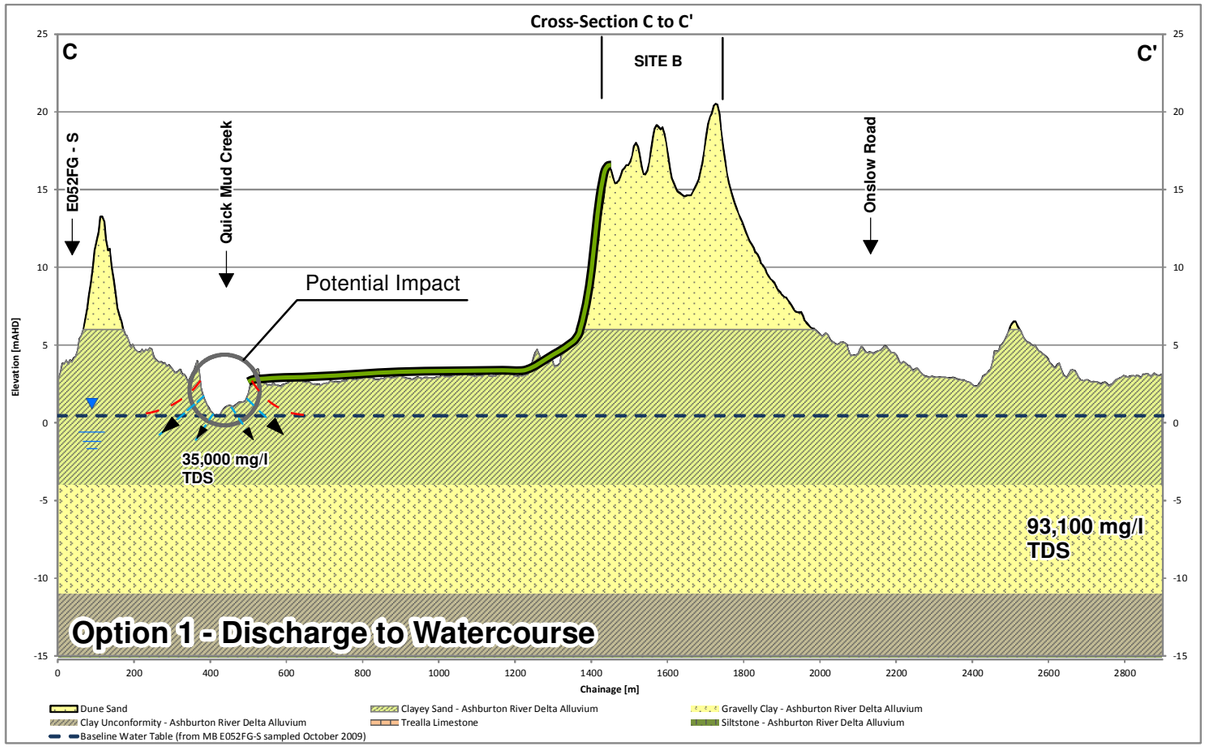
OPTION OVERVIEW AT CROSS-SECTION C-C' AND LOCALITY MAP

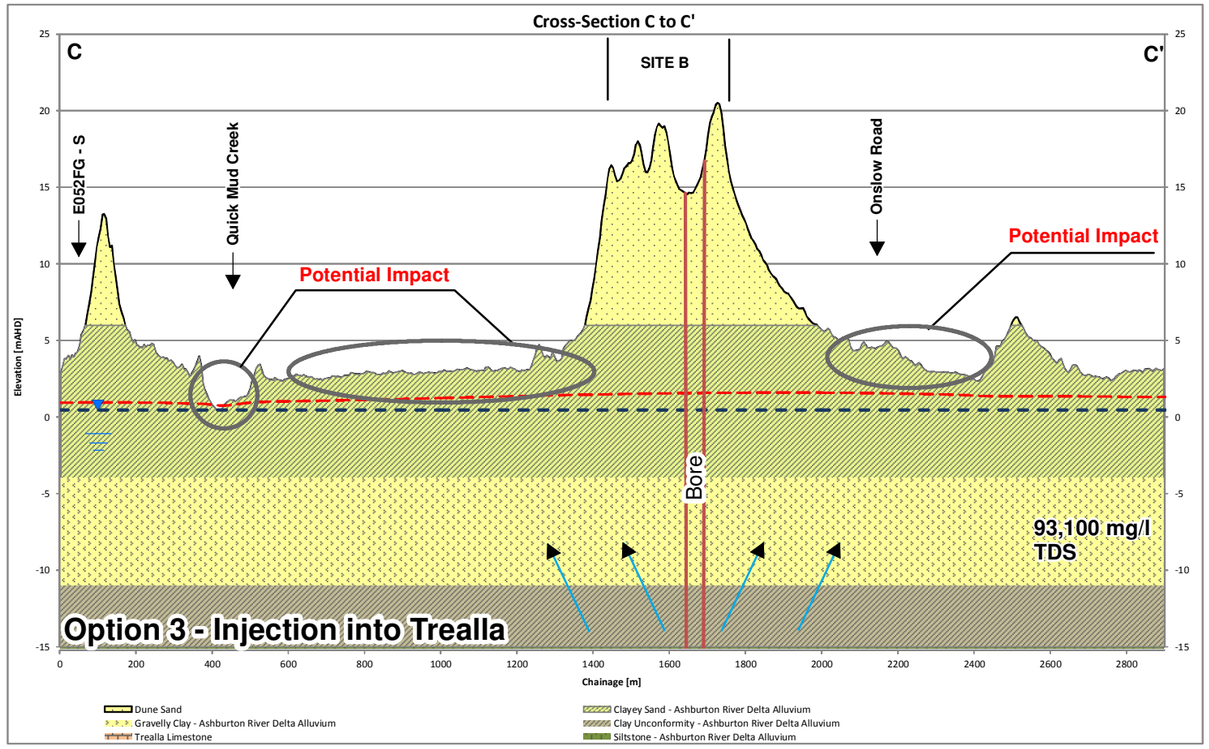
URS

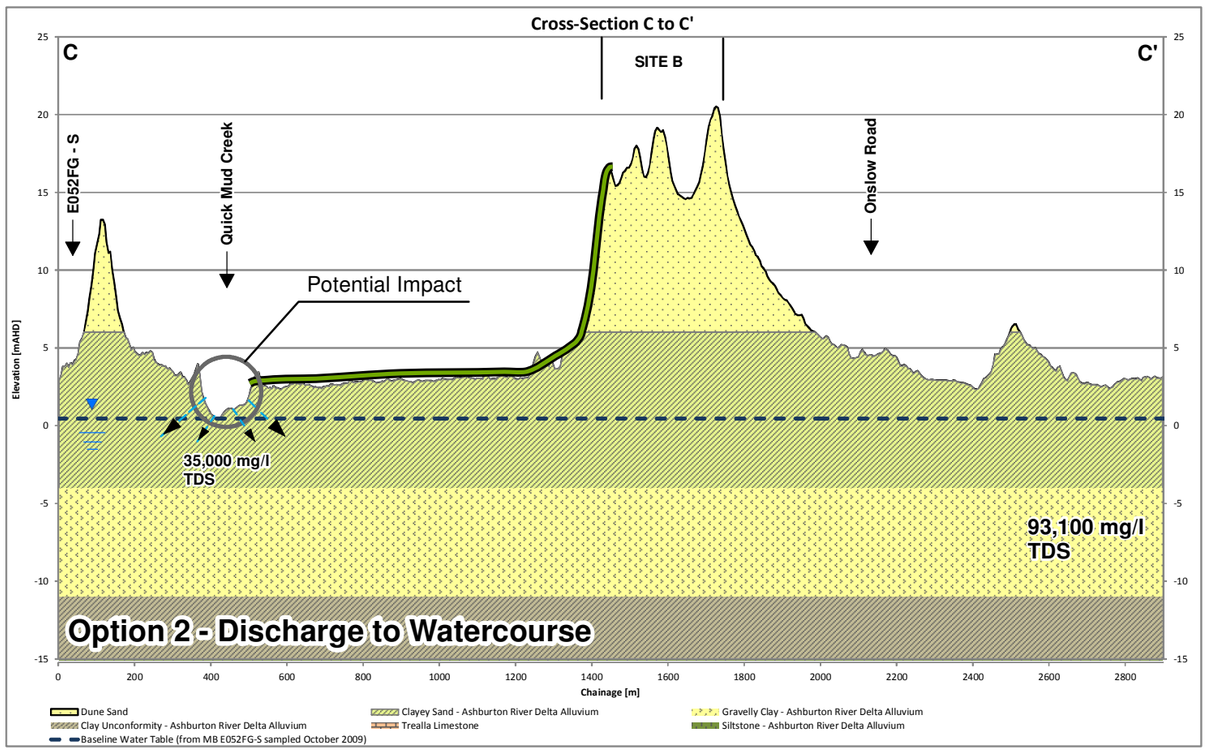
INFORMATION ON IMPEDIMENTS TO RESIDUAL SALINE STREAM DISPOSAL

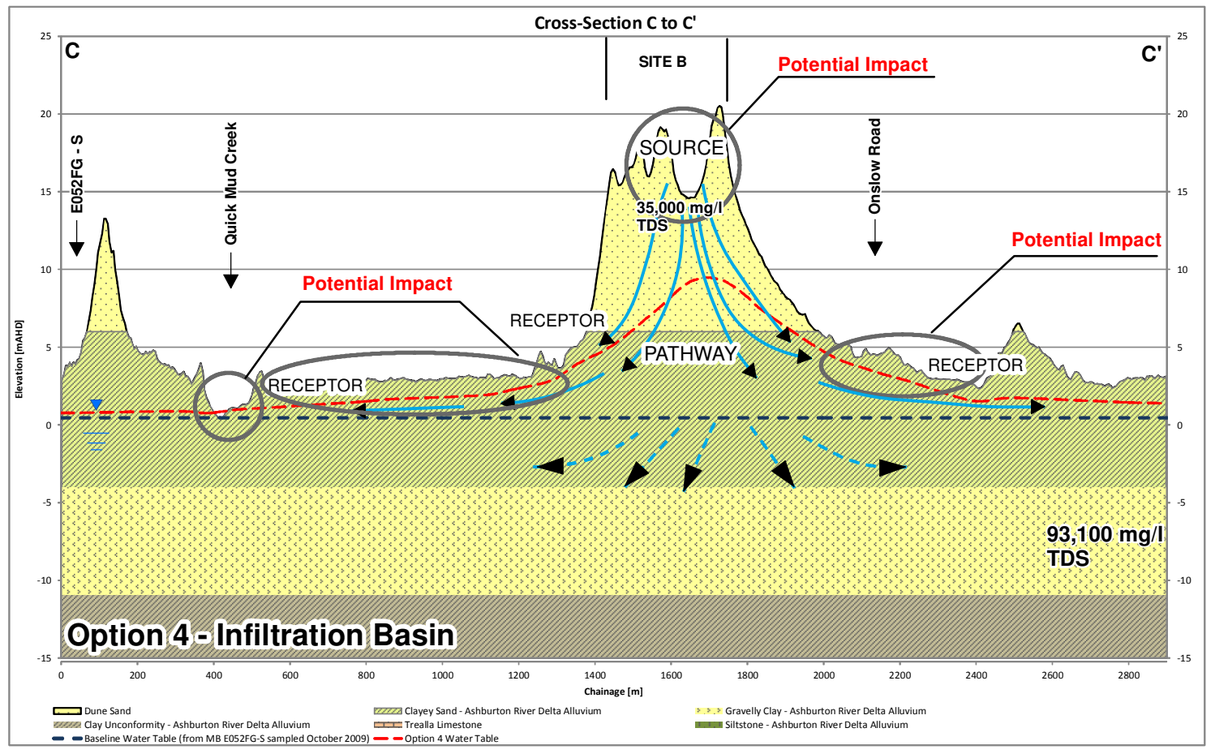
Figure: 3-2

File No: 42908178-WG-029.mxd | Drawn: AV | Approved: LS | Date: 2/4/2013 | Rev. A | A4









Chevron

ONSLOW WATER INFRASTRUCTURE UPGRADE PROJECT
DEFINITION OF IMPEDIMENTS TO RESIDUAL SALINE STREAM DISPOSAL

CONCEPTUAL CROSS-SECTIONS POTENTIAL REGULATOR RISK OPTIONS 1, 2, 3 AND 4

URS

INFORMATION ON IMPEDIMENTS TO TERESTRIAL RESIDUAL SALINE STREAM DISPOSAL

Figure: **3-3**

File No: **42908178-WG-030.mxd** Drawn: **LS** Approved: **IB** Date: **2/4/2013**

Rev. **A** A3

A

Appendix A Legislation

Appendix A - Regulatory Legislation and Guidelines

Legislation	Responsible Government Authority	Aspect/Trigger
Commonwealth Government Legislation		
Environment Protection and Biodiversity Conservation Act 1999	Department of Sustainability, Environment, Water, Population and Community (SEWPC)	Matters of National Environmental Significance • Listed threatened species and ecological communities • Migratory species
Western Australia State Legislation		
Parts IV and V of the Environmental Protection Act 1986 (EP Act 1986)	Office of the Environmental Protection Authority (OEPA), Western Australia Department of Environment and Conservation (DEC)	Primary environmental legislation within WA, relating to the prevention, control and abatement of pollution and environmental hazard for the conservation, preservation, protection, enhancement and management of the environment.
Environmental Protection Regulations 1987	Western Australia Department of Environment and Conservation (DEC)	Triggered if premises under Schedule 1.
Wildlife Conservation Act	DEC	Provides legal framework to protect and manage flora and fauna in Western Australia.
Rights in Water and Irrigation Act 1914	Department of Water (DoW)	Governs the regulation of water resources in WA. Regulatory licences and permits issued under this Act define water management and monitoring for individual projects.
Aboriginal Heritage Act 1972	WA Department of Indigenous Affairs.	State Act provides a legal framework for the preservation on behalf of the community of place and objects customarily used or traditional to the original inhabitants of Australia or their descendants.
Heritage of Western Australia Act 1990	EPA	Identify, conserve and where appropriate enhance those places within WA which are of significance to the cultural heritage.

Legislation	Responsible Government Authority	Aspect/Trigger
Western Australia Environmental Protection (Unauthorised Discharges) Regulations 2004	DEC	Regulations prohibit commercial activities from discharging certain wastes include petrol, sewage, degreasers, detergents and food wastes, and material with certain chemical compounds. Specially it is an offence to discharge sediment into the marine environment and to discharge brine in which are: acid with a pH less than 4; alkali with a pH more than 10, compounds of solutions of cyanide, chromium, cadmium, lead arsenic, mercury, nickel, zinc, copper; etc.
Position/Guidance Statements		
EPA Position Statement No. 2,	EPA	Provides an overview of EPA position on the clearing of native vegetation in WA with particular reference to clearing within the agricultural area.
EPA Position Statement No. 8, 2005	EPA	Environmental Protection in Natural Resource Management. An outline of the EPA role in natural resource management with respect to evaluating environmental performance.
EPA Guidance Statement No. 41: Assessment of Aboriginal Heritage 2004	EPA	Provides for the consideration of Aboriginal heritage matters to the extent that they may be affected by a development proposal on the physical or biological surroundings, and to ensure changes to the environment do not adversely affect matters of heritage significance to Aboriginal people.
Guidelines		
National Water Quality Management Strategy – the Environmental Quality	DEC, WA	Set of Environmental Values (EV) and Environmental Quality Objectives (EGO) for use in

Legislation	Responsible Government Authority	Aspect/Trigger
Management Framework (EQMF)		WA. The intent is that Proponents will agree to maintain the EVs and EQos through adherence to appropriate Environmental Quality Guidelines (EQG) and Environmental Quality Standards (EQS).
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000)	Commonwealth Australia	The ANZECC/ARMCANZ (2000) guidelines 'provide an authoritative guide for setting water quality objectives required to sustain current, or likely future, environmental values (uses) for natural and semi natural water resources in Australia and New Zealand'. The Water Quality Guidelines were prepared as part of Australia's National Water Quality Management Strategy.
Development of Framework for Assessing the Cumulative Impacts of Dewatering Discharge to Salt Lakes in the Goldfields of Western Australia	DoW	Framework for consideration of the cumulative impacts of dewatering discharge to salt lakes in the Goldfields of Western Australia. The purpose of this report was to present a risk matrix for dewatering discharge to salt lakes.

B

Appendix B EPBC Database Search

Australian Government

Department of Sustainability, Environment, Water, Population and Communities

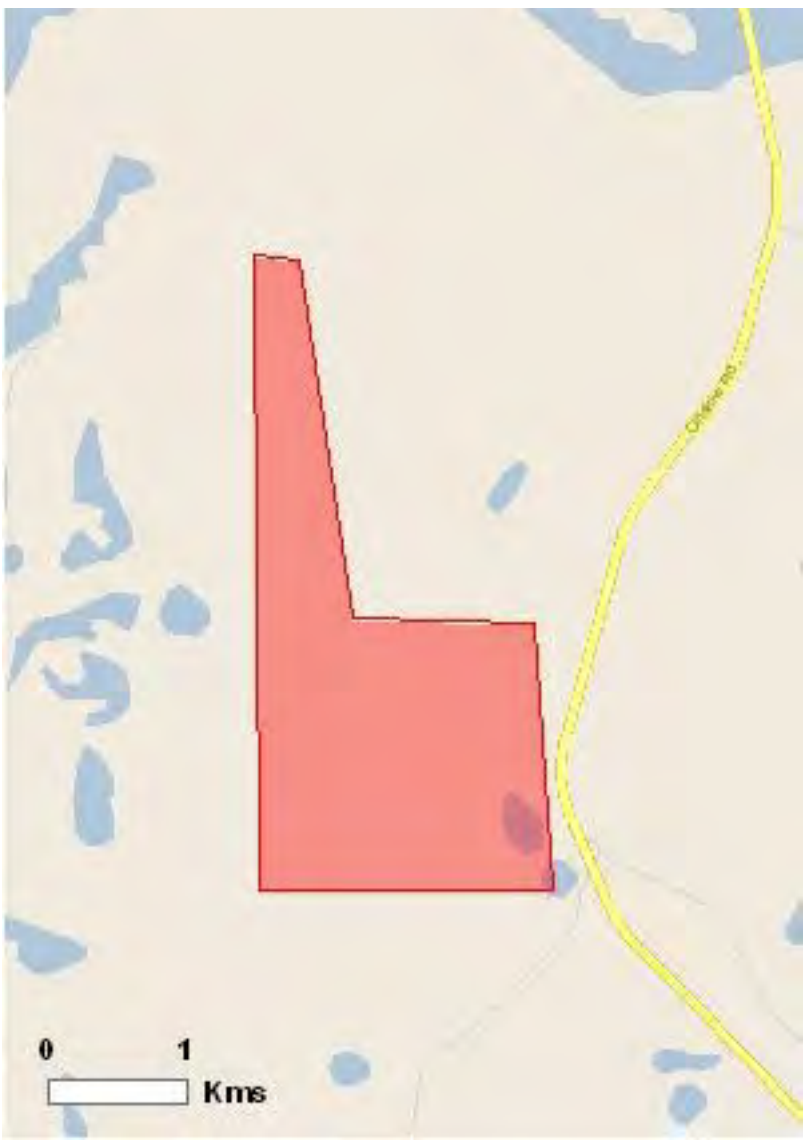
EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

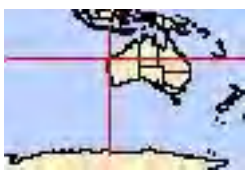
Report created: 12/12/12 21:08:24



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates

Buffer: 0.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Areas:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	2
Listed Migratory Species:	11

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate.

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	9
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

Place on the RNE:	None
State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	6
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Mammals		
Dasycercus cristicauda		
Mulgara [328]	Vulnerable	Species or species habitat likely to occur within area
Dasyurus hallucatus		
Northern Quoll [331]	Endangered	Species or species habitat may occur within area

Listed Migratory Species		[Resource Information]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba		
Great Egret, White Egret [59541]		Species or species habitat may occur within area
Ardea ibis		
Cattle Egret [59542]		Species or species habitat may occur within area
Sterna bengalensis		
Lesser Crested Tern [815]		Breeding known to occur within area
Migratory Terrestrial Species		
Haliaeetus leucogaster		
White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Hirundo rustica		
Barn Swallow [662]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Merops ornatus		
Rainbow Bee-eater [670]		Species or species habitat may occur within area
Migratory Wetlands Species		
Ardea alba		
Great Egret, White Egret [59541]		Species or species habitat may occur within area
Ardea ibis		
Cattle Egret [59542]		Species or species habitat may occur within area
Charadrius veredus		
Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Glareola maldivarum		
Oriental Pratincole [840]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba		
Great Egret, White Egret [59541]		Species or species habitat may occur within area
Ardea ibis		
Cattle Egret [59542]		Species or species habitat may occur within area
Charadrius veredus		
Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Glareola maldivarum		
Oriental Pratincole [840]		Species or species habitat may occur within area
Haliaeetus leucogaster		
White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Hirundo rustica		
Barn Swallow [662]		Species or species habitat may occur within area
Merops ornatus		
Rainbow Bee-eater [670]		Species or species habitat may occur within area
Sterna bengalensis		
Lesser Crested Tern [815]		Breeding known to occur within area

Extra Information

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Mammals		
Capra hircus Goat [2]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Prosopis spp. Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area

Coordinates

-21.78561 115.087175,-21.78561 115.067842,-21.74397 115.067545,-21.744267 115.070519,
-21.767764 115.074088,-21.768062 115.085985,-21.78561 115.087175

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Department of Environment, Climate Change and Water, New South Wales
-Department of Sustainability and Environment, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment and Natural Resources, South Australia
-Parks and Wildlife Service NT, NT Dept of Natural Resources, Environment and the Arts
-Environmental and Resource Management, Queensland
-Department of Environment and Conservation, Western Australia
-Department of the Environment, Climate Change, Energy and Water
-Birds Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-SA Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Atherton and Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
-State Forests of NSW
-Geoscience Australia
-CSIRO
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

Department of Sustainability, Environment, Water, Population and Communities
GPO Box 787
Canberra ACT 2601 Australia
+61 2 6274 1111

C

Appendix C Risk Matrix

Option 1 - Discharge to Quick Mud Creek with Residual Saline Stream RSS3

Key Aspects	Theme	Potential Change	Risk Trigger	Regulatory Guidelines	Regulatory Risk	Likely Impacts	Consequence Value	Likelihood of Occurrence	Risk of Impediment	Further Study	Impediment Identitified
Groundwater	Quality	Change Water/sediment quality in pH	Change the baseline pH significantly from the baseline. This changes in PH changes the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The brine pH is comprise bewteen 6 and 7. Sampling on the lcoal water table indicates similar pH	4	3	Low		No
		Change Water/sediment quality in salinity	Change the baseline TDS significantly from the baseline. Changes in salinity change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The brine is approximatley 40 to 50 % less saline than the superifical aquifer or the pool water sampled in Mud Creek	4	3	Low		No
		Change Water/sediment quality in nutrients	Change the baseline nutrients significantly from the baseline. Changes in nutrients change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The quantity of Nutrients sucha as Nitrate is very low	4	3	Low		No
		Change Water/sediment quality in metals	Change the baseline metals significantly from the baseline. Change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The groundwater table along the creek is showing under baseline conditions high concentrations of metal.	4	3	Low		No
		RadioNuclides Accumulation	The water might becoming a radioacitve concentrate over the years	Worlwide guidelines	Unacceptable	Not identified as an issue as the concentration is lower than the USA guidelines for environement discharge. However the concentration may be harmful over a couple of years if the creek is not flushed out by major floods.	3	3	High		Yes
		Strontium	The strontium (stable isotope) might accumulate significantly in the soil/water and contaminate the local vegetation and fauna. The trigger is clearly defined worldwide.	EPA USA	Unacceptable	Not identified as an issue as the concentration is lower than the USA guidelines for environement discharge.	4	3	Low		
		Plume contamination reaching drinkable resources	Modify significantly the composition of the drinking water	Drinkable Water Guidelines	Unacceptable	Not applicable as the superfical aquifer is not a drinkable aquifer and is most unlikely to be one the future	3	5	Low		No
Surface Water	Hydrology	Increased Flood Frequency and Increased Flood damage	Significant increase of Onslow Salt Flood Risk for about 0.2m	State-Wide Policy No 4	infrastructure for about 20 cm based on URS experience	demonstrate the low impact of Flood risk from the Wheatstone access road. The 100 yr event for the Mud	2	5	Low	2D Hydraulic Modelling	No
		Change in Flow Regime affecting the hydroperiods with potential impact on downstream aquatic communiites	Significant change in flow regime for small flood event such as 1:1 year return period.	State-Wide Policy No 4	Unacceptable alteration of dependant biotope downstream of the project or living along the creek	Site visits and aerial picures showing that no biotope are present within the low-floow channel	4	5	Very Low	2D Hydraulic Modelling combined with vegetation survey	No
		Stream Salinisation	Decreased useability of water by contaminating drinkable water	State-Wide Policy No 5	Unaccpetable of contamination of drinkable water	Not applicable as the creek is not a drinkable source and is unlikely to be one the future	3	5	Low	NA	No
	Geomorphology	Sedimentation	Rise the bed level that cause exacerbated downstream flood event by 0.2m	State-Wide Policy No 4	Unacceptable impact on downstream infrastructure for about 20 cm based on URS experience	The deposit of salt a the bottom might exacerbate the flood risk on downstream infratstreucutre. However it is expected dissoultion of salt when a flood come through.	3	3	Low	2D Hydraulic Modelling approach with simulated bed rising scenario	No
		Erosion of Discharge Point	Cause long-term erosion at the outlet		Impact to be mitigated	The outlet would be engineeried to be avoid bed erosion. The strucutre might be implemented dowstream of the Wheatstone Road.	4	4	Low	Engineering Approach	No
		Stream bed erosion	The scouring created by the brine flowpath reaches the water table and the creek becomes a groundwater discharge area.		lowered and impact the nearby vegetation	The slope is egative in the area of interest. Any scouring is expected	4	3	Low	Engineering Approach	No
		Footprint of plume on the surface	Not triggered. The plume is assessed in terms of change in flora, fauna and water resources impact but not just a footprint		Acceptable as long it is not creating harm to the environment	The modelling showned an impact area of 50 heactares and 5 km plume downstream of the discharge point	4	1	High		Yes
	Quality	Change Water/sediment quality in pH	changes in PH change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The brine pH is comprise bewteen 6 and 7. Sampling on the existing pool in contact with brine indicates similar pH	4	2	Very Low		No
		Change Water/sediment quality in salinity	Change the baseline TDS significantly from the baseline. Changes in salinity change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The brine is approximatley 40 to 50 % less saline than the superifical aquifer or the pool water sampled in Mud Creek	4	3	Low		No
		Change Water/sediment quality in nutrients	Change the baseline nutrients significantly from the baseline. Changes in nutrients change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The quantity of Nutrients sucha as Nitrate is very low	4	3	Low		No
		Change Water/sediment quality in metals	Change the baseline metals significantly from the baseline. Change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The groundwater table along the creek is showing under baseline conditions high concentrations of metal.	4	3	Low		No
		Strontium	The strontium (stable isotope) might accumulate significantly in the soil/water and contaminate the local vegetation and fauna. The trigger is clearly defined worldwide.	EPA USA	Unacceptable	Not identified as an issue as the concentration is lower than the USA guidelines for environement discharge.	4	3	Low		
		RadioNuclides Accumulation	The water might becoming a radioacitve concentrate over the years	Worldwide guidelines	Acceptable as long it is not creating harm to the environment	Not identified as an issue as the concentration is lower than the USA guidelines for environement discharge. However the concentration may be harmful over 2 years if the creek is not flushed.	3	3	Medium		Yes
Fauna	Impact on Stygofauna	Hyperperiods modification and change in chemistry of water and sediments reducing quality/quantity of habitat	Singificant loss of fauna habitat	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Significant impacts to stygofauna considered unacceptable	Baseline studies have not recorded significant stygofauna in the area. Discharge to creek not likely to create signficant g/w mounding	4	4	Low	Site specific stygofauna survey	No
	Impact on troglofauna	Hyperperiods modification and change in chemistry of water and sediments reducing quality/quantity of habitat	Singificant loss of fauna habitat	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Significant impacts to troglofauna considered unacceptable	No trogolofauna recorded from baseline studies.	4	5	Very Low	Site specific troglofauna survey	No
	Impact on fauna habitat	Hyperperiods modification and change in chemistry of water and sediments reducing quality/quantity of habitat	Loss of fauna habitat	EPA Action 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Sig. impacts will be unacceptable	Ephermal fauna in Quick Mud Creek is unknown, therefore a conservative approach has been undertaken, and assumed some may exist. Stream chemistry will not significantly change. Increased water flow may have a impact on fauna.	4	3	low	Fauna survey of Quick Mud Creek	No
	EPBC listed species	Hyperperiods modification and change in chemistry of water and sediments reducing quality/quantity of habitat	Degradation of EPBC listed species habitat	EPBC Act 1999	Trigger referal to commonwealth	No EPBC listed species in the area. However, if encountered will trigger referal to EPBC. Until confirmation through baseline survey possibility remains.	3	4	Low	Fauna survey of Quick Mud Creek	No
	Water birds/migratory species	Increased flow of water/change in water/sediment chemistry impacting water birds/migratory species	Distruption of EPBC listed species	EPBC Act 1999	Trigger referal to commonwealth	Baseline studies have not recorded EPBC listed species in the area. Until confirmation through baseline possibility remains of existance of water birds/migratory species. Increased water will trigger change in habitat and potential impact.	3	3	Medium	Fauna survey of Quick Mud Creek	Yes

	Prioirity Ecological Communities Listed by DEC	Change in groundwater levels/chemistry	Loss of fauna habitat	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Sig. impacts will be unacceptable	Baseline studies have indicated a low liklihood for schedule fauna occuring in the Wheatstone area, and a limited listing of priority fauna.	4	4	Low	Fauna survey of Quick Mud Creek	No
	Short Range Endemics	Change in groundwater levels/chemistry impact SRE habitat	Singificant loss of fauna habitat	EPA Action 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Sig. impacts will be unacceptable	Baseline studies have not found SRE's in area	2	5	Low	Fauna survey of Quick Mud Creek	No
Vegetation and Flora	Native vegetation	Change in water levels/chemistry may have adverse impact on native vegetation	Impact on vegetation	Environmental Offsets Position Statement 9. 2006	Unacceptable impact to native vegetation. Offsets for clearance of potentially good to excellent vegetation	There is no baseline information for the vegetation and flora along Quick Mud Creek. Extrapolation from Wheatstone baseline survey suggests vegetation is of significance, but of minor impact due to relatively small amount being impact compared to amount in the area, and the amount left in place upstream.	3	4	low	-Vegetation mapping along Quick Mud Creek - Study into specific effects of increased groundwater on Vegetation	No
	Priority Ecological Flora	Adverse impact on priority ecological fauna	Priority ecological flora present in the impact area	Wildlife Conservation Act 1950	DEC will consider impact to Priority Fauna unacceptable	Wheatstone baseline surveys do not indicate Priority Fauna. Along Quick Mud Creek, however, not all of the Creek has been surveyed.	3	4	low	-Vegetation mapping along Quick Mud Creek	Yes
	Threatened Species EPBC Act	Adverse impact on threatened species	EPBC listed present in impact area	EPBC Act 1999	Referal to commonwealth	No listed flora species known likely to occur in the area. However, no vegetation mapping along Quick Mud Creek	3	4	Low	-Vegetation mapping along Quick Mud Creek	No
	Clearance of native vegetation	Clearance of native vegetation for construction of pipeline	Offsets required for clearance of vegetation	Environmental Offsets Position Statement 9. 2006	Offsets associated with clearance of native vegetation	There is no baseline information for the vegetation and flora along Quick Mud Creek. Extrapolation from Wheatstone baseline survey suggests vegetation is of low conservation value, but condition of good to excellent native vegetation may result in cumulative impact and offsets. Groundwater mounding is unlikely to mound sufficiently to impact vegetation. Offsets may be required for clearance of good to excellent native vegetation. Negiation will be needed with OEPA.	4	3	Low	-Vegetation mapping along Quick Mud Creek	No
Conservation and Heritage	Disruption of heritage areas	G/w mounding impacting heritage areas	Signficant impact on heritage areas	Aboriginal Heritage Act 1972	Unacceptable impact to heritage	No heritage areas indicated in search	5	5	Low	-	NO

Option 2 - Discharge to Quick Mud Creek with Residual Saline Stream RSS4

Key Aspects	Theme	Potential Change	Risk Trigger	Regulatory Guidelines	Regulatory Risk	Likely Impacts	Consequence Value	Likelihood of Occurrence	Risk of Impediment	Further Study	Impediment Identitified
Groundwater	Quality	Change Water/sediment quality in pH	Change the baseline pH significantly from the baseline. This changes in PH change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The brine pH is comprise bewteen 6 and 7. Sampling on the lcoal water table indicates similar pH	4	3	Low		No
		Change Water/sediment quality in salinity	Change the baseline TDS significantly from the baseline. Changes in salinity change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The brine is approximatley 40 to 50 % less saline than the superifical aquifer or the pool water sampled in Mud Creek	4	3	Low		No
		Change Water/sediment quality in nutrients	Change the baseline nutrients significantly from the baseline. Changes in nutrients change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The quantity of Nutrients sucha as Nitrate is very low	4	3	Low		No
		Change Water/sediment quality in metals	Change the baseline metals significantly from the baseline. Change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The groundwater table along the creek is showing under baseline conditions high concentrations of metal.	4	3	Low		No
		RadioNuclides Accumulation	The water might becoming a radioacitve concentrate over the years	USA Guidelines	Unacceptable	Not present in the brine	6	1	High		No
		Plume contamination reaching drinkable resources	Modify significantly the composition of the drinking water	Drinkable Water Guidelines	Unacceptable	Not applicable as the superfical aquifer is not a drinkable aquifer and is most unlikely to be one the future	3	5	Low		No
Surface Water	Hydrology	Increased Flood Frequency and Increased Flood damage	Significant increase of Onslow Salt Flood Risk for about 0.2m	State-Wide Policy No 4	Unacceptable impact on downstream infrastructure for about 20 cm based on URS experience	Hydraulic Modeling have been achieved by URS In 2010 to demonstrate the low impact of Flood risk from the Wheatstone access road. The 100 yr event for the Mud Creek is estimated up to 1400 m3/s. Therefore the brine flow rate of 0.018 m3/s is unlikely to affect flood regime for extreme event.	2	5	Low	2D Hydraulic Modelling	No
		Change in Flow Regime affecting the hydroperiods with potential impact on downstream aquatic communiites	Significant change in flow regime for small flood event such as 1:1 year return period.	State-Wide Policy No 4	Unacceptable alteration of dependant biotope downstream of the project or living along the creek	Site visits and aerial picures showing that no biotope are present within the low-floow channel	4	5	Very Low	2D Hydraulic Modelling combined with vegetation survey	No
		Stream Salinisation	Decreased useability of water by contaminating drinkable water	State-Wide Policy No 5	Unaccpetable of contamination of drinkable water	Not applicable as the creek is not a drinkable source and is most unlikely to be one the future	3	5	Low	NA	No
	Geomorphology	Sedimentation	Rise the bed level that cause exacerbated downstream flood event by 0.2m	State-Wide Policy No 4	Unacceptable impact on downstream infrastructure for about 20 cm based on URS experience	The deposit of salt a the bottom might exacerbate the flood risk on downstream infratstreucutre. However it is expected dissoultion of salt when a flood come through.	3	3	Low	2D Hydraulic Modelling approach with simulated bed rising scenario	No
		Erosion of Discharge Point	Cause long-term erosion at the outlet		Impact to be mitigated	The outlet would be engineeried to be avoid bed erosion. The strucutre might be implemented dowstream of the Wheatstone Road.	4	4	Low	Engineering Approach	No
		Stream bed erosion	The scouring created by the brine flowpath reaches the water table and the creek becomes a groundwater discharge area.		Unacceptable if the water table is lowered and impact the nearby vegetation	The slope is egative in the area of interest. Any scouring is expected	4	3	Low	Engineering Approach	No
		Footprint of plume on the surface	Not triggered. The plume is assessed in terms of change in flora, fauna and water resources impact but not just a footprint		Acceptable as long it is not creating harm to the environment	The modelling showned an impact area of 50 heactares and 5 km plume downstream of the discharge point	4	1	High		Yes
	Quality	Change Water/sediment quality in pH	Change the baseline pH significantly from the baseline. This changes in PH change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The brine pH is comprise bewteen 6 and 7. Sampling on the existing pool in contact with brine indicates similar pH	4	2	Very Low		No
		Change Water/sediment quality in salinity	Change the baseline TDS significantly from the baseline. Changes in salinity change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The brine is approximatley 40 to 50 % less saline than the superifical aquifer or the pool water sampled in Mud Creek	4	3	Low		No
		Change Water/sediment quality in nutrients	Change the baseline nutrients significantly from the baseline. Changes in nutrients change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The quantity of Nutrients sucha as Nitrate is very low	4	3	Low		No
		Change Water/sediment quality in metals	Change the baseline metals significantly from the baseline. Change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The groundwater table along the creek is showing under baseline conditions high concentrations of metal.	4	3	Low		No
		RadioNuclides Accumulation	The water might becoming a radioacitve concentrate over the years	USA Guidelines	Acceptable as long it is not creating harm to the environment	Not present in the brine	6	1	Very Low		No
Fauna	Impact on Stygofauna	Hyperperiods modification and change in chemistry of water and sediments reducing quality/quantity of habitat	Singificant loss of fauna habitat	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Unacceptable impact to stygofauna	Baseline studies have not recorded significant stygofauna in the area. Discharge to creek not likely to create signficant g/w mounding	4	4	Low	Site specific stygofauna survey	No
	Impact on troglofauna	Hyperperiods modification and change in chemistry of water and sediments reducing quality/quantity of habitat	Singificant loss of fauna habitat	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Unacceptable impact to troglofauna	No trogolofauna recorded from baseline studies	4	5	Very Low	Site specific troglofauna survey	No
	Impact on fauna habitat	Hyperperiods modification and change in chemistry of water and sediments reducing quality/quantity of habitat	Loss of fauna habitat	EPA Action 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Sig. impacts will be unacceptable	No significant fauna habitats in the area. Stream chemistry will not significantly change. Increased water flow may not have a significant impact on fauna growth	5	2	Low	Fauna survey of Quick Mud Creek	No
	EPBC listed species	Hyperperiods modification and change in chemistry of water and sediments reducing quality/quantity of habitat	Degradation of EPBC listed species habitat	EPBC Act 1999	Trigger referal to commonwealth	No EPBC listed species in the area. However, if encountered will trigger referal to EPBC.	3	4	Low	Fauna survey of Quick Mud Creek	Yes
	Claypan fauna	Hyperperiods modification and change in chemistry of water and sediments reducing quality/quantity of habitat	Significant loss of claypan fauna	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Unacceptable impact to clayplan fauna	Claypans may exist downstream of Quick Mud Creek. Claypans surveyed as part of Wheatstone baseline showed reduced risk of specieis isolation to individual claypans within the project area.	5	4	Very low	Fauna survey of Quick Mud Creek	No
	Water birds/migratory species	Increased flow of water/change in water/sediment chemistry impacting water birds/migratory species	Distruption of EPBC listed species	EPBC Act 1999	Trigger referal to commonwealth	Baseline studies have not recorded EPBC listed species in the area. Until confirmation through baseline possibility remains of existance of water birds/migratory species. Increased water will trigger change in habitat and potential impact.	3	3	Medium	Fauna survey of Quick Mud Creek	Yes

	Prioirity Ecological Communities Listed by DEC	Hyperperiods modification and change in chemistry of water and sediments reducing quality/quantity of habitat	Loss of fauna habitat	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Sig. impacts will be unacceptable	Baseline studies have indicated a low liklihood fo schedule fauna occuring in the Wheatstone area, and a limited listing of priority fauna	4	3	Low	Fauna survey of Quick Mud Creek	No
	Short Range Endemics	Hyperperiods modification and change in chemistry of water and sediments reducing quality/quantity of habitat	Singificant loss of fauna habitat	EPA Action 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Sig. impacts will be unacceptable	Baseline studies have not found SRE's in area	2	5	Low	Fauna survey of Quick Mud Creek	No
Vegetation and Flora	Native vegetation	Change in water levels/chemistry may have adverse impact on 40 ha of native vegetation	Impact on vegetation	Environmental Offsets Position Statement 9. 2006	Unacceptable impact to native vegetation. Offsets for clearance of potentially good to excellent vegetation	There is no baseline information for the vegetation and flora along Quick Mud Creek. Extrapolation from Wheatstone baseline survey suggests vegetation is of significance, but of minor impact due to relatively small amount being impact compared to amount in the area, and the amount left in place upstream.	3	4	Low	-Vegetation mapping along Quick Mud Creek - Study into specific effects of increased groundwater on Vegetation	No
	Priority Ecological Flora	Adverse impact on priority ecological fauna	Priority ecological flora present in the impact area	Wildlife Conservation Act 1950	DEC will consider impact to Priority Fauna unacceptable	Wheatstone baseline surveys do not indicate Priority Fauna. Along Quick Mud Creek, however, not all of the Creek has been surveyed.	3	4	Low	Vegetation mapping along Quick Mud Creek	No
	Threatened Species EPBC Act	Adverse impact on threatened species	EPBC listed present in impact area	EPBC Act 1999	Referal to commonwealth	No listed flora species known from or likely to occur in the area. However, no vegetation mapping along Quick Mud Creek	3	4	Low	Vegetation mapping along Quick Mud Creek	No
	Clearance of native vegetation	Clearance of native vegetation for construction of pipeline	Offsets required for clearance of vegetation	Environmental Offsets Position Statement 9. 2006	Costs associated with clearance of native vegetation	Offsets may be required for clearance of good to excellent native vegetation. Negiation will be needed with OEPA.	4	3	Low	Vegetation mapping along Quick Mud Creek	No
Conservation and Heritage	Disruption of heritage areas	G/w mounding impacting heritage areas	Signficant impact on heritage areas	Aboriginal Heritage Act 1972	Unacceptable impact to heritage	No heritage areas indicated in search	5	5	Low		

Option 3 - Discharge by Injection into Trealla Limestone

Key Aspects	Theme	Potential Change	Risk Trigger	Regulatory Guidelines	Regulatory Risk	Likely Impact	Consequence Value	Likelihood of Occurrence	Risk of Impediment	Further Study	Impediment Identitified
Surface Water	Hydrology	Increased Flood Frequency and Increased Flood damage	Significant increase of Onslow Salt Flood Risk for about 0.2m	State-Wide Policy No 4	Unacceptable impact on downstream infrastructure for about 20 cm based on URS experience	Modflow Numerical Model showned that the mounding reaching the ground surface would be converted into Evaporation	4	5	Very Low	2D Hydraulic Modelling	No
		Change in Flow Regime affecting the hydroperiods with potential impact on downstream aquatic communiites	Significant change in flow regime for small flood event such as 1:1 year return period.	State-Wide Policy No 4	Unacceptable alteration of dependant biotope downstream of the project or living along the creek	Modflow Numerical Model showned that the mounding reaching the ground surface would be converted into Evaporation	4	5	Very Low	2D Hydraulic Modelling combined with vegetation survey	No
Groundwater	Quality	Change Water/sediment quality in pH	Change the baseline pH significantly from the baseline. This changes in PH change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The brine pH comprises bewteen 6 and 7. Sampling on the lcoal water table indicates similar pH	4	3	Low		No
		Change Water/sediment quality in salinity	Change the baseline TDS significantly from the baseline. Changes in salinity change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The brine is approximatley 40 to 50 % less saline than the superifical aquifer or the pool water sampled in Mud Creek	4	3	Low		No
		Change Water/sediment quality in nutrients	Change the baseline nutrients significantly from the baseline. Changes in nutrients change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The quantity of Nutrients sucha as Nitrate is very low	4	3	Low		No
		Change Water/sediment quality in metals	Change the baseline metals significantly from the baseline. Change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The groundwater table along the creek is showing under baseline conditions high concentrations of metal.	4	3	Low		No
		RadioNuclides Accumulation	The water might becoming a radioacitve concentrate over the years	USA Guidelines	Unacceptable	Not present in the brine	3	3	Low		Yes
		Plume contamination reaching drinkable resources	Modify significantly the composition of the drinking water	Drinkable Water Guidelines	Unacceptable	Not applicable as the Trealla aquifer is not a drinkable aquifer and is most unlikely to be one in the future	4	5	Very Low		No
	Quantity	Increase of Water table increasing the flood risk on downstream infrastructure	Rise the bed level that cause exacerbated downstream flood event by 0.2m	State-Wide Policy No 4	Unacceptable	The expected water table would not be above the ground level	3	4	Low		No
Fauna	Impact on Stygofauna	Change in groundwater levels/chemistry	Singificant loss of fauna habitat	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Unacceptable impact to stygofauna	Baseline studies have not recorded significant stygofauna in the area. G/w injection will likely create g/w mounding to surface removing all of stygofauna habitat	5	4	Low		No
	Impact on troglofauna	Change in groundwater levels/chemistry	Singificant loss of fauna habitat	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Unacceptable impact to troglofauna	No trogolofauna recorded from baseline studies.	5	5	Very Low		No
	Impact on fauna habitat	Groundwater mounding and change in chemistry of water and sediments reducing quality/quality of habitat	Loss of fauna habitat	EPA Action 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Significant impacts will be unacceptable	G/w injection will likely create g/w mounding to surface which is likely to have an adverse effect on vegetation	4	1	High		Yes
	EPBC listed species	Increased water flow and change in chemistry of water and sediments reducing quality/qunaity of habitat	Degradation of EPBC listed species habitat	EPBC Act 1999	Trigger referal to commonwealth	G/w injection will likely create g/w mounding to surface which is likely to have an adverse effect on vegetation	4	3	Low	Fauna survey of impacted area	No
	Claypan fauna	Increased water flow and change in chemistry of water and sediments reducing quality/quantity of habitat	Significant loss of claypan fauna	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Unacceptable impact to clayplan fauna	Groundwater mounding likely to innudate claypans.	5	2	Medium	Fauna survey of impacted area	Yes
	Water birds/migratory species	Increased flow of water/change in water/sediment chemistry impacting water birds/migratory species	Distruption of EPBC listed species	EPBC Act 1999	Trigger referal to commonwealth	Loss of habitat may impact migratory species.	4	4	Low	Fauna survey of impacted area	No
	Prioirity Ecological Communities Listed by DEC	Change in groundwater levels/chemistry	Loss of fauna habitat	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Significant impacts will be unacceptable	Baseline studies have indicated a low liklihood for schedule fauna occuring in the Wheatstone area, and a limited listing of priority fauna	4	3	Low	Fauna survey of impacted area	No
	Short Range Endemics	Change in groundwater levels/chemistry impact SRE habitat	Singificant loss of fauna habitat	EPA Action 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Significant impacts will be unacceptable	Baseline studies have not found SRE's in area	2	5	Low	Fauna survey of impacted area	No

Vegetation and Flora	Native vegetation	Change in water levels/chemistry may have adverse impact on 2,560 ha of native vegetation	Significant impact on vegetation	Environmental Offsets Position Statement 9. 2006	Unacceptable impact to significant native vegetation. Offsets for clearance of potentially good to excellent vegetation	Large area of native vegetation likely to be impacted by g/w mounding. However, of minor impact due to relatively small amount being impact compared to amount in the area and vegetation assemblages well represented in thearea. Possibility EPA may require offsets for impacts on vegetation of good to excellent condition.	2	2	Extreme	Flora survey of impacted area	Yes
	Priority Ecological Flora	Adverse impact on priority ecological flora	Priority ecological flora present in the impact area	Wildlife Conservation Act 1950	DEC will consider impact to Priority Fauna unacceptable	Baseline studies have shown priority flora in g/w mounding area, likely to be impacted.	3	4	Low	Flora survey of impacted area	No
	Threatened Species EPBC Act	Adverse impact on threatened species	EPBC listed present in impact area	EPBC Act 1999	Referal to commonwealth	No listed flora species known from or likely to occur in the area.	4	4	Low	Flora survey of impacted area	No
	Clearance of native vegetation	Clearance of native vegetation for borehole injection area	Offsets required for clearance of vegetation	Environmental Offsets Position Statement 9. 2006	Costs associated with offset for clearance of native vegetation	Limited clearance of native vegetation required. Possibility EPA may require offsets for removal of vegetation of good to excellent condition.	3	4	Low	Flora survey of impacted area	No
Conservation and Heritage	Disruption of heritage areas	G/w mounding impacting heritage areas	Signficant impact on heritage areas	Aboriginal Heritage Act 1972	Unacceptable impact to heritage	No heritage areas indicated in search	5	5	Low		No

Option 4 - Disposal by Infiltration Basin

Key Aspects	Theme	Potential Change	Risk Trigger	Regulatory Guidelines	Regulatory Risk	Likely Impact	Consequence Value	Likelihood of Occurrence	Risk of Impediment	Further Study	Impediment Identitified
Groundwater	Quality	Change Water/sediment quality in pH	Change the baseline pH significantly from the baseline. This changes in PH change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The brine pH is comprise bewteen 6 and 7. Sampling on the lcoal water table indicates similar pH	4	3	Low		No
		Change Water/sediment quality in salinity	Change the baseline TDS significantly from the baseline. Changes in salinity change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The brine is approximatley 40 to 50 % less saline than the superifical aquifer or the pool water sampled in Mud Creek	4	3	Low		No
		Change Water/sediment quality in nutrients	Change the baseline nutrients significantly from the baseline. Changes in nutrients change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The quantity of Nutrients sucha as Nitrate is very low	4	3	Low		No
		Change Water/sediment quality in metals	Change the baseline metals significantly from the baseline. Change the condition of mineral precipitation that may harm the environment	ANZEEC/ARMCANZ 2000	Acceptable as long it is not creating harm to the environment	The groundwater table along the creek is showing under baseline conditions high concentrations of metal.	4	3	Low		No
		RadioNuclides Accumulation	The water might becoming a radioacitve concentrate over the years	USA Guidelines	Unacceptable	Not present in the brine	3	3	Very Low		No
		Plume contamination reaching drinkable resources	Modify significantly the composition of the drinking water	Drinkable Water Guidelines	Unacceptable	Not applicable as the Trealla aquifer is not a drinkable aquifer and is most unlikely to be one in the future	4	5	Very Low		No
	Quantity	Increase of Water table increasing the flood risk on downstream infrastructure	Rise the bed level that cause exacerbated downstream flood event by 0.2m	State-Wide Policy No 4	Unacceptable	The expected water table would not be above the ground level	3	4	Low		No
Surface Water	`Hydrology	Increased Flood Frequency and Increased Flood damage	Significant increase of Onslow Salt Flood Risk for about 0.2m	State-Wide Policy No 4	Unacceptable impact on downstream infrastructure for about 20 cm based on URS experience	Modflow Numerical Model showned that the mounding reaching the ground surface would be converted into Evaporation	4	5	Very Low	2D Hydraulic Modelling	No
		Change in Flow Regime affecting the hydroperiods with potential impact on downstream aquatic communiites	Significant change in flow regime for small flood event such as 1:1 year return period.	State-Wide Policy No 4	Unacceptable alteration of dependant biotope downstream of the project or living along the creek	Modflow Numerical Model showned that the mounding reaching the ground surface would be converted into Evaporation	4	5	Very Low	2D Hydraulic Modelling combined with vegetation	No
Fauna	Impact on Stygofauna	Change in groundwater levels/chemistry	Singificant loss of fauna habitat	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Unacceptable impact to stygofauna	Baseline studies have not recorded significant stygofauna in the area. Infiltration will likely create g/w mounding to surface removing all of stygofauna habitat	5	4	Low	Fauna survey of impacted area	No
	Impact on troglofauna	Change in groundwater levels/chemistry	Singificant loss of fauna habitat	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Unacceptable impact to troglofauna	No trogolofauna recorded from baseline studies.	5	5	Very Low	Fauna survey of impacted area	No
	Impact on fauna habitat	Groundwater mounding and change in chemistry of water and sediments reducing quality/qunaity of habitat	Loss of fauna habitat	EPA Action 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Sig. impacts will be unacceptable	Infiltration will likely create g/w mounding to surface which is likely to have an adverse effect on vegetation	4	1	High	Fauna survey of impacted area	Yes
	EPBC listed species	Increased water flow and change in chemistry of water and sediments reducing quality/qunaity of habitat	Degradation of EPBC listed species habitat	EPBC Act 1999	Trigger referal to commonwealth	Infiltration will likely create g/w mounding to surface which is likely to have an adverse effect on vegetation	4	3	Low	Fauna survey of impacted area	No
	Claypan fauna	Increased water flow and change in chemistry of water and sediments reducing quality/quantity of habitat	Significant loss of claypan fauna	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Unacceptable impact to clayplan fauna	Groundwater mounding likely to innudate claypans.	5	2	Medium	Fauna survey of impacted area	Yes
	Water birds/migratory species	Increased flow of water/change in water/sediment chemistry impacting water birds/migratory species	Distruption of EPBC listed species	EPBC Act 1999	Trigger referal to commonwealth	Loss of habitat may impact migratory species.	4	4	Low	Fauna survey of impacted area	No
	Prioirity Ecological Communities Listed by DEC	Change in groundwater levels/chemistry	Loss of fauna habitat	EPA Act 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Sig. impacts will be unacceptable	Baseline studies have indicated a low liklihood fo schedule fauna occuring in the Wheatstone area, and a limited listing of priority fauna	4	3	Low	Fauna survey of impacted area	No
	Short Range Endemics	Change in groundwater levels/chemistry impact SRE habitat	Singificant loss of fauna habitat	EPA Action 1986 Wildlife Conservation Act 1950 EPA Guidance Statement No. 33 (2008)	Sig. impacts will be unacceptable	Baseline studies have not found SRE's in area	2	5	Low	Fauna survey of impacted area	No
Vegetation and Flora	Native vegetation	Change in water levels/chemistry may have adverse impact on 2581 ha of native vegetation	Significant impact on vegetation	Environmental Offsets Position Statement 9. 2006	Unacceptable impact to native vegetation. Offsets for clearance of potentially good to excellent vegetation	Large area of native vegetation likely to be impacted by g/w mounding. However, of minor impact due to relatively small amount being impact compared to amount in the area and vegetation assemblages well represented in theare. Possibility EPA may require offsets for impacts on vegetation of good to excellent condition.	3	2	High	Flora survey of impacted area	Yes
	Priority Ecological Flora	Adverse impact on priority ecological flora	Priority ecological flora present in the impact area	Wildlife Conservation Act 1950	DEC will consider impact to Priority Fauna unacceptable	Baseline studies have shown priority flora in g/w mounding area, likely to be impacted.	3	3	Medium	Flora survey of impacted area	Yes
	Threatened Species EPBC Act	Adverse impact on threatened species	EPBC listed present in impact area	EPBC Act 1999	Referal to commonwealth	No listed flora species known from or likely to occur in the area.	3	4	Low	Flora survey of impacted area	No
	Clearance of native vegetation	Clearance of native vegetation for borehole injection area	Offsets required for clearance of vegetation	Environmental Offsets Position Statement 9. 2006	Costs associated with offset for clearance of native vegetation	Limited clearance of native vegetation required. Possibility EPA may require offsets for removal of vegetation of good to excellent condition.	3	4	Low	Flora survey of impacted area	No
Conservation and Heritage	Disruption of heritage areas	G/w mounding impacting heritage areas	Signficant impact on heritage areas	Aboriginal Heritage Act 1972	Unacceptable impact to heritage	No heritage areas indicated in search	5	5	Low		No

URS Australia Pty Ltd
Level 4, 226 Adelaide TerracePerth WA 6000PO Box 6004, East Perth 6892AustraliaT: 61 8 9326 0100F: 61 8 9326 0296

www.ap.urscorp.com