FINAL REPORT

GLNG Environmental Impact Statement – Shallow Groundwater

Prepared for

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Glossary, Abbreviations and Acronyms

Abstraction	The removal of water from a resource e.g. the pumping of groundwater from an aquifer Interchangeable with extraction
Aerobic	A process taking place in the presence of oxygen
Alluvial or alluvium	
aquifer	An aquifer formed of unconsolidated material deposited by water, typically occurring adjacent to river channels and in buried or palaeochannels
Alluvium	A general term for unconsolidated deposits of inorganic materials (clay, silt, sand, gravel, boulders) deposited by flowing water
Anaerobic	A process taking place in the absence of oxygen
Anisotropic	Having some physical property that varies with direction
Aquatic	Associated with and dependant on water e.g. aquatic vegetation
Aquatic Ecosystems	The abiotic (physical and chemical) and biotic components, habitats and ecological processes contained within rivers and their riparian zones and reservoirs, lakes, wetlands and their fringing vegetation
Aquiclude	A bed, formation or group of formations essentially impervious to water
Aquifer	An aquifer is defined as a saturated permeable geological unit that is permeable enough to yield economic quantities of water to boreholes
Aquifer system	A heterogeneous body of intercalated permeable and less permeable material that acts as a water-yielding hydraulic unit of regional extent
Aquifer testing	The process whereby an aquifer is subjected to pumping from a borehole under controlled test conditions in order to determine the hydraulic parameters of the groundwater system through its response to stress of abstraction
Aquitard	A saturated geological unit with a relatively low permeability that retards and restricts the movement of water, but does not prevent the movement of water; while it may not readily yield water to boreholes and springs, it may act as a storage unit
Artesian aquifer	A confined aquifer with the piezometeric level above ground level
Artesian bore	Commonly used to describe a flowing borehole, where the piezometeric level is at an elevation higher than ground level
Attenuation	The breakdown or dilution of contaminated water as it passes through the earth's material
Available drawdown	The height of water above the depth at which the pump is set in a borehole at the time of water level measurement (m)
Bank storage	Water that percolates laterally from a river in flood into the adjacent geological material, some of which may flow back into the river during low-flow conditions
Baseflow	This is the amount of groundwater flowing into a river

Glossary, Abbreviations and Acronyms

Blow yield	The volume of water per unit of time blown from the borehole during drilling (l/s)
Boil-off gas	The LNG vapours that are produced as a result of heat input and pressure variations that occur within various LNG stages. Boil-off gas is often recovered for power generation within the LNG facilities
Bores	Includes a well, excavation, or any other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer. Interchangeable with boreholes, wells, piezometers
Borehole testing	The process whereby a borehole is subjected to pumping under controlled test conditions in order to determine the performance characteristics of a borehole as well as the aquifer hydraulic parameters
Brackish	Water that contains between 1,000 and 10,000 mg/l of dissolved solids
Brine	Water that contains more than 35,000 mg/l of dissolved solids
Carbonaceous	The defining attribute of a substance rich in carbon
Catchment	The area from which any rainfall will drain into the watercourse, contributing to the runoff at a particular point in a river system; synonymous with the term river basin
Cone of depression	The shape of the cone with convex upward, of the piezometeric groundwater surface which defines the area of influence of a borehole
Confined aquifer	An aquifer overlain by a confining layer of significantly lower hydraulic conductivity in which groundwater is under greater pressure than that of the atmosphere; the aquifer is bounded above and below by an aquiclude
Confining layer	A layer of low permeability material overlying an aquifer, which restricts the vertical movement of water
Conjunctive use	Combined use of surface and groundwater
Conservative	
Pollutants	Pollutants which move readily through the aquifer with little reaction with the rock matrix and which are unaffected by biodegradation
Contamination	The introduction of any substance into the environment by the action of man
Coquinite	Consolidated shell debris, mineral conglomerate
Cuestas	Ridges with a steep face on one side and a gentle slope on the other
Degradable	
Pollutants	Pollutants which readily breakdown
Discharge area	An area in which subsurface water, included water in the unsaturated and saturated zones, is discharged at the land surface

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Discharge rate	The volume of water per unit of time abstracted from a borehole (l/s)
Disconnected stream	A stream detached from and not in hydrological contact with the groundwater system below, a special case of an influent stream; also referred to as a detached stream
Dissolved solids	Minerals and organic matter dissolved in water
Drawdown	When pumping a borehole the water level drops from the rest water level and this is called the drawdown
Ecosystem	An organic community of plants, animals and bacteria and the physical and chemical environment they inhabit
Epeirogenic	The slow movements of the Earth's crust leading to the formation of features
Effective storage	The volume of groundwater an aquifer takes in and releases is limited by the storage capacity. Aquifers may be regularly recharged but have insufficient storage to contain the recharge thus seasonal seeps are formed and the aquifer is incapable of storing groundwater volumes over extended dry periods
Ephemeral river	These rivers are generally storm-event driven and flow occurs less that 20% of the time; these rivers have limited baseflow component with no groundwater discharge
Fault	A zone of displacement in rock formations resulting from forces of tension or compression in the earth’s crust
Fitness for use	Water quality is such that it meets the requirements for a particular use; domestic, agricultural, industrial, recreational, or environmental
Flow regime	Recorded or historical sequence of flows used to create a hydrological profile of a water resource
Fluvial	Relating to or arising from the action of flowing water in a river
Flux	Rate of groundwater flow per unit width of aquifer
Formation	A general term used to describe a sequence of rock layers
Fracture	Any break in a rock including cracks, joints, and faults
Fractured rock aquifer	An aquifer that owes its water-bearing properties to fracturing caused by folding and faulting
Fresh water	Water that contains less than 1,000 mg/l salts
Groundwater	Water found in the subsurface in the saturated zone below the water table or piezometeric surface i.e. the water table marks the upper surface of groundwater systems
Groundwater flow	The movement of water through openings and pore spaces in rocks below the water table i.e. in the saturated zone
Groundwater	

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resource	All groundwater available for beneficial use, including man, aquatic ecosystems and greater environment
Heavy metals	Those elements with atomic numbers greater than 36 in Group III through V of the periodic table
Heterogeneity	Heterogeneity means that a certain rock type differs everywhere
Heterogeneous	Refers to materials having different properties at different points; diverse in character or content; in reality, all aquifers are heterogeneous, although homogeneity is assumed to simply their analysis
Homogeneous	A characteristic of the geological unit in which hydraulic conductivity is independent of position or direction; opposite of heterogeneous
Hydraulic	
conductivity	Measure of the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/day)
Hydraulic gradient	This is the change in the hydraulic head over a certain distance
Hydraulic head	Elevation to which water will rise in a borehole connected to a point in an aquifer
Hydrology	The study of the properties, circulation and distribution of water
Infiltration	The downward movement of water from the atmosphere into the ground; not to confused with percolation
Intergranular flow	Flow that occurs between individual grains of rock
Interstices	Openings or void space in a rock capable of holding water
Isotropic	The condition of having properties that are uniform in all directions, opposite of anisotropic
Labile	Constantly undergoing or likely to undergo change; unstable
Lithic	Relating to or composed of stone
Lithology	The physical character of rocks
Major aquifer	Highly permeable formations, usually with a known or probable presence of significant fracturing, may be highly productive and able to support large abstractions for public supply and other purposes; water quality is generally very good
Minor aquifer	Fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability; aquifer extent may be limited and water quality variable
Non aquifer	Formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Groundwater bodies, which are essentially

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	impermeable, do not readily transmit water and/or have a water quality which renders it unfit for use
Nutrients	Substances that help living things grow, e.g. nitrogen, phosphate, potassium
Oxidation	The addition of oxygen to a compound; entails the loss of an electron
Palaeochannel	A buried stream channel
Paludal	Relating to or living in swamps or marshes
Perched aquifer	Aquifers that contain perched groundwater i.e. bodies of groundwater separated from an underlying body of groundwater by an unsaturated zone
Percolation	The process of the downward movement of water in the unsaturated zone under the influence of gravity and hydraulic forces; term used to differentiae from infiltration, which specially refers to the movement of water from the atmosphere into the ground
Permeability	The ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time (m/day)
Permeable	Materials that allow liquids to flow through it
pH	Absolute value of the decimal logarithm of the hydrogen-ion concentration (activity). Used as an indicator of acidity (pH < 7) or alkalinity (pH > 7)
Piezometeric level	The elevation to which groundwater levels rise in boreholes that penetrate confined or semi-confined aquifers
Piezometeric surface	An imaginary surface representing the piezometeric pressure or hydraulic head throughout all or part of a confined or semi-confined aquifer
Pollution	The introduction into the environment of any substance by the action of man, which is or results in significant harmful effects to man or the environment
Pollution plume	Area of degraded water in a stream or aquifer resulting from migration of a pollutant
Porosity	The porosity of a water-bearing formation is determined by that part of its volume consisting of openings or pores
Potable water	Water that is safe and palatable for human use
Preferential flow	The preferential movement of groundwater through more permeable zones in the subsurface
Primary aquifer	An aquifer in which water moves through the original interstices of the geological formation
Quartzose	Containing, or resembling, quartz; partaking of the nature or qualities of quartz
Recharge	Recharge is defined as the process by which water is added from outside to the zone of saturation of an aquifer, either directly into a formation, or indirectly by way of another formation

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Regolith	The mantle of fragmented or loose material of residual or transported origin, comprising rock debris, alluvium, aeolian deposits, and in situ weathered and decomposed rock and typically overlies bedrock; it includes soil
Rehabilitation	To restore to former condition or status
Remediation	To restore to health, requires that impact is reduced to some acceptable level
Resource	The quality of all aspects of a water resource including (a) the quality, pattern, timing, water level and assurance of instream flow, (b) the water quality, including the physical, chemical and biological characteristics of water, (c) the characteristic and condition of the instream and riparian habitat; and (d) the characteristics, condition and distribution of aquatic biota
Rest water level	The groundwater level in a borehole not influenced by abstraction; synonymous with static water level, but no groundwater levels are ever truly static as they continually respond to recharge, discharge and abstraction
River	A physical channel in which runoff will flow; generally larger than a stream, but often used interchangeably
Runoff	All surface and subsurface flow from a catchment, but in practice refers to the flow in a river i.e. excludes groundwater not discharged into a river
Safe Yield	Amount of water that can be withdrawn from an aquifer without producing an undesired effect like water level reaching the position of the main water yielding fracture
Saline water	Water that is generally considered unsuitable for human consumption or for irrigation because of its high content of dissolved solids
Sanitation	The treatment and disposal of waste from the human body and grey water generated through household activity
Saturated zone	The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere
Seasonal river	These rivers are driven by seasonal rainfall patterns and flow occurs between 20 % and 80 % of the time; these rivers have a limited baseflow component with little or no groundwater discharge
Secondary aquifer	An aquifer in which water moves through secondary openings and interstices, which developed after the rocks were formed i.e. weathering, fracturing, faulting
Secondary interstices	Openings in the rock that were developed by processes that affected the rocks after they were formed
Sediment	Particles derived from rocks or biological material that have been transported by air or water
Seep	A diffuse wetland area where interflow and groundwater emerges, usually at a slow rate or small volume, to become surface flow

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Semi confined aquifer	An aquifer that is partly confined by layers of lower permeability material through which recharge and discharge may occur, also referred to as a leaky aquifer
Sole source aquifer	An aquifer which is needed to supply 50% or more of the domestic water for a given area, and for which there are no reasonably available alternative water sources should the aquifer be impacted upon or depleted
Specific capacity	The rate of discharge of water well per unit of drawdown, usually expressed as m^3/d/m
Specific yield	Ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity from that mass
Spring	A point where groundwater emerges, usually as a result of topographical, lithological or structural controls
Static water level	Rest water level
Storage coefficient	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head
Storativity	Storage can be defined as the volume of water that a saturated confined aquifer releases from storage per unit surface area of the aquifer per unit decline in the water table. Quantifies the aquifers ability to release water
Surface runoff	The part of the total runoff that travels over the ground surface to reach a stream or river channel
Sustainable yield	Safe amount of water that can be abstracted from a borehole over a long period of time (usually 1 or 2 years) without the water level reaching the position of the pump or main water strike
TDS	Concentration of dissolved salts
Through flow	The movement of water horizontally beneath the land surface. It occurs once water has infiltrated the soil; the water moves downwards under gravity and because the soil becomes more compact and less permeable with increasing depth, water will begin to move sideways at speeds of between 0.005 to 0.3 m/h. It usually happens when the soil is completely saturated with water
Transmissivity	Transmissivity can be defined as the rate at which water is transferred through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the hydraulic conductivity and the thickness of the saturated portion of an aquifer. Transmissivity is the rate at which water moves through the aquifer
Tremie pipe	A narrow diameter pipe, which keeps the sealing materials from becoming bridged inside the well casing and prevents dissolution of liquid grout
Unconfined aquifer	An aquifer with no confining layer between the water table and the ground surface where the water table is free to fluctuate
Unsaturated zone	The part of the geological stratum above the water table where interstices and voids contain a combination of air and water; synonymous with zone of aeration or vadose zone

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Vadose zone	Same as unsaturated zone
Vulnerability	The tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer
Water table	Surface within the zone of saturation of an unconfined aquifer over which the pressure is atmospheric
Well field	A group of boreholes in a particular area usually used for groundwater abstraction purposes
Well point	Shallow, small diameter hole used to abstract groundwater from primary aquifers
Yield	The quantity of water removed from a water resource e.g. yield of a borehole

ADWG	Australian drinking water guidelines
APHA	American Public Health Association
APPEA	Australian Petroleum Production & Exploration Association Limited
BTEX	Benzene, toluene, ethylbenzene, xylene
CSG	Coal seam gas or coalbed methane
DNRW	Department of Natural Resources and Water
EIS	Environmental impacts statement
EMP	Environmental management plan
EPA	Queensland Environmental Protection Agency
EPP Water	Environmental Protection (Water) Policy and the Environmental Protection (Water) Amendment Policy (No.1) 2008
GAB	Great Artesian Basin
GLNG	Gladstone Liquefied Natural Gas project
HDD	Horizontal directional drilling
km	Kilometre
LNAPL	Light non-aqueous phase liquid
LNG	Liquefied natural gas
L/s	litres per second
Ma	Million years (geology)
mAHD	Measurements in metres relative to the Australian Height Datum
MAP	Mean annual precipitation

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mbgl	meters below ground level
m/day	meters per day
mbgs	meters below ground surface
µS/cm	micro Siemens per centimetre
mg/L	milligrams per litre
ML	Megalitre
mtpa	million tons per annum
NATA	National Association of Testing Authorities (Australia's national laboratory accreditation authority)
NEPM	National Environment Protection Measure
PJ	Petajoules
QDNR	Queensland Department of Natural Resources
SANTOS	Santos TOGA Pty Ltd
TDS	Total dissolved solids
TJ	Terajoule (10^{12} joules)
URS	URS Australia Pty Ltd

Executive Summary

It is the intention of Santos to develop and expand the CSG fields in the Surat and Bowen basins. Project development will aim at drilling and completing sufficient development wells to supply approximately 5,300 petajoules of CSG to the LNG facility on Curtis Island, near Gladstone.

URS was appointed by Santos to compile the required Environmental Impact Statement for the proposed Gladstone Liquefied Natural Gas Project. A study of the shallow groundwater resources was compiled for inclusion in the EIS. A review of the geological units mapped to outcrop within the study area and the registered bores within these units was conducted. Based on the average bore depths and available groundwater level data the shallow groundwater resources were identified to occur within 100 m.

CSG fields

An assessment of the shallow (near surface) formations indicated that there are minor shallow aquifers and aquitards developed within the CSG fields. The majority of the formations present have negligible permeability and are generally regarded as not containing groundwater in exploitable quantities. Groundwater quality is such that it renders the minor aquifers unusable or limited fitness for use. Records indicate that groundwater potential has been enhanced within areas of secondary processes, which has allowed for the development of discrete minor aquifers within the CSG fields. These shallow secondary aquifers seldom produce large quantities of water and are typically utilised for local stock watering supplies. The shallow groundwater regimes are recognised as having limited beneficial use.

The CSG operations will involve the removal of methane from the underlying coal seams after it has been desorbed from the coal by a reduction in the surrounding groundwater pressure. This pressure reduction is achieved by extracting groundwater and reducing the hydrostatic head of the groundwater system. Groundwater flow models, capable of predicting the potential depressurisation within the coal seams, were developed. The modelling allowed for an assessment of the possible resultant drawdowns within the coal seam aquifers as well as the possible impacts on the shallow groundwater resources. The models indicate limited impacts on the shallow groundwater resources and on existing bores within the coal seam aquifers.

Pipeline

A review of geology and hydrogeological data was conducted along the proposed gas transmission pipeline route. Discrete zones of increased groundwater resources were recognised associated with secondary processes and within interconnected extended alluvium deposits.

Pipeline installation and infrastructure were evaluated to determine possible risks to shallow groundwater. Based on the shallow pipeline installation depth, limited groundwater resources, and the minor contamination threat associated with the installation of the pipeline, it is envisaged that the impact of the CSG gas transmission pipeline on the shallow groundwater resources will be limited.

LNG facility

Shallow (< 8 m) unconfined and semi-confined alluvium aquifers with low to very low permeability were identified on site. These aquifers have limited abstraction potential and poor groundwater quality also reduces its fitness for use. Deeper (> 20 m) fractured rock aquifers with higher hydraulic conductivity values were intersected in the deeper monitoring bores. The deeper groundwater resources are brackish and occur within discrete zones of secondary alteration. The shallow groundwater resources are typically only utilised for stock watering and have restricted potential for use.

Executive Summary

An evaluation of the proposed CSG development process and activities was conducted to determine possible impacts to the shallow groundwater resources identified through out the project area. These potential impacts were evaluated and recommendations regarding shallow groundwater resource risk management were made as required.

1.1 Introduction

URS Australia Pty Ltd (URS) has been appointed by Santos to compile the required Environmental Impact Statement (EIS) for the proposed Gladstone Liquefied Natural Gas (GLNG) Project. A study of the shallow groundwater resources was compiled for inclusion in the EIS.

A review of the geological units mapped to outcrop within the study area and the registered bores within these units was conducted. Based on bore depths and groundwater level data the shallow groundwater resources, comprising weathered and fractured rock aquifers, were identified to occur within 100 m. The study aimed at characterising the groundwater resources within 100 m from surface. The deeper groundwater resources[1], associated with the coal seam aquifers, were defined to occur at depths greater than 100 m. The Bandana Formation, which is the coal seams targeted in the Fairview and Arcadia CSG fields occur at 500 to 1000 m. The Walloons Coal Seams (Birkhead Formation) are located at 170 to 933 m in the Roma CSG field. At these depths there is sufficient hydrostatic pressure is required to prevent the desorption of methane from the coal.

This report details the ambient shallow (< 100 m) groundwater resources at the proposed GLNG Project, including the coal seam gas (CSG) fields, the selected gas transmission pipeline route, and the liquefied natural gas (LNG) facility. The study evaluates the shallow groundwater regimes within the CSG project area and was compiled separately from the deep groundwater modelling study, which assessed the impacts of CSG depressurisation on the coal seam aquifers at depth (Matrixplus, 2009).

The report includes an assessment of potential impacts from the proposed gas generation operations, activities, and ancillary infrastructure on the shallow groundwater resources.

1.2 Project description

The proposed GLNG project is comprised of the exploration, development, and production of CSG in the Surat and Bowen Basin in Queensland. The CSG study areas, located in these two separate geological areas, include:

- The Roma area in the Surat Basin, within the upper reaches of the Murray-Darling Catchment; and
- The Fairview and Arcadia fields, within the Bowen Basin located within the Fitzroy Catchment.

A LNG facility is proposed on Curtis Island, offshore of Gladstone. The CSG produced will be piped to the LNG facility in a 435 km buried gas transmission pipeline.

In order to extract the CSG, depressurisation of the target coal seams causes methane desorption from the coal seam. The proposed depressurisation, coal seam associated water management, CSG infrastructure, and LNG operations can potentially impact on the shallow groundwater resources within the project area, which are predominantly utilised for stock watering purposes.

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[1] The deep groundwater resources were defined as overlying and underlying aquifers along with the coal seam aquifers. Aquifers considered were those assumed to be affected owing to their potential for vertical leakage (Matrixplus, 2009).

1.3 Objectives

The objective of the shallow groundwater study was to identify and characterise the shallow groundwater resources and evaluate the potential impacts associated with the following components of the proposed GLNG project:

- The development and expansion of the CSG fields, which will comprise production and appraisal well drilling activities. Although the design and construction of the CSG wells are such that the overlying aquifers are isolated from the coal seams the drilling activities may impact on the shallow utilised aquifers;
- The construction and installation of the proposed gas transmission gas transmission pipeline, which has the potential to impact on existing shallow (< 2 m) groundwater resources; and
- The construction and operation of the LNG facility, which could potentially impact on the shallow groundwater resources on Curtis Island.

The study also aims at addressing the requirements of the Terms of Reference (ToR), which include:

- A description of the Environmental Values; and
- Potential Impacts and Mitigation Measures.

1.4 Methodology

In order to achieve the scope of work, project objectives, and to compile the required information for the successful compilation of the groundwater section of the EIS, URS adopted a phased approach to the project. The phases included:

- Phase 1 – Data compilation and review;
- Phase 2 – Regulatory consultation;
- Phase 3 – Field investigations;
- Phase 4 – Establishment of baseline conditions;
- Phase 5 – Identification of potential impacts to shallow groundwater; and
- Phase 6 – Development of mitigation, management, and monitoring plans.

1.4.1 Phase 1 - Review of Information

The shallow groundwater assessment is based on a desktop review of available geological and hydrogeological information and additional data compiled during field programs conducted between June and October 2008.

The review and evaluation of data allowed for the compilation of the baseline groundwater descriptions and assessment of possible impacts. The assessments were based on the information obtained from the following data sources:

- A search of the Queensland Department of Natural Resources and Water (DNRW) groundwater database for registered bores located within the CSG study areas of Roma, Fairview, Arcadia, and the proposed LNG facility site at Curtis Island;
- Baralaba 1:250 000 Geological map (Sheet SG/55-4) and the accompanying notes;

- Biggs, A. and Power, E. (undated). Dryland salinity in the Queensland Murray-Daring Basin An overview of current knowledge. Department of Natural Resources and Mines report;
- Foster, B.A. (2007). A review of salinity occurrences in the Fitzroy Basin, Queensland. Department of Natural Resources and Water, Rockhampton. ISBN 9311662172037;
- Gladstone Special 1:100,000 Geology Map (Sheet 9150 & Part 9151) March 2006 Revised edition – Queensland Government Department of Natural Resources, Mines and Water;
- Reading, L.P. and Pearce, B.R. (2007). BC2C Modelling for the Fitzroy Basin, Queensland. Department of Natural Resources and Water, Queensland. ISBN 9311662172051;
- Roma 1:250 000 Geological map (Sheet SG/55-12) and the accompanying notes;
- Taroom 1:250 000 Geological map (Sheet SG/55-8) and the accompanying notes;
- URS (2008). Environmental Management plan for Fairview Project Area. Consultants report for Santos TOGA Pty Ltd, May 2008;
- URS (2007). Gladstone LNG Geotechnical and Environmental Constraints Assessment. Consultants draft report 42625593;
- URS (2007). Groundwater Impact Assessment, Injection of produced water into Timbury Hills Formation, Fairview Coal Seam gas Field. Consultants report Santos_Fairview_GWIA-R001 v1.doc;
- Santos (2007). Gladstone Liquefied natural gas initial advice statement, dated 19 July 2007; and
- Sinclair Knight Merz (2006). Fairview Coal Seam Gas. Consultants report QE09365 prepared for Santos Ltd; August 2006.

The information review included the groundwater (deep aquifer modelling) report compiled by Matrixplus, which modelled and predicted the impacts of dewatering associated with the CSG extraction within the CSG fields.

The environmental values of the water have been assessed according to relevant regulations (Section 1.5), guidelines and standards, and the values identified in the Environmental Protection (Water) Policy 1997 (EPP Water 1997) and the Environmental Protection Act 1994 Environmental Protection (Water) Amendment Policy (No.1) 2008 (EPP Water 2008).

The environmental values to be enhanced or protected are:

- Biological integrity of a pristine or modified aquatic ecosystem;
- Suitability for primary, secondary, and visual recreational use;
- Suitability for minimal treatment before supply as drinking water;
- Suitability for use in agriculture;
- Suitability for use in aquacultural use;
- Suitability for producing aquatic food for human consumption;
- Suitability for industrial use; and
- Cultural and spiritual values of the water.

A review of available data allowed for an initial description of the groundwater resources for each geological unit, which outcrops within the CSG project study area. This resulted in the identification of four environmental values of relevance to the groundwater regime within the CSG project study area. These include:

- Domestic use;
- Biological integrity (maintaining the water quality so the plants and animals living in the waterway can survive);
- Suitability for primary industry (livestock drinking water) use; and
- Suitability for primary industry (irrigation) use.

Shallow groundwater is recognised to be utilised primarily for stock water purposes. Small scale irrigation using groundwater is also recognised to occur from the various shallow aquifers within the large CSG field study area. Groundwater has also been assessed against the ANZECC guidelines (ANZECC, 2000) for the protection of 95% of species in a freshwater environment to consider the potential effect of discharge of groundwater into surface water bodies or groundwater dependant environments.

The investigation levels (ANZECC, 2000) adopted to encompass three of the defined environmental values and to provide a comparison of the groundwater analytical results include:

- The Trigger Levels for Freshwater Ecosystems – 95% protection level of species;
- The Short-term Trigger Values (STV) and Long-term Trigger Values (LTV) in Irrigation Water; and
- The Livestock Drinking Water Guidelines.

Groundwater hydrochemical data has also been compared to the Australian Water Quality Guidelines (AWQG, 2004) for suitability for domestic use.

1.4.2 Phase 2 – Regulatory Consultation

During May 2008 scoping meetings and discussions were held with the relevant authorities, the Department of Natural Resources and Water and the Queensland Environmental Protection Agency (EPA), in order to discuss the proposed groundwater studies for the GLNG EIS. The meeting included discussions regarding:

- The hydrogeology studies proposed for the GLNG project and the expectations of the regulatory authorities;
- The proposed field investigations;
- The authorities’ support of the extent and level of field investigations to be undertaken; and
- An agreed upon mechanism to communicate results and requirements with the stakeholders.

The successful scoping discussions ensured that the hydrogeological studies and outcomes would achieve the authorities’ expectations.

1.4.3 Phase 3 – Field Investigations

CSG Fields

Drilling targets were identified for the drilling and construction of monitoring bores within the shallow groundwater resources across the CSG field study areas. The sites were evaluated for accessibility and the required drilling approvals were obtained.

As the CSG fields cover a large area containing a significant amount of bores, as registered on the DNRW database, only a limited number of bores were required to verify the shallow groundwater characterisation. The bores were also drilled to allow for the construction of long term monitoring points within the CSG fields. The drilling program resulted in the drilling of 18 bores to assess the shallow groundwater resources. Ten of these boreholes were constructed as monitoring wells in order to obtain representative hydrogeological data. The remaining eight bores were dry when drilled and were rehabilitated.

Field measurements, including groundwater levels, were collected once the groundwater had stabilised within the bores, at least two days after drilling.

Due to limited groundwater being intersected during drilling only a select number of short duration pump out tests were conducted. Additional aquifer analysis was conducted using variable head tests. The resultant data were analysed to estimate hydraulic conductivity, transmissivity, and storage (where observation wells were available). The boreholes were equipped with automated borehole loggers, allowing for the capture of extended accurate water level data.

Groundwater samples were collected and stabilised / preserved on site prior to being delivered to an accredited analytical laboratory. The resultant hydrochemical analyses assisted with the baseline assessment of the hydrogeology.

LNG Facility

An evaluation of the underlying geology, aerial photography, topography, and the proposed LNG facility layout was conducted in order to select target areas for drilling and constructing monitoring boreholes on Curtis Island. A track mounted drilling rig was contracted to conduct rotary-air-percussion and auger drilling. Three boreholes were drilled into the alluvial and estuarine deposits and five boreholes were constructed within the weathered and fractured mudstone and greywacke units of the Wandilla Formation.

Variable head tests, comprising slug (rising) and falling head tests, were conducted to obtain site-specific hydraulic conductivity values for the underlying aquifers. The resultant data was assessed using standard analytical methods.

The boreholes were equipped with pressure transducers in order to monitor tidal and storm water recharge influences on the groundwater levels.

Groundwater samples were collected from the bores and analysed to determine the range of ambient hydrochemistry.

Gas Transmission Pipeline

A desktop review was conducted to assess groundwater resources along the proposed pipeline and to identify potential impacts. Sufficient desktop data was available for a high level assessment of groundwater resources along the 435 km route. No intrusive hydrogeological work was conducted as the potential impacts associated with the gas transmission pipeline are considered negligible; however, proposed studies have been compiled to assist in addressing potential impacts and implementing mitigation measures.

1.4.4 Phase 4 – Establishment of Baseline Conditions

All desktop and field investigation data was compiled and interrogated to determine the baseline hydrogeology, allowing for aquifer characterisation and hydrogeological conceptualisation.

The baseline conditions were established by:

- Determining piezometeric levels representative of the various aquifers;
- Evaluating aquifer characteristics;
- Assessing hydrochemistry; and
- Resource evaluation assessing current and potential use.

The environmental values of the groundwater resources were evaluated as per the EPP Water 2008.

The shallow groundwater resources were described according to the requirements of the ToR and included:

- The existing groundwater in terms of physical and chemical characteristics;
- Groundwater levels and flow;
- Present water uses (bores registered on the DNRW database);
- The environmental values according to the EPP (Water) 2008; and
- Surface water – groundwater interaction.

1.4.5 Phase 5 – Identification of Potential Impacts to the Shallow Groundwater

The proposed LNG operations, processes, and infrastructure have been evaluated and the potential impacts on the shallow groundwater were considered. The potential impacts were assessed based on possible consequence and likelihood. The impact assessment formed the basis of the site assessment protocol.

The threat and associated impact assessment specific to the groundwater resources was compiled using the methodology proposed by Skivington (Skivington, 1997) and the Risk Management guidelines (AS/NZS 4360, 2004). The impact assessment methodology is detailed as follows:

This method is a risk-based approach that does not rely on generating numerical answers or probability but can be used as a decision-making tool, which can assist in allocating expenditure. The flow chart used to assess the threat on the groundwater resources, is shown in **Figure 1-1**.

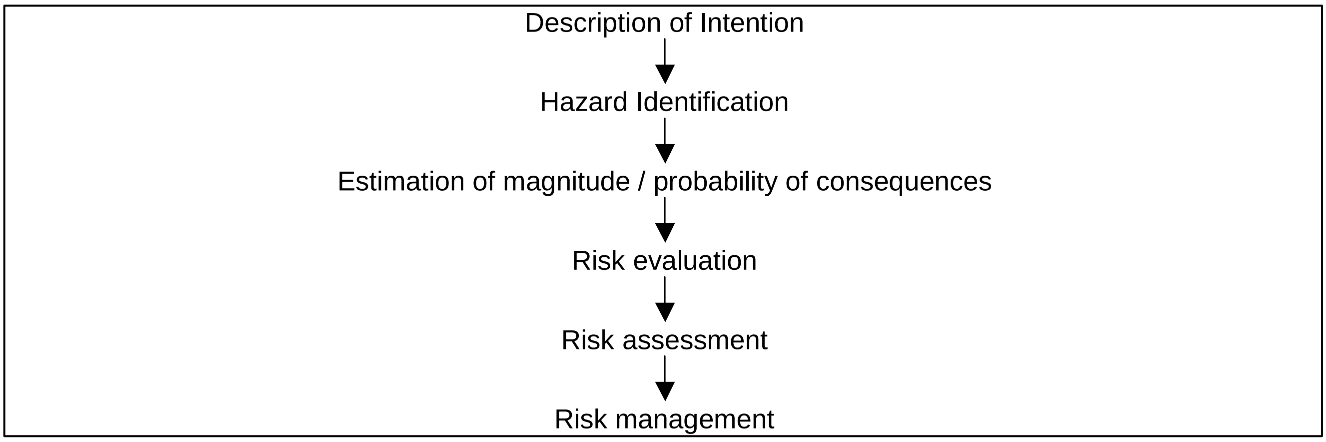

Figure 1-1 Flow Chart of the Groundwater Impact Assessment

The **description of intention** is to undertake the proposed project description, unless the impact assessment reveals intolerable risks.

The **hazard identification** allows for a list of potential hazards and possible consequences to be compiled in order to determine the modes of operation or process failure that need to be addressed.

For each separate identified hazard an assessment of the magnitude and probability of the consequences is conducted. This allows for an **estimate of risk** to be calculated. Simplistically the risk (R) can be considered as a product of the probability (P) and the magnitude (M) of a given consequence, i.e. R = P x M.

Each threat can be given a numerical value for comparison with the other hazards in order to aid in establishing the most serious threats.

The following values represent the various probabilities and magnitudes:

PROBABILITY	SCORE	MAGNITUDE
Almost Certain	5	Catastrophic
Likely	4	Major
Possible	3	Moderate
Unlikely	2	Minor
Rare	1	Insignificant

The definitions of the terms used above are as follows (AS/NZ 4360, 2004):

Probability / Likelihood

Rare	Will only occur in exceptional circumstances
Unlikely	Could occur but not expected
Possible	Could occur at some time
Likely	Will probably occur in most circumstances

Almost certain	Expected to occur in most circumstances

Magnitude / Consequences

Insignificant	Trivial environmental impact
Minor	Unreasonable interference with the environment
Moderate	Clearly visible impact to aquatic ecosystem, requires localised remediation
Major	Damage to the environment that requires significant remediation
Catastrophic	Environmental damage is irreversible, of high impact or widespread

The **risk evaluation** is concerned with determining the significance of the estimated risks on the shallow groundwater resources if the hazard is realised.

In order to assess the risk, the risk estimation and evaluation for each hazard is combined to obtain an overall **risk assessment**.

Using the risk assessment, **management** options can be developed. These vary from the “do nothing” option to risk altering.

The identification and evaluation of impacts have been compiled to include considerations compiled in the ToR, which include:

- Potential impacts of managing associated water, which include artificial recharge to the shallow groundwater resources;
- Potential impacts of the project on flow and quality of groundwater, which include the impacts of CSG depressurisation and resultant induced flow which could impact on the shallow groundwater resources and users;
- Potential regional impacts of groundwater extraction, which is considered in the deep groundwater study (Appendix P2 of the EIS);
- Chemical and physical properties of any waste water; impacts associated with water treatment waste storage and possible discharge have been considered;
- Risk of uncontrolled releases, where associated water ponds fail have been evaluated; and
- An assessment of the potential to contaminant shallow groundwater was conducted and evaluated.

1.4.6 Phase 6 - Mitigation, Management, and Monitoring Plans

This report was compiled based on the conceptual hydrogeology and potential impacts compiled from the desktop study and field investigations. The risk assessment of impacts allowed for the recommendation of impact mitigation, site management, and monitoring strategies, where required.

A detailed long-term groundwater monitoring program has been developed to allow for the evaluation of mitigation and measurement plans, as well as provide a measure of the impacts of the proposed GLNG project on the shallow groundwater regimes.

A site assessment protocol has been compiled as part of the Environmental Management Plan (EMP). This will allow the Santos; post EIS, to assess potential environmental impacts associated with the continued gas field development program.

1.5 Legal Framework

The relevant groundwater resource legislation identified with regards to the proposed GLNG project includes:

- The Great Artesian Basin Resource Operations Plan 2006;
- The Fitzroy Basin Water Resource Plan 1999;
- Petroleum and Gas (Production and Safety) Act 2004;
- Water Act 2000, Queensland;
- Environmental Protection Act 1994, Queensland;
- Environmental Protection (Water) Policy 1997, Queensland; and
- Environmental Protection Act 1994 Environmental Protection (Water) Amendment Policy (No.1) 2008.

1.5.1 The Great Artesian Basin Resource Operation Plan 2006

The Great Artesian Basin Resource Operation Plan identifies groundwater management areas and management units within each management area. A unit corresponds to a formation of a group of formations. For each unit a specified upper annual allocation (take) of water has been allocated under the plan. Allocation changes are made from time to time by the DNRW.

1.5.2 The Fitzroy Basin Water Resource Plan

The Water Resource Plan defines the availability of water in the plan area and regulates the taking of water from all surface water bodies. The amendment for the inclusion of groundwater has not yet been finalised.

1.5.3 Petroleum and Gas (Production and Safety) Act 2004 (P&G Act)

Under Section 185 of the P&G Act, a petroleum tenure holder may take or interfere with the groundwater whilst carrying out an authorised petroleum activity. Otherwise the petroleum holder can not take or interfere with or use water as defined under the Water Act, unless it has been authorised under the Water Act.

The water extraction rights for or during petroleum purposes as defined in the P&G Act include:

- Taking water when drilling a bore, however, the bore construction must comply to the regulation and be completed as a water supply bore;
- No limit to the volume of water that may be taken (Section 185 (3)); and
- The associated water can be used for the authorised mining activity or for domestic and stock purposes on the land covered by the tenure and adjoining land or by any land owned by the land owner (Section 186).

Section 187 of the P&G Act further identifies the requirements for water monitoring for associated water. Water monitoring is required for assessing compliance with the tenure. The following requirements are set out under this act:

- Gathering information about, or auditing an existing Water Act bore;
- Gathering information for an underground water impact report, pre-closure report, monitoring report, or review report;
- Monitoring the effect of the exercise of the underground water rights for the tenure;
- Constructing or plugging and abandoning a water observation bore; and
- Carrying out restoration measures in relation to an existing Water Act bore for which the make good obligation applies.

A petroleum tenure holder may also apply for a water monitoring authority (Section 190) which may include land outside the tenure area to allow the holder to comply with the tenure requirements. This allows the authority holder to carry out any water monitoring activity in the area of the authority (Section 194), i.e. gathering information about, or auditing an existing Water Act bore.

The holder of the tenure must provide a water impact report of its activities (Section 252 – 257). The P&G Act requires the fixing of a “trigger threshold” for aquifers in the area affected by the exercise of underground water rights for a petroleum tenure in order to prepare an underground impact report for the tenure. Section 253 states that “The petroleum tenure holder may ask the chief executive what the trigger threshold is for the aquifers”.

The trigger value is defined as “the water level drop in the aquifers that the chief executive considers would be a level that causes a significant reduction in the maximum pumping rate or flow rate of the existing Water Act bores in the area affected by the exercise of the underground water rights”. Hydraulic conductivity, geometry, and water levels of the aquifers are defined as the criteria to be considered in the definition of the trigger value, no time period over which the pumping is done is mentioned in the P&G Act.

1.5.4 Water Act 2000

A water licence may be required for taking or interfering with water (Section 204). If a water licence is granted to a petroleum tender holder, there may be a requirement under Section 214 (e) to carry out and report on a stated monitoring program.

1.5.5 Environmental Protection Act 1994

Conditions (Section 98) of the Environmental Protection Act 1994 (EPA) may be imposed on a petroleum activity. The EPA Act may:

- Ask the petroleum tenure holder to prepare environmental reports and prepare and carry out environmental programs;
- Limit the petroleum activities holder to change, replace, or operate any plant if the action can substantially increase the risk of environmental harm; and
- Order the activity to cease or be put on hold.

1.5.6 Environmental Protection (Water) Policy 1997

This Act has a monitoring component (Section 26) relating to monitoring the release of waste water on land or into water. The administering authority would decide on the level of monitoring dependant on the activity, the risk of harm to environmental values, and the frequency needed.

Impact monitoring may also be required (Section 27) if an administering authority is making a decision about an activity involving a release or potential release of waste water.

The direct release of water to surface water and to groundwater is regulated under Sections 18, 19, and 20. The release of water to surface water is only possible after an assessment of the water quality and the impact of mixing the released water with the existing water quality. The release of water to groundwater is only possible after an assessment of the impact on the environment and will only be allowed under certain aquifer conditions.

Section 21 which regulates the accidental release of water to the groundwater, requires that infiltration of release water to soil and groundwater be minimised or prevented and any release or potential release monitored against site baseline conditions.

A review of the 2008 amendment to the Environmental Protection Act 1994 Environmental Protection (Water) document, which came into effect on 01 January 2009 was conducted and included in the evaluation of the environmental values, with regards to the groundwater resources.

The proposed CSG field development portion of the GLNG project aims at developing and expanding CSG fields. The preliminary expansion will focus on the Roma, Fairview, and Arcadia gas fields (**Figure 2-1**).

The hydrogeological regimes associated with the geological units which outcrop within these areas have been assessed for inclusion in the GLNG EIS.

2.1 Desktop Assessment of Groundwater Geology and Aquifer Occurrence

A desktop assessment of the general groundwater geology and aquifer occurrence of the CSG fields and surrounding areas was undertaken. This included a review of available literature and an assessment of the water bore information contained in the DNRW groundwater and licensing database for registered bores.

2.1.1 Overview of the Geology of the CSG Fields

The main outcropping formations in the area belong to the little-deformed Jurassic-Cretaceous Surat Basin sequence. The CSG field project area covers the northern margin of the Surat Basin, with the regional dip of the formations to the south. Underlying the Surat Basin is a thick, gently folded, Permo-Triassic sequence of the north-south aligned Taroom Trough which is the subsurface extension of the Bowen Basin. To the north in the area of the Arcadia gas field the Bowen Basin is exposed at the surface.

The Fairview and Arcadia CSG fields lie on the western margin of the Taroom Trough in the southern extent of the Bowen Basin. Gas in this area is extracted from coal seams of the Late Permian Bandanna Formation of the Bowen Basin at depths of 500 to 1,000 m below surface.

The Roma CSG field lies within the Surat Basin, which consists of consolidated Jurassic, Cretaceous, and Tertiary sediments. The Jurassic aged coal measures of the Birkhead Formation[2] (referred within the context of the GLNG project as the Walloon Coal Measures) are the CSG target unit within the Roma field.

Table 2-1 presents the lithostratigraphy of the CSG fields. A map of the geology is presented in **Figure 2-2**, showing the proposed CSG fields to be developed during the GLNG Project.

The Bandanna Formation is underlain by the late Permian Black Alley Shale which is a succession of dominantly black claystone with white tuff beds. This shale unit is the oldest considered in this study. The Bandanna Formation comprises coal seams which are fractured and well-cleated. The coal seams are separated by predominantly competent siltstone and sandstone that restrict vertical leakage between the seams and the overlying and underlying units.

The Rewan Group conformably overlies the Bandanna Formation in the area of the gas fields, except to the southwest of the Fairview CSG field where the Precipice Sandstone aquifer directly overlies the Bandanna Formation and is in hydraulic connection with it (**Figure 2-3**). Although this occurs to the southwest of the Fairview CSG field consideration has been given to possible induced flow in this area in the deep groundwater study (Matrixplus, 2009). Limited bores intersect the Bandanna Formation due to depth and poor quality

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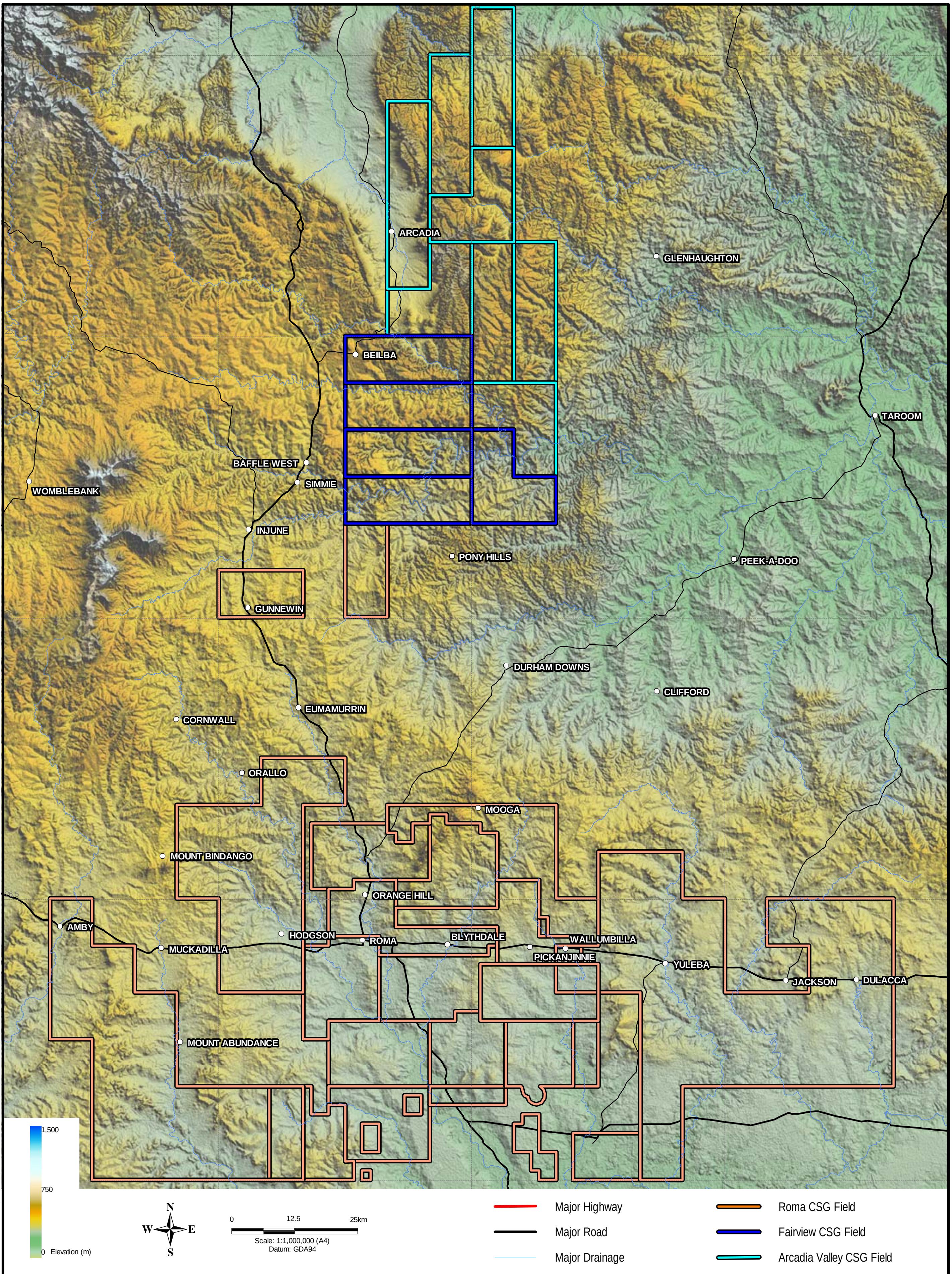
[2] The coal measures within the Birkhead Formation are the Surat Basin equivalent of the Walloon Coal Measures of the Clarens-Morton Basin (source: Geoscience Australia Stratigraphic Units database)



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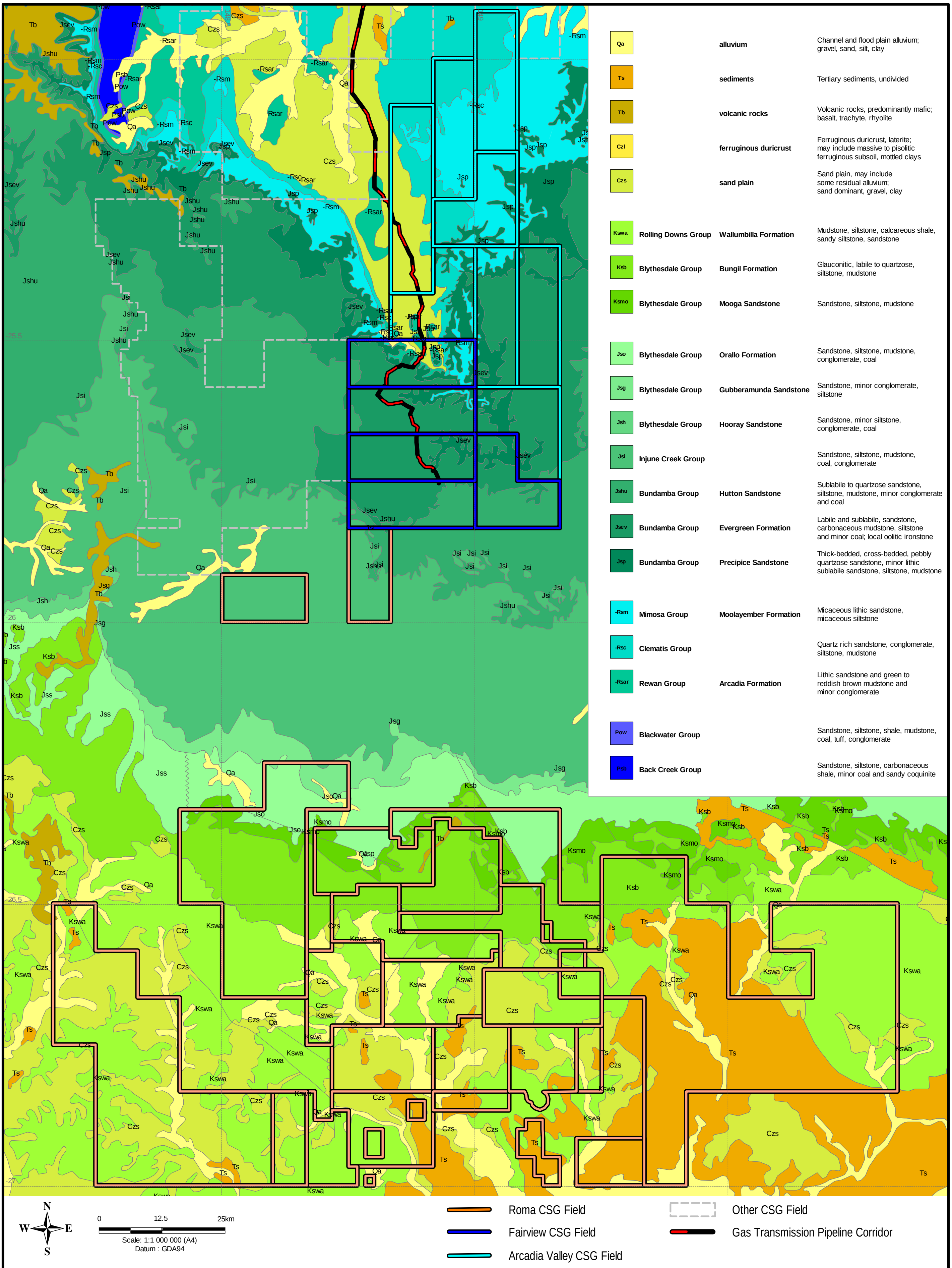
Client	Project	Title
LNG URS	GLADSTONE LNG PROJECT CSG FIELD SHALLOW GROUNDWATER ASSESSMENT	**LOCALITY PLAN SHOWING CSG FIELDS AND TOPOGRAPHICAL RELIEF**

Drawn: RG	Approved: JB	Date: 23-01-2009	Figure: **2-1**	Rev:B
Job No: **4262 6220**	File No: 42626220-g-571b.wor			**A4**



Qa		alluvium	Channel and flood plain alluvium; gravel, sand, silt, clay
Ts		sediments	Tertiary sediments, undivided
Tb		volcanic rocks	Volcanic rocks, predominantly mafic; basalt, trachyte, rhyolite
Czl		ferruginous duricrust	Ferruginous duricrust, laterite; may include massive to pisolitic ferruginous subsoil, mottled clays
Czs		sand plain	Sand plain, may include some residual alluvium; sand dominant, gravel, clay
Kswa	Rolling Downs Group	Wallumbilla Formation	Mudstone, siltstone, calcareous shale, sandy siltstone, sandstone
Ksb	Blythesdale Group	Bungil Formation	Glauconitic, labile to quartzose, siltstone, mudstone
Ksmo	Blythesdale Group	Mooga Sandstone	Sandstone, siltstone, mudstone
Jso	Blythesdale Group	Orallo Formation	Sandstone, siltstone, mudstone, conglomerate, coal
Jsg	Blythesdale Group	Gubberamunda Sandstone	Sandstone, minor conglomerate, siltstone
Jsh	Blythesdale Group	Hooray Sandstone	Sandstone, minor siltstone, conglomerate, coal
Jsi	Injune Creek Group		Sandstone, siltstone, mudstone, coal, conglomerate
Jshu	Bundamba Group	Hutton Sandstone	Sublabile to quartzose sandstone, siltstone, mudstone, minor conglomerate and coal
Jsev	Bundamba Group	Evergreen Formation	Labile and sublabile, sandstone, carbonaceous mudstone, siltstone and minor coal; local oolitic ironstone
Jsp	Bundamba Group	Precipice Sandstone	Thick-bedded, cross-bedded, pebbly quartzose sandstone, minor lithic sublabile sandstone, siltstone, mudstone
-Rsm	Mimosa Group	Moolayember Formation	Micaceous lithic sandstone, micaceous siltstone
-Rsc	Clematis Group		Quartz rich sandstone, conglomerate, siltstone, mudstone
-Rsar	Rewan Group	Arcadia Formation	Lithic sandstone and green to reddish brown mudstone and minor conglomerate
Pow	Blackwater Group		Sandstone, siltstone, shale, mudstone, coal, tuff, conglomerate
Psb	Back Creek Group		Sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite

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Client

URS

Project

GLADSTONE LNG PROJECT
SHALLOW GROUNDWATER ASSESSMENT

Title

GEOLOGICAL MAP
SHOWING CSG FIELDS

Drawn: RG
Approved: JB
Date: 23-01-2009
Job No: **4262 6220**
File No: 42626220-g-572.wor
Figure: **2-2**
Rev:A
A4

Table 2-1 Lithostratigraphy of the CSG Fields

Age	Group	Formation	Member	Lithology	Comments
Quaternary				Alluvium: unconsolidated sand, gravel, and clay	Stream deposits
				Alluvium, sand, gravel, and soil cover	Largely stream deposits, some possibly wind-blown
Tertiary				Basalt and olivine basalt flows	
				Sandstone, siltstone, claystone, conglomerate	Piedmont, fluvial, and lacustrine
Lower Cretaceous	Rolling Downs	Wallumbilla	Coreena	Siltstone, mudstone, fine sandstone; marine and shelly fossils	Delta deposit, near-shore marine
			Doncaster	Mudstone (carbonaceous in part), siltstone, fine quartzose sandstone, minor coquinite; calcareous concretions, marine shelly fossils	
	Blythesdale	Bungil	Minmi	Very fine to medium bedded lithic to quartzose sandstone, siltstone, and mudstone. Carbonaceous in part; marine shelly fossils	
			Nullawurt Sandstone	Very fine to fine bedded quartzose to sublabile sandstone, siltstone, mudstone; minor labile sandstone and coarse quartzose sandstone	Lakes and deltas deposit
			Kingull	Very fine to medium bedded clayey quartzose to labile sandstone; calcareous in part, mudstone; carbonaceous in part	Streams and deltas deposit
		Mooga Sandstone		Bedded quartzose to labile sandstone, in part clayey, calcareous, pebbly; mudstone; minor conglomerate at base	Streams and lakes deposit

Age	Group	Formation	Member	Lithology	Comments
Middle to Upper Jurassic		Orallo		Fine to medium bedded lithic to lithic sublabile sandstone, calcareous or clayey; siltstone and mudstone, carbonaceous in part; clay (bentonitic); minor coal	Streams, deltas, and lakes deposit
		Gubberamunda Sandstone		Cross-bedded quartzose to sublabile sandstone; conglomerate; siltstone	Streams
	Injune Creek (not present in Fairview north and Arcadia)	Westbourne		Grey carbonaceous micaceous siltstone grading to mudstone, very fine quartzose to sublabile sandstone	Lakes, deltas and streams
		Springbok Sandstone		Fine to coarse labile sandstone, in part calcareous; siltstone, mudstone; minor coal	Lakes and streams, andesitic volcanism in hinterland
		Birkhead (Walloon coal measures)		Calcareous labile and sublabile lithic sandstone, siltstone, shale, carbonaceous shale, coal	Paludal, swamp or marsh deposits CSG target in the Roma CSG field
		Eurombah Beds		Cross-bedded, thickly bedded, fine to coarse clayey labile sandstone, polymictic conglomerate, siltstone, mudstone	Lakes and streams
Lower to Middle Jurassic	Bundamba	Hutton Sandstone		Argillaceous sublabile and quartzose sandstone, minor mudstone, rare pebble conglomerate beds	Fluvial or lacustrine deposit
Lower Jurassic		Evergreen		Labile and sublabile sandstone, mudstone, shale, coal	Lacustrine; shallow water marine at top
			Westgrove Ironstone	Concretionary ironstone, oolitic or pelletal in places, chamositic when fresh; chamositic mudstone	Shallow water marine deposit
			Boxvale Sandstone	Quartzose sandstone, siltstone, coal	Fluvial or lacustrine deposit; possibly shallow water marine at top
		Precipice Sandstone		Bedded quartzose sandstone, sublabile lithic sandstone, siltstone	Fluvial deposit
Middle to Upper Triassic	Mimosa	Moolayember		Mudstone, lithic sandstone, lithic sublabile sandstone, conglomerate, shale, tuff	Fluvial, possibly lacustrine in part
		Clematis Sandstone		Sublabile and quartzose sandstone, volcanic pebble conglomerate, mudstone	Fluvial
Lower Triassic	Rewan	Rewan		Lithic sandstone, siltstone, and shale	

Age	Group	Formation	Member	Lithology	Comments
	Blackwater	Bandanna		Siltstone, mudstone, coal	CSG target in the Fairview and Arcadia CSG fields
Late Permian		Black Alley Shale		Shale	

groundwater. The Bandanna Formation is predominantly used for stock watering due to the typically poor quality and low yield of groundwater supply.

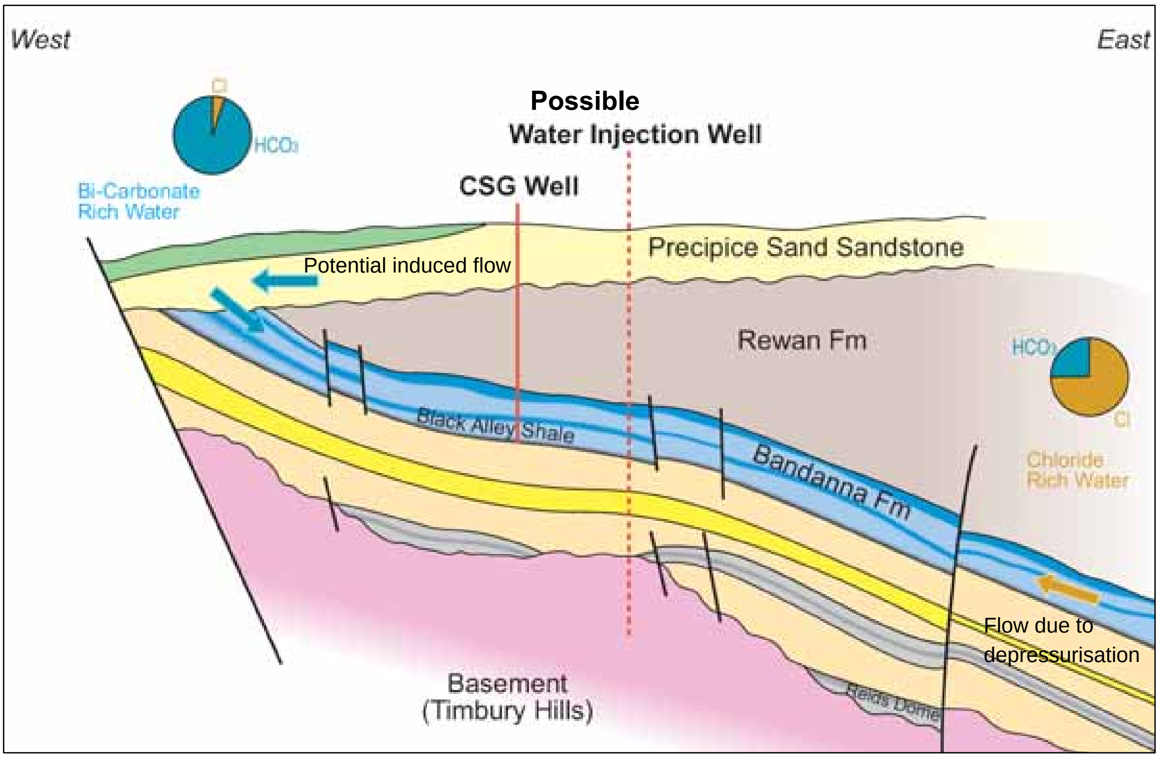


Figure 2-3 Schematic Cross Section southwest of Fairview CSG Field (Source: Santos)

The oldest unit which outcrops in the CSG field study area is the Triassic aged Rewan Group in Arcadia. The Rewan Group comprises lithic sandstone, siltstone, and shale. This Lower Triassic unit is conformably overlain by the Mimosa Group. The Mimosa Group consists of sandstone, conglomerate, siltstone and mudstone of the Clematis Sandstone; which is overlain by mudstone and sandstone units the Moolayember Formation. The Triassic Rewan Group, Moolayember Formation and Clematis Sandstone all outcrop in or near the Arcadia CSG field area. The Arcadia has been infilled with Cainozoic aged sandy sediments, which are overlain by Quaternary aged alluvial deposits along the drainages.

The unconformable contact between the Mimosa Group and the overlying Precipice Sandstone forms the boundary between the Bowen and Surat Basins. The Surat Basin contains up to 2500 m of mainly Jurassic clastic continental sedimentary rocks and lower Cretaceous marine beds largely obscured by Cainozoic alluvium. During the Jurassic period is characterised by coarse sand braided stream deposits grading up into finer sand and silt deposits of meandering streams. Labile sand, silt, mud and coal were laid down in swamps, lakes, deltas and shallow seas. Deposition changed from terrestrial to shallow marine during the Early Cretaceous. A series of marine transgressions and regressions deposited the Rolling Downs Group with deposition ceasing in the late Albian (Kingham, 1998).

The geology of the Surat Basin is characterised by the Jurassic deposition and the shallow marine environment that existed during the Early Cretaceous. Outcropping units laid down during the Jurassic period include the Precipice Sandstone, Evergreen Formation, Hutton Sandstone, Birkhead Formation, Springbok Sandstone, Westbourne Formation, Gubberamunda Sandstone, Orallo Formation, Mooga Sandstone, and Bungil

Formation. The Early Cretaceous marine transgression initiated deposition of the Rolling Downs Group. This group includes the Doncaster and Coreena members of the Wallumbilla Formation (Kingham, 1998).

The lower Jurassic aged Precipice Sandstone comprises cross bedded quartzose sandstone; sublabile lithic sandstone and mudstone. Outcrops of the Precipice Sandstone are of limited aerial extent and occur in cuestas around Arcadia.

The Precipice Sandstone is conformably overlain by labile and sublabile sandstone, mudstone, shale and coal of the Evergreen Formation. The argillaceous sublabile and quartzose sandstone with minor mudstone of the Hutton Sandstone overlies the Evergreen Formation. The Hutton Sandstone is overlain by the fine to coarse clayey labile sandstone, polymictic conglomerate, siltstone, and mudstone of the Eurombah Beds and the Birkhead Formation which comprises calcareous labile and sublabile lithic sandstone, siltstone, shale, carbonaceous shale and coal (the CSG coal seam target).

The thickness of the coal measures in the Roma CSG field ranges from 100 to 460 m, at depths ranging from 170 to 933 m below ground level. The coal seams are separated by silt and tight sand, which restricts vertical leakage between seams. The geology of the main units within the Roma CSG field is relatively uniform and unaltered across the CSG field.

The Springbok Sandstone, overlying the Birkhead Formation, comprises fine to coarse labile sandstone, siltstone, mudstone; minor coal. The carbonaceous and micaceous siltstone and mudstone, and very fine quartzose to sublabile sandstone of the Westbourne Formation overlie the Springbok Sandstone.

The quartzose to sublabile sandstone, conglomerate and siltstone of the Gubberamunda Sandstone is overlain by the fine to medium calcareous or clayey sandstone, siltstone, mudstone and minor coal of the Orallo Formation.

This was followed by the terrestrial deposition of quartzose to labile sandstone, mudstone and minor conglomerate of the Mooga Sandstone and concluded with the labile to quartzose siltstone and mudstone of the Bungil Formation.

The Lower Cretaceous marine transgression ended the fluvial cycles and initiated deposition of the Rolling Downs Group. The main shallow bedrock unit in the vicinity of Roma is the Lower Cretaceous aged Wallumbilla Formation comprising siltstone, mudstone, and fine grained sandstone.

The northern part of the Roma Gas Field area contains low hill sand scarps, due to outcropping sandstones of the Orallo Formation and Mooga Sandstone. The Bungil and Wallumbilla Formations give rise to typically flat topography. The Bungil Formation has been capped by Miocene aged basalt to the northeast of Roma in the Grafton Range. Large areas of poorly consolidated Tertiary aged sandstone and conglomerate unconformably overlie the Wallumbilla Formation to the south and southeast of Roma. The drainages have been infilled with alluvial sediments comprising Quaternary aged sand, gravel, and clay.

2.1.2 Overview of Structural Geology of the Gas Fields

Roma CSG Field

The Roma CSG Field area is located on the northern margin of the Jurassic-Cretaceous Surat Basin. The coal measures and main units (the Hutton Sandstone, Injune Creek Group, Gubberamunda Sandstone, and Mooga Sandstone) do not indicate deformation or complex faulted geology. The relatively uniform sediments dip to the south.

Seismic surveys indicated that the basement is block-faulted. Faulting and folding, recognised in the older subsurface strata, is either absent or attenuated in the outcropping Jurassic-Cretaceous sediments. Some features are, however, visible in outcrop in the Roma area. These include; the Alicker and Eurombah Anticlines, the Wallumbilla Fault, and a number of west-northwest trending faults.

The northwest trending Wallumbilla Fault is downthrown to the west, with a displacement of ± 450 m in the basement, but only around 30 m in the overlying sediments. Small northwest trending faults elsewhere in the area are probably related to the movements which formed the Wallumbilla Fault. These faults have limited vertical displacement (less than 15 m) and some are little more than joints. They are probably as a result of epeirogenic movements related to the Surat Basin in Tertiary times. These faults leave a clearer topographic imprint than the larger faults due to their age.

Fairview CSG Field

The study area at Fairview CSG Field is located within the complementary anticline to the Mimosa Syncline, located to the east. The anticline plunges south-southeast and corresponds to a southerly extension of the Comet Ridge in the geological basement.

Both structures developed throughout the Permian and Triassic time. After the period represented by the unconformity at the base of the Jurassic Precipice Sandstone (boundary between the Bowen and Surat Basins), folding on the pre-existing axes has been slight. In the anticlinal structure there are subsidiary minor folds, of which the Arcadia Anticline is the best exposed. The slight warping and minor faulting of the Jurassic succession may be related to the compaction of the underlying thick sequences of Permian and Triassic sediments.

The lower Triassic age Rewan Group separates the overlying sandstone units from the Bandanna Formation. This confining unit reduces the likelihood of vertical leakage. Due to erosion the Rewan is absent to the southwest of the Fairview CSG field. Where the Rewan is absent the lowermost sandstone aquifer, the Precipice Sandstone directly overlies the Bandanna Formation.

The Jurassic Hutton Sandstone, Evergreen Formation, Precipice Formation, and Boxvale Sandstone outcrop in the Fairview CSG field area.

Arcadia CSG Field

The main structural feature in the Arcadia CSG Field study area is the Comet Ridge, which comprises mainly Devonian age rocks and is covered by a relatively thin sequence of gently folded Permian and Triassic rocks.

The Permian- Triassic sequence was folded principally during late Triassic time. Possibly some of the deformation was brought about during the period of uplift and emergence in the Lower Permian. Fold axes are generally parallel, trending north-northwest, to the Comet Ridge axis. The amplitude of folding on the Comet Ridge is small and the axes are short and sinuous. The Permian-Triassic folds are truncated by the erosional unconformity surface on which the Lower Jurassic Precipice Sandstone was deposited. The Jurassic and Cainozoic rocks are not folded.

The Triassic rocks; Rewan Formation, Clematis Sandstone, and Moolayember Formation, all outcrop in or near the Arcadia area.

2.1.3 Overview of Regional Hydrogeology of the Gas Fields

Regional Hydrogeology

The Bowen and Surat Basins are stratigraphically and hydraulically connected, and form part of the GAB. The GAB is recognised as an asymmetrical basin, which tilts to the southwest, forming one of the largest artesian basins in the world. The GAB consists of a multi-layered confined aquifer system of permeable sandstone and low permeable siltstones and mudstones. The main GAB aquifers recognised within the CSG field areas are the Hutton Sandstone, Precipice Sandstone, and Clematis Sandstone units.

Roma CSG Field

Regional hydrogeological information compiled in the Roma geological series explanatory notes (Exon, 1971) provides an overview of aquifers and groundwater use in the Roma study area. Water for stock use is obtained from water bores, dams, and earth tanks. Bore water comes from various aquifers and is generally pumped from fairly shallow depths.

The main aquifer units within the Roma area are associated with the Precipice, Hutton, Gubberamunda, and Mooga Sandstones. Only the Mooga Sandstone is mapped to outcrop in the Roma Gas Field study area.

Groundwater potentiometric levels are identified to be well below ground level in the north and near surface in the south of Roma. All aquifers have a regional dip to the south. Numerous subartesian bores intersect aquifers at a shallow depth rather than the deep artesian resources. These bores are generally equipped to provide much smaller supplies than those from the deep artesian resources.

In the study area very few bores intersect the deeper groundwater resources, such as the Gubberamunda Sandstone and Hutton Sandstone. These aquifers are, therefore, generally the lowest producing aquifers in the study area. The best supplies however, in terms of quantity and quality, are associated with the Gubberamunda Sandstone.

Numerous bores have been drilled and constructed within the other sedimentary units, resulting in small brackish supplies.

The aquifers associated with the Hutton Sandstone are located some 600 m below surface at Roma.

Based on the geology within the study area, the structural geology, and the geomorphology the following conditions can arise to enhance groundwater occurrence within the study area:

- Saturated unconsolidated alluvial deposits along the river systems;
- Primary permeability units;
- The fractured transition zone between weathered and fresh bedrock;
- Contact zones between sedimentary rocks of different types;
- Contacts which may be open, enlarged, and loosened by weathering;

- Openings on discontinuities formed by the west-northwest trending faults;
- Stratigraphic unconformities;
- Zones of deeper weathering, and
- Fractures related to folding and / or tensional and decompressional stresses due to off-loading of overlying material.

Aquitards which form the confining beds include; the Orallo Formation, Westbourne Formation, Evergreen Formation, Moolayember Formation, and the Rewan Formation.

Fairview CSG Field

The groundwater resource potential of various formations outcropping in the Fairview CSG Field area has been assessed (Forbes, 1968). These include:

- The Clematis Sandstone which should produce good supplies of potable groundwater;
- The Moolayember Formation is generally impermeable and has little potential as an aquifer;
- The Precipice Sandstone has good aquifer potential and generally produces plentiful supplies of potable subartesian water;
- The Evergreen Formation is an aquitard;
- The Hutton Sandstone is not a reliable source, owing to erratic distribution and water quality is commonly brackish;
- The Birkhead Formation contains limited aquifers with brackish quality groundwater associated with coal seams; and
- The alluvium associated with larger streams can provide good supplies of groundwater from shallow depth.

The sedimentary bedrock units around Fairview are generally low permeability and contain brackish water, with the exception of the Precipice Sandstone, which is a productive aquifer for potable water.

The Fairview CSG Field is located within the upper reaches of the Dawson River Catchment, which forms part of the Fitzroy Basin. A salinity study, compiled by the DNRW, allowed for the compilation of regional hydrogeological information (DNRW, 2007). These data were used in the assessment of salinity issues within the Fitzroy Basin. The hydrogeological data relevant to the Fairview study area includes:

- Alluvial deposits are on average 15 m thick, with an average saturated thickness of 4.5 m. The alluvial deposits have enhanced groundwater potential due to relatively high hydraulic conductivity, ~10 m/day, and an average specific yield of 0.1. The sustainability of the groundwater resources associated with the alluvial material will, however, depend on the extent of the alluvial deposits and the effective storage.
- The aquifers associated with the sedimentary rocks within the hills of the upper catchment vary in thickness of between 20 to 25 m. The hydraulic conductivity of these rocks depends on secondary processes, such as weathering, faulting, etc., and ranges between 0.5 and 1.5 m/day. The specific yield of these formations is between 0.001 and 0.005. Groundwater quality may be saline due to the depositional nature of the rocks and the reduced rainfall recharge.

Based on the geology within the Fairview study area, the structural geology, and the geomorphology the following conditions can arise to enhance groundwater occurrence within the study area:

- Saturated unconsolidated alluvial deposits along the river systems;
- Primary aquifers;
- The fractured transition zone between weathered and fresh bedrock;
- Contact zones between sedimentary rocks of different types;
- Contacts which may be open, enlarged, and loosened by weathering;
- Openings on discontinuities formed by faulting / fracturing, and
- Zones of deeper weathering.

Arcadia CSG Field

Landholders in the area generally rely on tanks, dams, and permanent waterholes for stock watering (Olgers, 1966). Tertiary sediments, the Moolayember Formation, and the Clematis Sandstone are less reliable sources of stock quality groundwater, but many bores are drilled into these units.

Part of the Arcadia CSG Field is located within the upper reaches of the Comet River Catchment, which forms part of the Fitzroy Basin. A salinity study, compiled by the DNRW, provided the following hydrogeological data (DNRW, 2007):

- The alluvial material located within the Comet Catchment has enhanced groundwater potential due to high permeability, 5 m/day, and specific yield of 0.2. The alluvial is readily recharged through rainfall and river flows. The alluvial deposits are on average 20 m thick. Due the high recharge and limited aquifer extent the groundwater quality is typically of low salinity.
- The aquifers associated with the sedimentary rocks within the upper Comet Catchment have limited saturated thickness, 10 m, relatively low hydraulic permeability (0.1 m/day), and restricted storage. These aquifers are recognised as having low to moderate sustainable yields with variable hydrochemistry.

Part of the Arcadia CSG Field is located in the upper reaches of the Dawson River Catchment with hydrogeological conditions as discussed in the previous section on the Fairview CSG Field.

The exposure of GAB aquifers within the Arcadia and Fairview CSG Fields under artesian conditions, can allow for groundwater discharge (springs and seeps) to surface water. Variations in rainfall recharge (in the Great Dividing Range for example) or groundwater abstraction which exceeds recharge will result in the “mining” of groundwater and the reduction in groundwater discharge. The proposed project will not be depressurising the GAB aquifers directly and envisaged induced flow (as detailed in the deep groundwater study compiled by Matrixplus, 2009) will have limited impact on the shallow aquifer water levels within the CSG fields, thus the project is not envisaged to impact significantly on the groundwater / surface water interaction which results from artesian flows.

Boreholes drilled into GAB aquifers under artesian pressure, when left unchecked, will result in surface water flow. This adds to the natural runoff and groundwater baseflow recognised within river hydrographs. The uncontrolled flow from these bores is recognised as wasteful and is unsustainable. Over the long term this practice leads to a decline in artesian flows and groundwater levels. The Queensland Government has initiated the Great Artesian Basin Sustainability Initiative (GABSI) to allow for the rehabilitation of the unchecked bores and reduce losses. All bores to be drilled during the project will be constructed and managed to ensure no groundwater losses. The identification of artesian flows from open bores within the study area, including the gas transmission pipeline route, will be recorded and relayed to the DNRW. This groundwater / surface water interaction is recognised to be temporary and will be addressed by the GABSI process.

Based on the geology within the study area, the structural geology, and the geomorphology the following conditions can arise to enhance aquifer development within the study area:

- Saturated unconsolidated alluvial deposits along the river systems;
- Units with enhanced primary porosity and permeability;
- The fractured transition zone between weathered and fresh bedrock;
- Contact zones between sedimentary rocks of different types;
- Contacts which may be open, enlarged, and loosened by weathering;
- Openings on discontinuities formed by faulting / fracturing;
- Contact metamorphism with intrusive bodies;
- Stratigraphic unconformities;
- Zones of deeper weathering, and
- Fractures related to tensional and decompressional stresses due to folding of material.

2.2 Review of Groundwater Information in the DNRW Database

All available geological and hydrogeological information was obtained for the area enveloping the CSG fields to be developed during the GLNG Project. An assessment of the available geological descriptions allowed for the identification of bores which have intersected the various surficial geology, as described in **Section 2.1**. The available data allowed for an initial assessment of the groundwater resources associated with these units.

It is recognised that the DNRW groundwater database contains data which has not been validated or verified. Certain inaccuracies are expected, however, the available data is sufficient to allow for a high level assessment of the baseline hydrogeological characteristics of each geological unit.

2.2.1 Alluvium

Thirty-nine (39) boreholes were identified to have intersected alluvium from a review of the DNRW records. The limited and incomplete records indicate that the alluvial material within the study area is of limited thickness, a mean thickness of 4.26 m, of which approximately half is saturated. Thus the volumes of available groundwater are limited. The bores constructed into the alluvial material are shallow (average depth 11 m), and are, according to the DNRW logs, often constructed with pick and shovel. **Figure 2-4** presents the spread of boreholes constructed within the alluvium.

Groundwater levels, measured in the shallow bores constructed within the alluvial, are shallow (< 7 mbgl). These shallow groundwater levels and the relatively high hydraulic conductivity associated with the sand and gravel within the alluvial material indicate that the groundwater resources are vulnerable to contamination.

Four of the borehole records have hydrochemical data; these data are presented in **Table 2-2** and compared to the guidelines discussed in **Section 1.4.1**. This is done to provide a preliminary evaluation of the hydrochemistry.

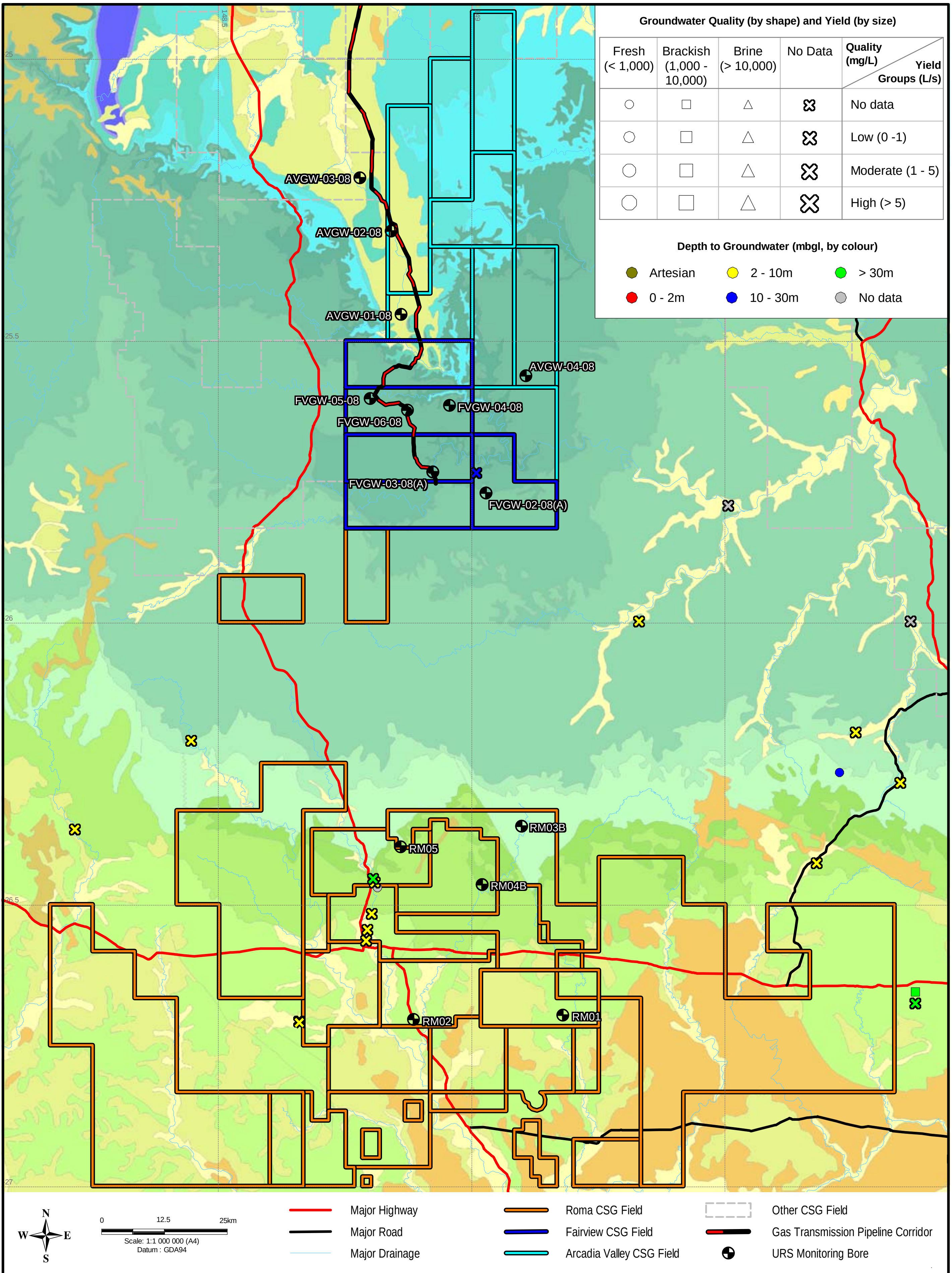
The hydrochemical results indicate variable groundwater quality, which is alkaline and sodium-chloride dominant. Dissolved metal concentrations vary and elevated iron and manganese have been recorded. These results indicate that the groundwater associated with the alluvium is typically not potable and has limited suitability for use.

Although the alluvium aquifers are identified as limited and containing poor quality groundwater a level of protection is required for the shallow permeable units as these aquifers can act as preferential flow paths for possible surface contaminants off site and impact on down stream users, surface water resources, and sensitive ecosystems (such as permanent pools).

Table 2-2 DNRW Database Hydrochemical Data for Alluvium in the CSG Fields

	Water Quality Guidelines						Borehole record number			
	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]	58655	42230628	42230629	47718
pH						6.5 – 8.5	8.3	8.0	8.0	7.3
Electrical Conductivity (µS/cm)							1,570	4,650	12,040	4,010
Calcium (mg/L)				1000	1000		43.2	190	362.9	60.8
Magnesium (mg/L)							10.4	125	316	49.1
Potassium (mg/L)							4	12.5	12	3.3
Sodium (mg/L)		115-460	115-460			180	311.5	650	1,949.4	749.8
Chloride (mg/L)		175-700	175-700			250	243.3	1,650	3874	991.5
Sulfate (mg/L)				1000	1000	500	99.7	2	587.6	0
Total Alkalinity (mg/l $CaCO_3$)							377	205	260	618
Copper (mg/L)	0.0014	0.2	5	0.1	0.1	0.08	0.01		0.1	0.01
Iron (mg/L)						0.3	0	0.02	0	4.26
Manganese (mg/L)	1.9	0.2	10			0.5	0	0.05	0.06	1.44
Zinc (mg/L)	0.008	2	5	20	20	3	0.02		0.01	0.01
Nitrate (mg/L N)						11.29 (50 mg/l NO_3)	1.3	1.28	0	0

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems
2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)
3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years)
4 – ANZECC 2000 Trigger Levels for Livestock Watering
5 – Australian Drinking Water Guidelines 2004



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GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

BORES WITHIN THE ALLUVIUM AQUIFERS

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Approved: JB
Date: 23-01-2009
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Surface Water / Groundwater Interaction

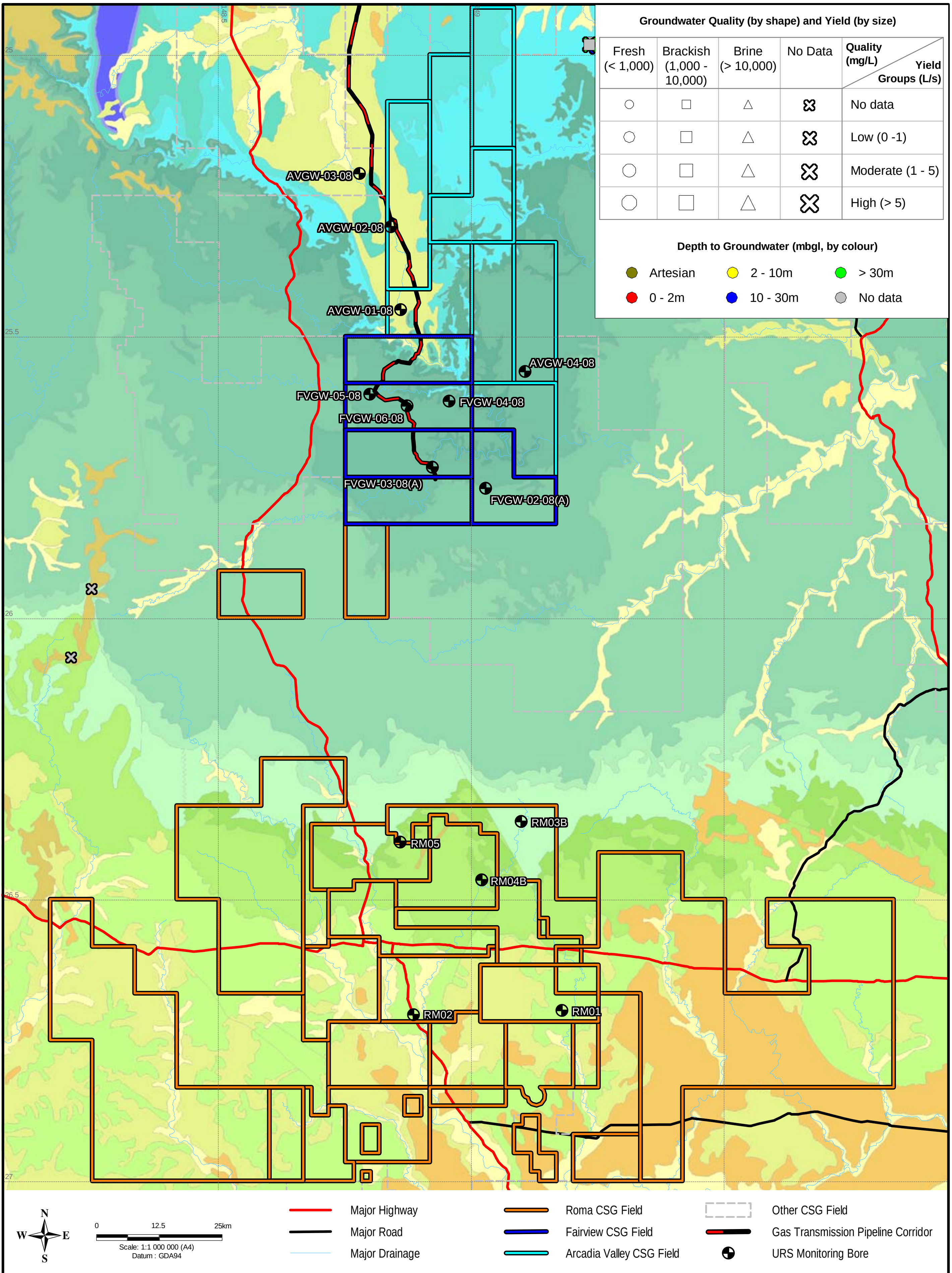
The alluvium aquifers receive recharge from both rainfall and stream flow during the wet seasons. The coarse grained material, sand and gravel, within the alluvium deposits provide increased storage capacity within the unit. This groundwater forms baseflow to the surface water courses once the flows in the rivers and streams decline. As the creeks within the CSG field areas are non-perennial the effective storage in the alluvium is recognised to be limited, i.e. there is insufficient groundwater held within the alluvium to provide baseflow through out the entire dry season. Alterations to the alluvium aquifers, in terms of removal or diversion, will therefore have limited impact on the surface water flow patterns.

2.2.2 Basalt

The limited extent of basalt in the area of the CSG fields results in few DNRW records containing data on the Miocene basalt lithology. The majority of bores installed in basalt are located north and east of the Arcadia Gas Field, with the shallow groundwater used for domestic and stock watering purposes in the area. The groundwater occurs within joints, weathered zones, and fractures within the basalt as well as along geological contacts with older host geology.

Borehole depths range from 6 to 100 m but are on average 40 m. This indicates that groundwater is intersected at shallow depths, probably on the weathered / fresh rock interface. Borehole yields recorded indicate a wide variation in yields, 0 to 23 L/s, indicating groundwater potential is enhanced based on secondary processes, such as faulting and fracturing,. The discrete zones of enhanced groundwater potential allow for an average borehole yield of 2.5 L/s. The sustainability of the yields is not known, however, rainfall data indicates regular seasonal recharge within the study area.

The locations of the DNRW registered bores in basalt are indicated in **Figure 2-5**. As all bores in the basalt are outside of the CSG field areas and will not be impacted by the gas field activities, they will not be discussed further.



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Title

BORES WITHIN
BASALT AQUIFERS

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Job No: **4262 6220**	File No: 42626220-g-574b.wor		Rev:B A4

2.2.3 Wallumbilla Formation

Limited data (55 boreholes) has been compiled for the boreholes drilled to intersect the mudstone and siltstone rocks of the Wallumbilla Formation within the study area (**Figure 2-6**). No yield or static water level data has been captured on the database. Borehole depths are shallow, averaging ± 40 m. The groundwater potential of the Wallumbilla Formation cannot be assessed based on the limited information.

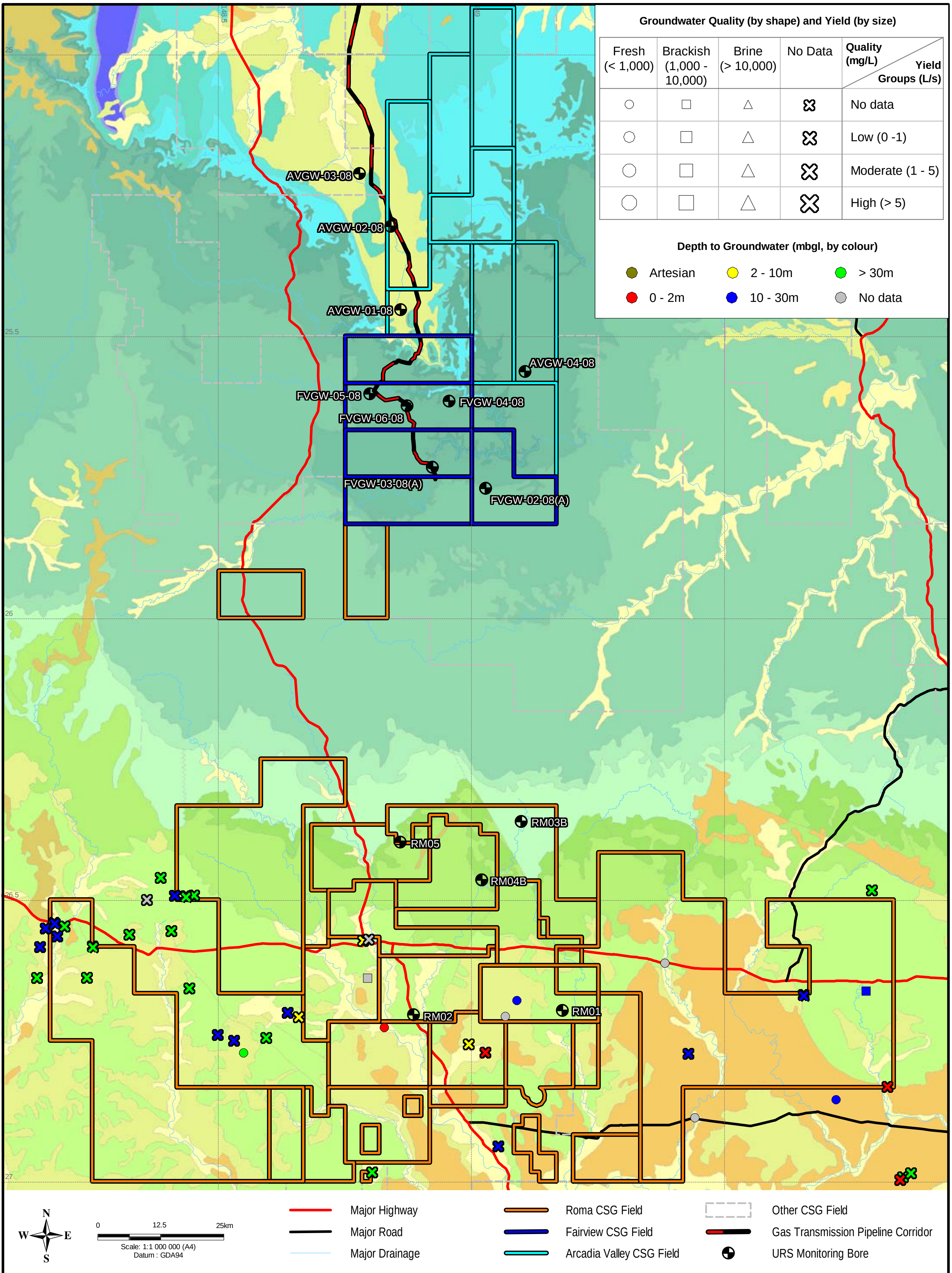
Numerous groundwater chemistry records have been captured for these bores. **Table 2-3** presents a summary of these data. The groundwater is sodium-chloride dominant and variable across the area. Groundwater is predominantly fresh but records indicate areas of brackish water within this unit. Low nitrate levels indicate that no anthropogenic contamination is evident.

Limited groundwater use associated with these sediments indicates that the Wallumbilla Formation should be considered when assessing areas for ancillary infrastructure, which could potentially impact on shallow groundwater.

Table 2-3 DNRW Database Hydrochemical Data Summary for the Wallumbilla Formation in the CSG Fields

	Water Quality Guidelines						20th Percentile	80th Percentile	Median	No. samples
	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]				
Conductivity (µS/cm)							1,500	1,828	1,650	15
pH (pH units)						6.5 – 8.5	8.16	8.72	8.5	15
Alkalinity (mg/L $CaCO_3$)							133.2	644.6	366.5	24
Sodium (mg/L)		115-460	115-460			180	368.4	1,070.16	441.65	24
Potassium (mg/L)							1.42	2.44	1.5	12
Calcium (mg/L)				1000	1000		2.88	95.26	8	23
Magnesium (mg/L)							0.7	11.18	1.4	23
Iron (mg/L)						0.3	0	0.17	0.055	8
Manganese (mg/L)	1.9	0.2	10			0.5	0.004	0.032	0.01	8
Chloride (mg/L)		175-700	175-700			250	157.62	1,686.3	192	24
Fluoride (mg/L)						1.5	0.23	1.34	0.75	21
Nitrate (mg/L N)						11.29	0	0.4	0	12
Sulfate (mg/L)				1000	1000	500	3.16	339.52	25	12

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems
2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)
3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years)
4 – ANZECC 2000 Trigger Levels for Livestock Watering
5 – Australian Drinking Water Guidelines 2004



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CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

BORES WITHIN THE WALLUMBILLA FORMATION

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Figure: **2-6**

Rev:B

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2.2.4 Bungil Formation

A large number of records were recovered for boreholes drilled and constructed within the Bungil Formation, which mainly comprises sandstone. The 603 records indicate that the unit has good groundwater supply potential with yields ranging between 0.2 and 6.3 L/s. The average yield is moderate, 1.7 L/s, indicating groundwater is not limited to discrete zones of secondary permeability. **Figure 2-7** indicates the location of these bores.

Both the borehole depth and groundwater levels are relatively deep when compared to the borehole records for the Wallumbilla Formation. The average borehole depth is 149 m and the average static water level is 48 mbgl. Limited groundwater level and elevation data indicates groundwater level variation is governed by confining conditions. Groundwater level data records indicate groundwater levels at 5 mbgl and 90 mbgl at elevations of 350 mAHD. This indicates discontinuous confining conditions within the Bungil Formation.

Groundwater quality records were analysed for boreholes which intersected the Bungil Formation units at depths not greater than 100 m. The groundwater quality results are presented in **Table 2-4**.

The available groundwater data indicates that the groundwater is brackish (Total dissolved solids[3] (TDS) > 1000 mg/l) and is sodium-chloride dominant. Possible contaminant sources need to be identified within the CSG fields and representative baseline data for the Bungil Formation units is required.

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[3] TDS was calculated based on the formula TDS = 0.51 x Electrical Conductivity (in µS/cm). 0.51 is used due to the groundwater being sodium chloride dominant.

Table 2-4 DNRW Database Hydrochemical Data Summary for the Bungil Formation in the CSG Fields

	Water Quality Guidelines						20th Percentile	80th Percentile	Median	No. samples
	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]				
Conductivity (µS/cm)							1,424	3,500	1,805	195
pH (pH units)						6.5 – 8.5	7.8	8.6	8.3	202
Alkalinity (mg/L $CaCO_3$)							189.8	667.8	392	292
Sodium (mg/L)		115-460	115-460			180	358	975.24	457.5	292
Potassium (mg/L)							1	3	1.7	127
Calcium (mg/L)				1000	1000		2	84.38	6	291
Magnesium (mg/L)							0.1	18.6	1.4	290
Iron (mg/L)						0.3	0	0.13	0.02	106
Manganese (mg/L)	1.9	0.2	10			0.5	0	0.02	0.01	93
Chloride (mg/L)		175-700	175-700			250	145	1,182	278.9	292
Fluoride (mg/L)						1.5	0.3	1.4	0.7	135
Nitrate (mg/L)						11.29	0	2.2	0.5	143
Sulfate (mg/L)				1000	1000	500	0	469.84	44.75	281
Zinc (mg/L)						3	0	0.01	0.005	12
Aluminium (mg/L)						0.2	0	0.008	0	12
Boron (mg/L)						4	0.1	1.18	0.95	12
Copper (mg/L)	0.0014	0.2	5	1	0.4	2	0	0.02	0.01	12

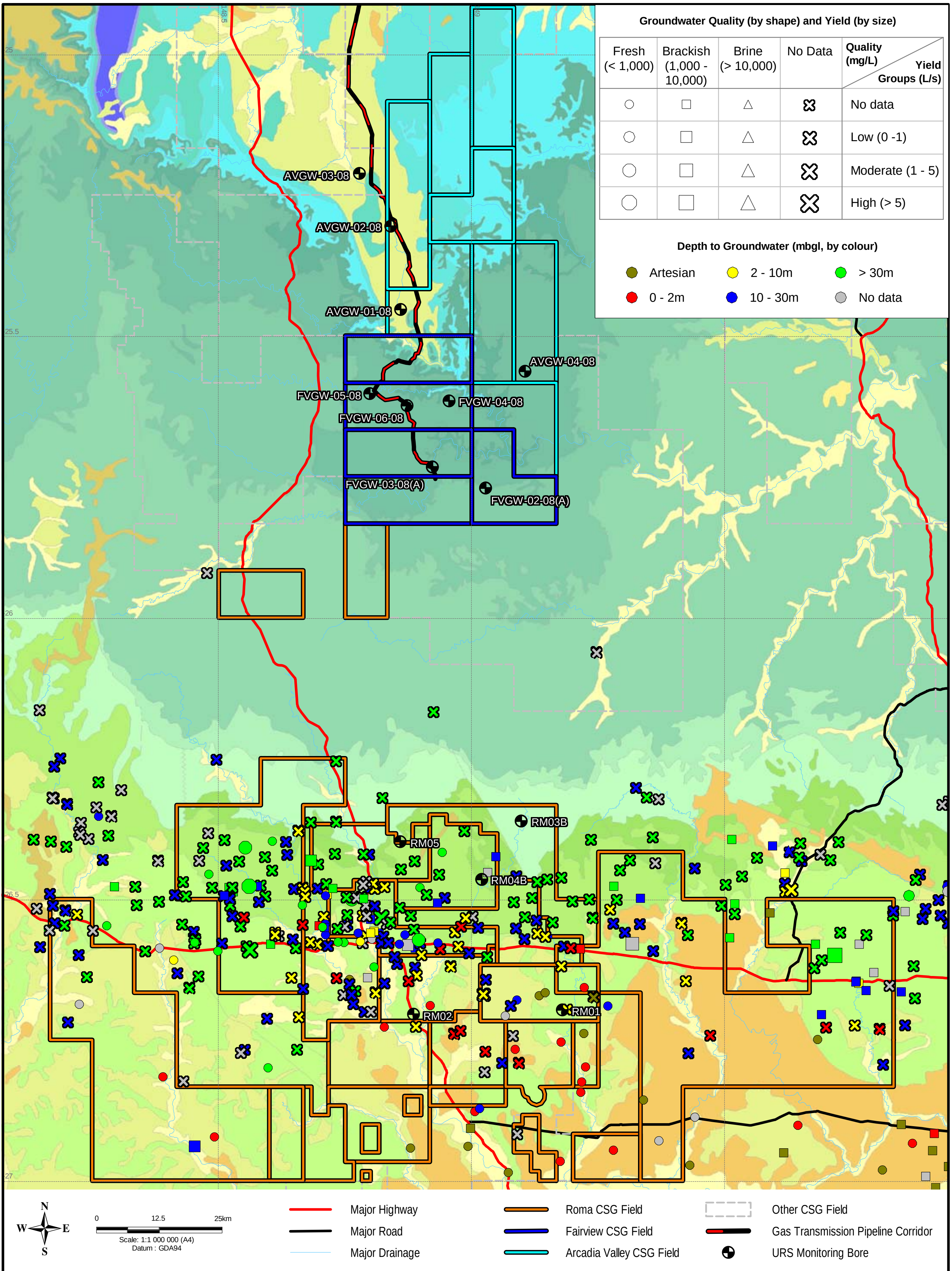
1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems

2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)

3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years)

4 – ANZECC 2000 Trigger Levels for Livestock Watering

5 – Australian Drinking Water Guidelines 2004



Groundwater Quality (by shape) and Yield (by size)

Fresh (< 1,000)	Brackish (1,000 - 10,000)	Brine (> 10,000)	No Data	**Quality (mg/L)** **Yield Groups (L/s)**
○	□	△	☒	No data
○	□	△	☒	Low (0 -1)
○	□	△	☒	Moderate (1 - 5)
○	□	△	☒	High (> 5)

Depth to Groundwater (mbgl, by colour)

● Artesian
● 2 - 10m
● > 30m
● 0 - 2m
● 10 - 30m
● No data

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GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

BORES WITHIN THE BUNGIL FORMATION

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Figure: **2-7**

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2.2.5 Mooga Sandstone

The Mooga Sandstone unit is extensively utilised across the CSG field study area. The DNRW records indicate the majority of the boreholes within the Mooga Sandstone have intersected the sandstone at depth. The data was edited to only assess the borehole records for bores which intersected the sandstone unit at depths not greater than 100 m, i.e. in order to assess shallow groundwater resources associated with the Mooga Sandstone. The resultant records indicate that the boreholes drilled into the Mooga Sandstone at outcrop or close to surface have an average borehole depth of 63 m and have an average yield of 1.19 L/s (**Figure 2-9**).

The records provide sufficient elevation and groundwater level data to assess the Bayesian Relationship between topography and groundwater levels. **Figure 2-8** shows the linear relationship between elevation and groundwater levels in meters above Australian Height Datum (m AHD). The groundwater level data shows a moderate correlation between groundwater levels and elevation, indicating that groundwater levels mimic topography. Confining conditions give rise to the elevated groundwater levels.

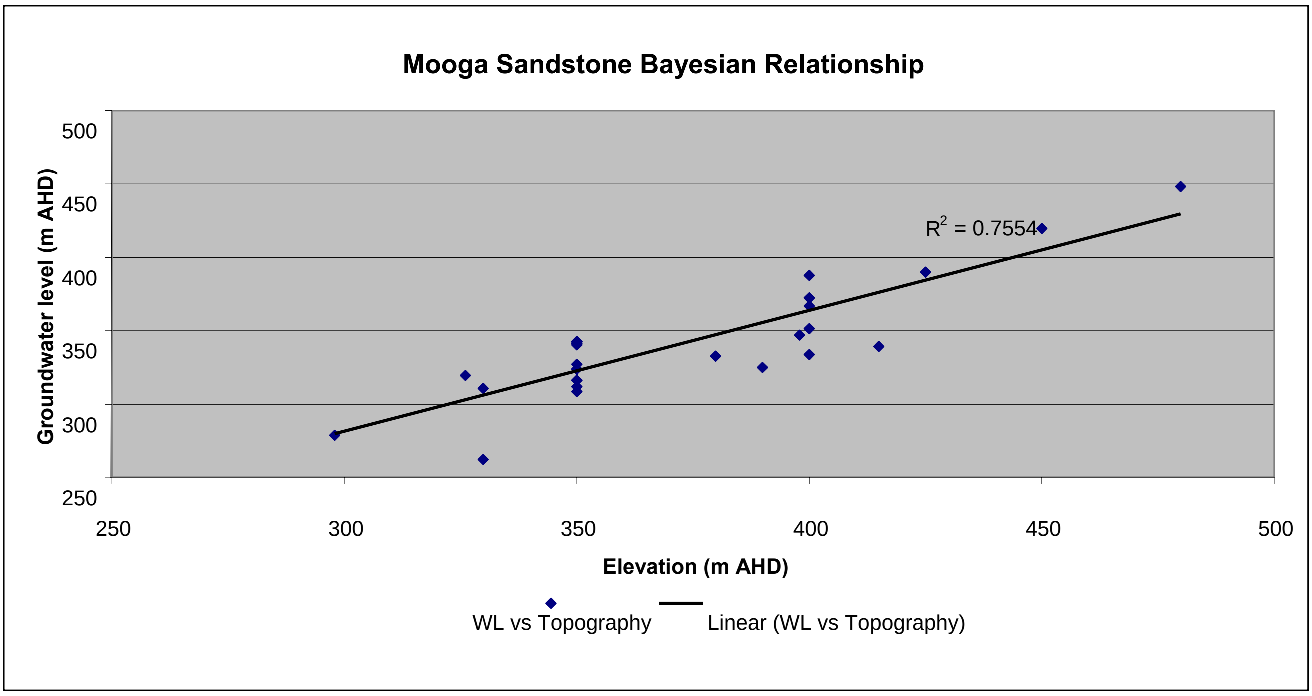
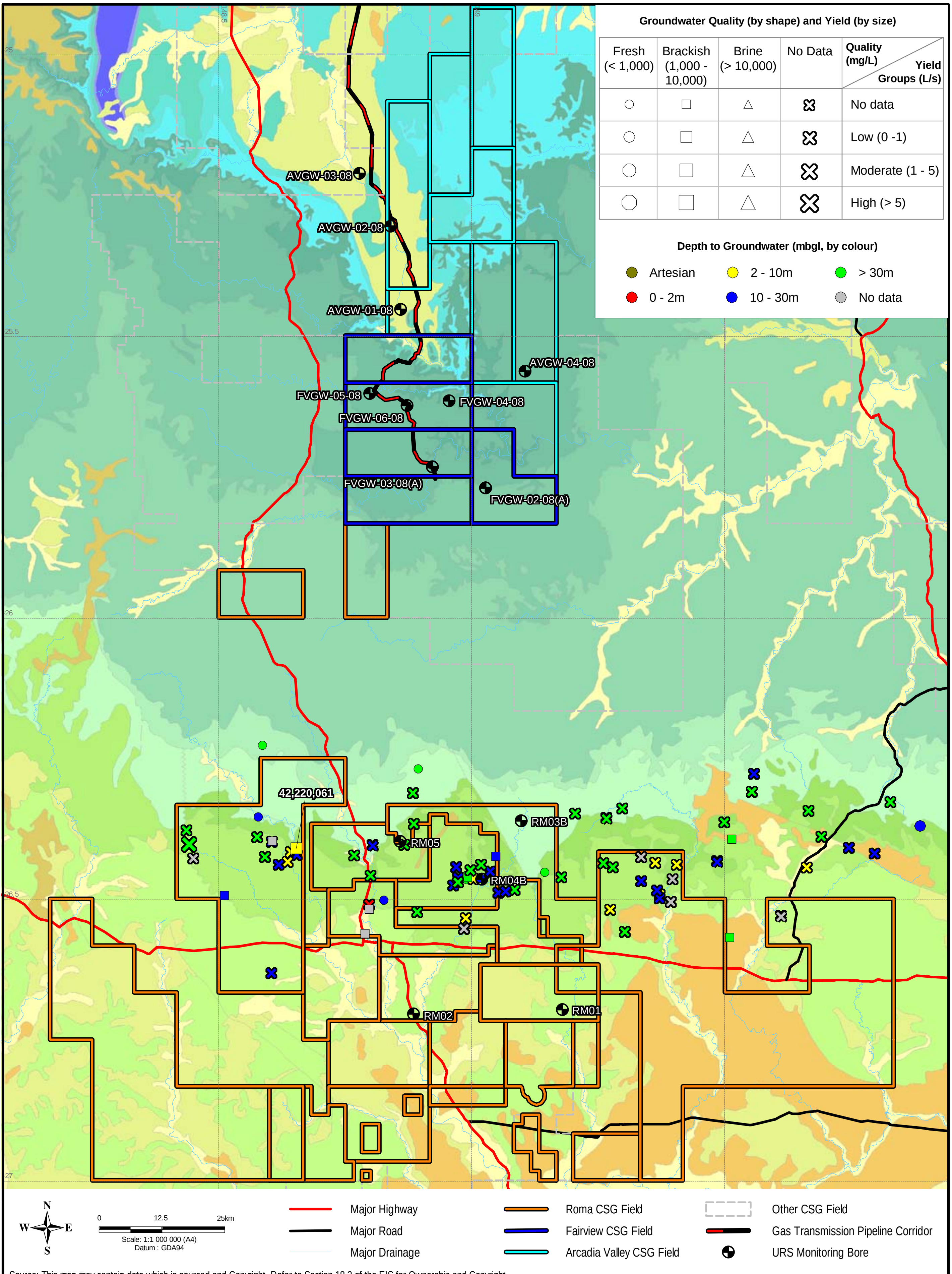


Figure 2-8 Groundwater – Elevation Relationship Data for the Mooga Sandstone



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GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

SHALLOW (< 100m)
BORES WITHIN THE
MOOGA SANDSTONE

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Figure: **2-9**

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A4

Long term groundwater level data has been recorded in DNRW monitoring bore 42220061, which indicate natural groundwater fluctuations within the Mooga Sandstone over time. Automated groundwater level readings indicate that groundwater levels fluctuate some 3 to 4 m over extended periods (**Figure 2-10**) but indicate limited fluctuations over a single year (**Figure 2-11**).

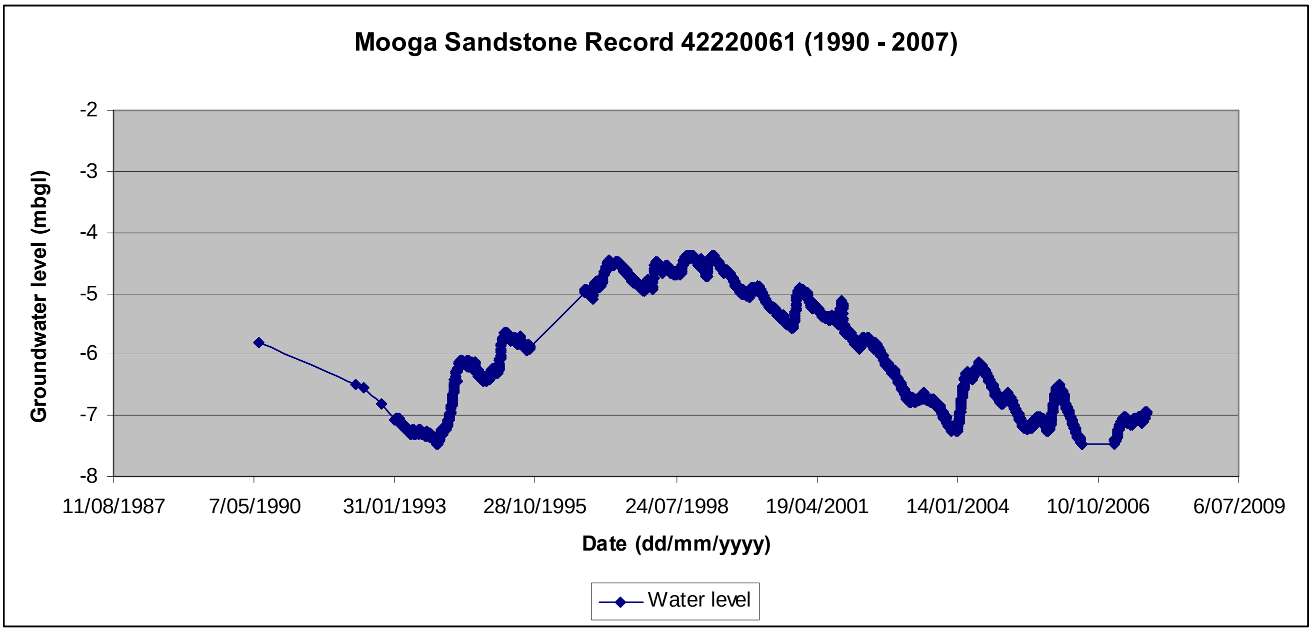


Figure 2-10 Long Term Groundwater Level Data for Bore 42220061, Mooga Sandstone

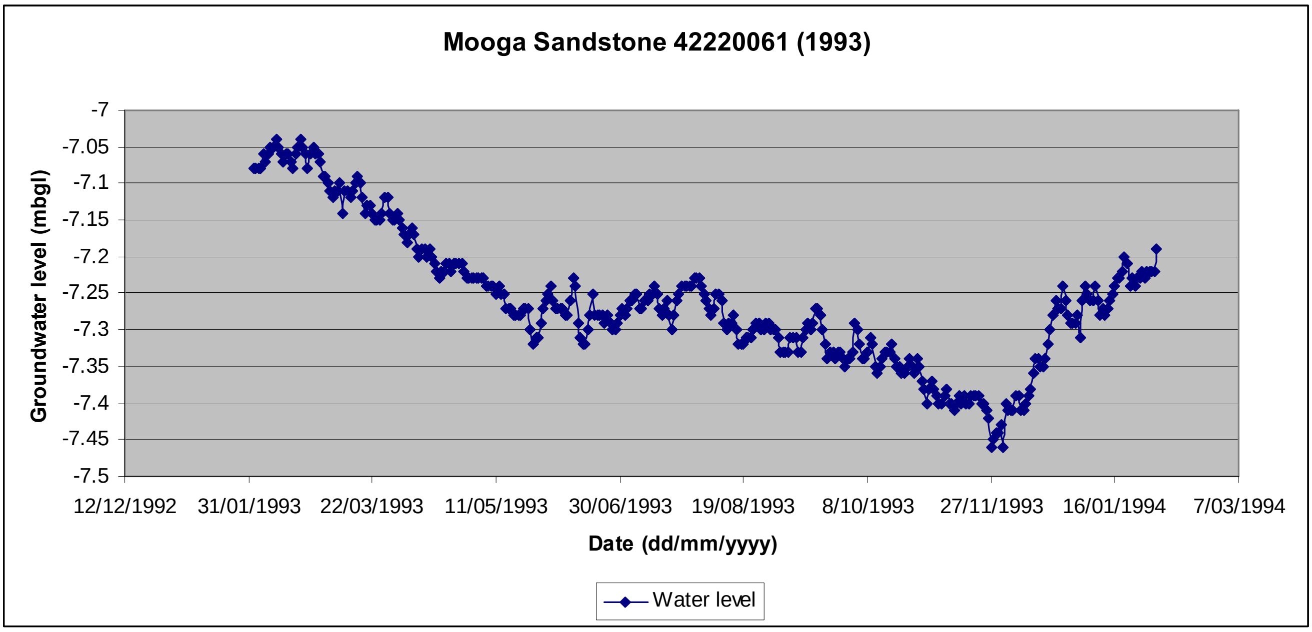


Figure 2-11 Short Duration (1 year) Groundwater Level Data for Bore 42220061, Mooga Sandstone

Groundwater level data indicate:

- Narrow range of natural fluctuations due to dry and wet seasons (0.5 m for 1993 data);
- Shallow groundwater levels resulting from the period of high rainfall (mean annual rainfall > 700 mm between 1995 and 2000, Bureau of Meteorology, 2008); and
- Limited effective storage as the groundwater levels return to pre-1995 levels after two below average rainfall years (425 mm/y in 2001 and 366 mm/y in 2002).

Hydrochemistry data indicates that the groundwater quality is similar to overlying lithologies in that it is sodium-chloride dominant and has, on average, elevated electrical conductivity concentrations. The average sulfate concentration value is elevated when compared to the other units mapped in the study area. **Table 2-5** presents a summary of the available hydrochemical data for the shallow groundwater associated with the Mooga Sandstone unit.

The high groundwater utilisation, rapid response to recharge, and variable hydrochemistry indicates the need to protect the Mooga Sandstone aquifer from possible groundwater contamination or dewatering.

Table 2-5 DNRW Database Hydrochemical Data Summary for the Moooga Sandstone in the CSG Fields

	Water Quality Guidelines						20th Percentile	80th Percentile	Median	No. samples
	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]				
Conductivity (µS/cm)							1,310	5,926	2,265	18
pH (pH units)						6.5 – 8.5	7.26	8.3	7.8	27
Alkalinity (mg/L $CaCO_3$)							110	416	299	37
Sodium (mg/L)		115-460	115-460			180	301	1,443	601	38
Potassium (mg/L)							0.92	4.82	4.25	14
Calcium (mg/L)				1000	1000		7.9	158	65	38
Magnesium (mg/L)							1.6	67.2	13.6	38
Iron (mg/L)						0.3	0	0.03	0	11
Manganese (mg/L)	1.9	0.2	10			0.5	0	0.16	0.02	11
Chloride (mg/L)		175-700	175-700			250	219	1,724	750	38
Fluoride (mg/L)						1.5	0.15	0.41	0.26	32
Nitrate (mg/L)						11.29	0	4.36	2.25	14
Sulfate (mg/L)				1000	1000	500	55	994	210	38
Zinc (mg/L)						3	0.004	0.04	0.01	3
Aluminium (mg/L)						0.2	0	0.006	0	3
Boron (mg/L)						4	0.9	1.08	0.9	3
Copper (mg/L)	0.0014	0.2	5	1	0.4	2	0	0.006	0	3

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems
2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)
3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years)
4 – ANZECC 2000 Trigger Levels for Livestock Watering
5 – Australian Drinking Water Guidelines 2004

2.2.6 Orallo Formation

Limited groundwater records are available for the Orallo Formation. This sandstone formation has the highest recorded yield (14.3 L/s) and highest average yield (4.6 L/s) of all of the units assessed in the Roma Gas Field area. The high yielding boreholes within this formation indicate the presence of secondary permeability which can act as preferential flow paths for groundwater. **Figure 2-13** presents the borehole locations.

The boreholes are on average 135 m deep, and the static water levels are relatively deep, averaging 40 mbgl. No elevation data is available for the boreholes recorded into this formation. Groundwater level data over a 38 month period for monitoring bore 13030806 is presented in **Figure 2-12**. The data indicates limited seasonal and long term fluctuations (± 1 m) in response to wet and dry seasons. The limited response may be as a result of overlying aquitards (low permeable units), which provide confining conditions and reduce direct recharge. Confined aquifer storage and large aquifer extent also reduces the influence of recharge or through flow on the groundwater levels and is recognised as typical of confined aquifers associated with the GAB units.

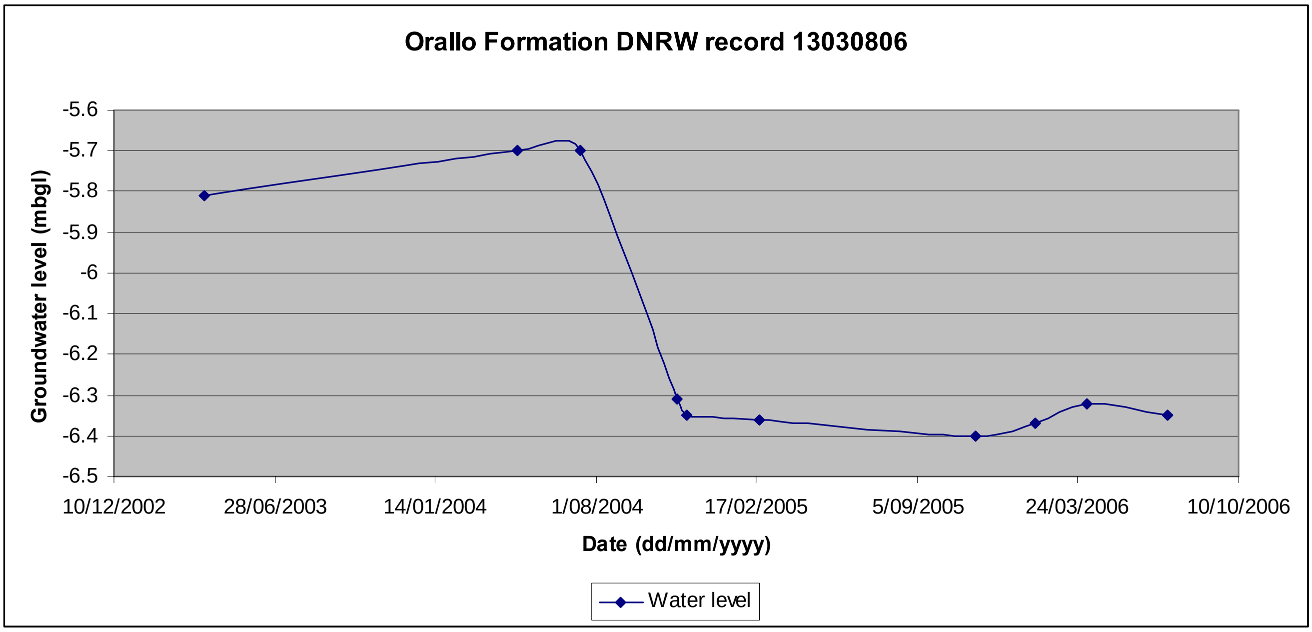
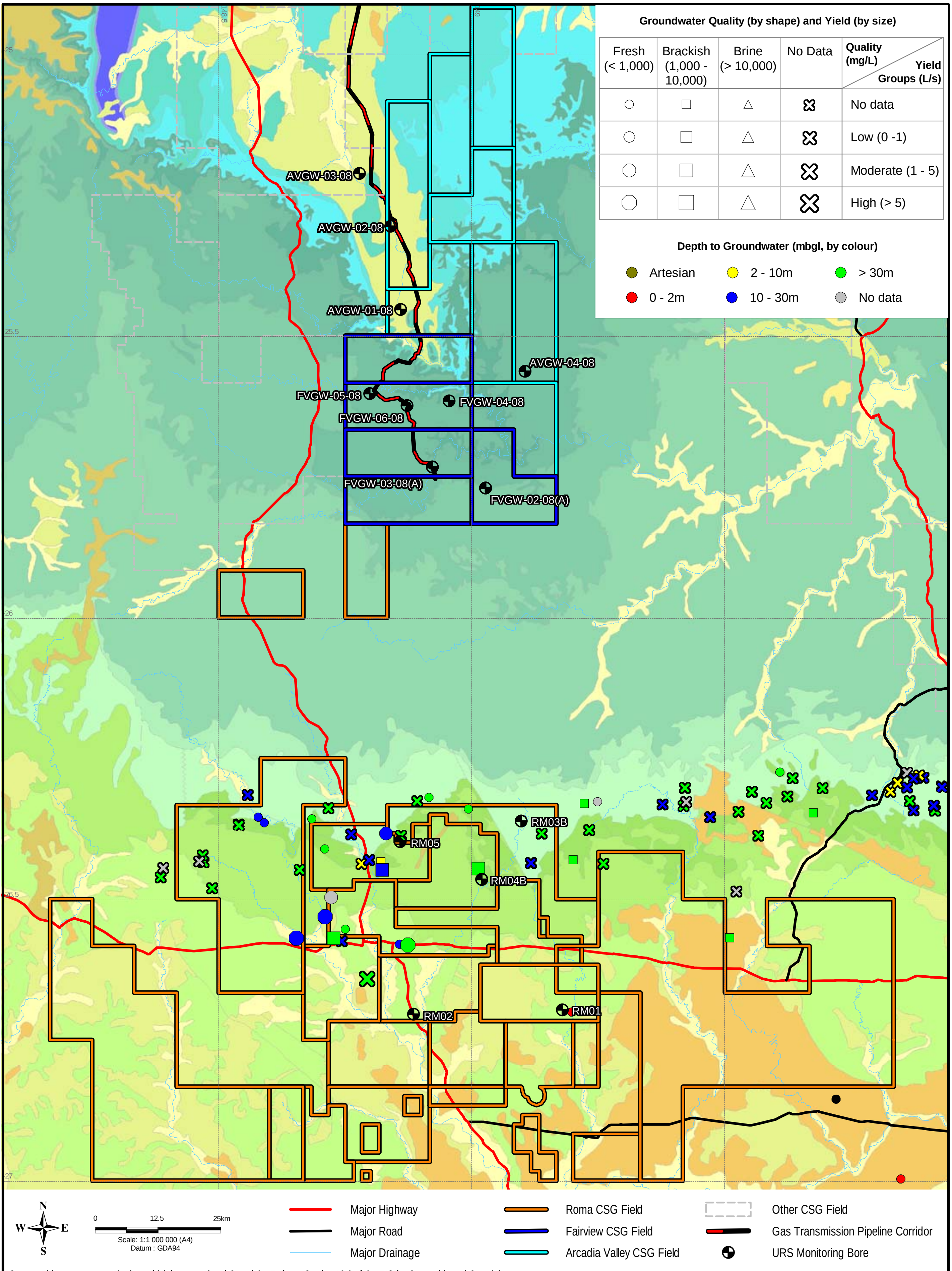


Figure 2-12 Groundwater Level Data for Bore 13030806, Orallo Formation

Groundwater chemistry information recorded for the Orallo Formation is presented in **Table 2-6**. The groundwater quality data is similar to the other data compiled for the local area. The groundwater is brackish and sodium-chloride dominant. Groundwater with TDS concentrations > 10 000 mg/l (brine) have been recorded from some bores within this unit and elevated levels of iron and fluoride have also been recorded within groundwater samples collected from this unit.

The high yielding boreholes within this formation indicate the presence of secondary permeability which can act as preferential flow paths for groundwater and possible contaminants.



Groundwater Quality (by shape) and Yield (by size)

Fresh (< 1,000)	Brackish (1,000 - 10,000)	Brine (> 10,000)	No Data	Quality (mg/L) / Yield Groups (L/s)
○	□	△	☒	No data
○	□	△	☒	Low (0 -1)
○	□	△	☒	Moderate (1 - 5)
○	□	△	☒	High (> 5)

Depth to Groundwater (mbgl, by colour)

● Artesian	● 2 - 10m	● > 30m
● 0 - 2m	● 10 - 30m	● No data

— Major Highway	— Roma CSG Field
— Major Road	— Fairview CSG Field
— Major Drainage	— Arcadia Valley CSG Field
▭ Other CSG Field	— Gas Transmission Pipeline Corridor
⊕ URS Monitoring Bore	

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Client

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GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

BORES WITHIN THE ORALLO FORMATION

Drawn: RG
Approved: JB
Date: 23-01-2009
Job No: **4262 6220**
File No: 42626220-g-578.wor

Figure: **2-13**

Rev:B

A4

Table 2-6 DNRW Database Hydrochemical Data Summary for the Orallo Formation in the CSG Fields

	Water Quality Guidelines						20th Percentile	80th Percentile	Median	No. samples
	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]				
Conductivity (µS/cm)							920	2,096	1,480	31
pH (pH units)						6.5 – 8.5	7.62	8.58	8.15	41
Alkalinity (mg/L $CaCO_3$)							180	580	355	46
Sodium (mg/L)		115-460	115-460			180	216	986	395	46
Potassium (mg/L)							0.8	6.2	1.5	23
Calcium (mg/L)				1000	1000		3.4	70	10	46
Magnesium (mg/L)							14	0.4	3	44
Iron (mg/L)						0.3	0	0.048	0.02	19
Manganese (mg/L)	1.9	0.2	10			0.5	0	0.03	0.01	15
Chloride (mg/L)		175-700	175-700			250	89	847	285	46
Fluoride (mg/L)						1.5	0.1	0.5	0.3	43
Nitrate (mg/L)						11.29	0	1.24	0	24
Sulfate (mg/L)				1000	1000	500	11	216	69	44

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems
2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)
3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years)
4 – ANZECC 2000 Trigger Levels for Livestock Watering
5 – Australian Drinking Water Guidelines 2004

2.2.7 Birkhead Formation (Walloons Coal Seams)

The Birkhead Formation, which comprises sandstone and coal seams, has a significant number of drilling records registered on the database. The Birkhead Formation is also referred to as the Walloons Coal Seams, which is the targeted for CSG production in the CSG fields. An assessment of the shallow boreholes, drilling depth less than 100 m, was conducted to assess the shallow groundwater resources associated with the Walloons Coal Seams within the Fairview study area (**Figure 2-15**). Few bores exist within the gas field tenements, with the majority located to the east of the Fairview and Arcadia gas fields. Based on an assessment of 141 borehole records the Birkhead Formation is recognised to have a low to moderate average borehole yield of 1.1 L/s. The groundwater potential is enhanced through secondary processes as yields range from 0.1 L/s to 12.6 L/s within this unit.

Groundwater level data, as shown in **Figure 2-14**, indicates that the groundwater levels correlate well with the surface elevation. This indicates that groundwater levels mimic topography. Groundwater level data, as recognised in Figure 2-14, indicates confining (artesian) conditions occur within this unit as groundwater level records show water levels above surface in several database entries.

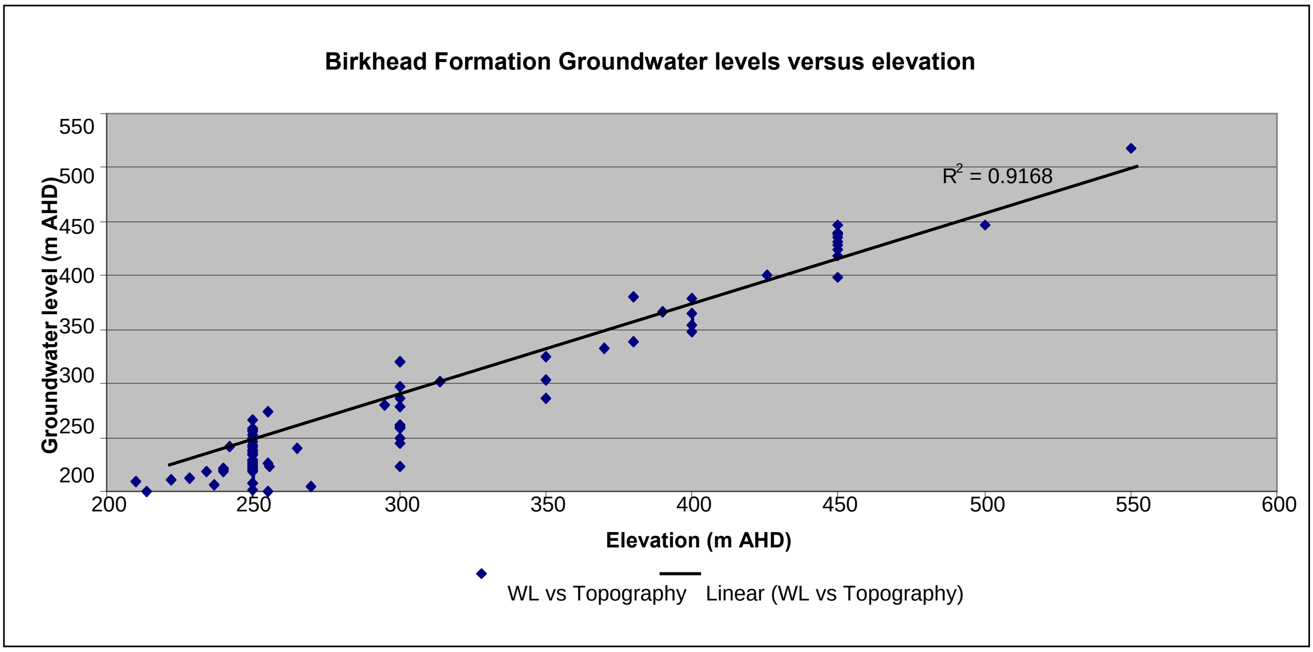
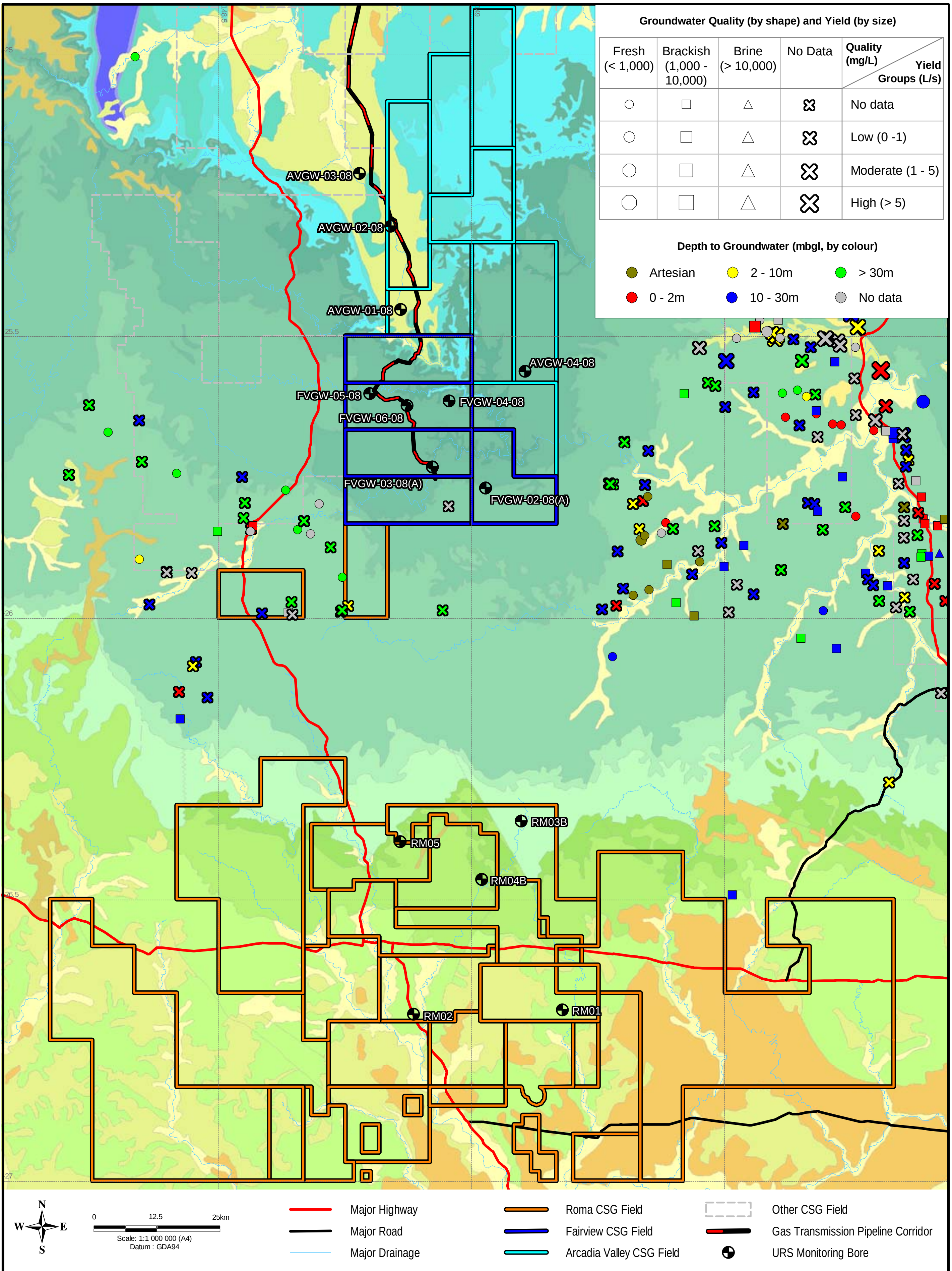


Figure 2-14 Groundwater – Elevation Relationship Data for the Birkhead Formation



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CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

SHALLOW (< 100m) BORES WITHIN THE BIRKHEAD FORMATION

Drawn: RG
Approved: JB
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File No: 42626220-g-579b.wor
Figure: **2-15**
Rev:B
A4

Limited long term groundwater level data is available for this formation. Database records indicate that 5 boreholes have been monitored for a minimum of 39 months. These data are presented in **Figure 2-16**.

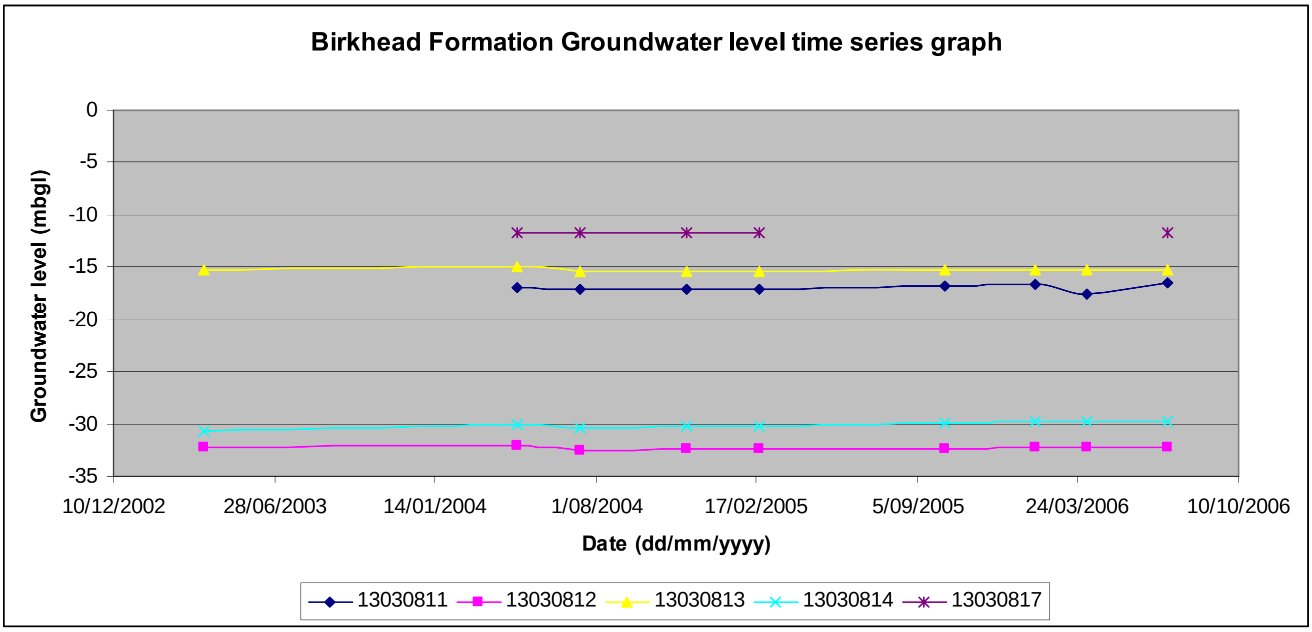


Figure 2-16 Groundwater Level Data for Selected Bores, Birkhead Formation

The long term groundwater level data is stable with limited seasonal fluctuations. These boreholes must penetrate aquifers which are confined from above and below by low permeable units, have large lateral extent, and large volume of water held in storage. These factors limit the groundwater level response to seasonal climatic changes.

The hydrochemistry associated with the shallow groundwater resources within the Birkhead Formation is summarised in **Table 2-7**. The groundwater is on average, brackish with elevated concentrations of sodium and chloride. Records indicate variable groundwater quality associated with this unit, with records of fresh, brackish, and brine groundwater quality based on TDS.

Incidents of high yielding bores, as a result of geological structures and secondary process, and artesian conditions indicate that the groundwater resources associated with this formation require protection.

Table 2-7 DNRW Database Hydrochemical Data Summary for the Birkhead Formation in the CSG Fields

	Water Quality Guidelines						20th Percentile	80th Percentile	Median	No. samples
	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]				
Conductivity (µS/cm)							944	3,160	1,550	118
pH (pH units)						6.5 – 8.5	7.7	8.5	8.05	131
Alkalinity (mg/L $CaCO_3$)							140	472	222	147
Sodium (mg/L)		115-460	115-460			180	223	918	469	147
Potassium (mg/L)							0.6	4.2	1.6	77
Calcium (mg/L)				1000	1000		2.5	25	6	146
Magnesium (mg/L)							0.2	7.6	1	147
Iron (mg/L)						0.3	0	0.1	0.01	45
Manganese (mg/L)	1.9	0.2	10			0.5	0	0.03	0.01	37
Chloride (mg/L)		175-700	175-700			250	130	1,289	425	147
Fluoride (mg/L)						1.5	0.1	0.9	0.26	138
Nitrate (mg/L)						11.29	0	1.2	0	75
Sulfate (mg/L)				1000	1000	500	0	13.6	2	137

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems
2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)
3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years)
4 – ANZECC 2000 Trigger Levels for Livestock Watering
5 – Australian Drinking Water Guidelines 2004

2.2.8 Hutton Sandstone

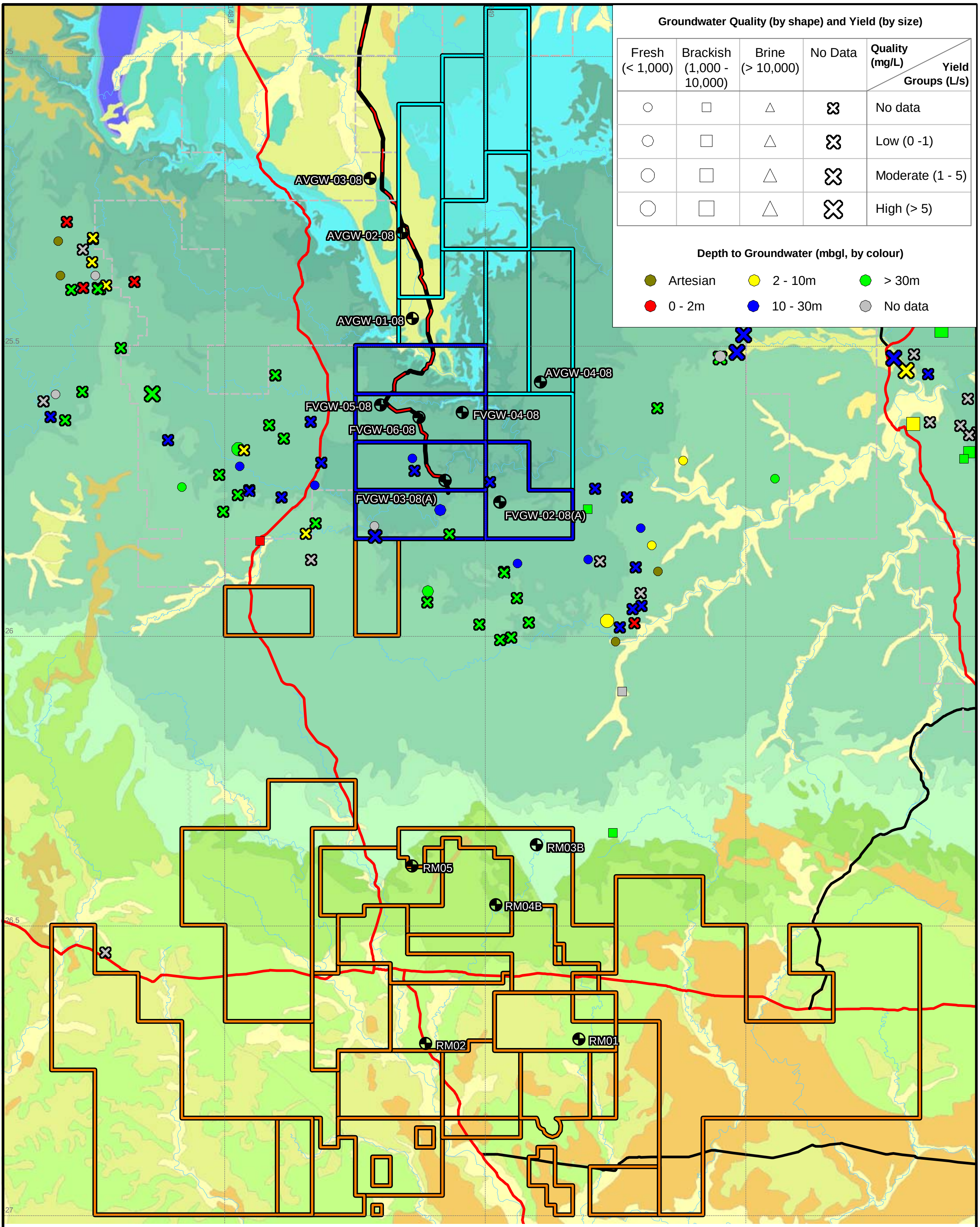
The Hutton Sandstone forms one of the major GAB aquifers within the CSG field study area due to its physical characteristics, thickness (120 to 180 m) and transmissivity, which results in significant groundwater bearing potential. Typical aquifer characteristics, based on previous URS studies, include:

Transmissivity	100 - 150 m^2/day
Storage	5 x 10^{-4}
Porosity	20 – 25%
Borehole yields	1.5 to 12 L/s

Available groundwater quality data indicates that the TDS values for the Hutton Sandstone average ± 590 mg/L (fresh water) and pH values range from 7.7 to 11.3. The groundwater is sodium, chloride and bicarbonate (Na, Cl-HCO_3) type. The average concentration of sodium is 910 mg/L, ranging from 500 to 1,100 mg/L. Chloride concentrations range from 90 to 850 mg/L.

Figure 2-18 presents long term groundwater level monitoring within the Hutton Sandstone. The groundwater levels are relatively stable over the 16 year record, with slight fluctuations in groundwater levels during the dry and wet seasons.

The good groundwater potential and high abstraction within the Hutton Sandstone aquifer indicates the need to protect this aquifer. **Figure 2-17** shows the outcrop of Hutton Sandstone and shallow (< 100 m deep) bores within this unit within the CSG study area.



Groundwater Quality (by shape) and Yield (by size)

Fresh (< 1,000)	Brackish (1,000 - 10,000)	Brine (> 10,000)	No Data	Quality (mg/L) Yield Groups (L/s)
○	□	△	✖	No data
○	□	△	✖	Low (0 -1)
○	□	△	✖	Moderate (1 - 5)
○	□	△	✖	High (> 5)

Depth to Groundwater (mbgl, by colour)

●	Artesian	●	2 - 10m	●	> 30m
●	0 - 2m	●	10 - 30m	●	No data

N
W E
S

0 12.5 25km
Scale: 1:1 000 000 (A4)
Datum : GDA94

—	Major Highway	—	Roma CSG Field	▭	Other CSG Field
—	Major Road	—	Fairview CSG Field	—	Gas Transmission Pipeline Corridor
—	Major Drainage	—	Arcadia Valley CSG Field	◐	URS Monitoring Bore

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GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

SHALLOW (< 100m)
BORES WITHIN THE
HUTTON SANDSTONE

Drawn: RG	Approved: JB	Date: 23-01-2009	Figure: **2-17**
Job No: **4262 6220**	File No: 42626220-g-580b.wor		Rev:B **A4**

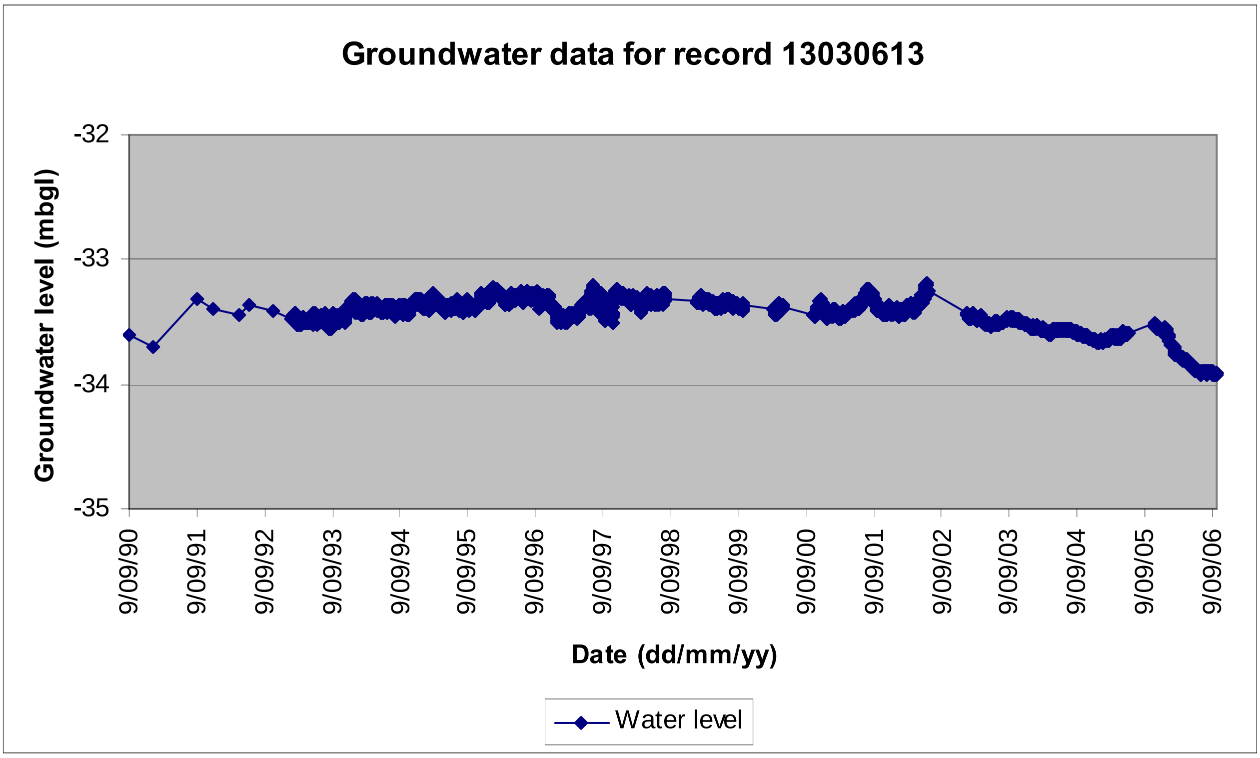


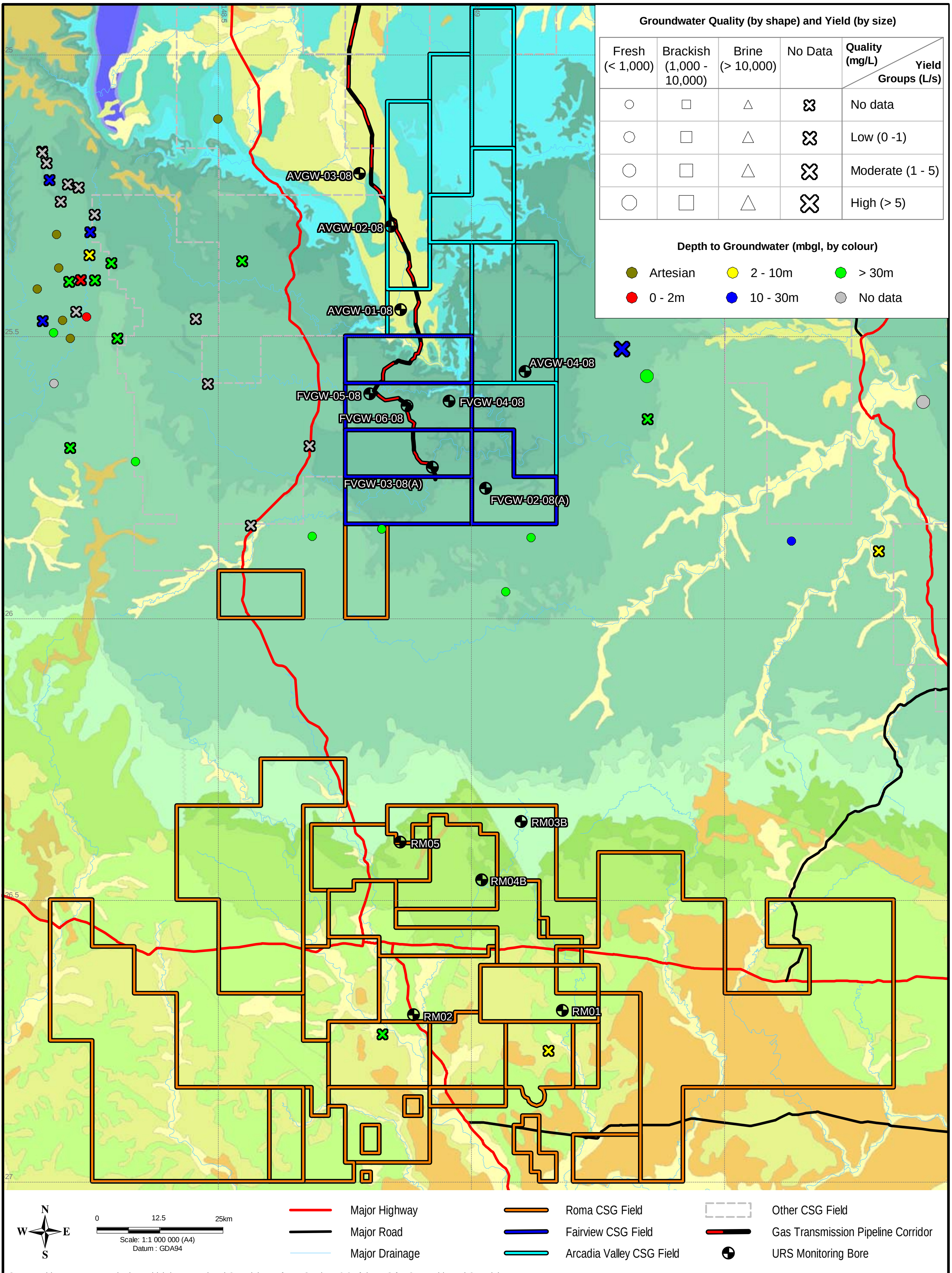
Figure 2-18 Groundwater Level Data for Bore 13030613, Hutton Sandstone

2.2.9 Boxvale Sandstone

The quartzose Boxvale Sandstone is a subunit of the Evergreen Formation and is of limited thickness and thus reduced groundwater potential when compared to the thicker sandstone units within the CSG field study area. The DNRW records indicate that the average borehole yield is moderate, 2 L/s, and the groundwater levels on record are relatively deep, averaging 65 mbgl. **Figure 2-19** shows the boreholes located within this unit.

The limited hydrochemistry data for the Boxvale Sandstone is summarised in **Table 2-8**. The groundwater is sodium-chloride dominant with a large variation in pH conditions. Elevated sulfate, iron, and low pH has been recorded in the groundwater associated with the Boxvale Sandstone. This may be as a result of the coal within this unit.

The depth of the groundwater reduces the groundwater vulnerability; however, the good quality groundwater (as indicated in the median results) indicates the need to protect the shallow groundwater resources associated with the Boxvale Sandstone.



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GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

BORES WITHIN THE BOXVALE SANDSTONE

Drawn: RG
Approved: JB
Date: 23-01-2009
Job No: **4262 6220**
File No: 42626220-g-581b.wor

Figure: **2-19**

Rev:B

A4

Table 2-8 DNRW Database Hydrochemical Data Summary for the Boxvale Sandstone in the CSG Fields

	Water Quality Guidelines						20th Percentile	80th Percentile	Median	No. samples
	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]				
Conductivity (µS/cm)							179	778	394	37
pH (pH units)						6.5 – 8.5	7	8.3	7.7	38
Alkalinity (mg/L $CaCO_3$)							63	214	145	44
Sodium (mg/L)		115-460	115-460			180	27	206	33	44
Potassium (mg/L)							1.7	6.7	4.3	29
Calcium (mg/L)				1000	1000		4	42	25	44
Magnesium (mg/L)							1	20	10	43
Iron (mg/L)						0.3	0	0.03	0	23
Manganese (mg/L)	1.9	0.2	10			0.5	0	0.05	0.02	20
Chloride (mg/L)		175-700	175-700			250	18	178	41	44
Fluoride (mg/L)						1.5	0.03	0.2	0.1	41
Nitrate (mg/L)						11.29	0	1	0	31
Sulfate (mg/L)				1000	1000	500	0	29	11	40
Zinc (mg/L)						3	0	0.042	0	5
Aluminium (mg/L)						0.2	0	0.01	0	5
Boron (mg/L)						4	0	0.02	0	5
Copper (mg/L)	0.0014	0.2	5	1	0.4	2	0.01	0.034	0.01	5

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems

2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)

3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years)

4 – ANZECC 2000 Trigger Levels for Livestock Watering

5 – Australian Drinking Water Guidelines 2004

2.2.10 Evergreen Formation

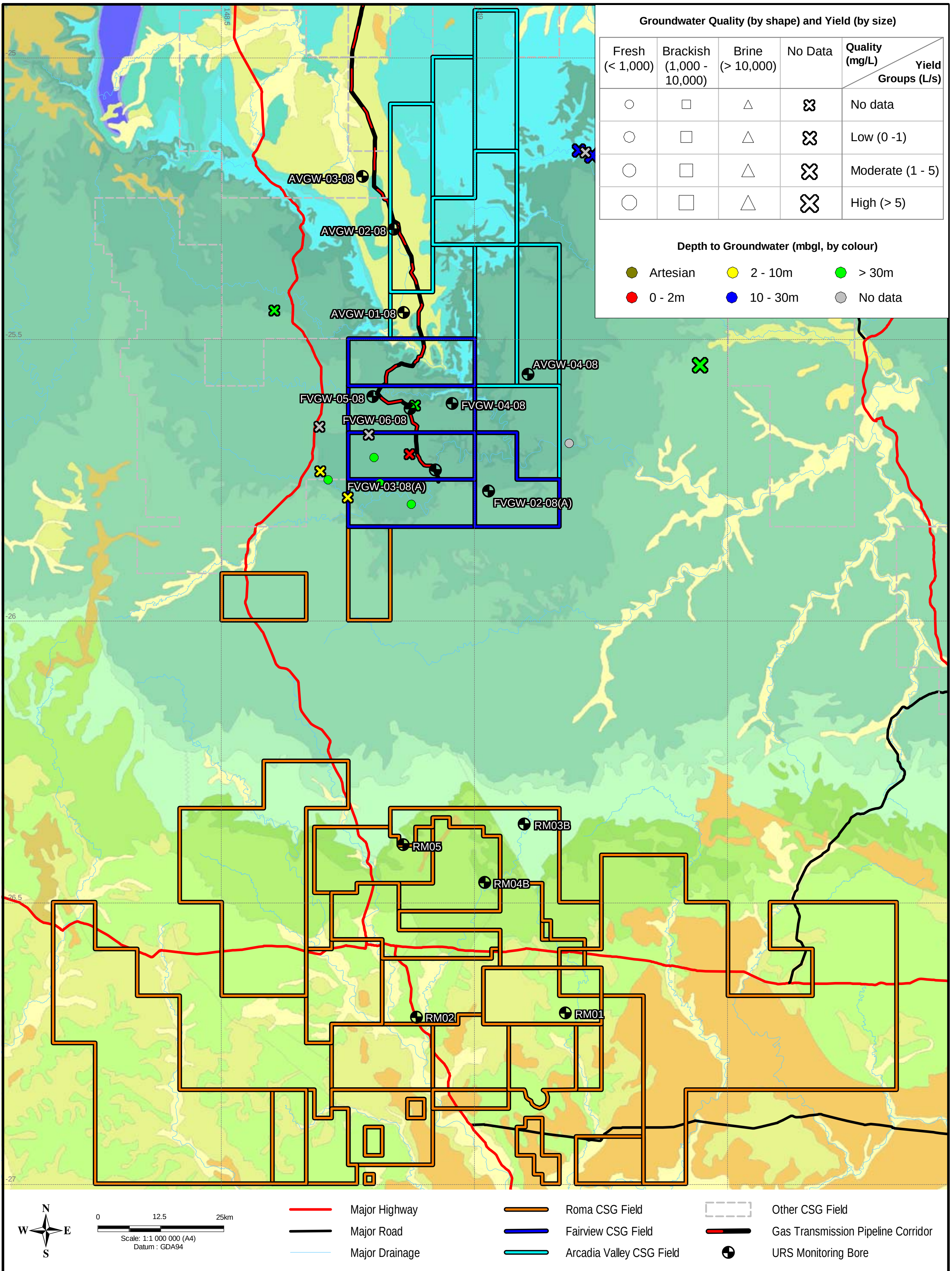
The shallow boreholes (< 100 m deep) constructed in the Evergreen Formation (excluding the Boxvale Sandstone) are low yielding (0.3 L/s average yield) and indicate limited groundwater resource potential when compared to the other units within the area (**Figure 2-20**).

Available groundwater level data indicates a linear relationship between groundwater levels and topography, thus groundwater flow mimics topography (**Figure 2-21**). The average depth to groundwater is 22 m.

The limited groundwater quality data, presented in **Table 2-9**, indicates that the groundwater is of good quality and the median results indicate that the groundwater is suitable for a wide range of uses. Elevated concentrations of iron have been recorded in some groundwater samples collected from this unit. Low sulfate concentrations are associated with the Evergreen Formation.

Long term hydrochemical monitoring of borehole 37201 within the Evergreen Formation indicates that the concentrations of major anions and cations vary over time but within a narrow margin, some 5 to 10 mg/L. **Figure 2-22** presents the hydrochemical data monitored from 1971 to 1994.

The sodium chloride dominant groundwater resources are limited and have restricted potential for moderate to high sustainable resource development. The good groundwater quality requires protection.



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GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

SHALLOW (< 100m)
BORES WITHIN THE
EVERGREEN FORMATION

Drawn: RG
Approved: JB
Date: 23-01-2009
Job No: **4262 6220**
File No: 42626220-g-582b.wor
Figure: **2-20**
Rev:B
A4

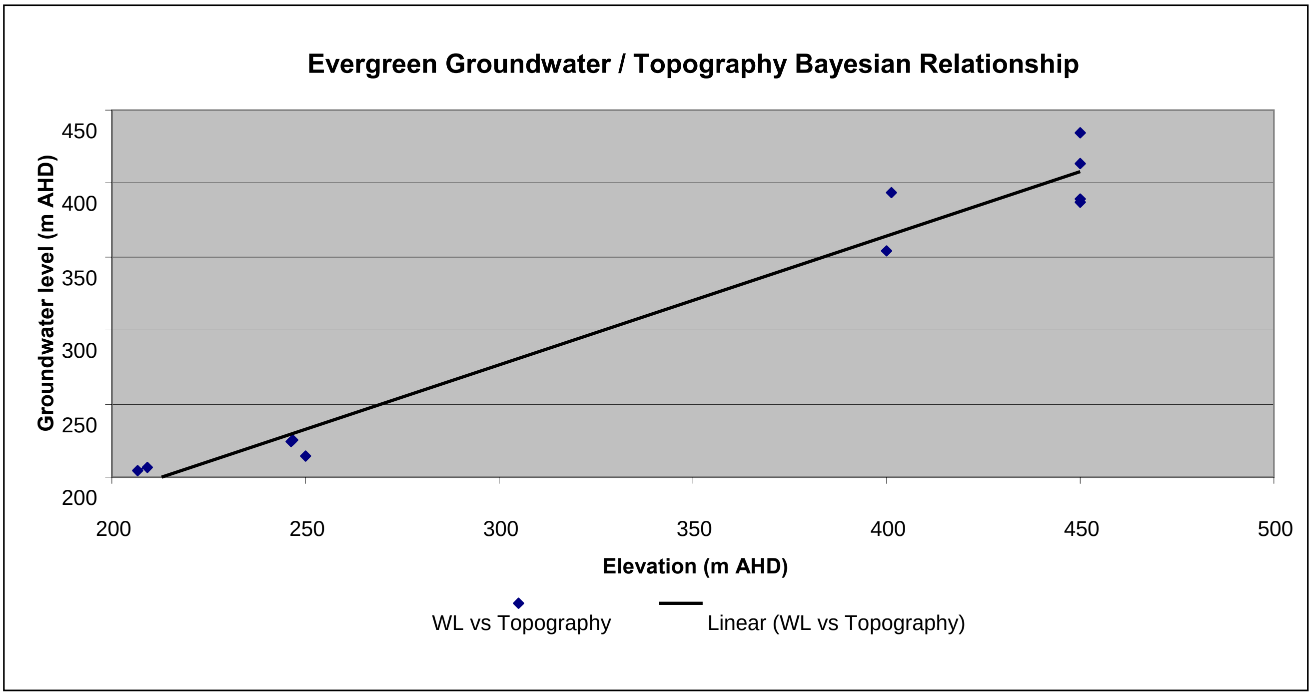


Figure 2-21 Groundwater – Elevation Relationship Data for the Evergreen Formation

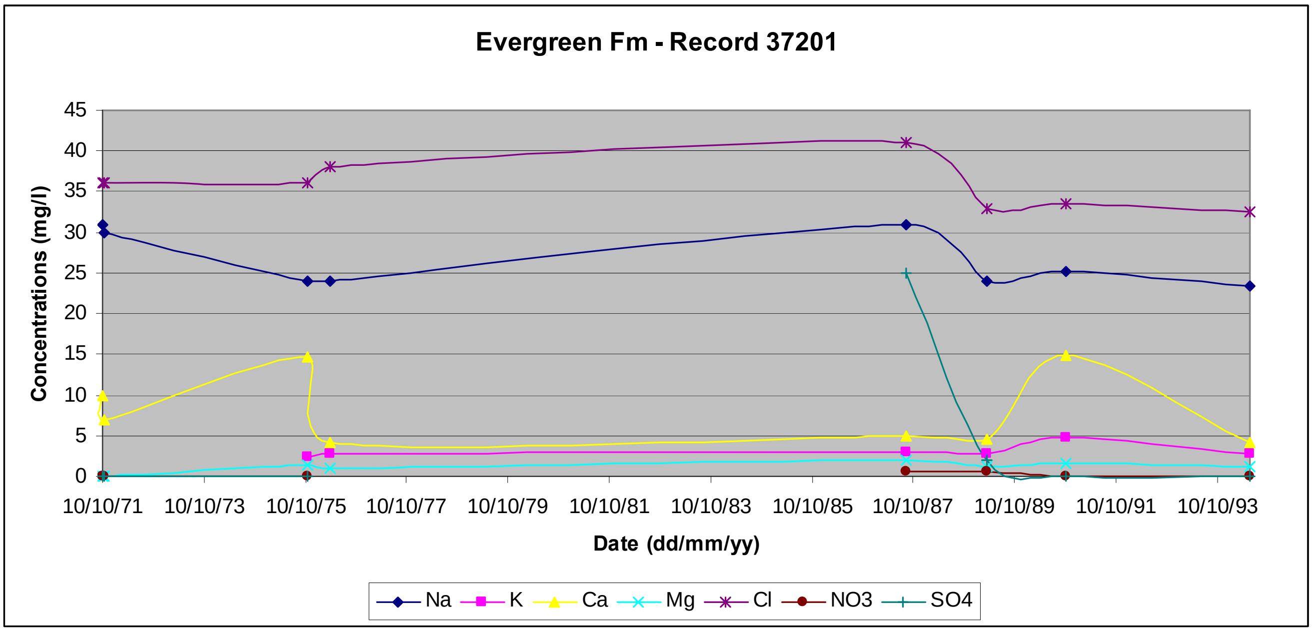


Figure 2-22 Groundwater Hydrochemical Data for Bore 37201, Evergreen Formation

Table 2-9 DNRW Database Hydrochemical Data Summary for the Evergreen Formation in the CSG Fields

	Water Quality Guidelines						20th Percentile	80th Percentile	Median	No. samples
	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]				
Conductivity (µS/cm)							150	334	220	52
pH (pH units)						6.5 – 8.5	6.78	7.9	7.45	60
Alkalinity (mg/L $CaCO_3$)							48	164	100	60
Sodium (mg/L)		115-460	115-460			180	26	63	44	58
Potassium (mg/L)							1.9	2.8	2.3	36
Calcium (mg/L)				1000	1000		2.1	17.6	4.3	58
Magnesium (mg/L)							0.28	2.28	0.7	55
Iron (mg/L)						0.3	0	0.06	0.02	25
Manganese (mg/L)	1.9	0.2	10			0.5	0	0.032	0.01	20
Chloride (mg/L)		175-700	175-700			250	10	48	19	58
Fluoride (mg/L)						1.5	0.1	0.36	0.2	55
Nitrate (mg/L)						11.29	0	0.5	0	35
Sulfate (mg/L)				1000	1000	500	0	2	0	48

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems
2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)
3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years)
4 – ANZECC 2000 Trigger Levels for Livestock Watering
5 – Australian Drinking Water Guidelines 2004

2.2.11 Precipice Sandstone

The Precipice Sandstone is another major GAB aquifer within the CSG field study area. DNRW records reveal a large number of deep boreholes have been drilled to intersect this aquifer at depth. In order to assess the shallow groundwater only the boreholes drilled to a maximum of 100 m were assessed (**Figure 2-24**). The average borehole yield for the shallow boreholes is relatively high, 4.9 L/s. The drilling reveals good groundwater potential through out the high transmissive aquifer unit.

Groundwater level measurements range from 0.5 to 54 m below surface and are 28 mbgl on average. No records of artesian conditions were recorded in the shallow boreholes (**Figure 2-23**).

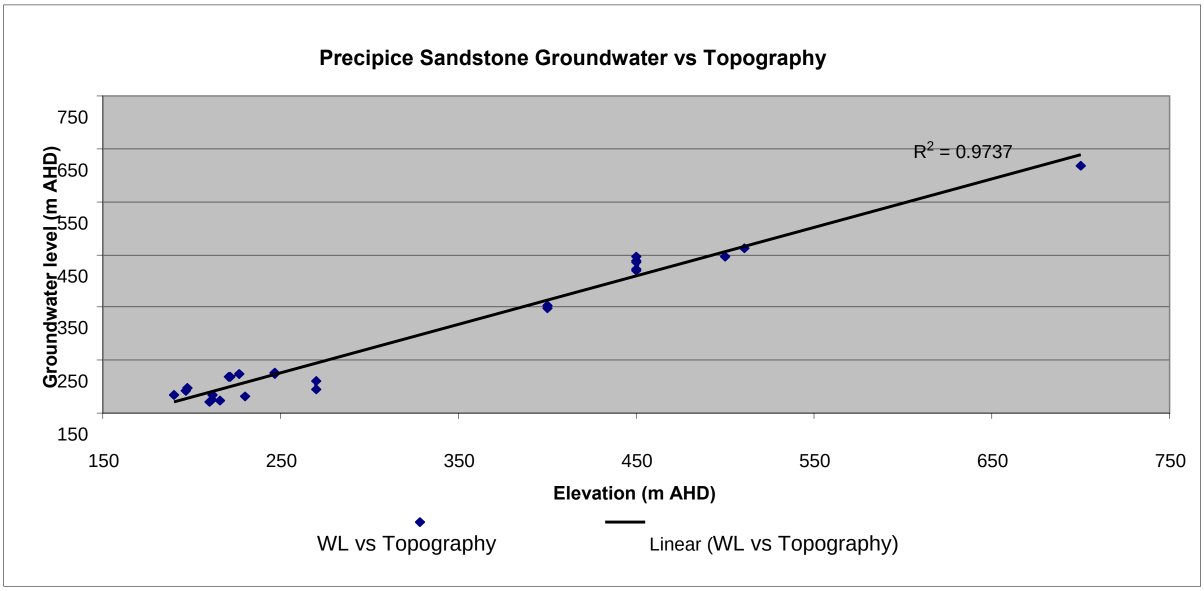
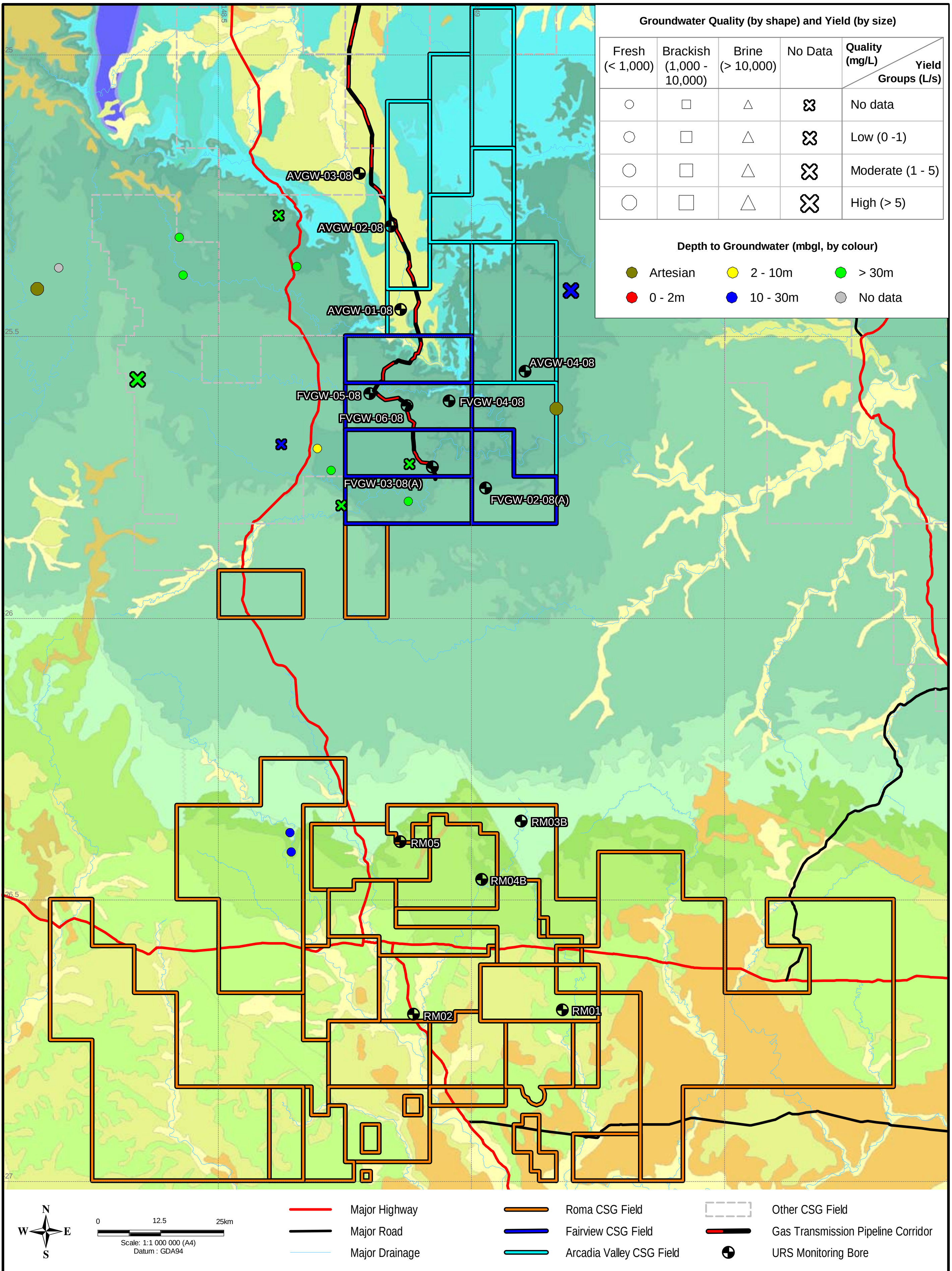


Figure 2-23 Groundwater – Elevation Relationship Data for the Precipice Sandstone

Groundwater quality data for the shallow groundwater resources associated with the Precipice Sandstone indicate that the groundwater is sodium-bicarbonate type water, which according to long term records (record 30484) does not indicate any significant changes or trends over time (**Figure 2-25**).



Groundwater Quality (by shape) and Yield (by size)

Fresh (< 1,000)	Brackish (1,000 - 10,000)	Brine (> 10,000)	No Data	Quality (mg/L) Yield Groups (L/s)
○	□	△	⊠	No data
○	□	△	⊠	Low (0 -1)
○	□	△	⊠	Moderate (1 - 5)
○	□	△	⊠	High (> 5)

Depth to Groundwater (mbgl, by colour)

●	Artesian	●	2 - 10m	●	> 30m
●	0 - 2m	●	10 - 30m	●	No data

━	Major Highway	━	Roma CSG Field	▭	Other CSG Field
━	Major Road	━	Fairview CSG Field	━	Gas Transmission Pipeline Corridor
━	Major Drainage	━	Arcadia Valley CSG Field	⊕	URS Monitoring Bore

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Project

GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

SHALLOW (< 100m)
BORES WITHIN THE
PRECIPICE FORMATION

Drawn: RG	Approved: JB	Date: 23-01-2009
Job No: **4262 6220**	File No: 42626220-g-583b.wor	

Figure: **2-24**

Rev:B

A4

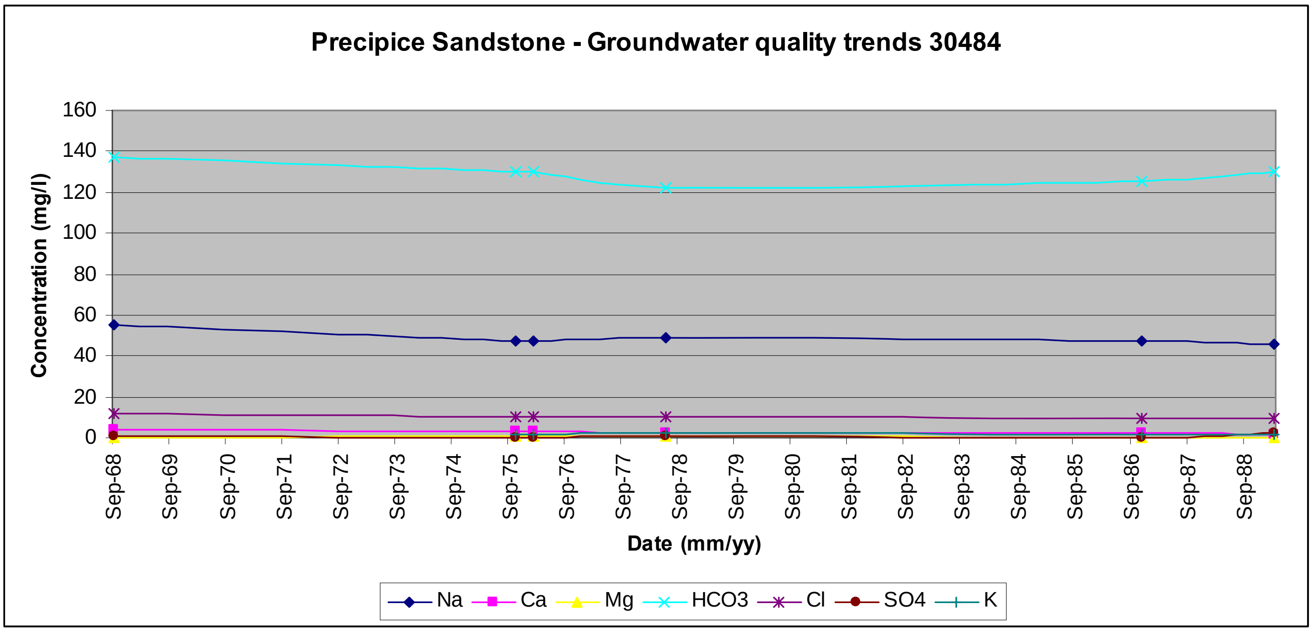


Figure 2-25 Groundwater Hydrochemical Data for Bore 30484, Precipice Sandstone

The hydrochemical data (**Table 2-10**) indicates that the groundwater is, on average, of good quality across the site. The good groundwater quality requires protection to ensure no deterioration in the quality.

Table 2-10 DNRW Database Hydrochemical Data Summary for the Precipice Sandstone in the CSG Fields

	Water Quality Guidelines						20th Percentile	80th Percentile	Median	No. samples
	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]				
Conductivity (µS/cm)							204	341	253	60
pH (pH units)						6.5 – 8.5	6.6	7.8	7.3	65
Alkalinity (mg/L $CaCO_3$)							46	147	100	65
Sodium (mg/L)		115-460	115-460			180	29	64	45	65
Potassium (mg/L)							1.8	4.1	2.3	41
Calcium (mg/L)				1000	1000		2.1	20	6.4	65
Magnesium (mg/L)							0.2	5.3	1.2	65
Iron (mg/L)						0.3	0	0.16	0.02	39
Manganese (mg/L)	1.9	0.2	10			0.5	0	0.08	0.01	30
Chloride (mg/L)		175-700	175-700			250	9	56	20	65
Fluoride (mg/L)						1.5	0.05	0.232	0.2	64
Nitrate (mg/L)						11.29	0	0.24	0	41
Sulfate (mg/L)				1000	1000	500	0	3	1.35	58

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems
2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)
3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years)
4 – ANZECC 2000 Trigger Levels for Livestock Watering
5 – Australian Drinking Water Guidelines 2004

2.2.12 Moolayember Formation

The Moolayember Formation, comprising mudstone and siltstone, has low permeability and is regarded as a confining layer between the Precipice Sandstone and Clematis Sandstone aquifers. Although the formation is recognised as having low groundwater potential a number of shallow (< 100 m) boreholes have been drilled into this formation within the study area (**Figure 2-27**).

The average borehole yield is low, 0.9 L/s, and yields range between 0.01 and 4.5 L/s. This indicates discrete zones of secondary processes can enhance the groundwater potential associated with this formation. Low sustainable abstraction is envisaged for the majority of the boreholes constructed.

Groundwater levels are ~ 20 m below surface, ranging between 8.5 and 52 mbgl, depending on topography. Available long term groundwater level data indicates only minor fluctuations to groundwater levels over time (**Figure 2-26**).

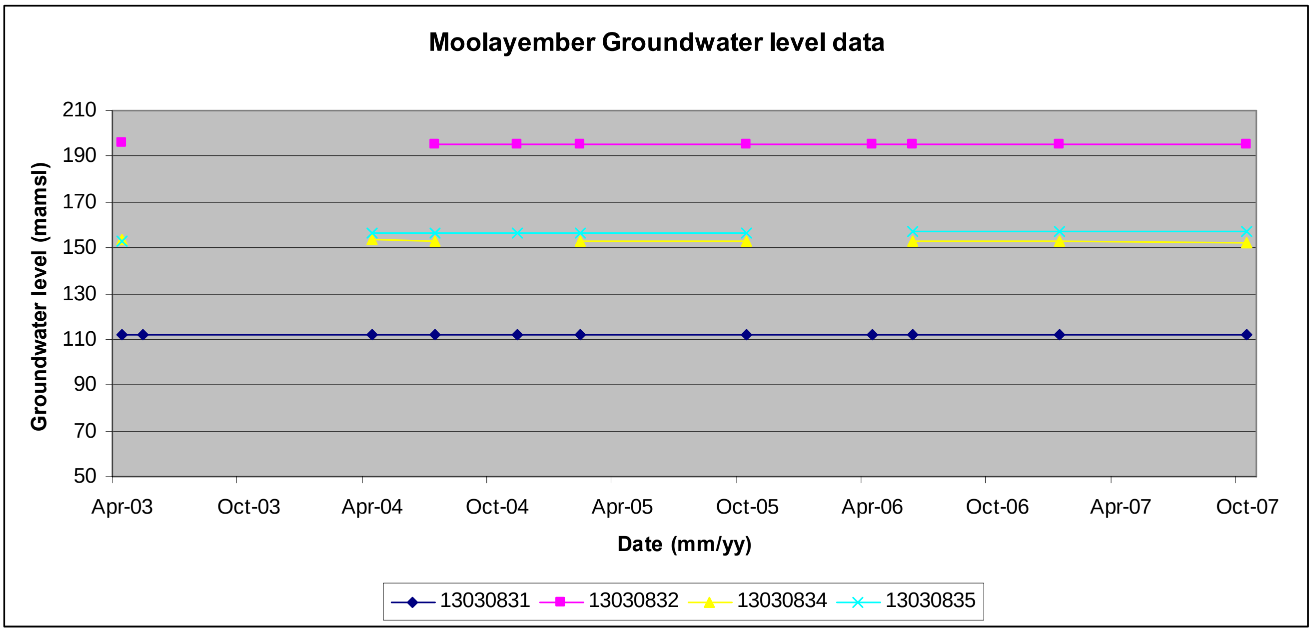
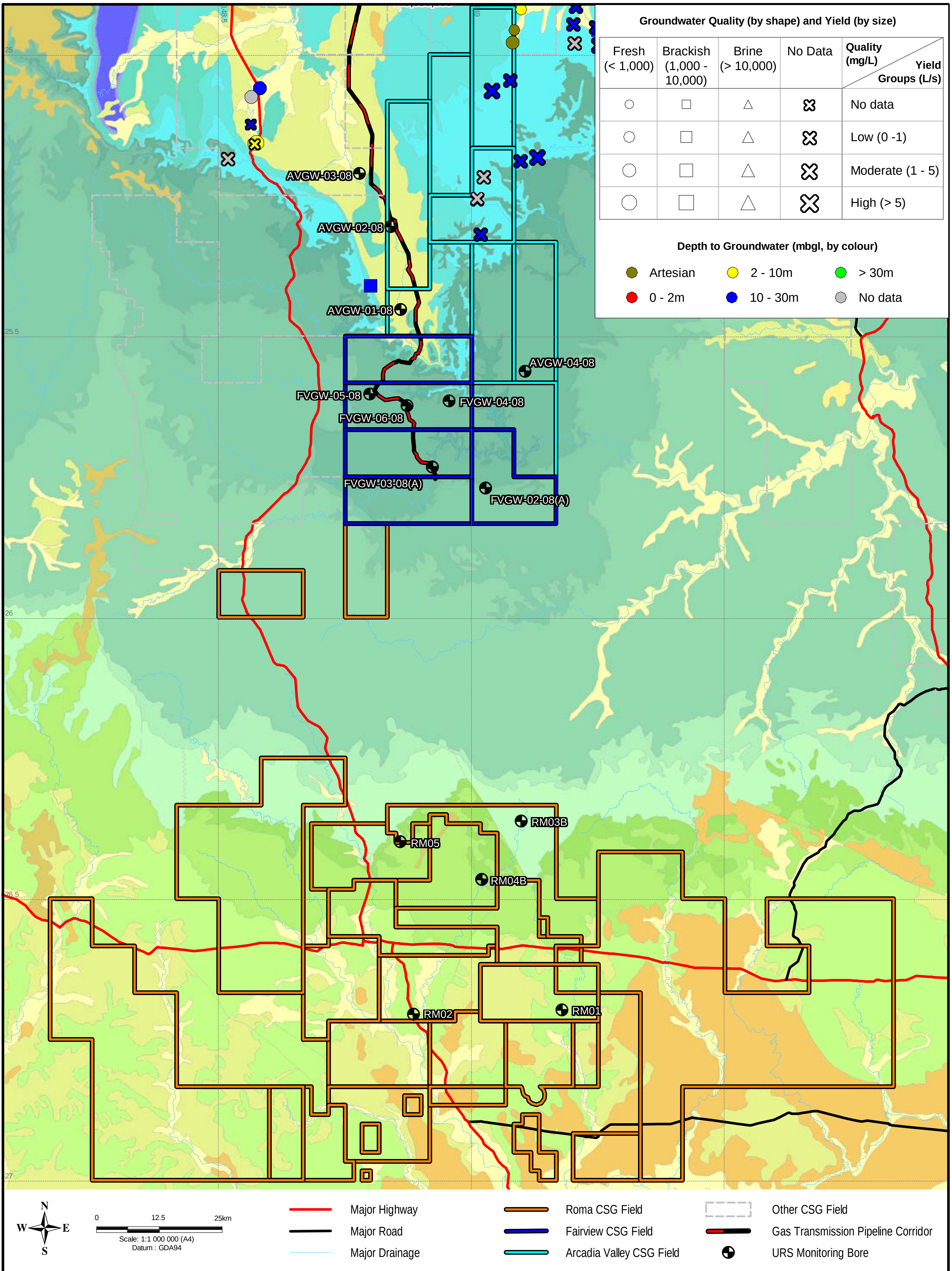


Figure 2-26 Groundwater Level Data for Selected Bores, Moolayember Formation

The rainfall data, for the Injune Post Office (Bureau of Meteorology, 2008), between 2003 and 2007 was variable with 2006 and 2007 rainfall being well below the mean annual rainfall for the area of 630 mm/yr. The groundwater levels do not indicate any variation in response to this dry period. Recharge rates are thus limited, even at outcrop and shallow depths, in the CSG field study area.

The hydrochemistry data (**Table 2-11**) indicates that the groundwater associated with the Moolayember Formation is sodium-chloride-bicarbonate type. Elevated manganese and low pH has been recorded from several boreholes within this unit. Long term groundwater quality monitoring has been conducted. The results, from borehole 18387, indicate natural fluctuations in chloride and sodium concentrations with time; while the remaining major anion and cation concentrations are relatively stable with time (**Figure 2-28**).

Alterations in groundwater levels and concentrations due to the proposed CSG operations will be difficult to identify unless marked changes are recorded.



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Client

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Project

GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

SHALLOW (<100m)
BORES WITHIN THE
MOOLAYEMBER FORMATION

Drawn: RG
Approved: JB
Date: 23-01-2009
Job No: **4262 6220**
File No: 42626220-g-584.wor
Figure: **2-27**
Rev:B
A4

Table 2-11 DNRW Database Hydrochemical Data Summary for the Moolayember Formation in the CSG Fields

	Water Quality Guidelines						20th Percentile	80th Percentile	Median	No. samples
	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]				
Conductivity (µS/cm)							571	5,790	870	103
pH (pH units)						6.5 – 8.5	7.4	8.2	7.8	97
Alkalinity (mg/L $CaCO_3$)							129	371	216	103
Sodium (mg/L)		115-460	115-460			180	76	948	143	107
Potassium (mg/L)							3	20	13	70
Calcium (mg/L)				1000	1000		9	88	26	104
Magnesium (mg/L)							4	68	23	101
Iron (mg/L)						0.3	0	0.084	0.01	37
Manganese (mg/L)	1.9	0.2	10			0.5	0	0.032	0.01	33
Chloride (mg/L)		175-700	175-700			250	57	1,401	106	107
Fluoride (mg/L)						1.5	0.1	0.5	0.2	97
Nitrate (mg/L)						11.29	0	0.84	0.5	69
Sulfate (mg/L)				1000	1000	500	2	36	6	103

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems
2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)
3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years)
4 – ANZECC 2000 Trigger Levels for Livestock Watering
5 – Australian Drinking Water Guidelines 2004

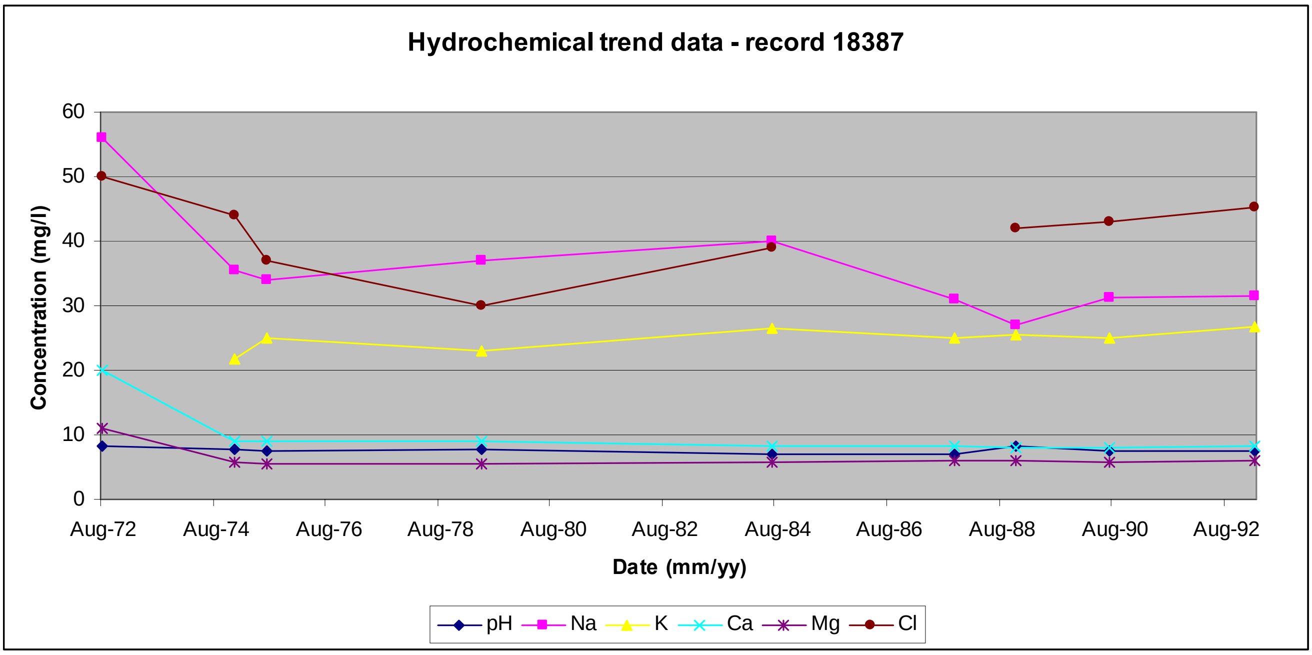


Figure 2-28 Groundwater Hydrochemical Data for Bore 18387, Moolayember Formation

Although the Moolayember Formation has low groundwater potential and records of poor groundwater quality, the groundwater resources require protection due to the high number of boreholes within this unit.

2.2.13 Clematis Sandstone

The medium grained quartz-rich sandstone of the Clematis Sandstone is a major aquifer unit. An evaluation of the shallow (< 100 m) boreholes (**Figure 2-30**) indicates that the shallow groundwater resources are confined in places and artesian conditions occur within boreholes constructed in this aquifer. The average depth to groundwater level is only 1 m. **Figure 2-29** indicates a moderate relationship between topography and groundwater levels due to the artesian conditions.

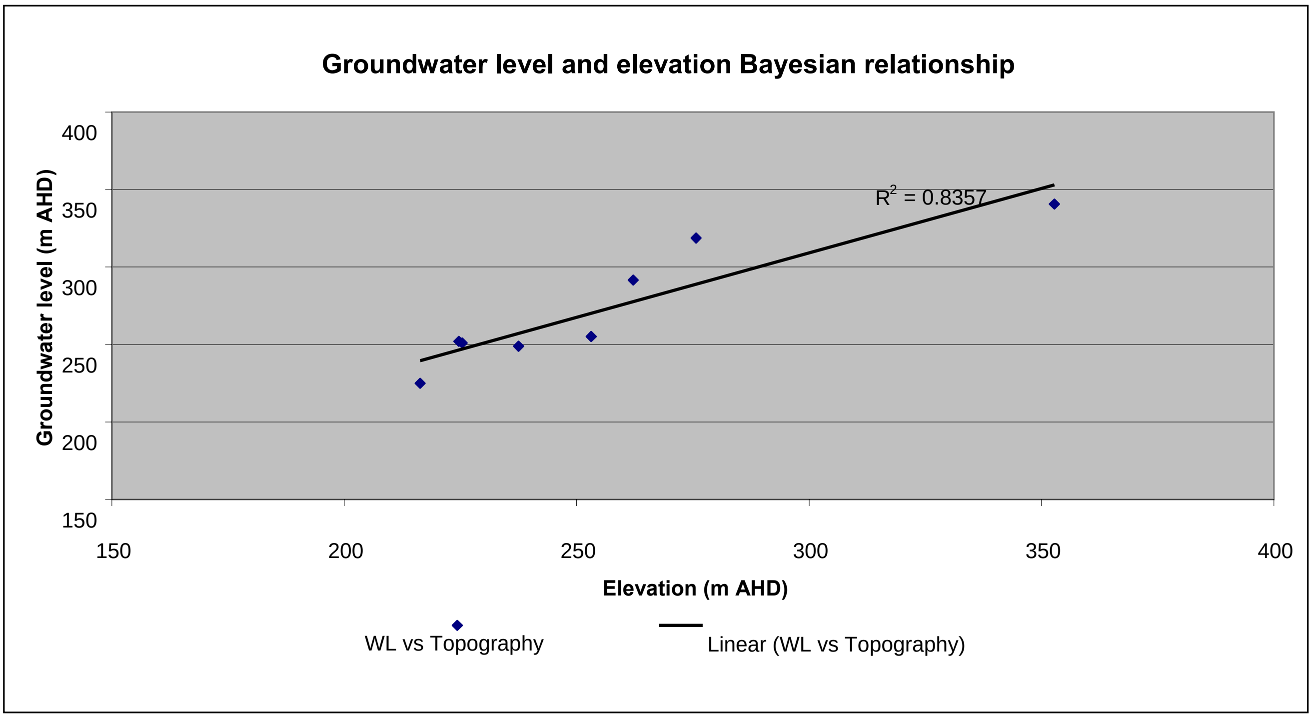
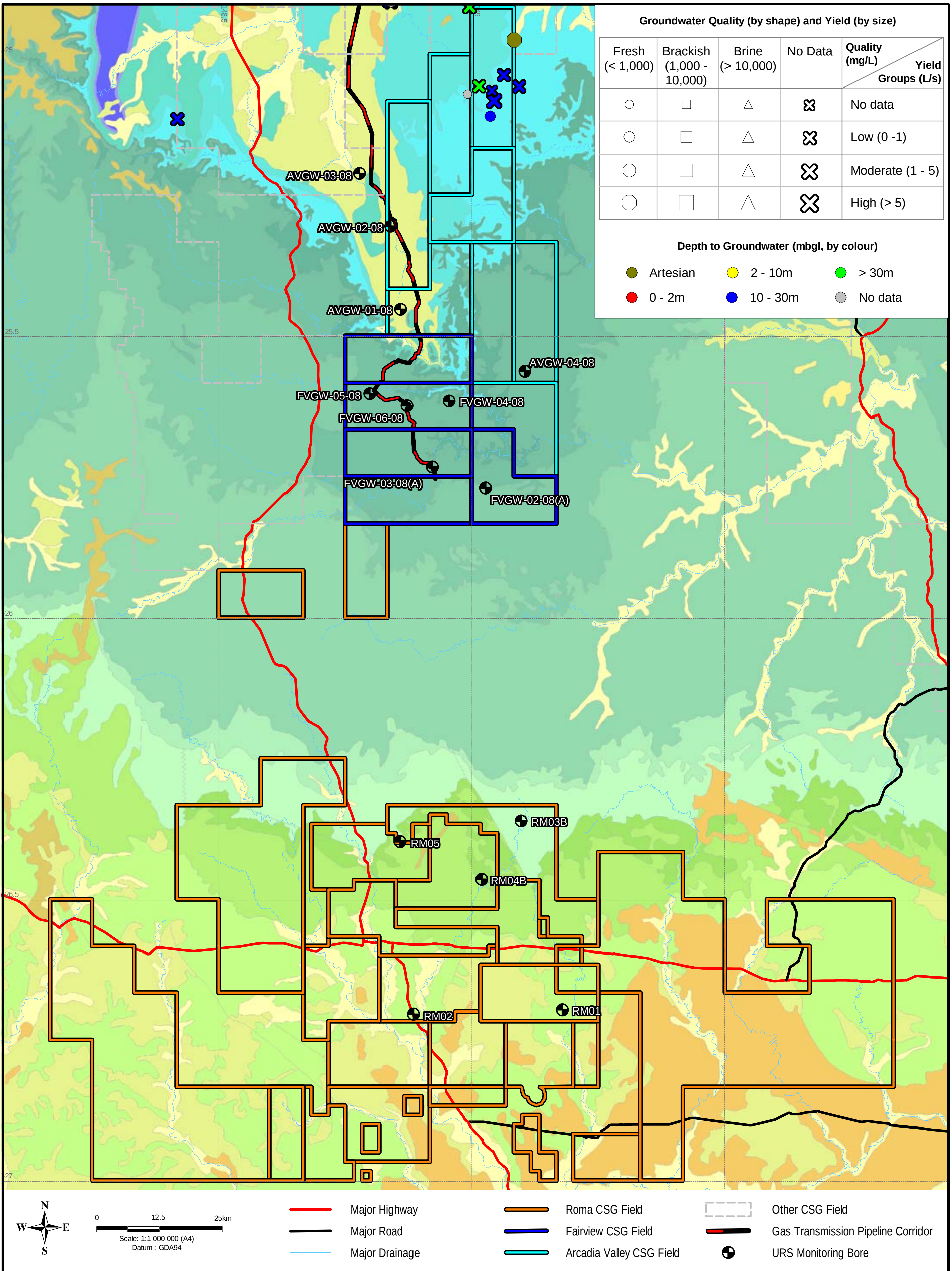


Figure 2-29 Groundwater – Elevation Relationship Data for the Clematis Sandstone

Borehole yield records indicate that the Clematis Sandstone intersected at shallow depths have moderate yields with an average of 3.65 L/s. The yield data does indicate the incidence of high yielding boreholes, ± 25 L/s, within this unit.

Long term groundwater quality data indicates that the hydrochemistry within the unit remains stable over time, indicating only minor fluctuations in concentrations (**Figure 2-31**). The groundwater type for borehole 37423 is sodium-bicarbonate.

The available hydrochemical data is summarised in **Table 2-12** and indicates that the groundwater is on average of good quality. The ambient groundwater quality data indicates records of elevated dissolved metals in some boreholes.



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GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

SHALLOW (< 100m)
BORES WITHIN THE
CLEMATIS FORMATION

Drawn: RG | Approved: JB | Date: 23-01-2009

Job No: **4262 6220** | File No: 42626220-g-585b.wor

Figure: **2-30**

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A4

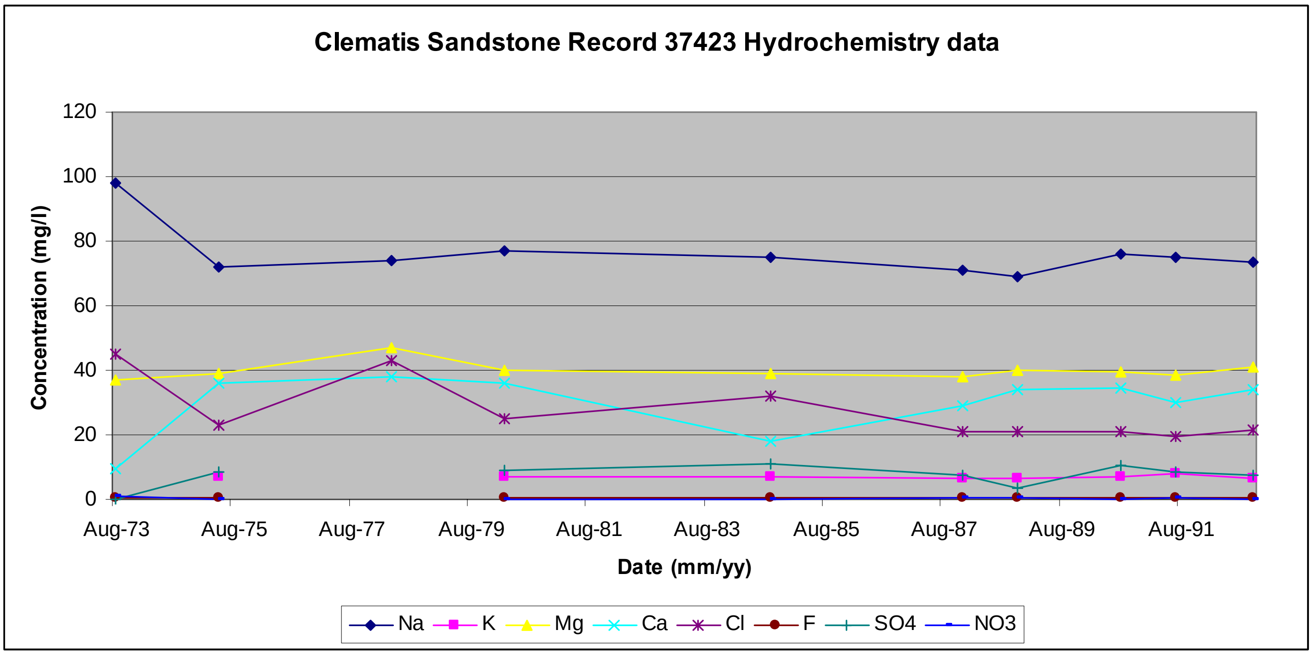


Figure 2-31 Groundwater Hydrochemical Data for Bore 37423, Clematis Sandstone

Table 2-12 DNRW Database Hydrochemical Data Summary for the Clematis Sandstone in the CSG Fields

	Water Quality Guidelines						20th Percentile	80th Percentile	Median	No. samples
	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]				
Conductivity (µS/cm)							225	1,050	660	66
pH (pH units)						6.5 – 8.5	7	8	7.7	65
Alkalinity (mg/L $CaCO_3$)							56	386	240	66
Sodium (mg/L)		115-460	115-460			180	23	122	75	66
Potassium (mg/L)							7	17	11	56
Calcium (mg/L)				1000	1000		4	40	19	66
Magnesium (mg/L)							4	40	20	66
Iron (mg/L)						0.3	0.01	0.03	0.01	39
Manganese (mg/L)	1.9	0.2	10			0.5	0.01	0.24	0.01	35
Chloride (mg/L)		175-700	175-700			250	32	79	51	66
Fluoride (mg/L)						1.5	0.1	0.3	0.12	64
Nitrate (mg/L)						11.29	0	0.5	0.5	55
Sulfate (mg/L)				1000	1000	500	2	21	8	63

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems
2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)
3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years)
4 – ANZECC 2000 Trigger Levels for Livestock Watering
5 – Australian Drinking Water Guidelines 2004

2.2.14 Rewan Formation.

The Rewan Formation comprises sandstone and siltstone, which has moderate groundwater potential as the records indicate high groundwater use, comprising shallow boreholes (average depth is 61 m) with moderate yields (average yield of 2.2 L/s). The boreholes recorded within this unit are shown on **Figure 2-34**.

The aquifers are unconfined within the shallow outcrop areas and the groundwater levels are relatively deep, ± 36 mbgl on average. The groundwater levels are recognised to mimic topography, as indicated in **Figure 2-32**.

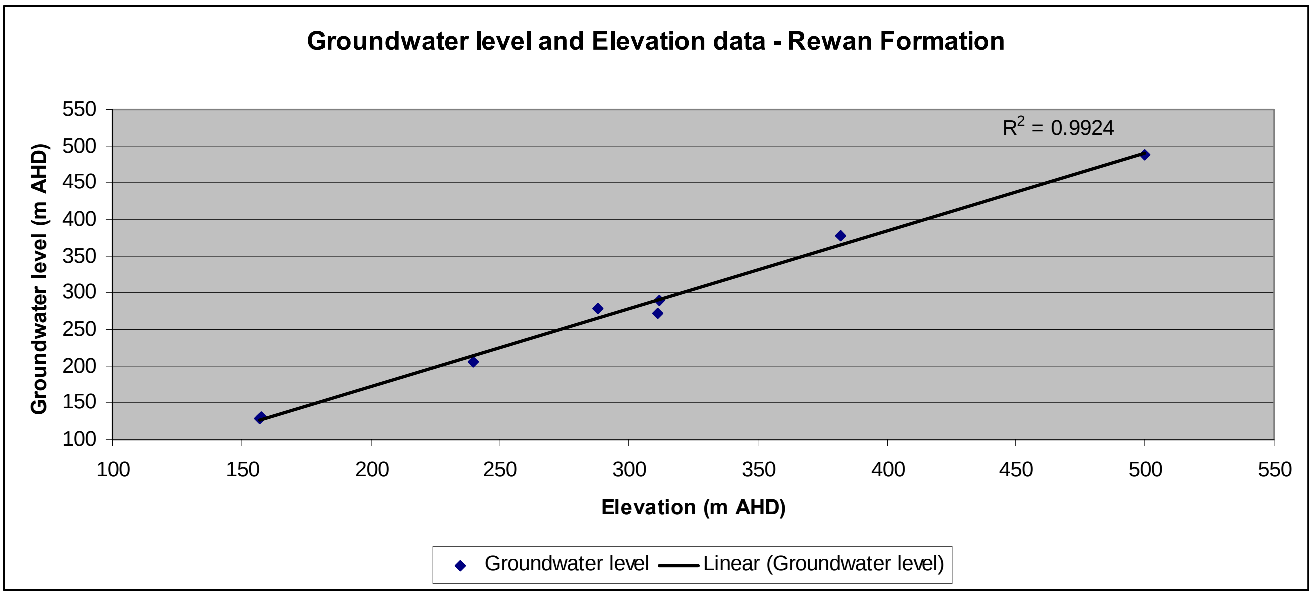


Figure 2-32 Groundwater – Elevation Relationship Data for the Rewan Formation

Long term groundwater level data is limited; borehole record 13030830 indicates minor fluctuations in groundwater level readings over time. Little or no changes in groundwater levels are evident from the data (**Figure 2-33**) even though the records cover dry and wet seasons.

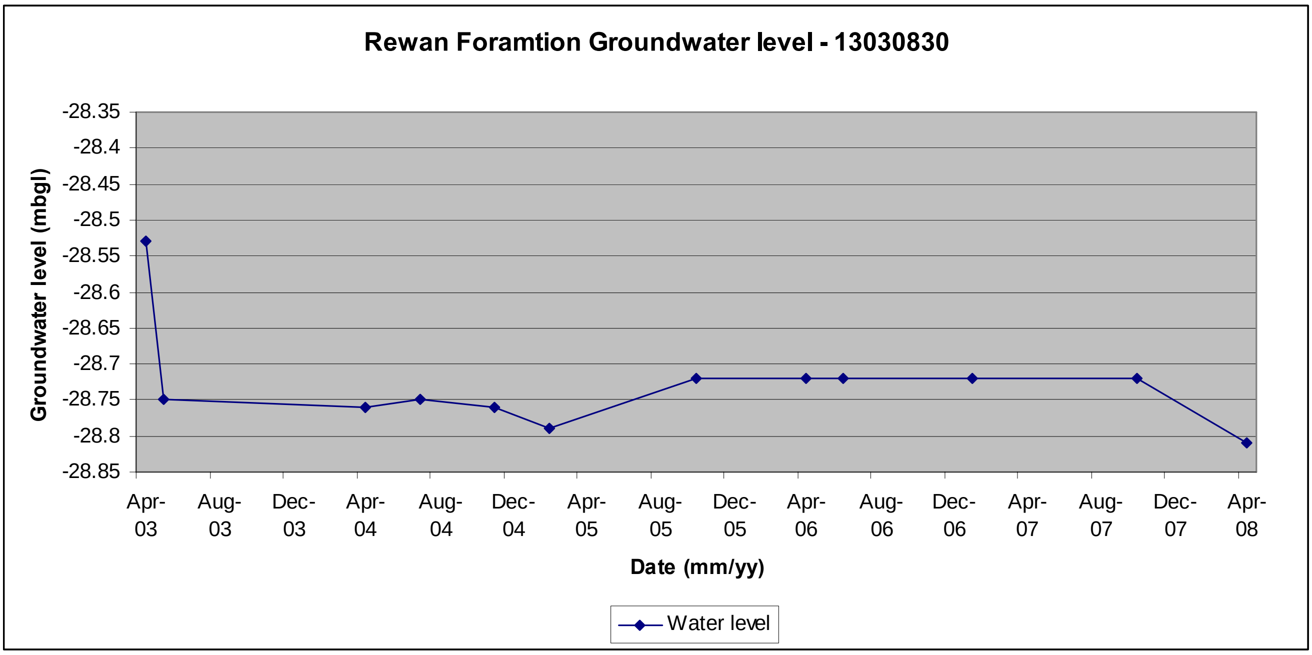
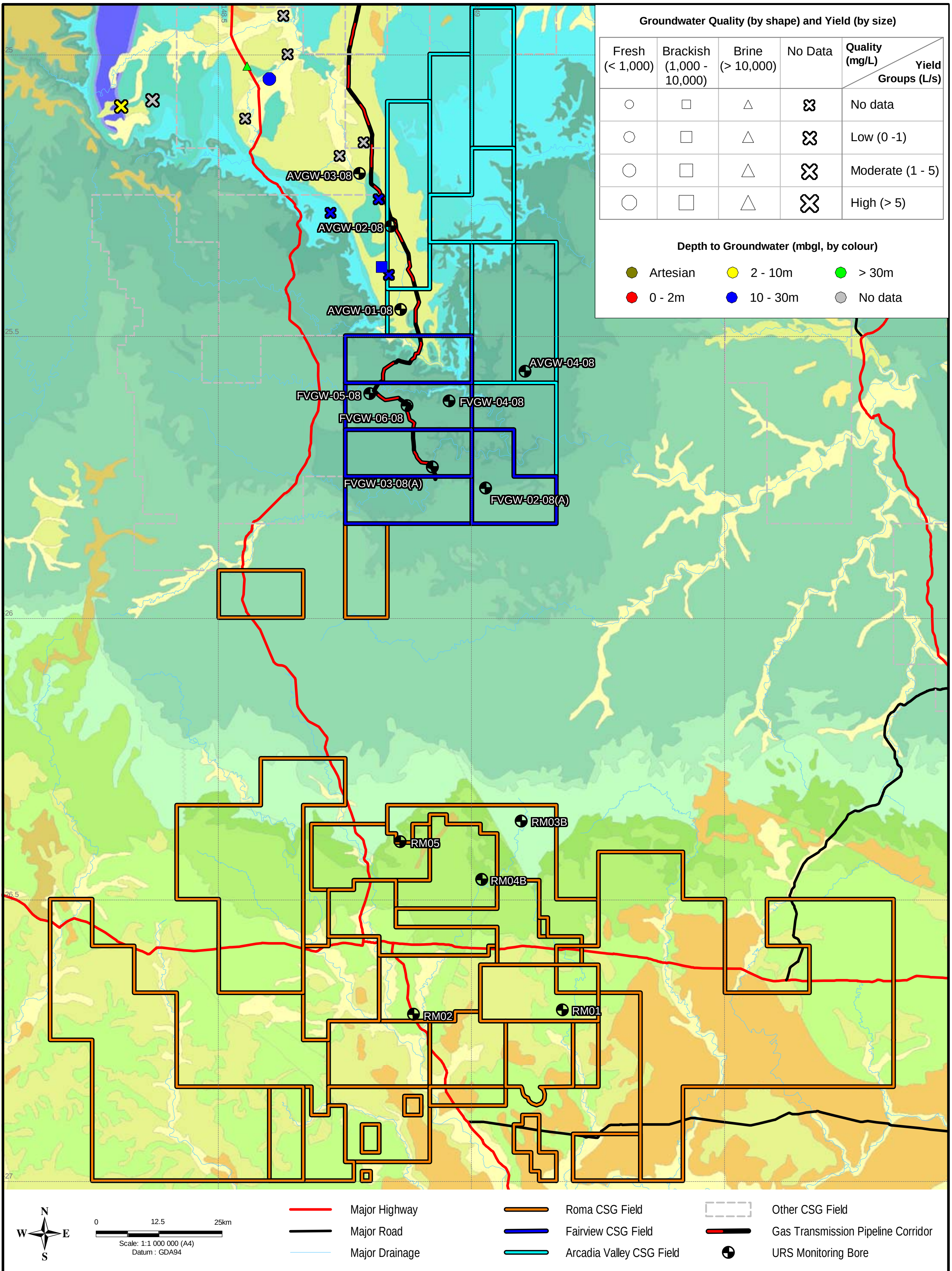


Figure 2-33 Groundwater Level Data for Bore 13030830, Rewan Formation



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GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

BORES WITHIN THE REWAN FORMATION

Drawn: RG

Approved: JB

Date: 23-01-2009

Job No: **4262 6220**

File No: 42626220-g-586b.wor

Figure: **2-34**

Rev:B

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Hydrochemical data for the Rewan Formation is limited with only 17 records recorded on the DNRW database. A summary of these data are presented in **Table 2-13**.

Groundwater quality is variable across this unit; however, it recognised to be generally of poor quality with elevated salinity (TDS > 10 000 mg/l in areas indicating brine groundwater occurrence). The groundwater is sodium-chloride dominant, with elevated potassium and sulfate when compared to the other groundwater within the CSG fields.

The deep groundwater and poor quality reduces the groundwater vulnerability and need for protection of this resource.

Table 2-13 DNRW Database Hydrochemical Data Summary for the Rewan Formation in the CSG Fields

	Water Quality Guidelines						20th Percentile	80th Percentile	Median	No. samples
	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]				
Conductivity (µS/cm)							3,400	21,400	9,100	17
pH (pH units)						6.5 – 8.5	7.22	8.08	7.6	17
Alkalinity (mg/L $CaCO_3$)							76	538	301	17
Sodium (mg/L)		115-460	115-460			180	4,015	1,717	1,750	17
Potassium (mg/L)							5.3	22.4	6.1	11
Calcium (mg/L)				1000	1000		20	756	132	17
Magnesium (mg/L)							26	264	76	17
Iron (mg/L)						0.3	0	0.08	0	7
Manganese (mg/L)	1.9	0.2	10			0.5	0	0.01	0	7
Chloride (mg/L)		175-700	175-700			250	810	7,928	3,316	17
Fluoride (mg/L)						1.5	0.02	0.5	0.175	16
Nitrate (mg/L)						11.29	0	2.7	0.3	12
Sulfate (mg/L)				1000	1000	500	0	20	2	16

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems
2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)
3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years)
4 – ANZECC 2000 Trigger Levels for Livestock Watering
5 – Australian Drinking Water Guidelines 2004

2.3 Fieldwork Undertaken in CSG Field Areas

The fieldwork approach adopted to evaluate the shallow groundwater conditions allowed for the limited assessment and collection of site specific data for the CSG fields that are currently developed or may be developed during the life of the project.

URS requested a search of the DNRW registered bore database during June 2008. The search revealed hundreds of bores within the CSG field study areas. The database was interrogated to assess only the shallow (< 30 m) borehole records. This eliminated the majority of the borehole records but left some 20 wells in and around the Roma field, and two wells in and around the Fairview and Arcadia fields. The search area for the Fairview and Arcadia was widened to include areas up to approximately 50 km away from these fields. This increased the number of shallow bore records to approximately 20 near these two fields. Most of the bores were located in low-lying areas; however, some bores were installed at higher elevations on the plateaus.

Groundwater level measurements at each of the shallow (< 30 m) registered bores were plotted on a topographic map of each of the three gas fields. Although the depth to water varied from approximately 2 to 25 mbgl, the majority of the wells recorded groundwater levels between 10 and 20 mbgl. The stratigraphic logs from these bores indicate that groundwater is intersected within the weathered sandstone, shale, and mudstone units, and is likely under unconfined to semi-confining conditions.

Based on the assessment of shallow groundwater conditions the field work component of the study allowed for the drilling and construction of shallow groundwater monitoring and assessment bores. The boreholes were drilled to a maximum depth of 60 m to ensure drilling continued to below regional groundwater levels.

2.3.1 Fieldwork Details

Based on the findings from the desktop review, drilling target areas were identified within the Roma, Fairview, and Arcadia CSG field areas. The sites, which were ratified by Santos, were selected in areas were groundwater levels are expected to be within 25 mbgl and where CSG field development has either commenced or is planned for in the near future. Most of the drilling targets were selected in low-lying areas adjacent to the major creeks. Several drilling positions were selected on top of the plateaus since the desktop study indicated shallow groundwater use within these areas and that borehole records indicate groundwater levels at these locations within 25 mbgl. The existing shallow (< 30 m) bores and the proposed drilling locations are presented on **Figure 2-35** to **Figure 2-37.**

Field reconnaissance visits, to assess site access, were conducted. The DNRW and Queensland EPA were consulted and stakeholder agreement was obtained.

A total of 18 boreholes were drilled in 14 separate areas, 5 in Roma, 5 in Fairview, and 4 in Arcadia. The majority of the geology intersected comprised interbedded sandstone, siltstone, and mudstone. Based on the drilling results 10 of the boreholes intersected groundwater (at depths of approximately 10 to 40 m below surface) and were constructed as monitoring wells. The remaining 8 dry bores were backfilled according to recognised industry accepted practices.

The boreholes were drilled at a diameter of 150 mm and, where suitable, 50 mm diameter PVC casing was installed. The boreholes were constructed as monitoring bores, which were completed by placing a washed gravel filter pack around the slotted casing. A bentonite clay seal was placed at least 3 meters above the filter pack and a cement grout was placed above this to prevent possible surface contamination entering the bores.

Client

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LNG

Project

GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Drawn: RG
Approved: JB
Date: 23-01-2009
Job No: **4262 6220**
File No: 42626220-g-611b.wor

Title

SHALLOW BORES (< 30m) AND NEW MONITORING BORES IN THE ROMA CSG STUDY AREA

Figure: **2-35**

Rev: B

A4

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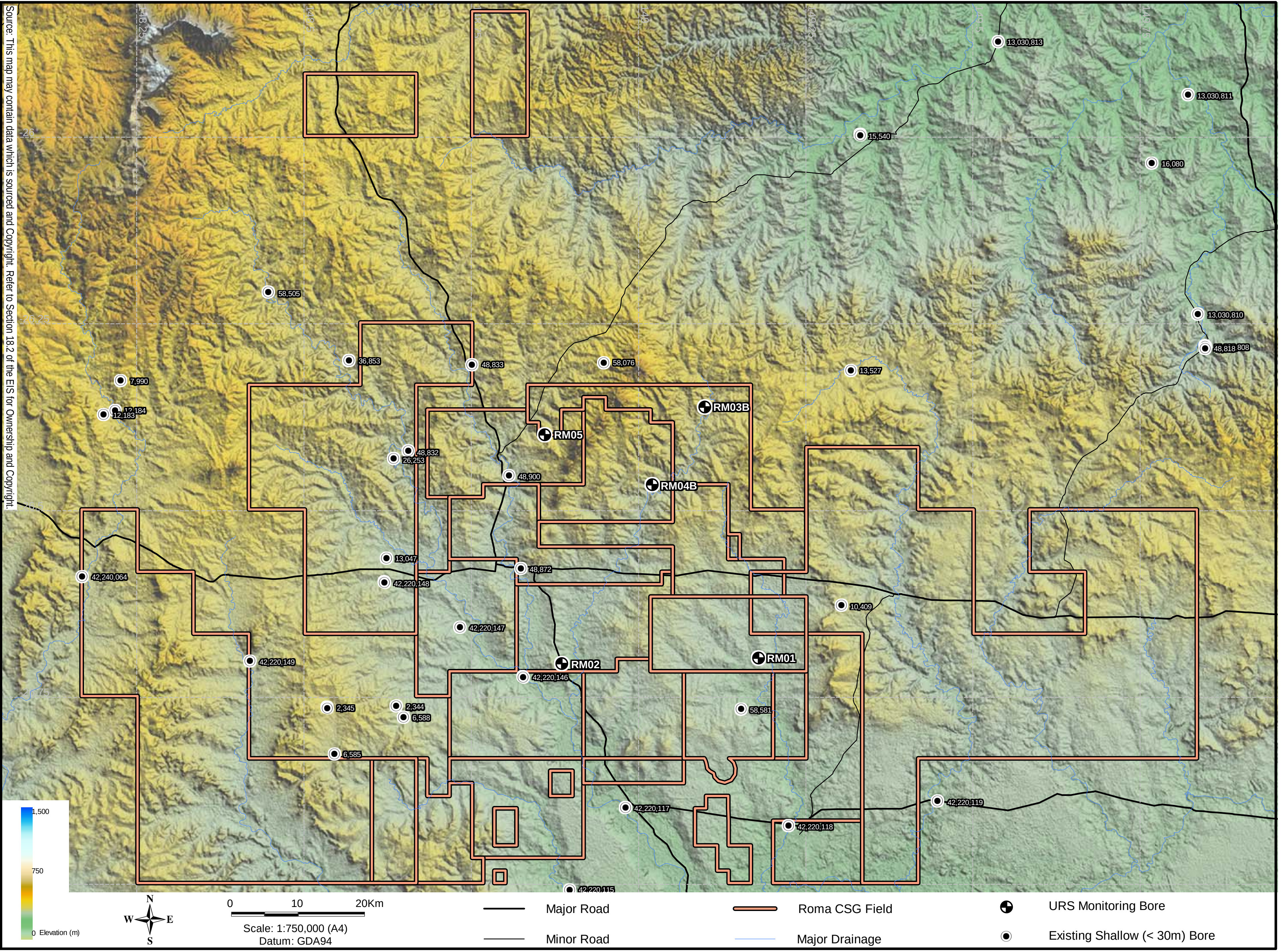

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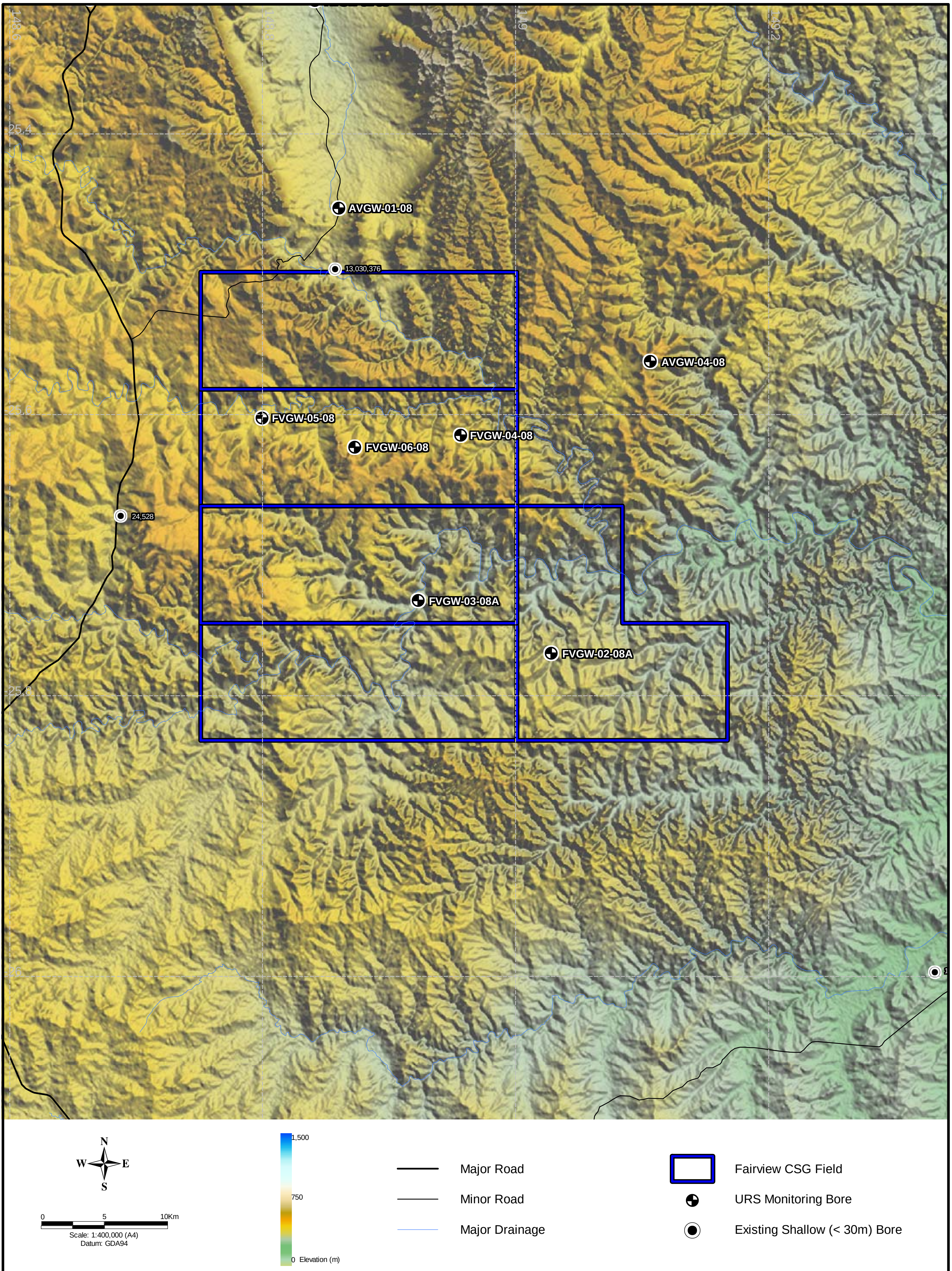

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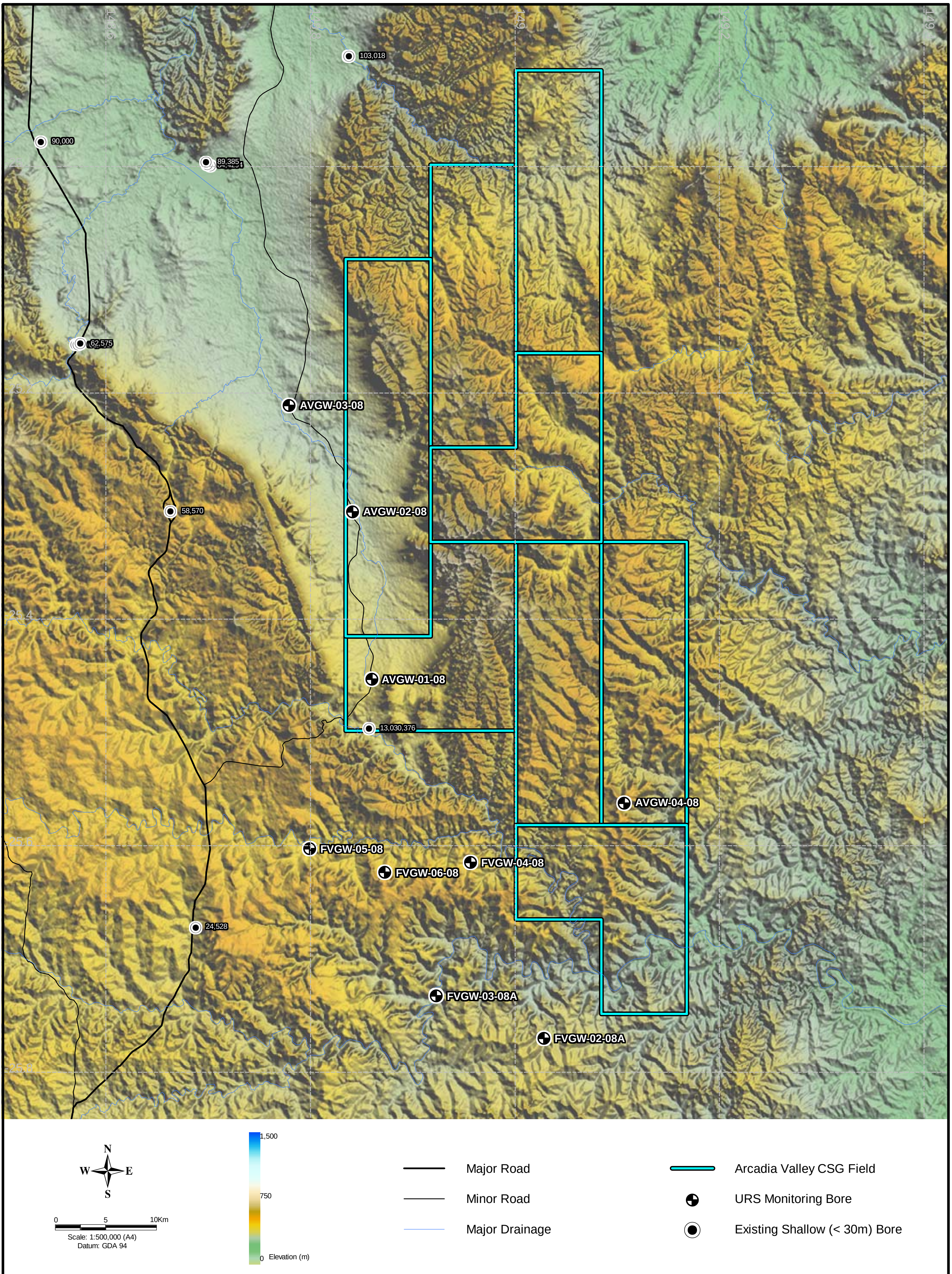
Client	Project	Title
LNG URS	GLADSTONE LNG PROJECT CSG FIELD SHALLOW GROUNDWATER ASSESSMENT	**SHALLOW BORES (< 30m) AND NEW MONITORING BORES IN THE FAIRVIEW CSG STUDY AREA**

Drawn: RG	Approved: JB	Date: 23-01-2009	Figure: **2-36**	Rev:B
Job No: **4262 6220**	File No: 42626220-g-612b.wor			**A4**



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GLADSTONE LNG PROJECT
CSG FIELD
SHALLOW GROUNDWATER ASSESSMENT

Title

SHALLOW BORES (< 30m) AND NEW MONITORING BORES IN THE ARCADIA VALLEY CSG STUDY AREA

Drawn: RG
Approved: JB
Date: 23-01-2009
Job No: **4262 6220**
File No: 42626220-g-613b.wor
Figure: **2-37**
Rev:B
A4

A lockable steel protective shroud has been placed over the monitoring bores in concrete to protect the piezometers from damage. The designs and construction adhere to the *Minimum Construction Requirements for Water Bores in Australia* (QDNR, 2003).

A summary of the drilling results is presented in **Table 2-14** and the borehole logs are presented in **Appendix A**. The bore locations are indicated on all the geological maps presented in **Section 2**.

Table 2-14 Drilling Results

Borehole	Depth (m)	SWL (mbgl)	Date	Lithology	Comments
Roma					
RM01	60	dry	02/09/2008	Mudstone	Backfilled to surface
RM02	50	dry	04/09/2008	Mudstone	Backfilled to surface
RM03	27	20.05	29/08/2008	Siltstone	Water in weathered zone
RM03B Observation well	29	20.2	30/08/2008	Siltstone	Water in weathered siltstone below mudstone
RM04	42	38.5	31/08/2008	Sandstone	Water within weathered sandstone
RM04B Observation well	39	24.6	01/09/2008	Mudstone, sandstone	Water on mudstone / sandstone contact
RM05	57	dry	03/09/2008	Mudstone	Backfilled to surface
Fairview					
FVGW-02--08	55	29.7	17/09/2008	Sandstone	Water intersected at 48.4 m
FVGW-02—08A	60	33.2	18/09/2008	Siltstone, sandstone	Water intersected at 48 m
FVGW-03--08	21	10.5	12/09/2008	Sandstone	Backfilled to 20.3 m
FVGW-03—08A	21	18.5	12/09/2008	Sandstone	Water within weathered sandstone
FVGW-04--08	60	dry	09/09/2008	Sandstone	Backfilled to surface
FVGW-05--08	40	15.5	11/09/2008	Siltstone	Backfilled to 21.7 m
FVGW-06--08	41	dry	17/09/2008	Siltstone	Backfilled to surface
Arcadia					
AVGW-01-08	30	dry	16/09/2008	Siltstone	Backfilled to surface
AVGW-02-08	34	dry	16/09/2008	Siltstone	Backfilled to surface
AVGW-03-08	40	25.8	14/09/2008	Mudstone, siltstone	Backfilled to 27 m
AVGW-04-08	60	dry	23/09/2008	Siltstone	Backfilled to surface

The boreholes were located based on topography and access, and the results indicate that the shallow groundwater resources within the Roma, Fairview, and Arcadia areas are restricted to discrete areas of secondary permeability. No significant water strikes or blow yields were recorded during the drilling.

During drilling the air lift yields were assessed. Due to the low yields only four pump-out tests could be conducted. A single falling (variable) head test was also conducted in order to obtain aquifer hydraulic parameters for the shallow aquifers in the CSG field study area.

2.3.2 Assessment of Aquifer Hydraulic Parameters

The monitoring boreholes that were drilled and constructed on site were pump tested to determine site-specific aquifer hydraulic characteristics, which assisted in describing the ambient hydrogeology. The aquifer testing comprised four short duration constant discharge tests and one falling head test. The results of the aquifer tests are presented in **Appendix B** and are summarised in **Table 2-15**.

Table 2-15 Aquifer Hydraulic Parameters

Pumping bore	Aquifer	Observation bore	Transmissivity (m^2/day)	Hydraulic conductivity (m/day)	Storativity	Method
RM04B	Weathered mudstone	RM04	0.3 to 1.7		0.00026	Cooper-Jacob
RM03B	Weathered siltstone	-	0.25		-	Cooper-Jacob
FVGW02-08	Weathered siltstone	FVGW02-08A	0.06 to 0.09		0.00001 to 0.00002	Cooper-Jacob
FVGW03-08	Fractured sandstone	-	0.1 to 0.3			Cooper-Jacob
FVGW05-08	Weathered sandstone	-		4×10^{-8} to 8×10^{-8}		Bouwer & Rice, Hvorslev

The results indicate poor groundwater resources within the bores drilled on site. The drilling and aquifer test data indicates that the majority of the surficial geology within the CSG fields has little or no groundwater potential in their unaltered state. The DNRW data indicates the occurrence of low to moderate yielding bores, indicating discrete zones of increased groundwater potential due to secondary processes. It is, therefore, envisaged that boreholes sited on underlying geological structures (faults and fractures) and within zones of alteration will have increased aquifer parameters compared to those presented in **Table 2-15**.

2.3.3 Assessment of Hydrochemistry

Representative groundwater samples were collected from selected new monitoring boreholes. The boreholes were purged and samples were stabilised / preserved on site and delivered to an accredited analytical laboratory, as discussed in **Section 1**. The field measurement and purge volume details are summarised in **Table 2-16**.

Table 2-16 Field Measurements

Bore	Dissolved oxygen (mg/L)	pH (pH units)	Electrical conductivity (µS/cm)	Temperature (ºC)	Redox potential (Eh)
RM03					
1 volume	1.26	6.58	627	25.5	28 mV
2 volume	0.79	6.80	616	32.2	55 mV
FVGW02					
1 volume	1.01	6.70	3,400	25.9	35 mV
2 volume	-	6.92	3,550	26.7	-4 mV
3 volume	0.18	7.05	3,440	26.9	-144 mV
4 volume	0.34	7.04	3,410	27.0	-92 mV
FVGW03					
1 volume	0.44	6.47	862	26.1	18 mV
2 volume	0.99	6.29	784	25.7	-13 mV
3 volume	2.32	6.28	788	25.9	-1 mV
4 volume	3.14	6.32	788	25.9	4 mV
FVGW05					
1 volume	0.85	6.65	550	21.0	56 mV
2 volume	0.76	6.58	587	21.0	62 mV
3 volume	3.20	6.93	565	21.8	130 mV
4 volume	3.39	6.67	570	22.8	106 mV
AVGW03					
1 volume	0.01	6.96	1,011	24.4	-238 mV
2 volume	0.12	6.97	1,132	22.6	-183 mV

The volume of groundwater within each bore was calculated based on borehole depth, static water level, and bore diameter data. Representative groundwater samples were collected on the removal (purging) of four times the bore volume, where possible. Bores that ran dry during purging were allowed to recover and then sampled.

The field measurements indicate that the groundwater associated with the RM03 borehole at Roma CSG field is neutral, low salinity groundwater, which is reducing and poorly oxygenated. The groundwater within the Fairview CSG field is similar to RM03, but indicates variable salinity. The groundwater sample from AVGW03 at Arcadia is poorly oxygenated, neutral, brackish, and is strongly reducing.

The hydrochemical results have been compared to the recognised guidelines, as described in **Section 1.1**. The results are presented in **Table 2-17** with the full laboratory results in **Appendix C**.

The groundwater samples collected from six of the new monitoring bores indicate that none of the samples are suitable for drinking when compared to the Australian Drinking Water guidelines (ADWG). Elevated concentrations of dissolved metals, when compared to the ANZECC Trigger Levels for Freshwater Ecosystems (95% protection level of species), indicates that the majority of the groundwater is unsuitable for discharge into the surface water resources. The groundwater has limited suitability of use for irrigation purposes but is suitable for livestock watering.

2.3.4 Aquifer / Resource Assessment

An assessment of the shallow groundwater resources, based on the field work completed to obtain site specific data, indicates that the shallow groundwater aquifer potential is limited. This is based on the generally poor groundwater quality, limited aquifer hydraulic parameters (hydraulic conductivity and storage), and negligible groundwater potential of the unaltered underlying formations.

The desktop study results revealed a large number of registered bores within and adjacent to the CSG fields, indicating that there are both aquitards and minor aquifers developed within the CSG fields. The DNRW records indicate that shallow bores can have good yields due to secondary processes, such as faulting, fracturing, etc. These secondary processes have allowed for the development of discrete minor aquifers within the CSG fields. These minor aquifers comprise weathered (intergranular) and fractured rock aquifers. The aquifers are envisaged to be limited and groundwater quality is variable. These aquifers seldom produce large quantities of water and are typically utilised for local stock watering supplies.

The shallow groundwater resources are recognised as having limited beneficial use. CSG operations, activities, and infrastructure could be located on unaltered sediments, which are recognised to have little to no groundwater resources, i.e. aquitards.

Table 2-17 Ambient Hydrochemical Data

Analytes	Freshwater 95%[1]	Irrigation LTV[2]	Irrigation STV[3]	Livestock Beef[4]	Livestock Sheep[4]	Drinking Water[5]	RM03	RM03B	FVGW02	FVGW03	FVGW05	AVGW03
T. Alkalinity (mg/L $CaCO_3$)							230	396	16	285	45	526
Sodium (mg/L)							5	6	5	5	6	9
Potassium (mg/L)							5	6	5	5	6	9
Calcium (mg/L)							9	67	3	73	66	48
Magnesium (mg/L)							9		3	21	33	15
Manganese (mg/L)		0.2	10			0.5	70		0.072	109	26	97
Chloride (mg/L)						250	70	92	18	36	26	5
Sulfate (mg/L)				0.5		500	93	92	18	36	16	5
Arsenic (mg/L)							0.002	0.011	0.005	0.018	0.011	0.014
Beryllium (mg/L)							0.001	0.001	3.2	0.001	0.001	0.001
Barium (mg/L)						0.7	0.022	0.036	3.2	0.126	0.467	0.230
Cadmium (mg/L)	0.0002			0.01			<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	0.001			1		0.05	0.002	0.001	<0.001	0.002	0.001	0.001
Cobalt (mg/L)				1			0.004	0.001	<0.001	0.022	0.009	<0.001
Copper (mg/L)	0.0014			1		2	<0.001	0.003	0.001	<0.001	<0.001	<0.001
Lead (mg/L)	0.0034			0.1		0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (mg/L)	0.011			1		0.02	0.029	0.002	<0.001	0.020	0.010	0.002
Vanadium (mg/L)							<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (mg/L)	0.008			20		3	0.006	0.006	0.005	0.046	0.012	<0.005

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems 2 – ANZECC 2000 Trigger Levels for Long Term Irrigation Use (100 years)
3 – ANZECC 2000 Trigger Levels for Short Term Irrigation Use (20 years) 4 – ANZECC 2000 Trigger Levels for Livestock Watering 5 – Australian Drinking Water Guidelines 2004

2.4 Existing Environmental Values

The environmental values of the shallow groundwater have been assessed according to the values identified in the EPP Water, including those compiled in the Environmental Protection (Water) 2008. The environmental values to be enhanced or protected are:

- Biological integrity of a pristine or modified aquatic ecosystem;
- Suitability for primary, secondary, and visual recreational use;
- Suitability for minimal treatment before supply as drinking water;
- Suitability for use in agriculture;
- Suitability for use in aquacultural use;
- Suitability for producing aquatic food for human consumption;
- Suitability for industrial use; and
- Cultural and spiritual values of the water.

The review of available data allowed for an initial assessment of the shallow groundwater resources associated with the geological outcrops within the vast CSG fields study area. The large number of bore records and available hydrogeological information allowed for an evaluation to the groundwater resource environment values. These include:

Biological integrity of a pristine or modified aquatic ecosystem

Shallow groundwater quality associated with the majority of the aquifers identified within the CSG fields has dissolved metals concentrations, which exceed the ANZECC guideline Trigger Levels for Freshwater Ecosystems. Discharge of this water can potentially impact on the biological integrity of the fresh water resources within the CSG fields. The dewatering of the shallow groundwater resources is not required during the CSG activities, thus no discharge of shallow groundwater will occur during the GLNG project.

Existing Groundwater Dependent Ecosystems need to be identified on site and monitored to ensure CSG operations and activities do not impact on these sensitive landscapes.

Suitability for recreational use

This category of environmental values is not considered relevant in relation to groundwater.

Suitability for minimal treatment before supply as drinking water

Available hydrochemical data from the DNRW database regarding the geological units mapped to outcrop in the CSG fields indicate that the groundwater quality is variable. Aquifers including GAB aquifers are recognised as having areas which contain brackish to brine groundwater quality. This groundwater would require complex and expensive treatment, such as reverse osmosis, to achieve drinking water quality to satisfy the Queensland Water Quality Guidelines 2006 or the Australian Drinking Water Guidelines 2004.

Issues of salinity and the ease of obtaining a rainwater tank supply are factors which preclude the potential for usage of the groundwater as a drinking water source.

Suitability for use in agriculture, aquaculture, aquatic food for human consumption

The large number of registered bores in the area indicates that irrigation and stock watering quality water is obtainable. Compared to the ANZECC (2000) guidelines, groundwater present within the bores indicates that the majority of the groundwater is suitable for livestock watering.

The water quality data suggests that the salinity is within or above the range recommended for irrigation of crops. The groundwater appears to have some potential use in terms of irrigation, depending on crop type, soil type and irrigation regime.

The GAB aquifers are recognised to have good quality groundwater, which could be utilised for aquaculture and the production of aquatic food for human consumption.

Suitability for industrial use

The groundwater quality is generally suitable for a large number of industrial processes including cooling water, process water, utility water, and wash water. As industrial processes require particular water quality, specific hydrochemical data will be required to evaluate suitability for use.

Industrial users generally have the capital required to drill and equip bores and if necessary appropriately treat the water before use. However, industrial users tend to require large volumes of water which would be unsustainable for the majority of shallow groundwater resources in the area.

Cultural and spiritual values

Based on the work completed, no specific groundwater resources of cultural or spiritual values were recognised. Artesian conditions may allow for permanent water pools or springs. These may have important cultural significance but insufficient data is currently available. These areas will require careful research as part of the CSG planning process.

The review allowed for the identification of four environmental values of relevance to the groundwater regime within the CSG field study area. These include domestic use, biological integrity (maintaining the water quality so the plants and animals living in the waterway can survive), suitability for primary industry (livestock drinking water) use, and suitability for primary industry (irrigation) use.

2.5 Potential Impacts – CSG Fields

In order to assess the potential impacts of the proposed CSG fields project an impact assessment, from a groundwater perspective, was compiled. The impact assessment allowed for the identification of impacts associated with the proposed CSG field development program, in particular:

- The CSG dewatering operations;
- The CSG associated water management process, and
- The construction and operation of associated CSG field infrastructure.

The potential hazards associated with the impacts, probability, magnitude (significance), and timing were assessed in order to develop the optimum risk reduction and threat mitigation measures, which are included in the Environmental Management Plan (EMP) for the proposed GLNG project.

The deep groundwater modelling study (Matrixplus, 2009) was utilised to evaluate the effects of the predicted dewatering of the coal seam aquifers on the shallow groundwater resources. Modelling indicates possible inter-aquifer transfer of groundwater, thus the dewatering activities are recognised to potentially impact on shallow groundwater resources. The potential impacts identified in the deep groundwater modelling study include:

- Drawdown of groundwater head levels within the CSG aquifers;
- Drawdown of groundwater head levels within overlying and underlying aquifers;
- Reduction of landholder bore yields;
- Reduction in stream baseflow as a result of groundwater discharge;
- Subsidence of the land surface overlying the CSG fields; and
- Post CSG extraction impacts.

These impacts were evaluated and issues regarding shallow groundwater resources were included in the shallow groundwater study impact assessment.

2.5.1 Description of intention

It is the intention of Santos to develop and expand the CSG fields in the Surat and Bowen basins in Queensland. The project will aim at drilling and completing sufficient development wells (± 1,400 wells after 2015) to supply approximately 5,300 petajoules (PJ) (140 billion m^3) of CSG to the proposed LNG facility in Gladstone.

An impact assessment was compiled to determine potential impacts associated with the proposed CSG field expansion and associated infrastructure on the groundwater resources.

The risk assessment aimed at providing information regarding the management of recognised impacts and allowing for the optimum management to mitigate the impacts.

2.5.2 CSG dewatering

Impact identification

The impacts associated with the required dewatering to facilitate CSG development are related to the changes in groundwater levels and availability, which can impact on surrounding users. The identified impacts associated with the dewatering on the shallow groundwater resources could include:

- Impacts of induced flow on the overlying lithological units;
- Interflow between aquifers, and
- Loss of shallow groundwater.

Estimation of probability and magnitude of the consequences of the impacts

The probability and magnitude of the consequences of any or all of the identified impacts occurring has been estimated. This exercise allows for the development of the correct management plan to ensure that the dewatering operations that can lead to the impacts are addressed. The correct management plans can reduce the possible negative impacts on the groundwater resources in the study area.

Table 2-18 provides a summary of the identified hazards, the consequences of the hazard becoming a reality, the probability of the hazard occurring, and the magnitude of these consequences. The definitions used in the table to describe the risk rating are discussed in Section 1.4.5.

Table 2-18 Potential Impacts on Shallow Groundwater Associated with CSG Dewatering

Impact	Consequence	Probability	Magnitude	Duration & Extent
Impacts of induced flow	Dewatering of coal seams can induce flow from overlying units, possibly causing dewatering and reduction in shallow groundwater resources	**Likely** Coal seams will be dewatering causing a negative pressure which can induce flow from surrounding units	**Minor** The dewatering can impact on the GAB aquifers however the dewatering is proposed away from areas where GAB aquifers are in direct contact with the coal seams	Will occur during the life of the project and post project
Interflow between aquifers – CSG exploration holes	Drilling can connect aquifers separated by aquitards, this could cause mixing or blending of hydrochemistry	**Possible** A large number of exploration holes have been drilled through the various units and not all seals / backfilling may be sufficient to prevent interflow	**Minor** Impacts of blending of groundwater, driven by differing piezometeric pressures, is envisaged to have a limited zone of influence	Pre-construction to beyond life of project
Interflow between aquifers – CSG wells	Drilling can connect aquifers separated by aquitards, this can allow for changes in hydrochemistry and increased dewatering impacts	**Rare** The drilling, construction, and design of the CSG development wells only allows for access to the coal seam aquifer[4]	**Minor** Impacts of CSG dewatering can be increased to impact on resources over a larger area resulting in the need to pump larger volumes of associated water	Not expected to occur if correct design and construction is conducted
Loss of shallow groundwater	Dewatering of shallow groundwater resources can impact on current users and surface water resources (reduction in baseflow)	**Unlikely** The thick succession of aquifers and aquitards between the coal measures and the shallow groundwater will limit impact	**Minor** The reduction in groundwater resources can impact on down stream users and groundwater reliant ecosystems	Will occur during the life of the project and beyond (during groundwater rebound)

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[4] The design is to include grouting of the entire annulus between the plain casing and the hole. Perforations in the casing are only located opposite the coal seams.

For the 5 recognised impacts, the risk estimates are evaluated as per the methodology discussed in **Section 1.4.5** and presented in **Table 2-19**.

Table 2-19 Impact Evaluation for CSG Dewatering

Impact	Probability	Magnitude	Risk estimate R = P x M
Impact 1: Impacts of induced flow	Likely (4)	Minor (2)	8
Impact 2: Interflow between aquifers – CSG exploration holes	Possible (3)	Minor (2)	6
Impact 3: Interflow between aquifers – CSG dewatering wells	Rare (1)	Minor (2)	2
Impact 4: Loss of shallow groundwater	Unlikely (2)	Minor (2)	4

The highest rated impact for CSG dewatering is recognised when dewatering of the coal seams results in induced flow from overlying or underlying aquifers. The proposed CSG dewatering could lead to the reduction in groundwater levels, especially in the coal seams.

Risk Evaluation

Impact 1: Impacts of induced flow

The dewatering of the aquitards located above and below the coal seam aquifers will have limited impact due to their depth and limited aquifer properties. The impact of the loss of these groundwater resources is limited as the potential for this resource to be utilised is reduced.

The induced dewatering of the hydraulically connected aquifers, where the confining aquitards are missing or connected by structures (faults), could increase the impact on groundwater resources due to decreased groundwater levels and yields.

Impact 2: Interflow between aquifers – CSG exploration holes

Numerous exploration wells have been drilled across the CSG fields in order to evaluate the gas deposits and coal deposits. These open holes if not sealed completely can allow for the direct interconnection between units of differing hydrochemistry. The resultant blending of fresh, brackish, and brine water can result in an alteration of groundwater quality. Thus drilling can potentially increase interconnection between units and the confining pressures can allow for groundwater movement within the bores.

Impact 3: Interflow between aquifers – CSG development wells

It is assumed that the drilling and construction of appraisal and development CSG boreholes will ensure that interflow between aquifers intersected within the bores will not occur.

Impact 4: Loss of shallow groundwater

The thick sequence of aquifers and aquitards and limited vertical connection indicates that the impacts of the coal seam dewatering on the shallow groundwater resources will be negligible.

Overall Risk Assessment

The overall risk to the shallow groundwater, based on the regional geology and hydrogeology (aquifers and aquitards), the large coal seam aquifer extent, and the relatively low groundwater abstraction for CSG development (in relation to the entire coal seams), is limited but will require monitoring to allow for effective assessment of the impact.

Monitoring will be conducted as per the result of the CSG Water Management Study, prepared for the DNRW, which states,

"In accordance with new legislative requirements for the CSG industry, management strategies and monitoring programs will be put in place to ensure confidence in long-term protection of the overlying/underlying aquifer units. No detailed estimation of groundwater impacts due to CSG development can be undertaken until dedicated site-specific monitoring programs are in operation, and baseline data are collected in accordance with emerging legislation for the CSG industry" (Parsons Brinckerhoff, 2004).

The on-going risk of potential groundwater blending, within the exploration holes, requires effective management. This could include an evaluation of the effectiveness of current backfilling and sealing procedures and exploration bore closure.

2.5.3 CSG Associated Water Management

Impact Identification

The impacts related with the management of CSG associated water will depend on the volumes of water to be stored and managed on surface. An associated water management study has been conducted to develop an adaptive CSG associated water management strategy based on recommendations compiled in the Queensland EPA operational policy for the management of associated water (EPA, 2007). The options could include; discharge into surface water resources (treated and untreated), deep well injection into suitable underlying formations, irrigated agriculture, forestry irrigation, etc. All of which will require storage and reticulation infrastructure, which have the potential to impact on the shallow groundwater resources.

The identified impacts associated with the CSG associated water on the shallow groundwater resources include:

- Poor quality artificial recharge from CSG associated water containment;
- Artificial recharge impacts on groundwater flow patterns;
- Impacts of treated water waste;
- Discharge impacts on alluvium aquifers; and
- Irrigation return water.

Additional impacts associated with the CSG associated water would relate to the disposal of the water through the use of deep well injection. The associated water would either be injected directly into a suitable aquifer at depth or treated and then injected into the deeper formation(s). The feasibility of deep well injection and the suggested mitigation measures regarding deep aquifer dewatering have been considered (Matrixplus, 2009).

Estimation of probability and magnitude of the consequences of the impacts

Optimum water management strategy details are provided in the associated water management strategy report (refer Appendix Q of the EIS). An assessment of the probability and magnitude of the consequences of any or all of the identified impacts occurring have been estimated. **Table 2-20** provides a summary of the potential impacts and the consequences of such impacts should they occur.

Table 2-20 Potential Impacts on Shallow Associated with CSG Associated Water

Impact	Consequence	Probability	Magnitude	Duration & Extent
Poor quality artificial recharge	The CSG associated water is of poor quality[5], seepage and recharge can potentially alter the hydrochemistry of the shallow groundwater	**Unlikely** Although the associated water will be contained in correctly designed and sized ponds, due to the large storage volumes involved with the CSG project there is a possibility of seepage or spillage occurring[6]	**Minor** The poor quality recharge can potentially alter hydrochemistry and impact on surrounding users, however due to the poor aquifers recognised on site the zone of influence will be limited	Life of project
Altered groundwater flow patterns	Seepage or spills from the water containment infrastructure can cause increases in the shallow groundwater levels (mounding), which results in flow away from the containment ponds	**Unlikely** Although the produced water will be contained in correctly designed and sized ponds, due to the large storage volumes involved with the CSG project there is a possibility of seepage or spillage occurring	**Minor** Assuming the associated water is not contained on alluvium aquifers the zone of influence around the containment areas is expected to be limited due to low hydraulic conductivity of the weathered sediments	Life of project until containment facilities are removed

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[5] Produced fluid generally includes a mixture of gaseous hydrocarbons, produced water, dissolved or suspended solids, produced solids such as sand or silt, and injected fluids and additives that may have been placed in the formation as a result of exploration and production activities.

[6] The storage facilities are sized for 1: 1000 year flood events and will be lined with a synthetic liner (e.g. HDPE)

Impact	Consequence	Probability	Magnitude	Duration & Extent
Treated water waste	Brine material generated during treatment is either stored in evaporation ponds or on site prior to injection into a saline aquifer. Seepage from these storage ponds can impact on the shallow groundwater	**Unlikely** The brine will be contained in correctly sized ponds however there is a possibility of seepage or spillage occurring	**Minor** The poor quality recharge can alter the hydrochemistry and impact on surrounding users, the envisaged limited volumes and high evaporation rates will reduce the magnitude	Life of project until the ponds are removed
Discharge of treated water on the alluvium aquifers	Increased recharge to the alluvium aquifers will occur if treated water is discharged into the adjacent creeks, this may result in erosion and removal of material. This would result in a reduction in alluvium material and impact post closure on the alluvium aquifer resources	**Unlikely** The discharge design will reduce the potential for scouring and the discharge points will vary over time	**Minor** The discharge will potentially reduce alluvium during the project, the reduction of a utilised resource will need to be evaluated	Post project
Irrigation return water	The treatment of CSG associated water will allow for additional water to be utilised for irrigation purposes. The irrigation allows for potential recharge and the mobilisation of nutrients (fertilisers) into the shallow groundwater. This could alter groundwater flow and chemistry over time.	**Unlikely** The increased irrigation is envisaged to be conducted at such a scale that it could impacted markedly on the groundwater flow regimes	**Insignificant** The short duration and limited additional volumes of recharge, across the entire large study area, will cause negligible deterioration of the shallow groundwater	Life of project

For the 5 potential impacts, the risk estimates are evaluated as per **Section 1.4.5** and summarised in **Table 2-21**.

Table 2-21 Shallow Groundwater Impact Evaluation for CSG Associated water

Impact	Probability	Magnitude	Risk estimate R = P x M
Impact 1: Poor quality artificial recharge	Unlikely (2)	Minor (2)	4
Impact 2: Altered groundwater flow patterns	Unlikely (2)	Minor (2)	4
Impact 3: Brine storage	Unlikely (2)	Minor (2)	4
Impact 4: Discharge of treated water on the alluvium aquifers	Unlikely (2)	Minor (2)	4
Impact 5: Irrigation return water	Unlikely (2)	Insignificant (1)	2

The impacts and risks associated with possible artificial recharge from the storage of poor quality water or brine on site are recognised to require management to ensure impacts are negated or reduced.

Risk Evaluation

Impact 1: Poor quality artificial recharge

The significance of this impact will depend on the volumes and quality of the seepage that enters the shallow groundwater. The containment facilities are assumed to be correctly sized and constructed to ensure capacity, thus reducing the risk.

Based on the use of composite (e.g. HDPE) linings and depth to groundwater, the potential threat of seepage is considered to be reduced.

Impact 2: Altered groundwater flow patterns

The impact of seepage from the containment facilities can potentially alter the groundwater patterns within a local area unless located on a preferential flow path (fault, fracture, etc.). The limited zone of influence compared to the large scale groundwater flow will reduce the significance of this impact.

Impact 3: Brine storage

The impact of seepage of brine water into the shallow aquifers can potentially alter the hydrochemistry, due to increased salinity. This could reduce the suitability for use for down stream users.

Impact 4: Discharge of treated water on the alluvium aquifers

The significance of this impact is based on the proposed discharge methodology and selection of discharge points. The correct discharge design to reduce scouring will reduce this potential impact.

Impact 5: Irrigation return water

The envisaged limited increase in recharge due to irrigation, compared to rainfall recharge volumes across the entire CSG field areas, is recognised as insignificant.

Overall Risk Assessment

The overall risk to shallow groundwater resources as a result of associated water is Low. Based on the need to contain large volumes of associated water on surface during the CSG operations the risk of artificial recharge, which could alter the nature of the shallow groundwater resources, will require mitigation measures to limit or negate the potential impacts. Recommendations regarding mitigation are presented in Section 2.6.

Failure Risk

Failure of an associated water pond is considered a limited risk to the shallow groundwater regimes. The loss of water from the pond would result in the rapid movement of water as sheet flow due to the low permeability of the soils and overburden. The rapid movement of water is considered not to allow significant increases in recharge to the shallow groundwater. The water will enter drainage lines which could allow for seepage from the creek beds to the underlying shallow aquifers. This seepage would occur over a large area thus reducing the accompanying salt load.

2.5.4 CSG infrastructure

Impact identification

Ancillary infrastructure associated with the CSG development and expansion within the CSG fields which may impact on shallow groundwater includes; development and appraisal wells, CSG networks and compressor stations, workers accommodation, work shops, maintenance and lay down yards. Possible impacts associated with these ancillary infrastructures include:

- Loss of recharge;
- Storage of chemicals, fuels and oils;
- Waste generation and storage; and
- Sanitation systems and practices.

Estimation of probability and magnitude of the consequences of the impacts

The changes in land use and the associated operations within the CSG fields can potentially impact on the shallow groundwater. An assessment of the consequences, possibilities, and magnitude of these impacts on the shallow groundwater has been compiled in **Table 2-22**.

Table 2-22 Potential Impacts Associated with CSG Ancillary Infrastructure

Impact	Consequence	Probability	Magnitude	Duration & Extent
Loss of recharge	The clearing of land for wells, plant, etc. and the alteration of topography can impact on rainfall recharge to the shallow groundwater regime	**Possible** Large areas around drill sites and compressor stations are cleared and levelled to facilitate CSG operations	**Minor** The alteration of a small percentage of the entire study area will have limited impacts on the groundwater recharge	Life of project
Storage of chemicals, fuels, oils	Spills or leaks of potential contaminants on surface can alter the shallow groundwater quality	**Unlikely** Correctly designed and constructed storage areas will be utilised on site	**Minor** Alterations to the groundwater quality can occur, however, limited volumes as a result of a spill or leak is assumed	Life of project
Waste generation and storage	The storage or disposal of waste generated during the CSG operations and activities can potentially impact on the groundwater	**Unlikely** Domestic and industrial waste will be generated in small volumes	**Minor** The waste will be managed and disposed using licensed contractors and disposed on licensed facilities	Life of project
Waste water and Sanitation	Sanitation systems associated with the accommodation and plants on site can potentially impact on the shallow groundwater	**Unlikely** Correctly designed, constructed and maintained ablutions (accommodation, change room, and toilet facilities) will be utilised on site	**Minor** All waste water will be correctly stored and disposed using licensed contractors	Life of project

The potential impacts and risks to the shallow groundwater resources associated with the CSG infrastructure were evaluated as per **Section 1.4.5** and summarised in **Table 2-23**.

Table 2-23 Impact Evaluation for CSG infrastructure

Impact	Probability	Magnitude	Risk estimate R = P x M
Impact 1: Loss of recharge	Possible (3)	Minor (2)	6
Impact 2: Chemical, fuel, oil storage	Unlikely (2)	Minor (2)	4
Impact 3: Waste generation and storage	Unlikely (2)	Minor (2)	4
Impact 4: Waste water and sanitation	Unlikely (2)	Minor (2)	4

Loss of recharge to the shallow groundwater is identified as having the highest potential based on the probability. The impacts will, however, be limited due to:

- The small disturbed areas compared to the entire CSG field project site;
- The low beneficial use of the shallow groundwater; and
- Limited recharge to the shallow groundwater away from the basin edges.

Risk Evaluation

Impact 1: Loss of recharge

The significance of this impact will depend on the total size of the disturbed areas, the recharge mechanisms at each disturbed area, and the proposed rehabilitation of the disturbed area. The low recharge within the centre of the CSG fields compared to the basin edges reduces the negative impact on the shallow groundwater.

Impact 2: Chemical, fuel, oil storage

The use of secondary containment (bunds) will reduce the likelihood of spills or leaks entering the groundwater. The implementation of correctly designed storage, handling procedures, and fuel reticulation facilities will reduce the potential impacts associated with the storage and transport of hazardous products.

Impact 3: Waste generation and storage

The risks associated with the management of waste generated during CSG operations, both domestic and industrial, will be reduced through the use of licensed contractors who will ensure the correct disposal, storage, handling, and transport methods, according to accepted industry practices, are adopted.

Impact 4: Waste water and sanitation

The correct waste water management systems to be utilised at the various sites, to contain and then dispose of waste water, will reduce the potential impacts associated with these limited volumes of water.

Overall Risk Assessment

The limited reduction in recharge and the containment and management processes to be adopted will only require monitoring to ensure the CSG infrastructure is not impacting negatively on the shallow groundwater. The overall risk is thus recognised to be Low.

2.6 Management and Mitigation Measures – CSG Fields

2.6.1 CSG Dewatering

Impacts of dewatering associated with CSG development could occur. The extent of dewatering, impacts on current users and future resources, and the evaluation of cumulative impacts (of other CSG projects dewatering the same coal seams across central Queensland) need to be evaluated through the life of the project.

The deep groundwater abstraction study compiled by Matrixplus (refer Appendix P2 of the EIS) for the GLNG project provides an indication of the extent of dewatering within the coal seam aquifers as well as predictions regarding possible induced flow from adjacent units. It is recommended that appraisal boreholes drilled to the coal seams, not used for CSG operations, be modified to allow for the monitoring of groundwater levels within the coal seams. These boreholes can, if feasible, be equipped with piezometers to allow for the monitoring of additional aquifers within the CSG fields.

An evaluation of geology has been conducted to allow for the identification of areas where the coal seams are potentially in close contact with GAB aquifers, as these areas have increased potential for inter-aquifer flow. Monitoring boreholes or existing bores within these areas are required to allow for the monitoring of groundwater levels as well as hydrochemistry. The evaluation of groundwater quality will allow for an assessment of hydrochemical trends over time to determine whether groundwater quality in the coal seams is being altered through the induced flow from surrounding aquifers.

A regional bore census of groundwater users within these areas is currently underway to allow for the monitoring of neighbouring bores, which could potentially be impacted by dewatering operations (as identified in the groundwater model simulations, EIS Appendix P2). DNRW data indicates that long term groundwater level data within the various units do not vary significantly over time in response to recharge or extended dry periods (where not affected by abstraction). This data is required prior to CSG dewatering to allow for baseline conditions to be accurately determined and allow for comparisons to evaluate possible dewatering impacts. It is recommended that site specific groundwater level data is obtained prior to the CSG dewatering commencing.

Background groundwater level monitoring is recommended in order to assess natural responses to varying climate conditions.

The potential impacts of dewatering include lowering of groundwater levels and possible reduction in bore yields. It is therefore recommended that for subartesian aquifers selected bores are monitored using automated groundwater level monitors. The groundwater levels are to be monitored in shallow (< 100 m), moderate (± 200 m), and deep (coal seam) bores to assess groundwater level responses. The aquifers to be monitored are those identified as being impacted through induced flow, which include the Precipice Sandstone, Hutton Sandstone, and the coal seam aquifers, depending on the CSG field. The groundwater level data must be accurate, reliable, and should provide weekly groundwater level information. Records of rainfall, hydrochemistry, and water abstraction are required on a regular basis to facilitate the compilation of a groundwater balance of the study area. This information can be utilised to recalibrate the deep groundwater models, constructed by Matrixplus, to allow for more accurate predictions and simulations of dewatering over time.

Trigger levels, regarding declines in groundwater levels, are required to assess and manage the impacts of dewatering. Suggested trigger levels[7], regarding declines in available drawdown within bores, will be used to assess and manage the impacts of dewatering. Groundwater level variations are to be monitored. Should available drawdown (the column of water above the pump inlet) vary by 10% then this will act as an early warning trigger. If the early warning trigger assessment indicates that dewatering is conclusively found to be the cause of the groundwater level impact then a water replacement plan will have to be compiled to make good the loss of water. This plan would allow for the sourcing and replacement of the same quantity and quality of water lost to the affected groundwater user. Should the available drawdown in a bore decrease by 25% then the water replacement plan / strategy would be implemented. Compensation provisions are allowed according to the P&G Act and should be considered when implementing any water replacement plans. Sources of water will be identified depending on the location of the impacted supplies and could include treated associated water.

This mitigation strategy, to reduce the negative impact of loss of groundwater supplies, requires the compilation of accurate information to be obtained during the regional bore census and pre-CSG operations monitoring.

The design and construction of the CSG wells is considered satisfactory to ensure that no interaction between aquifers via the wells. Well integrity monitoring could be conducted on each well to ensure construction according to design.

All exploration wells within the CSG fields, historic and proposed, will need to be backfilled (if not modified as monitoring piezometers) to prevent them acting as direct conduits between aquifers. The backfilling, to ensure an effective seal, could comprise cement with 5% bentonite.

2.6.2 CSG Water Management

The large CSG field area and number of envisaged production wells will result in the reticulation and storage of large volumes of associated water on the surface. The storage of water[8], either prior to treatment or the resultant brine after treatment, can potentially seep, leak, or spill (over the spillways) and cause alterations to the groundwater flow patterns and hydrochemistry. The ponds have been designed and will be constructed to limit this risk.

Geophysical surveys, comprising magnetic and electromagnetic techniques, could be employed during pond site selections, to ensure that the ponds are not located on underlying geological structures, which can act as preferential flow paths.

In order to reduce the potential for artificial recharge the correct design and sizing of the associated water containment facilities is ensured. The dams are correctly sized (to prevent overflow and adhere to regulations) and will be constructed to have a low permeability base. This will reduce spillage risk and infiltration. The size calculations include for rainfall events based on a minimum of the 1:1000 year flood events.

The design and water management should allow for sufficient free board to ensure dam safety and limited overtopping risks.

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[7] Trigger values must be discussed and agreed upon with the relevant regulatory bodies.

[8] Consideration for the construction of dams containing associated water is given by the regulatory authorities if the dams are designed to include impermeable synthetic linings, such as HDPE.

It is suggested that down gradient secondary containment facilities, such as toe dams, be included in the design of the brine storage facilities, if utilised.

Groundwater level and quality monitoring is required adjacent to the proposed associated water storage facilities to ensure the effectiveness of designs, maintenance, and management. Monitoring recommendations include:

- Existing boreholes should be used, up and down gradient of the storage facilities where possible, or else new monitoring boreholes must be constructed.
- One ± 60 m deep borehole located 50 m up gradient of each water storage facility is suggested, to provide shallow ambient groundwater data.
- Two ± 60 m deep boreholes, located at 5 and 15 m, down gradient of each water storage facility, based on geophysical survey, i.e. scientifically sited to intersect potential preferential flow paths.
- Automated monitoring of groundwater levels and rainfall data at each facility. Monitoring should begin prior to the start of construction.
- Groundwater quality monitoring, comprising major anions and cations, selected dissolved metals, and CSG water indicators. It is recommended that groundwater sampling is conducted quarterly at first and then reduced to bi-annually with time.
- All existing boreholes located within the dam footprints must be backfilled using a cement – bentonite slurry so as to prevent direct migration of potentially poor quality water into the aquifers.

Management (of water volumes in the ponds) and maintenance of the ponds and reticulation pipelines is required to minimise the volumes of water than can be “lost” to the groundwater. This should commence at the start of operations and continue for the life of the project.

The use of treated associated water will require groundwater monitoring programs (both groundwater levels and quality) to be developed to assist in determining the impacts of the treated water use on the shallow groundwater. The monitoring could include shallow (± 20 to 60 m) boreholes within the alluvium aquifers and within irrigated lands. Alterations to groundwater levels, groundwater flow patterns, and hydrochemistry need to be monitored to evaluate the possible impact of artificial recharge, which are deemed limited at this point.

Groundwater monitoring in shallow boreholes constructed in the same geological units located away from the storage facilities is recommended across the site. This will allow for the assessment of natural salinity changes. This should be done to aid in assessing the potential impacts of the storage facilities. Natural changes in salinity can for example occur due to:

- Exposure of impermeable rock intersected in the monitoring holes, which leads to the leaching of salts into the groundwater;
- The change in groundwater levels (possibly due to removal of vegetation), such that the groundwater rises into salt accumulation zones within the unsaturated zone;
- Prolonged periods of drought leading to deterioration in groundwater quality, and
- Anthropogenic influences from land use such as irrigation.

2.6.3 CSG Infrastructure

Recharge changes due to changes in land use within the CSG fields is envisaged to be limited due to the relatively small area compared to the entire CSG field area. Monitoring conducted to evaluate dewatering (**Section 2.6.1**) will also allow for an assessment of reduced recharge to the shallow groundwater resources.

Minor hydrocarbons may be present within the associated water and oils can potentially be present in other waste water streams. Such water will require treatment prior to any reuse on site (e.g. possible irrigation water). To reduce the probability of uncontained oil releases entering the water system, the following recommendations are made:

- Contain all oil storage facilities within a bunded area;
- Site records regarding clean up of spills and accurate volumes of fuel / oil are kept in the IMS system; and
- Maintain accurate records of oil volumes, purchased, used, disposed, and recycled.

The mitigation measures should be included in the design phase and regular (bi-annual) groundwater sampling for light non-aqueous phase liquids (LNAPL) should be conducted during CSG operations, adjacent to the bunded areas.

The conveyance and storage of hazardous chemicals and effluents should be through or in suitably sealed infrastructure, including tiles and coatings, concrete channels, trenches, and sumps. All chemicals are to be stored in above ground storage tanks located within suitable secondary containment (bunded) areas. Due to the threat to human health and the environment, it is recommended that all sealed infrastructures be inspected annually by a qualified person (e.g. civil engineer). Recommendations with respect to repair procedures must be compiled and conducted by a recognised specialist. The sealing and suitable material selection is to be conducted during the design phase.

The management of waste, domestic and industrial, stored in industry standard facilities will require the use of licensed contractors. Bi-annual audits of disposal facilities, disposal permits, and working conditions ought to be conducted to ensure adherence to the regulations.

2.6.4 CSG Decommissioning

Once the dewatering has ceased these associated water ponds could either be utilised by landowners or the decommissioning and rehabilitation of the dams to pre-CSG operational conditions. As the dams are to be designed and constructed using a composite liner it is envisaged that the required rehabilitation will allow the disturbed areas to be restored to pre-CSG condition.

2.6.5 Water Supply Usage and Waste Water Disposal

The impacts associated with water supply usage and waste water disposal are detailed in EIS Appendix Q Associated Water Management Strategy.

The impacts on shallow groundwater are considered as follows:

- No shallow groundwater will be used for water supply during the project;
- The impacts of pond failure on the shallow groundwater have been considered;
- The potential impacts of poor quality associated water or brine (waste from treated associated water) on the shallow groundwater has been considered;

- The need or otherwise for licensing any dams has no relevance to the shallow groundwater; and
- The engineering design standards have been considered when evaluating the potential impacts on the shallow groundwater resources.

3.1 Proposed Gas Transmission Pipeline Details

The gas transmission pipeline will be a buried, high pressure steel pipeline. It will be designed in accordance with the requirements of AS 2885 Pipelines – Gas and Liquid Petroleum and constructed in accordance with the Australian Pipeline Industry Association's Code of Environmental Practice (APIA, 2005). The proposed 435 km gas transmission pipeline will be buried for its entire length. The construction will be undertaken over approximately a 24 month period. The 32" to 42" diameter gas transmission pipeline, capable of operating at pressures of 10.6 to 15.3 megapascals, is designed to deliver up to 2000 TJ/day of feed CSG to the proposed LNG facility at Curtis Island.

The pipeline easement will be 30 m wide, which is wide enough to accommodate one or more pipelines. The gas transmission pipeline will normally be installed to a minimum depth of 0.75 m below ground level, which will be increased to 1.2 m in high consequence areas, such as watercourses, cropping / cultivation areas, and road / rail crossings. Gas transmission pipeline installation depths at water crossings will range between 1.2 and 2 m, and deeper if a crossing is made using directional drilling techniques.

The gas transmission pipeline will be constructed by either of two methods:

- Trenching; or
- Horizontal Directional Drilling (HDD).

Trenching involves the mechanical excavation of soil, regolith, and shallow bedrock in order to facilitate laying of the gas transmission pipeline. Blasting or the addition of formation stabiliser may be utilised, depending on the competency of the underlying lithology.

The use of HDD techniques reduces above ground impacts; however, the technique can introduce drilling mud and fluids directly into shallow aquifers. Drilling fluids, such as bentonite, are utilised for lubrication and wall stability to facilitate the drilling and pipeline installation. Bentonite, a natural clay, can enter fractures, expand, and alter the permeability of the intersected units.

As the gas transmission pipeline will carry CSG the main impacts identified with regards to shallow groundwater are related to alterations to aquifer hydraulic parameters associated with the installation of the gas transmission pipeline.

3.2 Preliminary Assessment of Geology and Hydrogeology

The selected gas transmission pipeline route for consideration in the EIS is presented in **Figure 3-1**[9]. The route is described in the surface water technical study (refer Appendix O in the EIS) and summarised below.

The route originates in the plateau country of the Great Dividing Range northeast of Injune. Soils associated with the plateau consist mainly of sandy soils, often very shallow or stony, with areas of sandstone rock outcrop. The Great Dividing Range outcrop is a major recharge area for the sandstone aquifers within the GAB sequence. Seasonal seepage and discharge from the confined aquifers can occur within the Great Dividing Range, depending on topography and hydrostatic pressures. This seepage may sustain groundwater

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[9] Due to the length of the gas transmission pipeline Figure 3-1 has been divided into three drawings, Figure 3-1a, Figure 3-1b, and Figure 3-1c.

dependent environments through discharge to creeks water holes. An assessment of the geology, elevation, and groundwater levels along the route through these competent formations will allow for an assessment of potential groundwater seepage, and thus vulnerable shallow groundwater resources.

Qe		estuarine and delta deposits	Estuarine, tidal delta deposits; coastal mud flats
Qdc		coastal dunes	Coastal dunes, beach ridge, barrier beach, foredune & shoreface sands
Qa		alluvium	Channel and flood plain alluvium; gravel, sand, silt, clay
Tb		volcanic rocks	Volcanic rocks, predominantly mafic; basalt, trachyte, rhyolite
Tobi		Biloela Formation	Mudstone, siltstone, oil shale, sandstone, minor lignite, coal and limestone
Ts		sediments	Tertiary sediments, undivided
Czs		sand plain	Sand plain, may include some residual alluvium; sand dominant, gravel, clay
Ka		trachyte	Trachyte, volcaniclastics, quartz porphyry, rhyolite aplite, granodiorite, diorite, gabbro
Kf		volcaniclastics	Intermediate and acid volcaniclastics and flows, rhyolite flow
Jshu	**Bundamba Group**	Hutton Sandstone	Sublabile to quartzose sandstone, siltstone, mudstone, minor conglomerate and coal
Jsev	**Bundamba Group**	Evergreen Formation	Labile and sublabile, sandstone, carbonaceous mudstone, siltstone and minor coal; local oolitic ironstone
Jsp	**Bundamba Group**	Precipice Sandstone	Thick-bedded, cross-bedded, pebbly quartzose sandstone, minor lithic sublabile sandstone, siltstone, mudstone
-Rsc	**Clematis Group**		Quartz rich sandstone, conglomerate, siltstone, mudstone
-Rgvo		Voewood Granite	Pale pink to grey medium-grained biotite granite, locally with pyrite along joint planes
-Rsm	**Mimosa Group**	Moolayember Formation	Micaceous lithic sandstone, micaceous siltstone
-Rsar	**Rewan Group**	Arcadia Formation	Lithic sandstone and green to reddish brown mudstone and minor conglomerate
-Rfw		Winterbourne Volcanics	Rhyolite, trachyte, ignimbrite, rhyolitic breccia, tuff, minor basalt
-Roc		Callide Coal Measures	Poorly sorted polymictic pebble to boulder conglomerate, sandstone, siltstone, coal seams, felsic tuff
Pgg	**Galloway Plains Igneous Complex**		Grey to dark grey medium-grained biotite-hornblende quartz diorite and augite-hypersthene-hornblende quartz gabbro
Pg		granodiorite	Granodiorite, granite, monzogranite, diorite, amphibolite, rhyolite
Pgd		hornblende diorite	Hornblende diorite, biotite-hornblend quartz diorite, monzodiorite, monzonite
Pgcg	**Littlemore Suite**	Craiglands Quartz Monzodiorite	Grey to pink medium-grained hornblende quartz monzodiorite, hornblende-augite quartz diorite, biotite-hornblende quartz diorite
Pdy		gabbro 39,477	Gabbro, diorite
Pdsa		Sawnee Gabbro	Grey medium-grained hornblende gabbro
Pgdu	**Dumgree Suite**	Dumgree Tonalite	Pale grey medium-grained leucocratic biotite-hornblende tonalite; grey medium-grained hornblende quartz diorite
Pgbc	**Galloway Plains Igneous Complex**	Bocoolima Granodiorite	Deeply weathered grey medium-grained biotite-hornblende granodiorite
Pgzz		Zig Zag Granodiorite	Pale grey medium-grained hornblende-biotite tonalite, locally with patches of epidote alteration
Pgma		Mannersley Granodiorite	Porphyritic biotite-hornblende quartz microdiorite with abundant secondary biotite along joints
Pgrs	**Littlemore Suite**	Redshirt Granite	Pink medium to coarse-grained hornblende-biotite granite with minor tourmaline pegmatite

Pgrp	**Rocky Point Granodiorite**		Grey to pinkish grey medium-grained biotite-hornblende granodiorite, locally with poikilitic K feldspar
Pgta	**Targinie Quartz Monzonite**		Hornblende-biotite quartz monzonite, quartz-alunite alteration
Pwch	**Berserker Group**	Chalmers Formation	Siltstone, lithic sandstone, rhyolitic to andesitic volcaniclastic breccia, rhyolitic and dacitic tuff, minor andesitic tuff
Psla	**Berserker Group**	Lakes Creek Formation	Siltstone and lithic sandstone
Pain		Inverness Volcanics	Trachyte to dacite, volcanic breccia; numerous small hornblende quartz monzodiorite intrusions
Psb	**Back Creek Group**		Sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite
Pow	**Blackwater Group**		Sandstone, siltstone, shale, mudstone, coal, tuff, conglomerate
Psbe		Berserker beds	Siltstone, lithofeldspathic sandstone, intermediate to felsic intrusive and extrusive domes, volcanic breccia, minor conglomerates
Pwyo		Youlambie Conglomerate	Polymictic conglomerate, felsic volcaniclastic sandstone, carbonaceous siltstone, dacitic to rhyolitic ignimbrite, breccia, mudstone, minor coal
Pbr		Rookwood Volcanics	Basalt and high-level mafic intrusives, minor rhyodacite lava, volcaniclastic breccias, sandstones, siltstones, mudstone
Pwsm		Smoky beds	Andesitic conglomerate and sandstone, mudstone, minor andesite lava
Pwcb	**Back Creek Group**	Camboon Volcanics	Andesite, basalt, dacite, rhyolitic tuff and flows, conglomerate, sandstone, siltstone, breccia
Cwrg	**Rockhampton Group**		Mudstone, siltstone, volcaniclastic sandstone, polymictic conglomerate, ooid-bearing sandstone, oolitic limestone
Cssh		Shoalwater Formation	Quartzose sandstone, mudstone; local quartz-muscovite-biotite schist
Cl		siltstone 39,453	Siltstone, sandstone, conglomerate, limestone, mudstone
Cft		Torsdale Volcanics	Dacitic to rhyolitic ignimbrite, volcaniclastic rocks and lava; subordinate andesitic rocks; volcanilithic conglomerate and sandstone
Cggd		Glandore Quartz Monzonite	Medium-grained, biotite-hornblende granite, granodiorite or monzonite, biotite granite, hornblende diorite
Cswa		Wandilla Formation	Mudstone, lithic sandstone, siltstone, jasper, chert, slate; local schist
Dwba	**Curtis Island Group**	Doonside Formation	Basaltic to andesitic lava and volcaniclastic rocks, felsic volcaniclastic rocks, chert, mudstone, limestone
Dsd	**Curtis Island Group**	Doonside Formation	Chert, jasper, mudstone, siltstone, lithic sandstone, tuff, limestone, and altered basalt
Dwya		Yarwun beds	Interbedded sandstone and siltstone, dacitic to rhyolitic volcaniclastic conglomerate with rip-up clasts, limestone
Dwtm		Three Moon Conglomerate	Andesitic to basaltic polymictic conglomerate, lithofeldspathic sandstone, siltstone, mudstone, andesite, minor acid tuff, limestone
Dwbc		Balaclava Formation	Rhyolitic volcaniclastic sandstone and conglomerate, minor ignimbrite, rare rhyolite, siltstone and oolitic limestone
Dsal		Mount Alma Formation	Sandstone, siltstone and thick beds of conglomerate with andesitic to dacitic clasts and siltstone rip-up-clasts, fossilifereous limestone
Dwrc	**Capella Creek Group**	Raspberry Creek Formation	Basaltic to rhyolitic volcaniclastic sandstone and conglomerate and minor lavas, siltstone, mudstone, chert, jasper, limestone
Dwlo		Lochenbar beds	Andesitic breccia and conglomerate, feldspatholithic sandstone, amygdaloidal locally porphyritic andesite, siltstone
Sfer		Erebus beds	Dacitic to rhyolitic volcaniclastic sandstone and conglomerate, minor siltstone, fossiliferous limestone and marble
Sfmh		Mount Holly beds	Basaltic to andesitic (rarely dacitic and rhyolitic) volcaniclastic sandstone and conglomerate, limestone, siltstone, andesite

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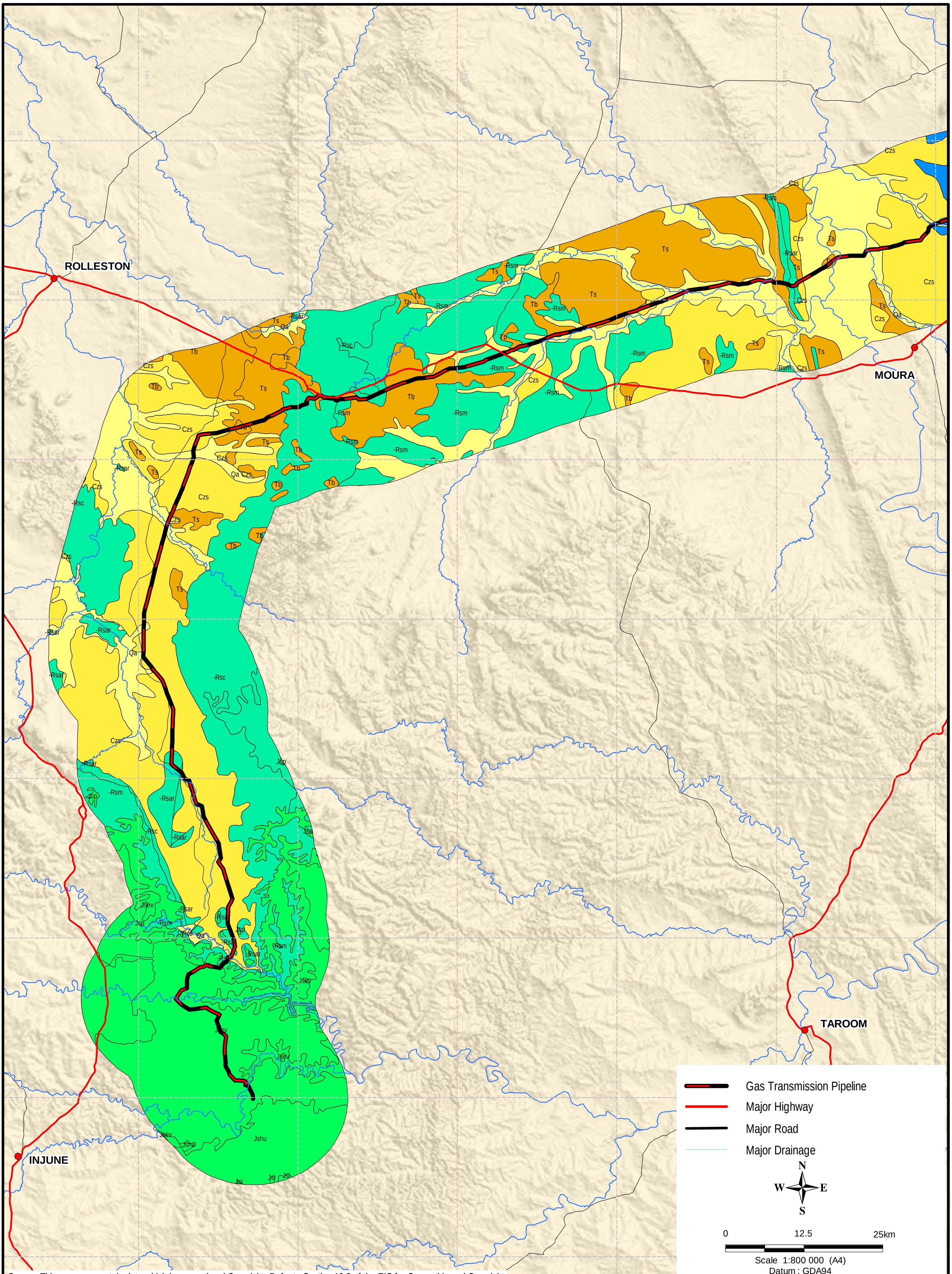
Client

Project
GLADSTONE LNG PROJECT
GAS TRANSMISSION PIPELINE
SHALLOW GROUNDWATER ASSESSMENT

Title
GAS TRANSMISSION PIPELINE CORRIDOR AND REGIONAL GEOLOGY

Drawn: RG
Approved: JB
Date: 23-01-2009
Job No: **4262 6220**
File No: 42626220-g-587b.wor
Figure: **3-1(a)**
Rev:B
A4



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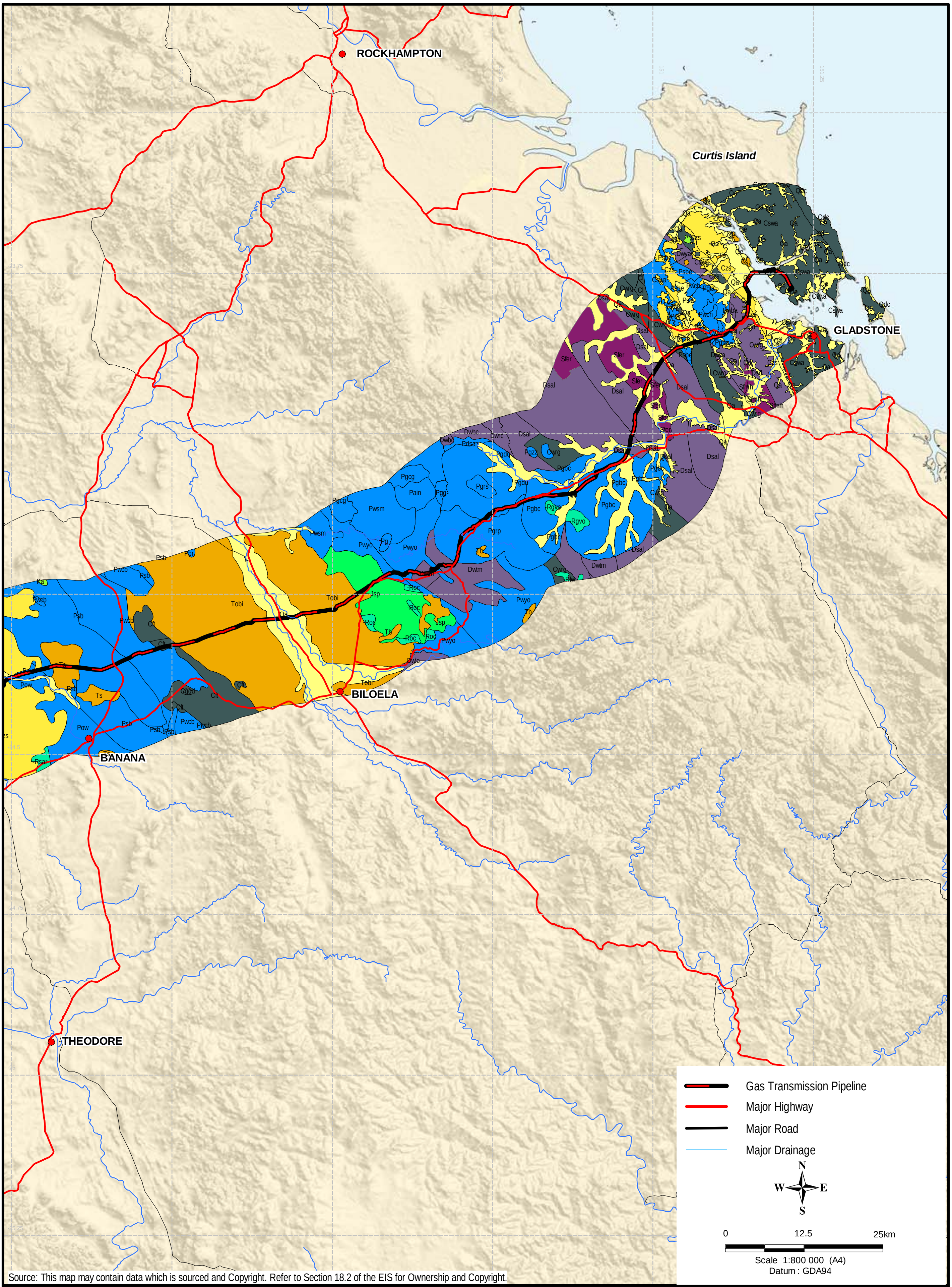
Client	Project	Title
	GLADSTONE LNG PROJECT GAS TRANSMISSION PIPELINE SHALLOW GROUNDWATER ASSESSMENT	**GAS TRANSMISSION PIPELINE CORRIDOR AND REGIONAL GEOLOGY**

Drawn: RG	Approved: JB	Date: 23-01-2009	Figure: **3-1(b)**	Rev:B
Job No: **4262 6220**	File No: 42626220-g-587.wor			**A4**



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Client

LNG

URS

Project

GLADSTONE LNG PROJECT
GAS TRANSMISSION PIPELINE
SHALLOW GROUNDWATER ASSESSMENT

Title

GAS TRANSMISSION PIPELINE CORRIDOR AND REGIONAL GEOLOGY

Drawn: RG
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Figure: **3-1(c)**

Rev:B

A4

At the base of the escarpment, the proposed gas transmission pipeline route intersects alluvium-rich sandy floodplain alluvium of the upper Dawson River.

This alluvium material is recognised to contain shallow groundwater resources, used for agriculture, which are vulnerable to surface contamination due to increased porosity and permeability in the sand and gravel material. These resources also have enhanced storage and recharge, which allows for moderate sustainable abstraction where the alluvium has large extent (spatial and depth) and interconnectivity.

The gas transmission pipeline route proceeds northward through the Arcadia, which consists of gently sloping fans containing sandy soils and areas of medium to heavy clay. Broad alluvial plains of the Brown River and other streams within the Arcadia are dominated by expansive uniform clay soils. The low permeability of the clay allows for the protection of deeper weathered and fractured rock aquifers within the sediments below the clay.

East of the Expedition Range the alignment traverses mainly undulating plains and lowland as well as the floodplains of Zamia Creek, Mimosa Creek, the Dawson River, Banana Creek and other streams, all of which contain large areas of mainly cracking and non-cracking clay soils and sandy soils. Groundwater potential is enhanced within these floodplains due to the increased recharge (both rainfall and creek flow), storage, and transmissivity. The groundwater in these floodplains is used for agriculture, both stock watering and irrigation.

To the east of the Leichhardt Highway the gas transmission pipeline easement traverses undulating and gently inclined plains underlain by Tertiary sediments, which comprise sandstone, siltstone, claystone and conglomerate, and the floodplains of Kroombit Creek and Callide Creek. The soils within this section of the gas transmission pipeline route comprise cracking and non-cracking clays (in the lowlands) and sandy surface soils on the lower slopes of low rises. The Tertiary sediments, in their pristine state, have low groundwater potential and require secondary processes, such as faulting, weathering, etc., to enhance the groundwater potential, and are generally of limited use. Saturated sandy soils can provide storage and recharge to the underlying secondary aquifers.

The floodplains of the Calliope River and its major tributaries comprise cracking clay soils and thin loamy surface soils. The thin clay-rich soils are envisaged to have limited permeability and transmissivity. The alluvial sediments have the potential to be used for stock watering and irrigation.

The final portion of the gas transmission pipeline route crosses undulating plains and gently inclined slopes with sandy and loamy surface soils. The coastal areas comprise coastal estuarine tidal marine flats that have mainly deep soft saline clay, silt and muddy sand soils. The groundwater resources, as identified in the proposed LNG Facility study area (**Section 4**), are limited with poor groundwater quality.

A review of the available geological maps indicate limited geological structures along the proposed gas transmission pipeline route, however, areas of potential instability and enhanced groundwater potential can occur. Large faults have been mapped within the surficial geology, especially in the sandstone units along the route. These faults, if active, can impact on the structural integrity of the gas transmission pipeline. The faulting can also increase the groundwater potential of the country rocks.

The review of available data allowed for an initial assessment of the shallow groundwater resources along the proposed pipeline alignment. Groundwater is recognised as being utilised for domestic and stock watering purposes from shallow groundwater resources. Small scale irrigation using groundwater is also recognised to occur from the various shallow aquifers within the large study area.

3.3 Potential Impacts of the Gas Transmission Pipeline on the Shallow Groundwater

Based on the project description data, the following details are important when considering potential impacts on the shallow groundwater:

- The gas transmission pipeline is to be installed within a ± 1 m deep trench or drill hole;
- The gas transmission pipeline will be buried along the entire length of the route; and
- The gas transmission pipeline will be installed below rivers, streams, and wetlands (if any).

The possible impacts of the trenching, HDD, gas transmission pipeline installation and backfilling on the groundwater, based on similar studies, include:

- The alteration of recharge (increased) along the trench;
- The alteration of permeability, porosity, and storage within the trench (altered soil / regolith);
- The impact of blasting on aquifers (fractured rock) and existing boreholes;
- Alterations in shallow groundwater flow patterns, localised along the trench;
- Temporary dewatering during the installation of the gas transmission pipeline in areas of shallow groundwater near surface water bodies;
- Alterations in permeability due to HDD; and
- Possible contamination source.

Based on the shallow nature of the trenches and the overall deep groundwater, it is envisaged that the impact on the shallow groundwater (reduction or increase in hydraulic characteristics) will be negligible except where the gas transmission pipeline directly intersects shallow groundwater.

Shallow groundwater intersected during trenching must be recorded as these shallow groundwater conditions can impact on the cathode protection afforded to the gas transmission pipeline.

The shallow groundwater could be temporarily impacted on during any possible dewatering of a section of the trench during the gas transmission pipeline installation. The impact would be limited to immediately adjacent to the trench and only temporary.

Blasting of rock outcrop can alter fracture patterns and cause collapse or damage to nearby (± 200 m) boreholes. A bore census along sections of the selected route, where blasting is required, should be conducted to identify any boreholes that may be impacted on during blasting for the gas transmission pipeline installation. The identification of springs and seeps within the census zone is also required to ensure blasting does not alter flow patterns resulting in spring migration.

HDD requires the use of drilling fluids and muds to facilitate the installation of a gas transmission pipeline sleeve. These drilling additives can potentially have long term impacts on localised aquifers through the reduction in permeability.

During construction, hydrostatic pressure testing of the pipeline will be conducted. The water used to conduct the hydrostatic testing may contain additives such as biocides and corrosion inhibitors. These chemicals have the potential to impact on groundwater quality if accidentally released.

Records of pumped volumes within the gas transmission pipeline and regular testing of the line will ensure the integrity of the gas transmission pipeline during operation.

Potential sources of onsite pollution during the construction phase predominantly comprise diesel and other petroleum-based fuels and lubricants used by excavation and construction machinery. The use of fuels and chemicals on site will involve refuelling of vehicles and maintenance during the construction of the gas transmission pipeline. Potential aqueous waste streams will include oily waste water (from equipment wash water), potentially “dirty” runoff from maintenance and chemical storage areas, potentially contaminated drainage from fuel oil storage areas, oil-filled transformer yard areas, and general wash down water. The ponding or runoff of water from these potential source areas, during rainfall events, can act as artificial recharge to the shallow groundwater. Waste water from accommodation camps has the potential to contaminate aquifers locally. The management systems to be utilised at on site to contain, treat and then dispose of waste water, will reduce the potential impacts associated with these limited volumes of water.

3.4 Mitigation

The preliminary assessment of the gas transmission pipeline route, the shallow nature of the gas transmission pipeline installation, and the limited groundwater contamination potential of the feed gas, indicate that the proposed gas transmission pipeline will have limited impact on the groundwater resources. Mitigation recommendations made based on the preliminary assessments include the need for the collection of accurate site-specific data.

Sections of the pipeline route through competent (hard rock) formations may require blasting, which could impact on existing boreholes. Construction of the pipeline under watercourses will potentially require dewatering of the watercourse sediments, which will have a temporary impact on surrounding (alluvial) aquifers.

A borehole census, conducted within a ± 200 m radius of areas where blasting or creek crossings are envisaged, will allow for the identification of all groundwater use and users (including springs and seeps). The hydrocensus data to be collected must include groundwater levels, abstraction rates, pumping equipment (status and depth), borehole depth, and casing details. Data collected before and after (blasting and dewatering) can be compared to determine any impacts on the existing users. The dewatering will only impact temporarily, however, rehabilitation of boreholes impacted by blasting (collapse) may be required.

The use of HDD in areas where shallow groundwater is being utilised, i.e. with alluvium aquifers adjacent to creek crossings, can potentially impact on the groundwater permeability, transmissivity, and storage of the aquifers. It is recommended that in order to minimise the alteration to the groundwater resources biodegradable drilling fluids and mud, which breakdown with time, be utilised. This will reduce the zone of influence the HDD will have on the shallow aquifers.

Due to potential instability and shallow groundwater vulnerability, the gas transmission pipeline route should avoid faults where possible and follow the shortest possible route under alluvium aquifers.

Secondary containment (bunded) storage areas for possible contaminants should be included on site to prevent poor quality runoff, ponding of water, and poor quality artificial recharge. Spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) need to be kept on site. Any significant leaks or spills of hazardous materials must be cleaned up according to appropriate emergency clean-up operations immediately. This is done to prevent possible mobilisation of contaminants into the groundwater. Any contaminants or major spillages of stored material in the bunded areas should be collected by licensed waste collection and transport contractors for disposal off site at a licensed facility.

Waste water from wash down areas can be directed through oil and grease traps / separators and stored in settlement/evaporation ponds for re-use. Separated hydrocarbon material is to be removed offsite by licensed waste collection and transport contractors to a licensed recycling/disposal facility.

The gas transmission pipeline's integrity will be verified by hydrostatic testing. This testing forms the key component of the commissioning phase for the project. Testing water could potentially be treated with chemicals such a biocide, oxygen scavengers, and corrosion inhibitors, which if spilt or leaked could impact on the shallow groundwater. All spills or leaks should be managed as discussed above.

The disposal of the waste testing water could cause localised impacts on the groundwater regime, thus the disposal should be undertaken using approved environmental procedures, potentially discharging into evaporation ponds or disposal to a regulated waste collector.

3.5 Monitoring

A short duration monitoring program should be developed and conducted during the commissioning of the gas transmission pipeline. The monitoring should include:

- The accurate recording of pumped volumes within the gas transmission pipeline during hydrostatic testing; and
- Monitoring of selected existing boreholes adjacent to the gas transmission pipeline in high consequence areas.

During operations groundwater monitoring could be considered at points identified adjacent to groundwater dependent ecosystems (GDE). The groundwater monitoring, groundwater levels and hydrochemistry (organic compounds associated with CSG and selected elements including nitrogen and sulfur), would allow for the evaluation of the integrity of the gas transmission pipeline.

4.1 Existing Environment – LNG Facility

4.1.1 Review of Information

The description of hydrogeological conditions at the proposed LNG facility site, located on Curtis Island off Gladstone, was based on a review of the following information:

- Gladstone Special 1:100 000 geological map (Sheet 9150 and Part 9151);
- Groundwater Resources of Queensland 1:2 500 000 hydrogeological map; and
- Groundwater bore information from the DNRW groundwater database.

A search of the DNRW registered bore database revealed that only one groundwater bore has been installed and registered within a 2 km radius of the proposed LNG Facility site.

4.1.2 Liquefied Natural Gas Export Facility

It is proposed that the LNG facility will be constructed and operated on Curtis Island. The liquefaction (cooling to below boiling point) of the coal seam methane will allow for the production of clear, colourless, odourless liquid, which is neither corrosive nor toxic. Cooling of the feed gas to -161ºC, is required to produce the LNG.

The gas produced at the CSG fields contains methane (97 to 98%) with low concentrations of hydrocarbons, water, carbon dioxide, nitrogen gas, oxygen, and sulphur compounds. These compounds are removed prior to the cryogenic process. The typical cascade processes to clean, refrigerate, and liquefy the gas includes:

- Feed gas receiving and metering;
- A series of refrigerant compressors and heat exchangers to clean the gas, i.e. remove sulphur, propane, ethylene, water, carbon dioxide;
- Pre-cooling;
- Liquefaction;
- Storage, and
- Loading and shipping.

Boil-off gas is typically utilised as fuel gas to assist in providing power for the electricity required on site.

The envisaged process and LNG operations can potentially impact on the shallow groundwater resources due to the storage and use of chemicals and fuels on site.

4.1.3 Groundwater Geology and Aquifer Occurrence

The main geological unit underlying the proposed LNG facility site is the late Devonian to early Carboniferous aged Wandilla Formation, which forms part of the Curtis Island Group. The Wandilla Formation comprises sediments and metamorphic units, including mudstone, lithic sandstone, siltstone, jasper, chert, slate, and schist. The low grade metamorphism relates to the complex structural geology associated with the New England orogeny and north northwest trending faults associated with the Narrows Graben structure. Structural deformation in the Wandilla Formation has produced foliations dipping from 38° to 84° in a northeast and easterly direction. Vertical foliations are also present. These result in north northwest trending ridges of more competent quartz greywacke and flatter areas of altered mudstone.

Granite dykes have been mapped adjacent to the LNG facility site. Faulting occurs within the south-western portion of Curtis Island. These zones of secondary alteration are associated with the complex structural geology of the study area. Manganese deposits have been mapped within the Wandilla Formation on islands adjacent to Curtis Island. Turquoise deposits were recorded on older geological maps of Curtis Island; however, these have been removed from the most recent maps. Groundwater results indicate elevated concentrations of dissolved metals (manganese) and metalloids (arsenic) (Section 4.1.6) within shallow and deeper aquifers. Based on the complex structural geology of the area it is considered that tectonics, resulting in intrusive bodies and metamorphism, have caused alteration and the natural elevated concentrations (compared to similar geological units) of metals within the Wandilla Formation units.

Quaternary aged alluvial and colluvial deposits, comprising silt, sand, and gravel, overlie the Wandilla Formation units. The overburden is between 0.5 and 1.5 m thick on the high-lying ridges and 3 to 5 m thick on the flat areas. Thicker alluvium has been deposited along the drainages lines draining the island. Quaternary aged mud, sand, and gravel estuarine deposits flank the shores in many places at the LNG facility site.

Based on the structural geology it is envisaged that palaeovalleys may occur on Curtis Island, possibly below the proposed LNG facility footprint. The palaeovalleys are typically filled with gravel and sand and overlain by clay-rich estuarine deposits.

Based on the structural geology and depositional processes the preliminary conceptualisation of the groundwater regime includes two separate aquifers within the study area. The palaeovalleys will contain confined aquifers with saline groundwater quality. These aquifers are overlain by unconfined aquifers associated with the alluvial and colluvial deposits, which are recently recharged and contain fresh groundwater. Limited interaction or mixing of groundwater is expected due to the low permeability of the confining clay material and the density differences in the groundwater.

To evaluate the site hydrogeology in the LNG facility study area, eight (8) groundwater monitoring bores (GW1, GW2S, GW2D, GW3, GW4S, GW4D, GW5, and GW6) were drilled and constructed during May 2008. The locations of these bores are shown in **Figure 4-1** and the bore logs are presented in **Appendix D**.

The lithology logged during drilling in the Wandilla Formation included mudstone, sand, gravel, and weathered greywacke (logged as conglomerate due to the resultant drill chip returns retrieved during percussion drilling). The sediments within the alluvium and estuarine deposits comprise clay, sandy clay, sand, and gravel.

Drilling logs provided site-specific and representative geological and hydrogeological data for the proposed LNG site. No palaeovalleys were recorded, however, geotechnical drilling for Santos in the dredge area has indicated artesian conditions during drilling, which are indicative of deeper (± 16 m deep) confined aquifers.

The installation of the groundwater monitoring bores allowed for the identification of groundwater within several different units, including:

- Unconsolidated alluvial deposits along the drainage lines;
- The transition zone between weathered and competent bedrock;
- Fractures within the bedrock directly below the transition zone; and
- Zones of deeper weathering.

The following aquifer types have been identified beneath the proposed LNG Facility:

- Perched aquifers, possibly related to clay lenses and tidal fluctuations;
- Alluvium aquifers, adjacent to drainage lines;
- Weathered (intergranular) aquifers; and
- Fractured rock aquifers.

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Client

Project

GLADSTONE LNG PROJECT
LNG FACILITY
SHALLOW GROUNDWATER ASSESSMENT

Title

MONITORING BORES ON LNG FACILITY SITE

Drawn: RG
Approved: JB
Date: 23-01-2009
Job No: **4262 6220**
File No: 42626220-g-614.wor
Figure: **4-1**
Rev:B
A4

4.1.4 Hydraulic Parameters

Falling head tests were conducted within the monitoring wells to provide estimates of the hydraulic conductivity of the various aquifers and aquitards. Analysis of the data using standard analytical methods (Hvorslev, 1951 and Bouwer and Rice, 1976) is provided in **Appendix E**. A summary of the analysis results is provided in **Table 4-1**.

The hydraulic conductivity of the alluvial and estuarine aquifers ranges from 3.05 x 10^{-3} to 6.43 x 10^{-2} m/day. The relatively low hydraulic conductivity and the likelihood that these aquifers are not regionally extensive indicate that groundwater extraction at high rates would not be sustainable from this unit.

Table 4-1 Hydraulic Conductivity of Various Aquifers/Aquitards

Monitoring Bore ID	Hole depth (m)	Static groundwater level (mbgl)	Static groundwater level (m AHD)	Aquifer / Aquitard Material	Hydraulic Conductivity (m/day)
Alluvial / Estuarine Deposits					
GW4S	7.7	4.4	-1.2	Clay and Sandy Clay	4.4 x 10^{-3}
GW5	3	1.6	1.6	Clay and Sandy Clay	6.4 x 10^{-2}
GW6	5	4.6	1.8	Clay with trace sand	3.0 x 10^{-3}
Wandilla Formation					
GW1	22.2	9.8	1.7	Fractured greywacke	1.2
GW2S	6	Dry	Dry	Silty, Sandy Clay and Mudstone	NAD
GW2D	24	22.5	1.6	Weathered greywacke	1.8 x 10^{-2}
GW3	6	2.4	0.01	Fractured greywacke	NAD
GW4D	27	5.6	-0.11	Sand and Gravel greywacke	9.6 x 10^{-1}

NAD – Not Able to be Determined: bore was dry or the recovery was very slow.

The hydraulic conductivity of the Wandilla Formation is comparatively higher than the alluvial and estuarine aquifers, ranging from 0.01 to 1.165 m/day. Primary permeability in the Wandilla Formation is likely to be limited by the fine grain size of the formations. However, the presence of fractures within this formation may result in a higher permeability as indicated by the results above. Where the strata are more fractured, the unit may have local zones of moderate to high hydraulic conductivity as at GW1 and GW4D. As the fracturing within the bedrock aquifer is not expected to be regionally extensive, groundwater extraction at high rates would not be sustainable in the long term.

The resultant aquifer hydraulic parameters indicate that shallow groundwater has limited resource potential.

4.1.5 Groundwater Levels and Flow

A summary of the drilling results and the resultant groundwater level data for each monitoring bore installed in the study are summarised in **Table 4-2**.

The available groundwater level data, across a large area of undulating topography, was obtained from both alluvium and bedrock aquifers. These data do not allow for the accurate depiction of the groundwater flow patterns within the study area. The groundwater data, converted to m AHD, was compared to the elevation data to assess the relationship between the groundwater levels and topography. Both aquifers indicate very poor relationships between elevation and groundwater levels; this indicates non-continuous confining layers across the site, leading to variable piezometeric levels within the monitoring bores. The variable hydrostatic pressures lead to complex groundwater flow patterns on Curtis Island.

Long term (48 hr) groundwater level records in borehole GW4D (**Figure 4-2**), which is screened in the Wandilla Formation, indicates slight variations in groundwater levels over time due to variations on barometric pressure and tidal influences. This tidal influence adds to the complexity of the groundwater flow patterns.

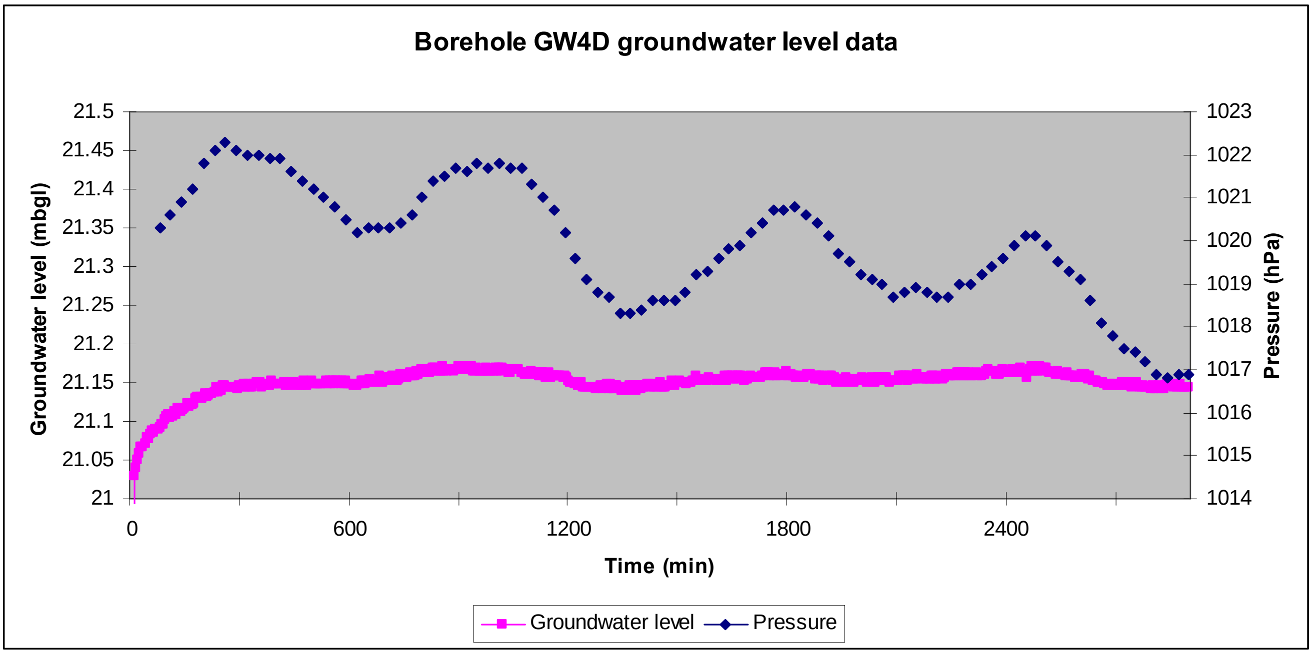

Figure 4-2 Groundwater Level Data Borehole GW4D

The available data and continued monitoring will be used for comparison during operations. This will assist with the assessment of potential impacts on the groundwater resources.

It is recommended that additional nested piezometers, within the alluvium and bedrock aquifers, are constructed. The piezometers once surveyed and equipped with automatic groundwater level records, can provide additional groundwater level information to provide a more accurate assessment of the groundwater flow patterns.

Table 4-2 Summary of Hydrogeological Conditions Observed at Monitoring Bores

Monitoring Bore ID	Date Installed	Easting (m)	Northing (m)	Elevation (m AHD)	Hole Depth (mbgl)	Aquifer / Aquitard Material	Screen Interval (mbgl)	Aquifer Type	SWL (mbgl)	SWL (m AHD)
Alluvial / Estuarine Deposits										
GW4S	8/5/2008	318547.849	7368757.635	2.6	7.7	Clay and Sandy Clay	4.7 – 7.7	Unconfined	4.4	-1.8
GW5	9/5/2008	319699.331	7368502.67	2.5	3	Clay and Sandy Clay	1 – 2.7	Unconfined	1.6	0.9
GW6	9/5/2008	318789.577	7368334.003	5.6	5	Clay with trace sand	2 – 5	Unconfined	4.6	1.0
Wandilla Formation										
GW1	11/5/2008	317537.803	7369428.566	8.9	22.2	Fractured greywacke	16.2 – 22.2	Confined	9.8	-0.9
GW2S	20/5/2008	318197.964	7369337.488	19.8	6	Silty, Sandy Clay and Mudstone	3 – 6	NAD	Dry	Dry
GW2D	10/5/2008	318196.392	7369336.355	19.7	24	Weathered greywacke	18 – 24	Confined	22.5	-2.8
GW3	11/5/2008	317411.82	7369164.126	3.4	6	Fractured greywacke	3 – 6	Unconfined	2.4	0.9
GW4D	20/5/2008	318551.245	7368755.536	2.7	27	Sand and Gravel greywacke	20.9 – 26.9	Confined	5.6	-2.9

NAD – Not Able to be Determined: bore was dry.

SWL = Static Water Level

4.1.6 Groundwater Quality

A summary of the field measurements collected from the monitoring bores during the study is provided in **Table 4-3**.

Table 4-3 In Situ Field Parameters for LNG Facility Site Monitoring Bores

Monitoring Bore ID	Date of Measure	SWL (mbgl)	Dissolved Oxygen (ppm)	Electrical Conductivity (µS/cm) / TDS (mg/L)	pH*	Eh (mV)
Alluvial / Estuarine Deposits						
GW4S	17/6/2008	4.4	0.10	9,060 / 5,436	5.71	-230
GW5	17/6/2008	1.6	0.72	28,800 / 17,280	3.59	301
GW6	17/6/2008	4.6	0.40	24,000 / 14,400	6.66	-149
Wandilla Formation						
GW1	18/6/2008	9.8	1.73	3,590 / 2,154	6.54	-48
GW2S	17/6/2008	Dry	NAD	NAD	NAD	NAD
GW2D	17/6/2008	22.5	1.66	2,360 / 1,416	6.58	-84
GW3	19/6/2008	2.5	0.01	18,290 / 10,974	6.86	-222
GW4D	17/6/2008	5.6	0.11	13,960 / 8,376	7.36	-80

NAD – Not Able to be Determined: bore was dry.

SWL – Static Water Level

* The pH values were measured by the laboratory.

The electrical conductivity and total dissolved solids (TDS) measured in the monitoring bores indicate that the groundwater is brackish in the deeper boreholes (GW1, GW2D, and GW4D) and brine in the shallow bores (GW5, GW6, and GW3). These results suggest that there is limited interaction between the shallow and deep aquifers. This result is consistent with the presence of fine grain materials between the shallow and deep aquifers observed during installation of the soil bores. Groundwater in shallow borehole GW4S is brackish (TDS 5,436 mg/l) which may be attributable to dilution from surface water runoff. The groundwater in the shallow and deep bores has an acidic to neutral pH and is generally reducing, with the exception of GW5 which is oxidized.

Groundwater samples were collected using low-flow pumps or disposable bailers and stabilised / preserved according to recognised protocols (APHA, 1992) prior to delivery to a NATA accredited analytical laboratory. The groundwater samples from the monitoring boreholes were analysed for major ions and select dissolved metals (National Environment Protection Measure (NEPM) 13 metal suite). A summary of the analytical results is provided in **Table 4-4**, with the full laboratory reports provided in **Appendix F**. The environmental values of the water have been assessed according to the values identified in the EPP Water (1997). The two environmental values of relevance to the groundwater at the site are biological integrity (maintaining the water quality so the plants and animals living in the waterways can survive); and suitability for primary industry (livestock) use.

The investigation levels (ANZECC, 2000) adopted to encompass the two defined environmental values and to provide a comparison of the groundwater analytical results include:

- The Trigger Levels for Freshwater Ecosystems – 95% protection level of species;
- The Trigger Levels for Marine Ecosystems – 95% protection level of species; and
- The Livestock Drinking Water Guidelines – Beef.

The results are compiled in **Table 4-4** and discussed below.

The groundwater results were evaluated against the ANZECC guidelines for livestock drinking water and the protection of 95% of species in both freshwater and marine environments to consider the potential effect of discharge of groundwater into surface water bodies, groundwater dependant environments, and marine environments.

In general, groundwater in all site monitoring bores except GW4D is suitable for livestock drinking water. The concentration of calcium in GW4D (1,350 mg/l) exceeds the ANZECC guideline (1,000 mg/l). The groundwater from this bore would require blending prior to use for stock watering.

The concentration of dissolved arsenic in groundwater from all bores (with the exception of GW5) exceeds the ANZECC guidelines for freshwater aquatic environments (0.013 mg/l As). The concentrations of dissolved manganese in groundwater from all bores are above the ANZECC guidelines for freshwater aquatic environments (1.9 mg/l Mn). The concentrations of dissolved cadmium, chromium, nickel, and zinc from some bores are above the ANZECC guidelines for freshwater aquatic environments.

The concentrations of dissolved cobalt in groundwater from all bores are above the ANZECC guidelines for marine aquatic environments (0.001 mg/l Co). The concentrations of dissolved chromium, copper, lead, nickel, and zinc from some bores are above the ANZECC guidelines for marine aquatic environments.

The groundwater, from both shallow (< 8 m) and deep (> 20 m) boreholes, is recognised as not suitable for discharge into the fresh or marine water environments.

Treatment may be required for industrial use, which could result in waste material, which would require the correct industry accepted handling, storage, and disposal practices.

Domestic Use

Groundwater samples collected from seven of the eight monitoring bores (GW2S was drilled dry) indicated elevated concentrations of a wide range of dissolved metals. The analytical hydrochemical data was compared to the ADWG to illustrate the elevated nature of the dissolved metal concentrations. Table 4-5 presents the comparison.

Elevated concentrations of dissolved solids, sodium, chloride, and sulfate were recorded in the majority of the groundwater samples above the ADWG guideline values. Concentrations of dissolved metals, arsenic, manganese, and nickel, were recorded in the majority of the groundwater samples. These results indicate that naturally elevated concentrations, as a result of the host geology (no indications of large scale contaminant sources on site[10]); occur both spatially across the site and vertically in the aquifers (both shallow and deep bores). The poor quality reduces the suitability for use and treatment of groundwater will be required before it could be utilised for domestic purposes.

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[10] Refer to Contaminated land study for the EIS

Table 4-4 Summary of Hydrochemical Analytical Results

Analytes	Units	ANZECC 2000			GW1 18/06/08	GW2D 17/06/08	GW3 19/06/08	GW4D 17/06/08	GW4S 17/06/08	GW5 17/06/08	GW6 17/06/08
		Freshwater - 95%[1]	Marine Water - 95%[2]	Livestock – Beef[3]							
pH	pH units	ne	ne	ne	6.54	6.58	6.86	7.36	5.71	3.59	6.66
Bicarbonate Alkalinity as $CaCO_3$	mg/L	ne	ne	ne	217	315	826	156	390	<1	255
Carbonate Alkalinity as $CaCO_3$	mg/L	ne	ne	ne	<1	<1	<1	<1	<1	<1	<1
Hydroxide Alkalinity as $CaCO_3$	mg/L	ne	ne	ne	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity	mg/L	ne	ne	ne	217	315	826	156	390	<1	255
Calcium	mg/L	ne	ne	1000	142	86	305	**1350**	541	443	544
Magnesium	mg/L	ne	ne	ne	136	125	620	1180	583	1070	828
Potassium	mg/L	ne	ne	ne	2	2	103	5	10	146	7
Sodium	mg/L	ne	ne	ne	474	184	4200	1500	946	6030	3510
Chloride	mg/L	ne	ne	ne	1080	550	8900	8040	3830	12800	8280
Sulfate	mg/L	ne	ne	ne	71	8	482	592	26	2110	541

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems

2 – ANZECC 2000 Trigger Levels for Marine Ecosystems – 95% protection level of species

3 - ANZECC 2000 Trigger Levels for Livestock Watering

Analytes	Units	ANZECC 2000			GW1 18/06/08	GW2D 17/06/08	GW3 19/06/08	GW4D 17/06/08	GW4S 17/06/08	GW5 17/06/08	GW6 17/06/08
		Freshwater - 95%[1]	Marine Water - 95%[2]	Livestock – Beef[3]							
Arsenic	mg/L	0.013	ne	0.5	**0.047**	**0.078**	**0.083**	**0.018**	**0.06**	<0.001	**0.094**
Barium	mg/L	ne	ne	ne	0.153	0.163	0.78	0.517	2.31	0.126	0.631
Beryllium	mg/L	ne	ne	ne	<0.001	<0.001	0.001	<0.001	0.002	0.022	0.001
Cadmium	mg/L	0.0002	0.0055	0.01	**0.0003**	<0.0001	0.0002	0.0002	0.0001	**0.001**	**0.0004**
Chromium	mg/L	0.001	0.0044	1	<0.001	<0.001	<0.001	<0.001	**0.002**	**0.013**	**0.002**
Cobalt	mg/L	ne	0.001	1	**0.03**	**0.044**	**0.033**	**0.029**	**0.4**	**0.485**	**0.112**
Copper	mg/L	0.0014	0.0013	1	<0.001	<0.001	0.001	0.001	**0.002**	**0.012**	**0.002**
Lead	mg/L	0.0034	0.0044	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	**0.063**	<0.001
Manganese	mg/L	1.9	ne	ne	**17.4**	**39.9**	**59.9**	**11.5**	**33.1**	**16**	**27.8**
Mercury	mg/L	0.0006	0.0004	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	mg/L	0.011	0.07	1	**0.141**	**0.013**	**0.094**	**0.035**	**0.028**	**0.534**	**0.086**
Vanadium	mg/L	ne	0.1	ne	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	0.008	0.015	20	**0.201**	**0.01**	**0.018**	**0.019**	**0.023**	**0.59**	**0.04**

1 – ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems

2 – ANZECC 2000 Trigger Levels for Marine Ecosystems – 95% protection level of species

3 - ANZECC 2000 Trigger Levels for Livestock Watering

Table 4-5 Hydrochemical Results Compared to ADWG

Analytes	Units	ADWG	GW1 18/06/08	GW2D 17/06/08	GW3 19/06/08	GW4D 17/06/08	GW4S 17/06/08	GW5 17/06/08	GW6 17/06/08
pH	pH units	6.5 – 8.5	6.54	6.58	6.86	7.36	5.71	3.59	6.66
Bicarbonate Alkalinity as $CaCO_3$	mg/L	-	217	315	826	156	390	<1	255
Carbonate Alkalinity as $CaCO_3$	mg/L	-	<1	<1	<1	<1	<1	<1	<1
Hydroxide Alkalinity as $CaCO_3$	mg/L	-	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity	mg/L	-	217	315	826	156	390	<1	255
Calcium	mg/L	-	142	86	305	**1350**	541	443	544
Magnesium	mg/L	-	136	125	620	1180	583	1070	828
Potassium	mg/L	-	2	2	103	5	10	146	7
Sodium	mg/L	180	474	184	4200	1500	946	6030	3510
Chloride	mg/L	250	1080	550	8900	8040	3830	12800	8280
Sulfate	mg/L	500	71	8	482	592	26	2110	541

Analytes	Units	ADWG	GW1 18/06/08	GW2D 17/06/08	GW3 19/06/08	GW4D 17/06/08	GW4S 17/06/08	GW5 17/06/08	GW6 17/06/08
Arsenic	mg/L	0.007	**0.047**	**0.078**	**0.083**	**0.018**	**0.06**	<0.001	**0.094**
Barium	mg/L	0.7	0.153	0.163	**0.78**	0.517	**2.31**	0.126	0.631
Beryllium	mg/L	-	<0.001	<0.001	0.001	<0.001	0.002	0.022	0.001
Cadmium	mg/L	0.002	0.0003	<0.0001	0.0002	0.0002	0.0001	0.001	0.0004
Chromium	mg/L	0.05	<0.001	<0.001	<0.001	<0.001	0.002	0.013	0.002
Cobalt	mg/L	**-**	0.03	0.044	0.033	0.029	0.4	0.485	0.112
Copper	mg/L	2	<0.001	<0.001	0.001	0.001	0.002	0.012	0.002
Lead	mg/L	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	**0.063**	<0.001
Manganese	mg/L	0.5	**17.4**	**39.9**	**59.9**	**11.5**	**33.1**	**16**	**27.8**
Mercury	mg/L	0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	mg/L	0.02	**0.141**	0.013	**0.094**	**0.035**	**0.028**	**0.534**	**0.086**
Vanadium	mg/L	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	**3**	0.201	0.01	0.018	0.019	0.023	0.59	0.04

Groundwater intersected during construction and possible dewatering is expected to contain elevated concentrations of arsenic, as recorded in the majority of the groundwater samples. The groundwater will require correct storage, handling, and disposal protocols to ensure environmental, health, and safety compliance.

4.1.7 Groundwater Recharge

The study area receives regular rainfall and associated recharge. The rainfall data for Gladstone (**Figure 4-3**) indicates that the study area receives some 1000 mm/year on average.

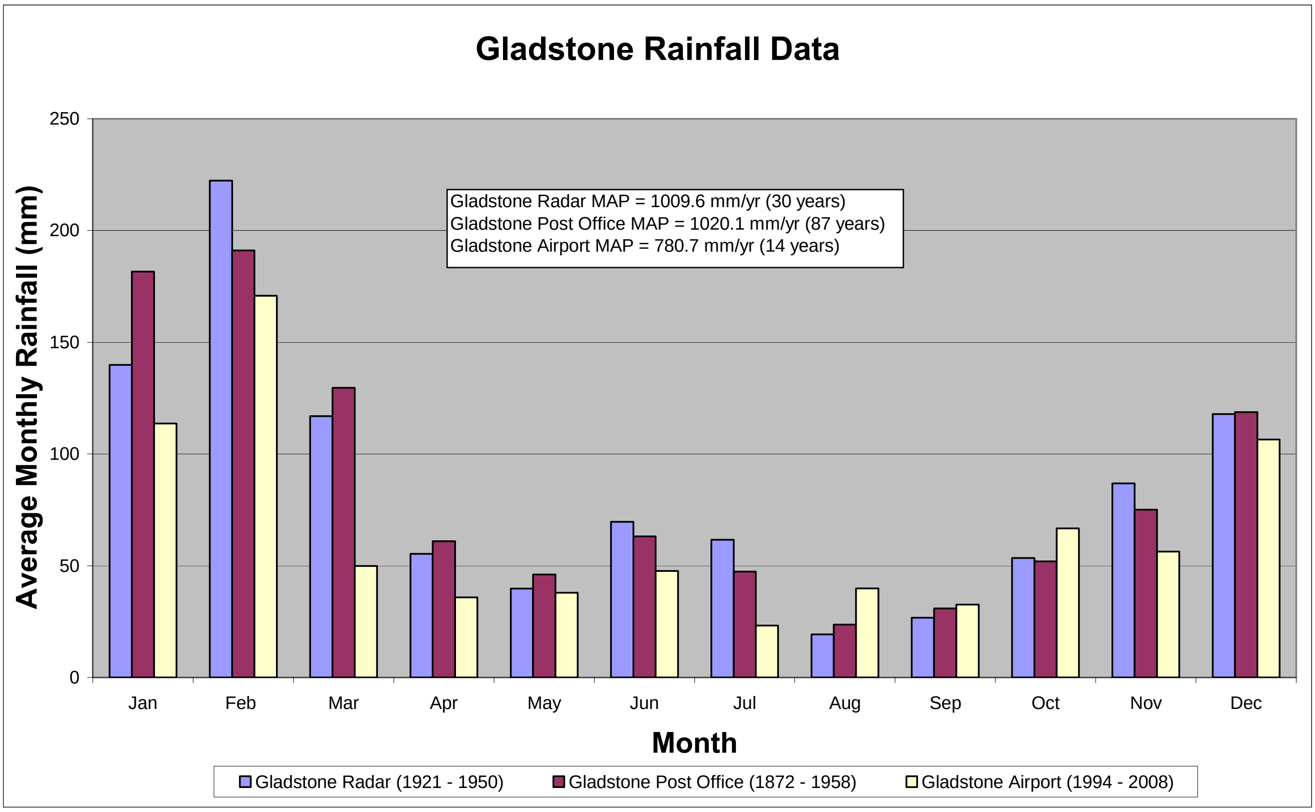


Figure 4-3 Rainfall data (Source: Bureau of Meteorology)

The conservation of chloride method for determination of aquifer recharge was used to determine the rainfall recharge to both shallow and deep groundwater. For the shallow groundwater (borehole depth < 8 m), the following input information was utilised:

Average annual rainfall	1,000 mm/yr
Chloride in rain	8 mg/L Cl (coastal value for 1000 mm/yr rainfall) (Recharge, 2000)
Dry deposition chloride	0.64 mg/L Cl (0.8 * Cl of rain, a spray / mist factor for coast areas)
Average Chloride in groundwater	8,452.5 mg/L (average for GW4S, GW5, GW6, and GW3)
Average annual recharge (mm)	1 mm/yr (0.1% of mean annual precipitation [MAP])

For the deeper (boreholes > 20 m) an average chloride concentration of 3,223 mg/L Cl (GW1, GW2D, and GW4D) was utilised. The average annual recharge is estimated at 3 mm/yr (0.3% of MAP).

4.1.8 Groundwater Use in Neighbouring Areas

No significant groundwater usage has been registered on the DNRW groundwater database within the study area. Only one borehole (RN 91325) is registered in the LNG facility study area. The limited information for this bore is summarised in **Table 4-6**.

Table 4-6 Summary of Borehole RN 91325

Item	Details
Easting	318603
Northing	7368993
Depth	27.3 m
Casing	0 – 22.2 m plain 140 mm Ø PVC 22.2 – 27.3 m slotted PVC
Log	0 -1 SOIL 1 – 2.7 brown CLAY 2.7 – 7.5 CLAY and boulders 7.5 – 22.7 white CLAY 22.7 – 27.27 MUDSTONE Wandilla Formation
Quality	EC = 12,000 µS/cm (TDS = 6,120 mg/l)
Yield	3 l/s
Static water level	10.6 mbgl (13/09/1993)

The borehole is located within the centre of the proposed LNG facility study area and is currently utilised for stock watering. The borehole intersects fractured rock aquifers within the Wandilla Formation mudstone, resulting in moderate yields of brackish groundwater.

The borehole, if not utilised at the LNG facility, can be utilised for monitoring purposes. Should the borehole be located within proposed LNG facility footprint then the borehole should be backfilled with cement and bentonite to prevent potential surface contaminants entering the groundwater.

4.1.9 Summary

The initial hydrogeological conceptualisation has been revised based on the field work results. Drilling results do not indicate the presence of confined palaeovalleys aquifers within the study area but does reveal two aquifers within the LNG facility study area.

Shallow alluvium aquifers

Drilling intersected shallow (< 8 m) unconfined and semi-confined aquifers, which comprise very poor quality brine groundwater. The shallow aquifers are associated mainly with alluvium material deposited along drainage lines. These aquifers have low to very low permeability (**Section 4.1.4**), 0.003 to 0.06 m/day, and receive limited rainfall recharge (0.1% of MAP). The alluvium material has limited saturated thickness, thus the shallow groundwater has limited abstraction potential and fitness for use. The shallow groundwater resources within the study area are considered to have limited groundwater value.

Deeper fractured rock aquifers

Geotechnical drilling in the area indicates the potential for artesian conditions within the underlying units. No palaeovalleys or artesian aquifers, however, were intersected during the groundwater resource drilling program. Zones of secondary alteration, weathering and fracturing, were recorded in the borehole logs indicating secondary permeability, which is recognised in the hydraulic conductivity calculations for the deeper boreholes (> 20 m).

The deeper groundwater resources are brackish with salinity concentrations at lower values than the upper groundwater resources. This indicates that the confining layers above the deep aquifers limit the ingress of brine water. The drilling results indicate discrete zones of secondary alteration and the rainfall recharge to these aquifers is limited (0.3% of MAP).

Ambient groundwater quality is poor and reduces the suitability for use. Naturally occurring elevated concentrations of dissolved solids and metals have been recorded within the majority of groundwater samples collected from the monitoring bores on site.

4.2 Environmental Values

The two environmental values of relevance to groundwater protection at the site are biological integrity (maintaining the water quality so the plants and animals living in the waterway can survive); and suitability for primary industry (livestock) use.

The environmental values of the water have been assessed according to the values identified in the EPP Water. The environmental values to be enhanced or protected are:

- Biological integrity of a pristine or modified aquatic ecosystem;
- Suitability for primary, secondary, and visual recreational use;
- Suitability for minimal treatment before supply as drinking water;
- Suitability for use in agriculture;
- Suitability for use in aquacultural use;
- Suitability for producing aquatic food for human consumption;
- Suitability for industrial use; and
- Cultural and spiritual values of the water.

The review of available data allowed for a preliminary assessment of the shallow groundwater resources associated with the lithologies present within the LNG facility study area. The available information allowed for limited evaluation to the groundwater resource environment values, these include:

Biological integrity of a pristine or modified aquatic ecosystem

The discharge from the majority of the aquifers identified will potentially impact on the biological integrity of the water resources within the LNG facility area as elevated dissolved solids and metal concentrations exceed the ANZEEC guidelines Trigger Levels for Freshwater and Marine Ecosystems. The naturally occurring discharge of shallow groundwater into the water resources occurs at concentrations above the ANZEEC guidelines. This discharge will decrease during the GLNG project due to alterations to the aquifers and recharge.

Existing Groundwater Dependent Ecosystems need to be identified on site and monitored to ensure LNG operations and activities do not impact on any potentially sensitive landscapes.

Suitability for recreational use

This category of environmental values is not considered relevant in relation to groundwater.

Suitability for minimal treatment before supply as drinking water

All groundwater samples collected in and adjacent to the proposed LNG facility site are recognised to not be suitable for drinking purposes and thus would require treatment to achieve recognised drinking water quality guidelines. This groundwater would require complex and expensive treatment, such as reverse osmosis, to achieve drinking water quality to satisfy the Queensland Water Quality Guidelines 2006 or the Australian Drinking Water Guidelines 2004.

Issues of salinity, elevated dissolved solids and metal concentrations, and the ease of obtaining a rainwater tank supply are factors which preclude the usage and potential for usage of the groundwater as a drinking water source.

Suitability for use in agriculture, aquaculture, aquatic food for human consumption

The water quality data indicates that the salinity is above the range recommended for irrigation of crops. Thus the groundwater appears to have limited potential use in terms of irrigation, depending on crop type, soil type and irrigation regime.

The recognised aquifers contain limited groundwater (low sustainable bore yields), which is inferred to reduce the suitability for use in aquaculture or the production of aquatic food for human consumption as these activities would typically require reliable assured water supplies. The availability of sea water locally would preclude the use of the saline groundwater in aquaculture.

Suitability for industrial use

The groundwater quality is generally suitable for a large number of industrial processes including; cooling water, process water, utility water, and wash water. As industrial processes require particular water quality, specific hydrochemical data will be required to evaluate suitability for use.

Limited opportunities for industrial use are currently available on Curtis Island. Industrial users tend to require large volumes of water which would be unsustainable for the groundwater resources identified within the LNG facility study area.

Cultural and spiritual values

Insufficient data is available to consider cultural and spiritual values. Any culturally significant, from an anthropological, archaeological, historic, sacred, or scientific significance, need to be identified when considering the LNG facility planning.

The groundwater resource, as recognised in little or no current groundwater usage, restricted future development potential, and poor ambient groundwater quality within the proposed LNG facility footprint is of limited value. Blending of the groundwater can increase the suitability for use for stock watering.

4.3 Potential Impacts

An impact and risk assessment, from a groundwater perspective, was compiled according to the methodologies described in **Section 1.4**. The risk assessment allowed for the identification of possible impacts associated with the proposed LNG facility during construction and operational phases. The impacts associated with dredging and deposition of marine sediments is not considered in this EIS study but is discussed briefly in Section 4.2.3 and Section 5 cumulative impacts.

The potential impacts were assessed to include probability, significance, and duration. This allowed for the development of mitigation measures and optimum monitoring programs.

4.3.1 Description of Intention

Santos intends to construct and operate a LNG facility sized for a nominal rate of between 3 and 4 million tons per annum (mtpa) of LNG initially, potentially expanding to 10 mtpa. The LNG facility will allow for gas cleaning, refrigeration and liquefaction to liquefy the natural gas, and the storage of LNG.

A risk assessment was compiled to evaluate potential impacts associated with the proposed LNG facility on the groundwater resources.

4.3.2 LNG Construction

Impact identification

The impacts associated with the construction of the LNG facility include:

- Excavation dewatering;
- Compression of underlying aquifers;
- Hydrocarbon and chemical releases; and
- Contractor accommodation.

Estimation of probability and magnitude of the consequences of the impacts

The probability and magnitude of the consequences of any or all of the identified impacts occurring is detailed in **Table 4-7**. The table provides a summary of the identified impacts, the consequences of the impacts, the probability of the impacts, and the magnitude of these consequences. The impact evaluations allowed for the identification of the risk which requires management. The definitions used in the table to describe the risk rating are discussed in Section 1.4.5.

Table 4-7 Construction Phase Impacts at the LNG Facility

Impact	Consequence	Probability	Magnitude	Duration & Extent
Dewatering of excavations	Generates volumes of poor quality water on site, alters groundwater flow patterns. Potential acid soil conditions could cause deterioration in groundwater quality.	**Possible** Shallow groundwater (< 5 mbgl) is present on site, but within low permeability units which may not require dewatering. Deep excavations may require dewatering. Foundations could comprise piling to bedrock without dewatering.	**Minor** Groundwater resources utilised on site could be altered. Groundwater quality is not suitable for direct discharge into marine or surface water.	Short duration during the construction phase.
Compression	Buildings and roads constructed on site will reduce recharge and compact the aquifers below the infrastructure, this will result in permanent alteration to aquifers over a small percentage of the entire site.	**Likely** Infrastructure is to be constructed on the site.	**Minor** The shallow groundwater to be impacted has poor groundwater potential and is of poor quality	Permanent
Hydrocarbon releases	The spills from oils, fuels, workshops, etc. on the construction site can impact on the hydrochemistry	**Unlikely** Fuels and potentially hazardous materials will be kept and used on site but are envisaged to occur within bunded areas	**Moderate** The hydrocarbon compounds can migrate off site and enter the marine and surface water environments	Construction and operations phase
Contractor accommodation	Sanitation systems associated with the accommodation on site can potentially impact on the shallow groundwater	**Unlikely** Accommodation, change rooms, and toilet facilities will be utilised on site	**Minor** All waste water will be stored and disposed using licensed contractors	Life of project

The potential impacts and risks to the shallow groundwater resources associated with the LNG facility during construction were evaluated as per **Section 1.4.5** and summarised in **Table 4-8**.

Table 4-8 Impact Evaluation for CSG Infrastructure

Impact	Probability	Magnitude	Risk estimate R = P x M
Impact 1: Dewatering of excavations	Possible (3)	Minor (2)	6
Impact 2: Compression of aquifers	Likely (4)	Minor (2)	8
Impact 3: Fuel, oil management	Unlikely (2)	Moderate (3)	6
Impact 4: Waste water and sanitation	Unlikely (2)	Minor (2)	4

Dewatering and the permanent alteration of the underlying formations is identified as having the highest potential impact. The impacts will, however, be limited as only limited groundwater resources are recognised within the proposed LNG site.

Risk Evaluation

Impact 1: Dewatering of excavations

Groundwater level measurements indicate that the groundwater table within the alluvial and estuarine formations is generally less than 5 mbgl. It is envisaged that neither foundations nor pilings will require dewatering. However, any deep excavations at the LNG facility will require dewatering, which will likely be minimal due to the very low permeability of the shallow saturated clay-rich material. During dewatering the groundwater should not be discharged directly to the local drainage system, but instead be utilised for livestock watering, used for dust suppression, or suitably captured in storage facilities. Any dewatering must include consideration of the presence of acid sulphate soils.

Impact 2: Compression of aquifers

Compression of the ground surface associated with the construction of roads and buildings is not expected to significantly reduce recharge (due to altered permeability) to the groundwater resources beneath the site. The pre-construction permeability of the weathered residual soils and the upper alluvial and estuarine soils is already very low (consequently reducing the potential for pollution of the groundwater from construction activities). Therefore, any minor reductions in recharge infiltration due to compaction should be negligible.

Saturated aquifers, when compressed, could result in seeps occurring adjacent to the impacted area. The limited groundwater resources and low permeability but high porosity (clays) will reduce the impact of temporary seeps forming on site.

Impact 3: Fuel, oil storage

The potential release of hydrocarbons (construction vehicle fuels and workshop oils and lubricants), as well as other stored chemicals, can potentially impact on the underlying and down gradient aquifers. Workshop areas, vehicle and equipment wash-down areas, and equipment and machinery repair areas all have the potential to spill fuels, lubricants, solvents, or other hazardous products. The design and material selection for the fuel and chemical storage areas should include spill containment bunding, appropriate sealing, and dirty water runoff containment. This will reduce the risk of groundwater contamination resulting from fuel and chemical spills and leaks.

Secondary containment (bunded) areas for fuels and hazardous products must be provided with spill cleanup kits in accordance with relevant Australian standards. All transfers of fuels and chemicals must be controlled and managed to prevent spillage outside bunded areas. Potential for leaks and spills from operating equipment will be reduced by ensuring that all equipment is regularly maintained.

The low permeability of the soils and bedrock will enable isolation and remediation of potential spills. Any accidental spills will be assessed on a case-by-case basis and remediated, which may include excavation and disposal of any contaminated soil in accordance with the requirements of the EPA.

Impact 4: Waste water and sanitation

The correct waste water management systems to be utilised at the various sites, to contain and then dispose of waste water, will reduce the potential impacts associated with these limited volumes of water.

4.3.3 LNG Operational Phase

Impact Identification

The potential impacts associated with the operation of the LNG facility on the shallow groundwater are:

- Recharge reduction;
- Compression of underlying aquifers;
- Chemical and fuel storage; and
- Waste management.

The Gladstone Port Authority is in the process of obtaining planning approvals for a dredge disposal area north of Wiggins Island (a separate process that is not considered in this EIS). This is Santos' preferred location, however Santos has also considered a number of other potential alternative disposal locations on Curtis Island. The deposition of wet marine dredge material can potentially result in the artificial recharge of underlying aquifers causing an alteration of the hydrochemistry and potential migration of poor quality groundwater off site, which could enter fresh and marine water environments. The impacts of this proposed deposition will rely on the volumes and quality of water associated with the marine dredge material. Additional information regarding the physical and chemical characteristics of the dredge material and the hydrogeology of each proposed candidate site would be required to further assess the potential impacts on the groundwater resources on Curtis Island.

Estimation of probability and magnitude of the consequences of the impacts

The probability, magnitude, and consequences of any or all of the potential impacts occurring are presented in **Table 4-9**. The table provides a summary of the identified impacts, the consequences of the impacts, the probability of the impacts, and the magnitude of these consequences.

The impact evaluations allowed for the identification of the risk which requires management.

Table 4-9 Impacts Associated with LNG Facility Operational Phase

Impact	Consequence	Probability	Magnitude	Duration & Extent
Loss of recharge	The plant and infrastructure footprint, will alter the topography and reduce rainfall recharge to the shallow groundwater regime	**Likely** Large areas of site will be cleared and levelled to facilitate infrastructure	**Minor** Very low recharge rates are recognised on site, a small reduction within the entire study area will have limited impacts on the groundwater resources	Life of project
Compaction of aquifers	Alteration of aquifer parameters and the formation of temporary seeps	**Likely** Compaction will occur during construction, further compaction could occur under the large storage tanks once filled with liquefied gas	**Minor** The shallow groundwater to be impacted has poor groundwater potential and is of poor quality	Permanent
Storage of chemicals, fuels, oils	Spills or leaks of potential contaminants on surface can alter the shallow groundwater quality and migrate off site	**Unlikely** Correctly designed and constructed storage areas will be utilised on site	**Minor** Alterations to the groundwater quality can occur, however, limited volumes as a result of a spill or leak is assumed	Life of project
Waste generation and storage	The storage or disposal of waste generated during the gas cleaning and LNG operations and activities can potentially impact on the groundwater	**Unlikely** Domestic and industrial waste will be generated in small volumes	**Minor** The waste will be managed and disposed using licensed contractors and disposed on licensed facilities	Life of project

The potential impacts to the shallow groundwater resources associated with the LNG facility operational phase were evaluated as per **Section 1.4.5** and summarised in **Table 4-10**.

Table 4-10 Impact Evaluation for CSG Infrastructure

Impact	Probability	Magnitude	Risk estimate R = P x M
Impact 1: Loss of recharge	Likely (4)	Minor (2)	8
Impact 2: Compression of aquifers	Likely (4)	Minor (2)	8
Impact 3: Fuel, oil management	Unlikely (2)	Minor (2)	4
Impact 4: Waste management	Unlikely (2)	Minor (2)	4

The permanent alteration of the underlying aquifers, due to compaction, is identified as having the highest potential impact. The alteration of the aquifers is envisaged to be limited due to the poor groundwater potential associated with the shallow aquifers on site, both quantity and quality.

Risk Evaluation

Impact 1: Loss of Recharge

The LNG facility will cover a significant area of the ground surface with concrete slabs, and in doing so will reduce the surface coverage of outcrop (or recharge zone) for the alluvial, estuarine, and bedrock aquifers. However the pre-construction permeability of the weathered residual soils and the upper alluvial and estuarine soils is already very low and any reductions in recharge infiltration should be negligible compared to the total extent of the alluvial, estuarine, and bedrock aquifer recharge areas.

Suppression of the groundwater level by the reduced infiltration in this area is expected to be minimal as the groundwater levels measured are ± 5 mbgl in the alluvial and estuarine aquifer. The groundwater level will be maintained by infiltration in surrounding areas, the connection of the alluvium to the drainage lines and the estuarine deposits to the ocean.

Impact 2: Compression of aquifers

The weight of the facility, especially the large LNG tanks when filled, can cause further compaction of the underlying material. This could alter the permeability of these units and cause (temporary) inundation in areas adjacent to the compacted areas. The low permeability and storage of the alluvium and estuarine deposits will reduce the extent of these impacts to immediately adjacent to the facilities. The already low groundwater potential of these units will be reduced further but as these aquifers have little groundwater potential and poor groundwater quality the impacts are considered as small-scale alterations.

Impact 3: Fuel, oil storage

The potential release to ground of hydrocarbons, as well as other stored chemicals, may impact on the underlying soils and aquifers down-gradient of areas of fuel storage and usage, and chemical storage and usage, if these areas are not managed appropriately. Workshop areas, vehicle and equipment wash down areas and equipment and machinery repair areas all have the potential to spill fuels, lubricants, solvents, or other potentially hazardous products. Refrigerants and compressor oils (stock and spent) are envisaged to be stored on site. Appropriate design of fuel and chemical storage areas, which includes spill containment bunding and sealing the surface area, will reduce the risk of groundwater contamination resulting from fuel and chemical spills. Bunded storage areas for fuels and dangerous goods will be provided with spill cleanup kits in accordance with the relevant Australian standards. The development of a rapid response plan and training will ensure the impacts of spills, leaks, or accidents are reduced. All transfers of fuels and chemicals will be controlled and managed to prevent spillage outside bunded areas.

Impact 4: Waste management

Gas cleaning treatment may result in waste (e.g. sulfur) stockpiles before the waste is transported to a disposal facility. These areas could act as surface contaminant sources to the shallow groundwater resources. Rainfall infiltration and poor quality runoff can seep into the underlying groundwater and alter the hydrochemistry.

In order to manage these potential impacts the stockpiles could be stored on concrete bases and clean / “dirty“ water separation system, comprising berms and trenches, can be installed around the bases. It is recommended that all disturbed areas be levelled / landscaped to facilitate runoff and prevent ponding. All resultant dirty runoff can then be captured in synthetic membrane lined or compacted clay lined ponds.

4.3.4 LNG Decommissioning Phase

Limited groundwater abstraction currently occurs within the proposed LNG facility study area. The exiting bore RN91325 (Section 4.1.8) will have to be rehabilitated or replaced to ensure the current groundwater use is returned at the end of the project. An assessment of the bore, if still available, is to be conducted. It is recommended that the bore is to be rehabilitated or replaced at the end of the project.

4.3.5 Mitigation Strategies and Management Plans

General Groundwater Monitoring Program

A groundwater monitoring bore network should be established by installation of groundwater monitoring bores at strategic locations throughout the facility site, including but not limited to the monitoring bores installed for the EIS studies. The monitoring program should be initiated prior to the operational phase and continued for the life of the LNG facility. The monitoring should be conducted on a quarterly basis. An annual review of the monitoring program will allow for an evaluation of the effectiveness of each monitoring location and to assess where new locations and modifications to the monitoring program may be needed. A special monitoring round should also be undertaken in the event of a significant environmental incident.

Regular monitoring of the network should continue to enable an understanding of seasonal water table fluctuations and include groundwater depth and groundwater quality measurements. The objectives of the groundwater monitoring program are to:

- Detect potential groundwater impacts early, so that effective mitigation procedures can be developed and instigated;
- Determine the characteristics and trends of any contaminated groundwater flowing offsite; and
- Identify whether any potential contaminants are varying in concentration or extent.

The monitoring program should include the following minimum water quality parameters:

- pH, electrical conductivity, and Total dissolved solids (TDS);
- Dissolved metals (NEPM 13 metal scan) plus iron (Fe);

- Major anions and cations plus fluoride, nitrate, and bicarbonate;
- Total petroleum hydrocarbons (C_6-C_{36} fractions) and BTEX (benzene, toluene, ethylbenzene, xylene) constituents for bores down-gradient of fuel and oil supplies/use only; and
- Sulfur compounds.

Monitoring of groundwater levels and groundwater quality should commence prior to construction of the LNG facility to obtain additional long term baseline data at each monitoring location. This data should be used to determine the natural variability in the groundwater system. Evaluation of the baseline monitoring data can be used to establish trigger levels of key parameters which can be used as a quantitative method of determining whether unexpected impacts are occurring during construction or operation. Where monitoring results indicate levels in excess of the trigger values, an investigation appropriate for the situation should be conducted to assess the need to implement management/mitigation/remedial measures.

Hydrocarbon and Chemical Contamination

Areas of hydrocarbon and chemical storage will have spill control measures and regular inspection regimes in order to prevent and monitor activities that could potentially lead to contamination of groundwater. Spill control measures for hydrocarbon facilities can include concrete slab bases that are bunded with oil-water separators installed on all hydrocarbon above-ground storage, refuelling, and wash down areas. Bunded areas for hydrocarbon and chemicals storage should be provided with spill cleanup kits in accordance with the relevant Australian Standards. All transfers of fuels and chemicals will be controlled and managed to prevent spillage outside bunded areas.

Potential for leaks and spills from operating equipment will be reduced by ensuring that all equipment is well maintained.

Installation and monitoring of the monitoring bore network on-site, including down-gradient of all potential contaminant sources, will enable early detection of any contaminated seepage.

The low permeability of the alluvial and estuarine soils and weathered bedrock will enable isolation and remediation of potential spills. Any accidental spills will be assessed on a case by case basis and remediated, which may include excavation and disposal of any contaminated soil to a licensed facility, in accordance with the requirements of the EPA.

Arsenic

Due to the elevated concentration of naturally occurring arsenic it is recommended that deep excavations below groundwater table be avoided if possible and the use of piling be considered. Where excavations are present, groundwater will require characterisation to determine suitability for discharge. Where unsuitable the following management measures could be adopted:

- Provide dewatering water for stock watering;
- Containment, treatment and discharge;
- Containment in ponds, solar evaporation and subsequent salt disposal off site; or
- Containment, blending and discharge via an envisaged sewage treatment facility.

5.1 Cumulative Impacts

An assessment of current and proposed projects within the LNG facility study area was conducted to determine possible cumulative impacts with regards to the shallow groundwater resources. **Table 5-1** presents an evaluation of the projects and the possible consequences. Note that no relevant proposed project information was available for the CSG field study area, therefore, no assessment of cumulative impacts has been undertaken for the project component.

Table 5-1 Possible Cumulative Impacts of Shallow Groundwater

Project - Proponent	Description	Location	Relationship to GLNG Project	Shallow Groundwater Impacts			
				Probability	Magnitude	Consequences	Evaluation
Gladstone LNG Project – Arrow Energy and LNG Ltd	A natural gas liquefaction plant and associated infrastructure and facilities would be built at Fisherman's Landing Wharf (FLW). Wharf loading facilities at FLW No. 5 would be upgraded. Coal Seam Gas (CSG) would be sourced from gas fields operated by Arrow Energy NL via the proposed Central Queensland Gas Gas transmission pipeline. The CSG will be liquefied, stored and loaded onto vessels for export. (EPA, 2008)	Fisherman's Landing Wharf, Gladstone	Another Gladstone based LNG project. Delivery gas transmission pipeline may coincide in part with the alignment of the Santos gas transmission pipeline. May be overlapping construction phases.	Nil	Nil	No cumulative impact on shallow groundwater as this LNG facility will be sufficiently far away so as not to have an impact	No additional impact on the LNG facility
				Possible May coincide in part with the alignment of the Santos gas transmission pipeline	Moderate Increased disturbance to shallow ground conditions	Additional possible contaminant source, increased alteration to shallow aquifers, increases remediation difficulties due to additional buried infrastructure	Monitoring data evaluation must be able to determine contaminant source to effectively implement remediation
Sun LNG Project – Sunshine Gas and Sojitz Corp	A natural gas liquefaction plant and associated infrastructure and facilities would be built at FLW. Wharf loading facilities at FLW No.5 would be upgraded. A five km lateral gas transmission	Fisherman's Landing Wharf, Gladstone	Another Gladstone based LNG plant. May be overlapping construction phases.	Nil	Nil	No cumulative impact on shallow groundwater as this LNG plant will be sufficiently far away so as not to have an	No additional impact on the LNG facility

Project - Proponent	Description	Location	Relationship to GLNG Project	Shallow Groundwater Impacts			
				Probability	Magnitude	Consequences	Evaluation
	pipeline would be constructed to deliver natural gas from the Gladstone City Gas Gate to the plant. (EPA, 2008)					impact	
Queensland Curtis LNG project – QGC Ltd and BG Group	The Queensland Curtis LNG Project proposes to develop an integrated LNG project comprising three principal components: Expansion of coal seam gas operations in the Surat Basin A 380 km gas transmission pipeline to Gladstone A LNG processing plant on Curtis Island with a port facility for exports.	Gas field in the Surat Basin and LNG plant on Curtis Island	Another Gladstone based LNG project. Delivery gas transmission pipeline may coincide in part with the alignment of the Santos gas transmission pipeline. May be overlapping construction phases. Curtis Island road access and approach channel for shipping to be shared with GLNG.	Likely Additional dewatering of coal seams in the Surat Basin will increase the zone of influence created by dewatering	Moderate Increased groundwater level drawdown will occur where the drawdown cones overlap Dewatering will occur more rapidly	Additional surface infrastructure which could alter shallow groundwater, recharge reduction, additional exploration holes, re-evaluation of trigger levels and more rapid implementation of water replacement plans	The increased zone of influence and the larger volumes of associated water stored on surface will require increased monitoring between CSG operations to accurately determine impacts
				Possible May coincide in part with the alignment of the Santos gas transmission pipeline	Moderate Increased disturbance to shallow ground conditions	Additional possible contaminant source, increased alteration to shallow aquifers, increases remediation difficulties due to additional buried infrastructure	Monitoring data evaluation must be able to determine contaminant source to effectively implement remediation
				Likely Proposed LNG plant will be located on Curtis Island	Moderate Increased impacts, same as identified for GLNG LNG Plant, will occur on limited groundwater resources	Reduced recharge, increased disturbed area footprint on the island Permanent alteration to aquifers due to compaction will occur	Poor quality and limited aquifers will be impacted over larger area resulting in loss of usable groundwater resources for life of

Project - Proponent	Description	Location	Relationship to GLNG Project	Shallow Groundwater Impacts			
				Probability	Magnitude	Consequences	Evaluation
						over larger area Additional contaminant sources	projects Need additional monitoring between plants, accurate groundwater flow patterns to evaluate individual impacts and determine responsibility for contamination, if any
Central Queensland Gas Gas transmission pipeline – AGL and Arrow Energy	A 440 km high pressure gas transmission gas transmission pipeline in Central Queensland from Moranbah to Gladstone. (DIP 2008)	Moranbah to Gladstone	Gas transmission pipeline may coincide in part with the alignment of the Santos gas transmission pipeline.	Possible May coincide in part with the alignment of the Santos gas transmission pipeline	Moderate Increased disturbance to shallow ground conditions	Additional possible contaminant source, increased alteration to shallow aquifers, increases remediation difficulties due to additional buried infrastructure	Monitoring data evaluation must be able to determine contaminant source to effectively implement remediation
Yarwun Alumina Refinery Expansion – Rio Tinto	Stage 2 of the existing Yarwun Alumina Refinery including a gas-fired cogeneration facility.	Yarwun, Gladstone	Construction likely to be substantially completed prior to commencement of GLNG construction	Nil	Nil	No cumulative impact on shallow groundwater as this LNG plant will be sufficiently far away so as not to have an impact	No additional impact on the LNG plant facility
Boyne Smelter – Boyne Smelters	Construction of new baking furnace and upgrade of crane runway	Boyne Island, Gladstone	Construction likely to be substantially completed prior to commencement of GLNG construction	Nil	Nil	No cumulative impact on shallow groundwater as this LNG plant will be sufficiently far away so	No additional impact on the LNG plant facility

Project - Proponent	Description	Location	Relationship to GLNG Project	Shallow Groundwater Impacts			
				Probability	Magnitude	Consequences	Evaluation
						as not to have an impact	
Wiggins Island Coal Terminal – Gladstone Ports Corporation and Qld Rail	New coal terminal and associated rail infrastructure	Wiggins Island, Gladstone	May be overlapping construction phases.	Nil	Nil	No cumulative impact on shallow groundwater as this LNG plant will be sufficiently far away so as not to have an impact	No additional impact on the LNG plant facility
Gladstone Pacific Nickel Refinery – Gladstone Pacific Nickel	New nickel refinery and residue storage facility including ore importing facility at the proposed Wiggins Island terminal	Yarwun, Gladstone	May be overlapping construction phases.	Nil	Nil	No cumulative impact on shallow groundwater as this LNG plant will be sufficiently far away so as not to have an impact	No additional impact on the LNG plant facility

In addition to the identified projects tabled above it is currently being considered to dredge marine sediments offshore of Curtis Island to facilitate the LNG vessels. The dredge material may be deposited on a portion of Curtis Island adjacent to the proposed LNG facility. This dredging process is not considered in detail in the technical report. It is envisaged that possible impacts associated with the disposal of wet marine sediments will have a cumulative impact on the shallow groundwater resources due to increase disturbed area, reduced recharge, compaction of underlying aquifers, and the alteration of hydrochemistry. Monitoring points will have to be modified to evaluate the impacts and allow for the generation of management measures to ensure reduced impacts.

A preliminary assessment of the potential cumulative impacts of current and proposed projects identified in **Table 5-1** indicates that the possible impacts associated with the GLNG project will have increased area of influence and will occur more rapidly. The impacts are associated with increased dewatering, increased contaminant sources, and larger disturbed areas.

The implementation of proposed mitigation measures will allow for the impacts associated with the GLNG project on the groundwater resources to be diminished or removed. It is envisaged that similar mitigation measures will be included in the other projects. There will, however, be impacts which will occur due to the nature of the projects, these include:

- Dewatering;
- Gas transmission pipeline installation; and
- LNG footprint.

Monitoring, as discussed in **Sections 2.6**, **3.5** and **4.2**, will allow for the assessment of these impacts and allow for the apportioning of responsibility. This will require the sharing of information and the development of working group(s) amongst the various projects to allow for the identification of impact and the development of optimum remediation strategies.

6.1 Site Assessment Protocol

Confirmed footprint details of the CSG field development are not finalised at this stage and will not be finalised until appraisal drilling programs are complete. These programs will be conducted progressively over the life of the project. Thus the layout of production wells and associated infrastructure, including associated water dams, field compressor plants, in-field gas transmission pipeline networks, and workers accommodation areas have not yet been finalised. In order to ensure the impacts to the shallow groundwater are minimised a site assessment protocol, from a groundwater perspective, has been compiled. This is to be implemented as part of the phase 2 impact assessment program (post EIS) and will draw on the results of this EIS study. The use of the recommended investigations provided in the protocols will allow for informed decision making.

6.1.1 CSG Infrastructure

Site suitability assessments, from a groundwater perspective, are to be conducted when identifying areas for the construction and operation of associated water containment dams, treated water facilities and associated brine storage facilities, field compressor plants, workshops and related storage areas, and accommodation facilities.

The recommended protocols recognised for the optimum site selection and site suitability include:

- Identification of candidate sites based on topography, distance from surface water, and considering current land use;
- Determine surficial geology and associated hydrogeology; including aquifer types and hydrochemistry (preferable sites would be underlain by surficial geology with recognised poor groundwater resources, both quantity and quality);
- Conduct assessment of structural geology including geophysical surveys;
- Conduct a hydrocensus within the sub-catchment of each candidate site (to a maximum distance of 1 km), identify all bores, GDE, groundwater use and users;
- Conduct a site suitability study, risk assessment, and groundwater vulnerability assessment for each candidate site; select most suitable site[11];
- Design, construct, and maintain all infrastructure to ensure minimum risk of failure and artificial recharge;
- Determine all existing bores within the infrastructure footprints, backfill and seal the bores prior to construction;
- Drill and construct a minimum of three monitoring bores; one up gradient and two down gradient of the infrastructure;
- Identify or construct a monitoring point sufficiently far from the selected site to monitor ambient groundwater quality and natural groundwater fluctuations within the same geology;
- Monitor hydrochemistry (major anions and cations and selected dissolved metals) on a quarterly basis and groundwater levels (using automated groundwater level records) on a weekly basis;

---

[11] Additional biophysical and social criteria are assumed to be considered during the site selection process

- Collect site-specific climate data;
- Evaluate operations, accident reports, monitoring data, and climate data on a regular basis; minimum annually; and
- Compile hydrogeological assessment report for decision making and knowledge transfer.

These are the minimum studies required to ensure informed decisions can be made and motivated.

6.1.2 Gas Transmission Pipeline

Although the gas transmission pipeline will not be subject to post EIS phase 2 studies (as proposed for the CSG fields), site assessment protocols have been compiled for the gas transmission pipeline construction phase of the development. These include:

- Structural geology assessment to identify faults;
- Determine shortest routes across zones of instability or shallow vulnerable groundwater resources, where possible;
- Identify areas containing artesian flows;
- Identify zones of competent rock which will require blasting;
- Conduct hydrocensus in areas of HDD and blasting; identify GDE and current groundwater use;
- Identify mine areas, mine resources, rehabilitated areas, underground workings, and mine waste dumps;
- Determine mine lease areas to identify areas of mineral sterilisation; and
- Provide access to these data for transparency.

Monitoring of bores adjacent to proposed disturbed high consequence areas, before and after the installation of the gas transmission pipeline will allow for the evaluation of the impacts on the shallow groundwater use.

6.1.3 Monitoring Summary

The impact assessment and evaluation of cumulative impacts allowed for the compilation of mitigation measures to reduce the impacts of the proposed CSG operations and activities on the shallow groundwater. In order to assess the effectiveness of these mitigation measures a series of recommendations regarding monitoring have been compiled. A summary of the proposed monitoring program is presented in **Table 6-1**.

The monitoring data, evaluation and comparisons to baseline and predictions must be made available to allow for effective data sharing and knowledge transfer. This will assist in decision making and disputes resolution.

Table 6-1 Proposed Monitoring Program

Operation / activity	Monitoring point	Monitoring feature	Frequency	Details
CSG dewatering	Modified appraisal holes	Monitor groundwater levels within coal seams	Weekly – automated water level recorders	Modify appraisal holes to assess dewatering extent
	Neighbouring bores within GAB aquifers	Monitor possible induced flow from aquifers to coal seams	Weekly – automated water level recorders Start monitoring before CSG operations to get baseline data	Identify geology and determine suitable monitoring holes or drill monitoring holes into GAB aquifers
Background	Determine monitoring points outside of CSG disturbance area	Monitor natural fluctuations in groundwater levels and ambient hydrochemical trends	Weekly groundwater level measurements Quarterly hydrochemical analysis comprising major ions, nitrate, fluoride, sulfur, NEPM dissolved metals plus iron	Develop a database of ambient hydrogeological information for comparison to evaluate possible CSG impacts
CSG resource development	Production bores	Down-the-hole monitoring of EC to determine ingress zones and stratification	After the construction of each production bore	Confirm borehole construction does not allow interconnection between aquifers
CSG associated water	Monitoring bores	Monitor groundwater levels and hydrochemistry up and down gradient of the infrastructure	Weekly – automated water level recorders Quarterly hydrochemical analysis comprising major ions, nitrate, fluoride, sulfur, NEPM dissolved metals plus iron Rainfall data - daily	One ± 60 m bore 50 m up gradient of the infrastructure, two ± 60 m bores down gradient bores, 5 m and 15 m from the infrastructure
Gas transmission pipeline (only during construction)	Neighbouring bores within ± 200 m of blasting or HDD	Monitor possible reduction in groundwater resources or damage to bores, springs or seeps during installation	Assess groundwater point before installation – yield, water level, flow rate, depth, casing depth, equipment status Assess the same after installation Monitor groundwater level and	Determine possible alterations to groundwater resource due to installation of gas transmission pipeline

Operation / activity	Monitoring point	Monitoring feature	Frequency	Details
			quality before and after hydrostatic tests or cleaning of gas transmission pipeline	
Gas transmission pipeline infrastructure (booster pumps)	Neighbouring bores within ± 100 m from gas transmission pipeline surface infrastructure	Monitor groundwater levels and hydrochemistry to determine any alteration / deterioration with time due to CSG surface operations	Monitor groundwater levels monthly Monitor groundwater quality quarterly initially and them bi-annually. Determine major ions and NEPM metals	Evaluate possible impacts due to spills / leaks at surface infrastructure along the route
LNG Facility	Existing monitoring bores plus additional monitoring points to be identified based on final layout plan	Monitor groundwater levels and hydrochemistry up and down gradient of the LNG facility	Daily – automated water level recorders Quarterly hydrochemical analysis comprising major ions, nitrate, fluoride, sulfur, NEPM dissolved metals plus iron Rainfall data - daily	One ± 60 m bore 50 m up gradient of the infrastructure, two ± 60 m bores down gradient bores, 5 m and 15 m from the water impoundments, waste storage areas, chemicals / flammable liquids storage areas

A baseline description of the geology and hydrogeology was compiled for each of the GLNG project aspects. The descriptions are based on available data and site specific data. The descriptions include aquifer types and hydrochemistry, which allowed for an assessment of the environmental values of the shallow groundwater resources.

The study was conducted to compile and evaluate sufficient data to ensure the objectives of the ToR were addressed. Discussions with relevant authorities ensured that the shallow groundwater study addressed the authorities' expectations.

DNRW database data and hydrogeological parameters, obtained from drilling 18 bores, allowed for the baseline characterisation of all surficial geological units within the CSG fields.

The drilling and construction of groundwater monitoring boreholes within the LNG facility study area allowed for the identification of aquifers and compile baseline information, which can be used for comparison purposes during the LNG operations to assess possible impacts on the groundwater.

A desktop review was conducted of the proposed gas transmission pipeline in order to assess groundwater resources and potential impacts. No site-specific data was compiled; however, potential impacts were identified and mitigation measures have been recommended.

The proposed LNG operations, processes, and infrastructure have been evaluated and the potential impacts on the shallow groundwater were identified. The significance of these impacts, based on their consequence and likelihood, was compiled. This allowed for the compilation of threat reduction and mitigation measures to be compiled. A detailed, long-term groundwater monitoring program has been developed to allow for the evaluation of mitigation and measurement plans, as well as provide a measure of the impacts of the proposed GLNG project on the shallow groundwater regimes.

The potential impacts of the CSG field activities are associated with the CSG development (dewatering), the management of associated water, and the construction and operation of ancillary CSG field infrastructure. The CSG field activities can potentially lead to reductions in groundwater resources, artificial recharge with poor quality water, and the creation of surface contaminant sources. Mitigation measures recommended for the CSG field operations and activities include amongst others the setting of trigger levels to assist in developing and implementing water replacement strategies, the optimum design and construction of dams to reduce risk of seepage, and the use of licensed waste management companies to ensure the correct storage, handling, and disposal of generated waste.

The construction and installation of the gas transmission pipeline can potentially impact on the shallow groundwater resources, especially in areas where blasting or horizontal directional drilling is required. It is recommended that a census of groundwater resources and use be conducted within these areas along the route to determine pre- and post-construction hydrogeological conditions. This will allow for the evaluation of impacts and the need for rehabilitation and water replacement plans.

Limited groundwater resources have been identified within the proposed LNG facility study area, these groundwater resources will, however, be permanently altered during construction and operation of the LNG facility. The lost of current groundwater usage may need to be replaced.

A high level evaluation of potential cumulative impacts has been conducted based on limited information regarding the existing and proposed projects which have been identified within the same GLNG project study area. The implementation of proposed mitigation measures will allow the envisaged impacts of the GLNG project on the groundwater resources to be diminished or removed. It is envisaged that similar mitigation measures may be included in the other projects. There will, however, be impacts which will occur due to the nature of the projects; these include increased dewatering (extent and rate of impact), gas transmission pipeline installation, and LNG footprint. It is recommended that information sharing and working groups be set up to allow for the identification of impact and the development of optimum remediation strategies.

A site assessment protocol for the continued evaluation of CSG field activities has been compiled, from a groundwater perspective, as the CSG field development footprint will rely on ongoing appraisal drilling throughout the life of the project. The implementation of site suitability and assessment studies will allow for informed decision making to ensure reduced negative environmental impacts.

Opportunities identified during the study which can potentially assist with ensuring the sustainability of the project and reducing the impacts of CSG operations on the shallow groundwater include:

- Convert unused CSG production bores to water supply bores from GAB aquifers; can provide a source of good quality groundwater to replace impacted groundwater resources;
- Develop a catchment management interest or management group, which includes all key groundwater users within catchments containing CSG operations. This will allow for holistic management of groundwater resources, the development of water use strategies, community involvement, and ensuring longevity of water schemes;
- The construction and calibration of a regional groundwater model would allow for the simulation of the combined dewatering allowing for predictions regarding cumulative drawdown cones and groundwater abstraction volumes; the model could be used to evaluate injection of CSG associated water;
- Research into re-injection of CSG associated water, crystallisation of treated water residue, phytoremediation, and chemical bonding properties in industrial processes;
- Commercial aquaculture opportunities;
- The utilisation of CSG associated water as an alternative water source; and
- The protection and recovery (rebound) of GAB aquifers.

APHA Method 1060. (1992). General introduction: collection and preservation of samples, standard methods for the examination of water and wastewater, 18th edition. American Public Health Association, Washington DC, United States.

Australian and New Zealand Environment and Conservation Council, (ANZECC, 2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Paper No. 4, October 2000.

Australian Government National Health and Medical Research Council, 2004.National Water Quality Management Strategy Australian Drinking Water Guidelines 6. http://www.nhmrc.gov.au\

Australian Standards AS 3780-1994: The storage and handling of corrosive substances. http://www.standards.com.au

Australian Standards AS 1940-2004: The storage and handling of flammable and combustible liquids. http://www.standards.com.au

Biggs, A. and Power, E. (undated). Dryland salinity in the Queensland Murray-Daring Basin An overview of current knowledge. Department of Natural Resources and Mines report.

Bouwer, H. and R.C. Rice, (1976). A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. Water Resources Research, vol. 12, no. 3, pp. 423-428.

Climate statistics data from the Bureau of Meteorology. http://www.bom.gov.au

Exon, N.F. (1971). 1: 250 000 Geological Series explanatory notes ROMA QUEENSLAND sheet SG55/12 international index. Bureau of Mineral Resources, Geology and Geophysics. Hobart, Tasmania.

Forbes, V.R. (1968). 1: 250 000 Geological Series explanatory notes TAROOM QUEENSLAND sheet SG/55-8 international index. Bureau of Mineral Resources, Geology and Geophysics. Canberra, ACT.

Foster, B.A. (2007). A review of salinity occurrences in the Fitzroy Basin, Queensland. Department of Natural Resources and Water, Rockhampton. ISBN 9311662172037.

Hvorslev, M.J., (1951). Time Lag and Soil Permeability in Ground-Water Observations, bul. no. 26, Waterways Experiment Station, Corps of Engineers, U.S. Army, Vicksburg, Mississippi

Kingham, R. (1998). Geology of the Murray-Darling Basin – Simplified Lithostratigraphic Groupings. AGSO Record 1998/21. Australian Geological Survey Organisation.

Matrixplus. (2009). Groundwater (Deep Aquifer Modelling) for Santos GLNG Environmental Impact Statement. Project Number SAN801, January 2009.

Olgers, F. (1966). 1: 250 000 Geological Series explanatory notes BARALABA, QLD sheet SG/55-4 international index. Geological Survey of Queensland, Canberra, ACT.

Parsons Brinckerhoff Australia Pty Ltd. (2004) Coal Seam Gas Water Management Study. Prepared for the Queensland Department of Natural Resources, Mines and Energy, Report No. NRO0011, August 2004.

Queensland Department of Natural Resources and Water groundwater and licensing database for registered bores

Queensland Department of Natural Resources. (2003). Minimum Construction Requirements for Water Bores in Australia Edition 2. Mines and Energy Library, the State Library of Queensland and the National Library, Canberra

Queensland Government Department of Natural Resources, Mines and Water, (2006). Gladstone Special 1:100,000 Geology Map (Sheet 9150 & Part 9151) March 2006 Revised Edition.

Queensland Government Environmental Protection Agency, 2007. Operational policy Management of water produced in association with petroleum activities (associated water).

Queensland Parliamentary Counsel, 2007. Environmental Protection Act 1994 Environmental Protection (Water) Policy 1997.

Queensland Parliamentary Counsel, 2008. Environmental Protection Act 1994 Environmental Protection (Water) Amendment Policy (No.1) 2008.

Queensland Parliamentary Counsel 2008. Petroleum and Gas (Production and Safety) Act 2004.

Reading, L.P. and Pearce, B.R. (2007). BC2C Modelling for the Fitzroy Basin, Queensland. Department of Natural Resources and Water, Queensland. ISBN 9311662172051.

Roarty, M. (2008). Australia's natural gas: issues and trends. Research paper no. 25 2007-08, Department of the Parliamentary Library, Parliament House, Canberra.

Santos (2007). Gladstone Liquefied natural gas initial advice statement, dated 19 July 2007.

Sinclair Knight Merz (2006). Fairview Coal Seam Gas. Consultants report QE09365 prepared for Santos Ltd; August 2006.

Skivington, P. (1998). Risk assessment for water quality management. South African Water Research Commission, Report No. TT 90/97. Pretoria, South Africa

Standards Australia/Standards New Zealand (2004). Risk management guidelines companion to AS/NZS 4360:2004, Standards Australia International, Sydney, NSW.

Standards Australia/Standards New Zealand (2004). Risk management AS/NZS 4360:2004, Standards Australia International, Sydney, NSW.

URS (2008). Environmental Management plan for Fairview Project Area. Consultants report for Santos TOGA Pty Ltd, May 2008.

URS (2007). Gladstone LNG Geotechnical and Environmental Constraints Assessment. Consultants draft report 42625593.

URS (2007). Groundwater Impact Assessment, Injection of produced water into Timbury Hills Formation, Fairview Coal Seam gas Field. Consultants report Santos_Fairview_GWIA-R001 v1.doc.

Van Tonder, G. and Xu, Y. (2000). Recharge program to estimate groundwater recharge and the groundwater reserve. Institute for Groundwater Studies, University of the Free State, South Africa.

Wikipedia contributors, "Coalbed methane," *Wikipedia, The Free Encyclopedia,* http://en.wikipedia.org/w/index.php?title=Coalbed_methane&oldid=239612636

Appendix A: CSG Field borehole logs

Sheet 1 of 4

URS Australia Pty Ltd

Monitoring Well AVGW-01-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

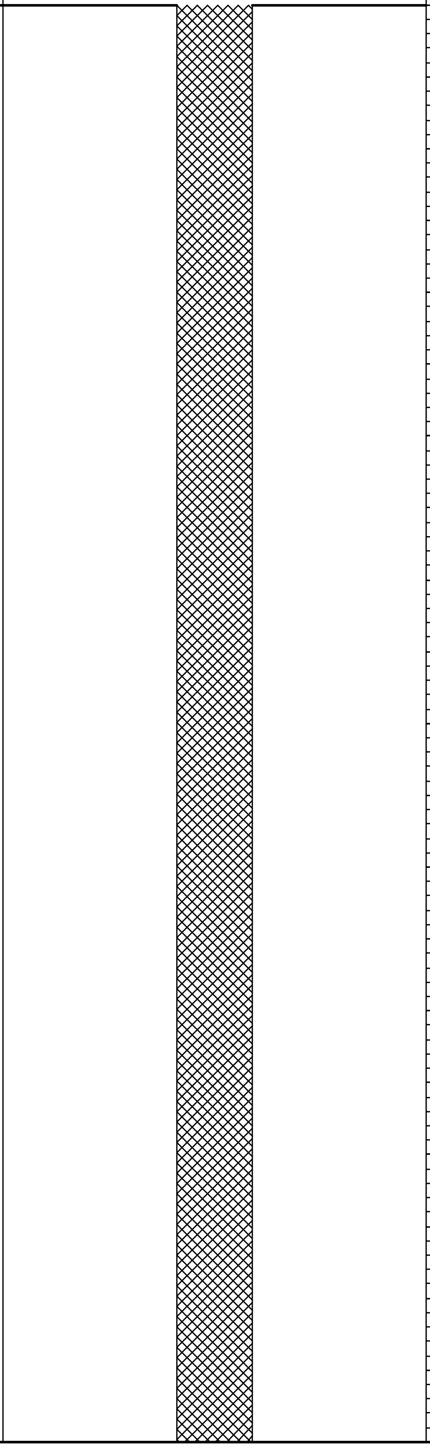
Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **16-9-08**
Date Finished: **16-9-08**

Relative Level: mAHD
Coordinates: 687043 mE
7183717 mN
Permit No:

Client: **Santos Ltd**



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			0		SANDY CLAY: dark brown, low plasticity, moderately stiff, sand is very fine to fine grained (~25%), dry.						L	D	
			1		As previous, lighter in colour, 70% Cl, 15% Sa, 15% Si.								
			3		SILTY CLAY: dark red-brown, low to medium plasticity, stiff to very stiff, brittle, 70% Cl, 20% Si, 10% fine sand.						L-M		
			5		As previous, softer, malleable, 70% Cl, 25% Si, 5% fine sand.								
			6		As previous, stiff clays present as fine lenses in strata (~10 mm max)								
			7		SILTSTONE: highly weathered, purple to red brown, weak, becoming harder with depth. More structured.								
			8		As previous, prominent fine grey bands (~1mm), possibly a larger lens (~300mm) present.								
			9		Stronger than previous, stiff, less grey banding.								

REMARKS:

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Monitoring Well AVGW-01-08

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Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

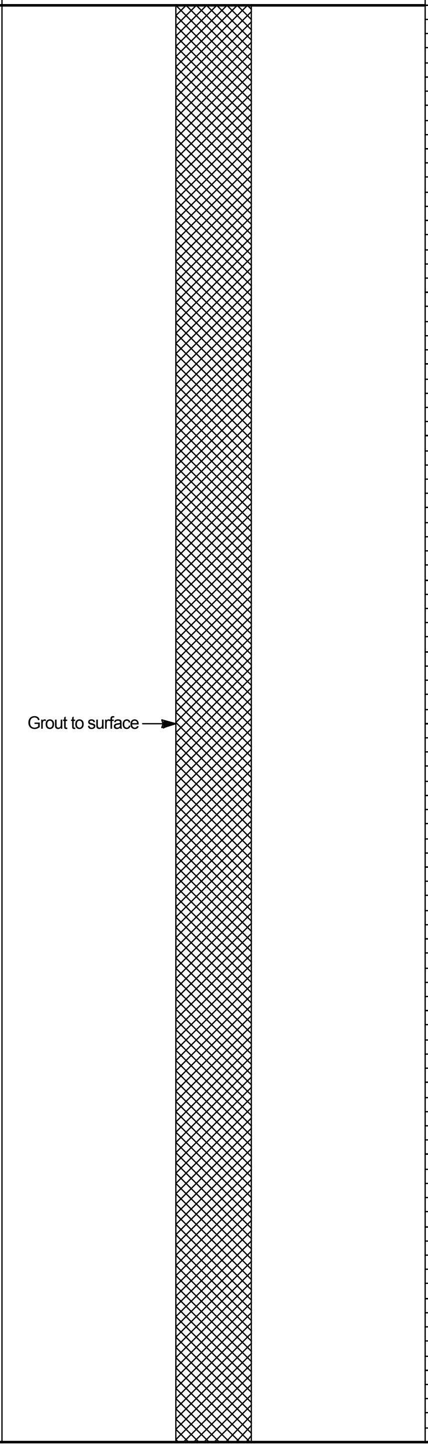
Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **16-9-08**
Date Finished: **16-9-08**

Relative Level: mAHD
Coordinates: 687043 mE
7183717 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | WELL CONSTRUCTION DETAILS | DESCRIPTION OF STRATA



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			10										
			11		Fine purple and grey banded structure.								
			12		Entirely purple-brown, no coloured banding, still banded/foliated structure.								
			13										
			14										
			15										
			16		As previous, with sharp colour change to bright pale blue/grey, no banding.								
			17										
			18										
			19		Some yellow brown fragments in structure.								

REMARKS:

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Monitoring Well AVGW-01-08

URS Australia Pty. Ltd.
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Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **16-9-08**
Date Finished: **16-9-08**

Relative Level: mAHD
Coordinates: 687043 mE
7183717 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | WELL CONSTRUCTION DETAILS | DESCRIPTION OF STRATA

Sample Type	Sampling and Observations	PID (ppm)	Well Construction Details	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			▨	20	× ×									
			▨	21	× ×									
			▨	22	× ×	Purple-brown to slightly grey, more stiff, more prominent structure.								
			▨	23	× ×	Darker in colour.								
			▨	24	× ×									
			▨	25	× ×	More brown in colour.								
			▨	26	× ×									
			▨	27	× ×	SILTSTONE: slightly to moderately weathered, purple brown and grey brown, fine banding (1mm), firm.								
			▨	28	× ×	As previous, colour change to blue-grey, banding not prominent.								
			▨	29	× ×	As previous, stiff to very stiff.								

REMARKS:

Sheet 4 of 4

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Monitoring Well AVGW-01-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **MR** Checked By: **AW** Date Started: **16-9-08** Date Finished: **16-9-08**	Relative Level: mAHD Coordinates: 687043 mE 7183717 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				30		EOH @ 30 mBGL. No water intercepted. No well installed.								
				31										
				32										
				33										
				34										
				35										
				36										
				37										
				38										
				39										

REMARKS:

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Monitoring Well AVGW-02-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
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Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

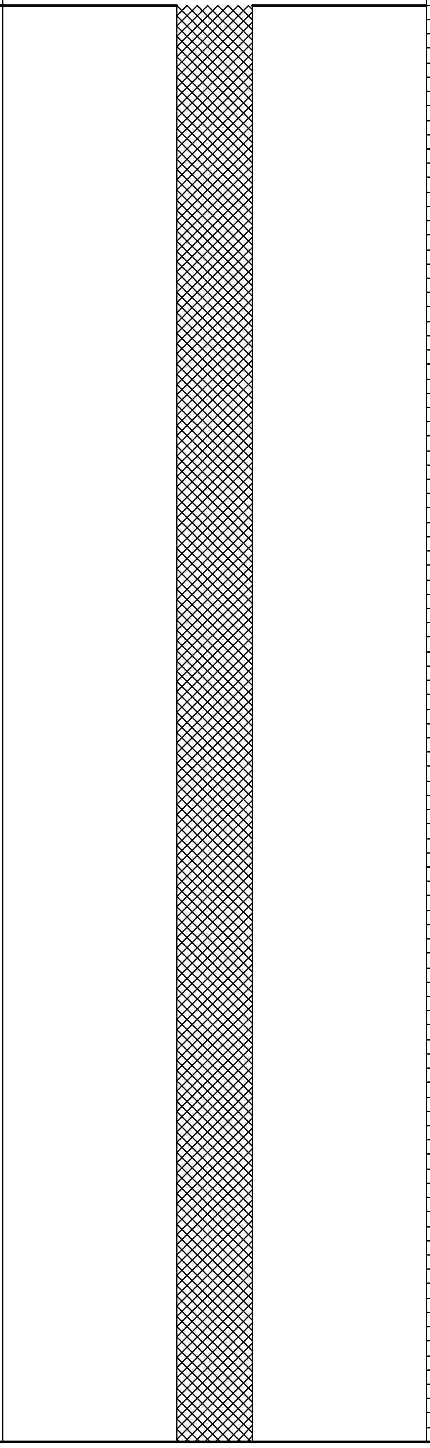
Drilling Method: **Rotary Air / Mud Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **14-9-08**
Date Finished: **16-9-08**

Relative Level: mAHD
Coordinates: 685356 mE
7200122 mN
Permit No:

Client: **Santos Ltd**

WELL CONSTRUCTION DETAILS



SAMPLING DETAILS				DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			0	▨	SILTY CLAY: dark brown, low to medium plasticity, organic matter throughout, slightly moist.						L-M	SM	
			1	⁘	SILTY SAND: red brown, fine grained, well sorted, minor dark brown clay bands around 1m, dry.			F				D	
			2	▨	CLAY: dark brown, high plasticity, very stiff, waxy, dense. Dry.						H		
			3	▨	SILTY CLAY: brown to red-brown, low to medium plasticity, moderately friable, dry. 60% Cl, 25% Si, 15% Sa. As previous, 60% Cl, 20% Si, 20% Sa.						L-M		
			5	▨	CLAYEY SAND: red-brown, fine grained, well sorted, with semi-cemented low plasticity sandy clay aggregates. As previous, sand is very fine grained.								
			7	⁘	SAND: red brown to pale pinkish brown, fine to coarse grained (mostly fine), with some grains to 5mm, sub-rounded, quartzose, trace silt <5%. As previous, large quartz grains to ~8mm. Red brown, black and white grains prominent. Broad range of grain sizes, well sorted.			F-C					

REMARKS:

Sheet 2 of 4

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Monitoring Well AVGW-02-08

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Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air / Mud Boring**

Logged By: **MR**
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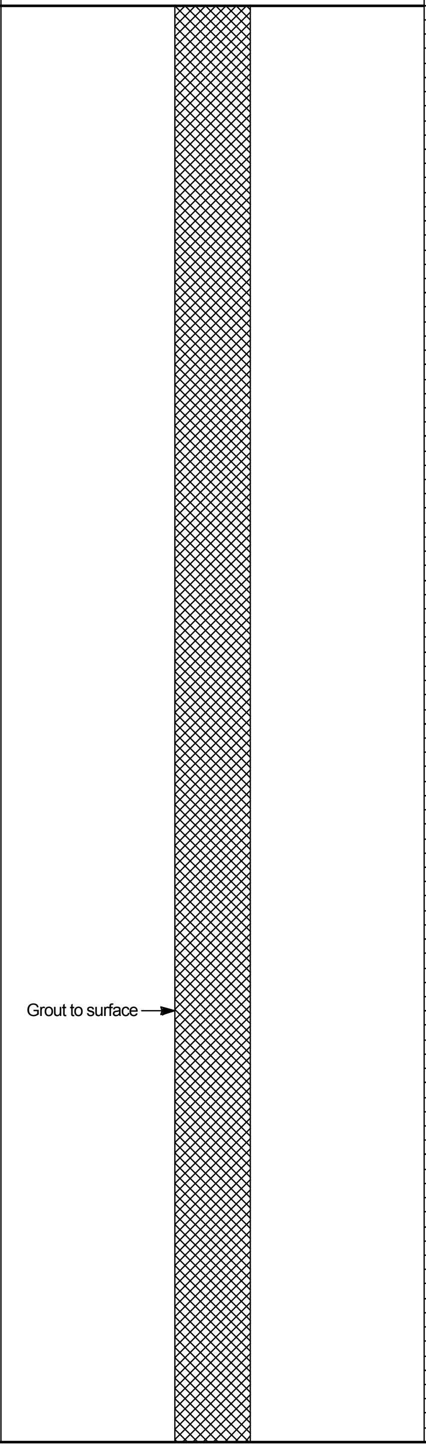
Date Started: **14-9-08**
Date Finished: **16-9-08**

Relative Level: mAHD
Coordinates: 685356 mE
7200122 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS
Sample Type	Sampling and Observations	PID (ppm)	



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
10		No sample return from 10-13 mBGL. Expected to be fine sand.								
13		CLAY: brown to red-brown, medium plasticity, medium stiff, moderately friable, slightly sticky, trace medium grained sand						M		
14		SAND: light brown/white/red brown, fine to coarse grained (mostly fine), well sorted, coarse grains are sub-rounded, possibly ferruginous parts, dry.			F-C					
15		SILTY SAND: grey green to brown, fine to coarse grained (fine prominent), some grains to 8mm, some ferruginised parts. 80% Sa, 20% Si.			F-C					
17		SILTY SANDY CLAY: brown to red, medium plasticity, stiff. 60% Cl, 30% Sa, 30% Si.								
19		SILTY CLAY (EW SILTSTONE): dark red-brown with grey and white fragments, medium plasticity, friable, dry.							D	

REMARKS:

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Monitoring Well AVGW-02-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
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Drilling Method: **Rotary Air / Mud Boring**	Logged By: **MR** Checked By: **AW** Date Started: **14-9-08** Date Finished: **16-9-08**	Relative Level: mAHD Coordinates: 685356 mE 7200122 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				20	▨	As previous, less grey material.								
				21	▨	As previous, soft to firm, low plasticity, trace fine grained sand. 60% Cl, 55% Si, <5% Sa.								
				22	▨	As previous, purple brown, fine banded structure evident (<1mm bands), slightly more stiff.								
				23	▨	As previous, darker, almost no sand detectable.								
				24	▨	Grading to CLAYEY SILT: red-brown with grey and light brown bands (prominent; 1mm). 65% Si, 30% Cl, <5% fine sand.								
				25	× ×	SILTSTONE: moderately to highly weathered, very weak, red-brown with fine grey bands (~1mm), equigranular, very fine grained, becoming well structured.								
				26	× ×	As previous, predominantly grey to purple. Banding less prominent, although statum possibly constitutes 200-300mm lens in itself.								
				27	× ×	Fine banding again prominent.								
				28	× ×									
				29	× ×									

REMARKS:

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Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air / Mud Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **14-9-08**
Date Finished: **16-9-08**

Relative Level: mAHD
Coordinates: 685356 mE
7200122 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			▩	30	× ×	As previous, darker in colour, fine banding prominent								
			▩	31	× ×	As previous, blue-grey, dry.								
			▩	32	× ×	Bright blue-grey, more highly weathered, no banding evident.								
			▩	33	× ×									
				34		As previous EOH @ 34 mBGL. No water intercepted. Well not installed.								
				35										
				36										
				37										
				38										
				39										

REMARKS:

Sheet 1 of 5

URS Australia Pty Ltd

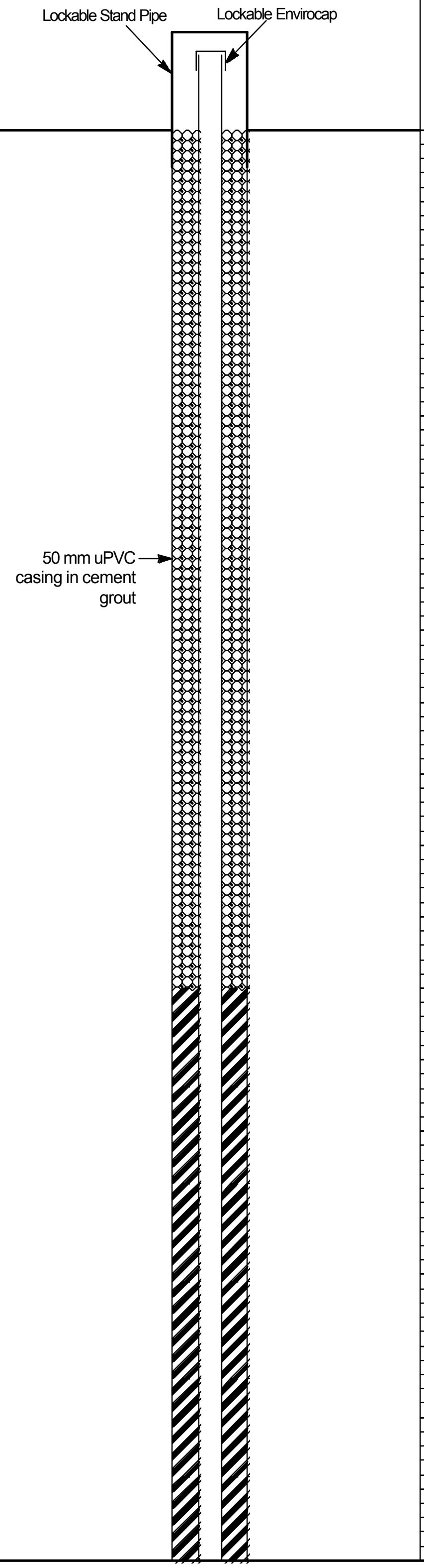
Monitoring Well AVGW-03-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air / Mud Boring**	Logged By: **MR** Checked By: **AW** Date Started: **13-9-08** Date Finished: **14-9-08**	Relative Level: mAHD Coordinates: 679249 mE 7210597 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0		SILTY SAND: light brown, fine grained, well sorted, 60% fine sand, ~30% silt, 10% clay, dry.			F				D	
1		SILTY CLAY: dark brown mottled light brown, medium plasticity, soft, mouldable, dry to slightly moist.						M	D-SM	
2		SANDY CLAY: brown mottled grey, high plasticity, waxy, sand is fine grained, dry.						H	D	
3		Brown, medium plasticity.								
4		SAND: light brown, fine to medium grained, poorly sorted, trace white medium grained sand. Dry.							D	
5										
6		Trace dark organic clay/peat aggregates (2mm).								
7		Pale yellow brown, less clay/peat.								
8										
9		GRAVELLY SAND/CONGLOMERATE: light brown, fine to coarse grained, poorly sorted, with fg-cg quartz and sandstone gravels, generally			F-C	SA				

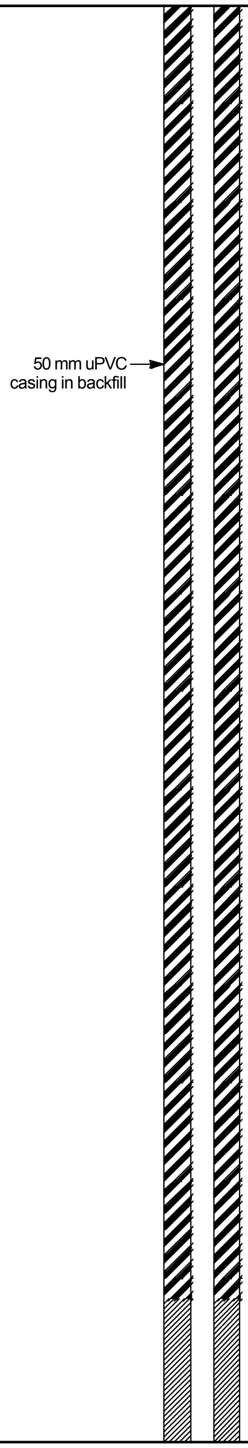
REMARKS:

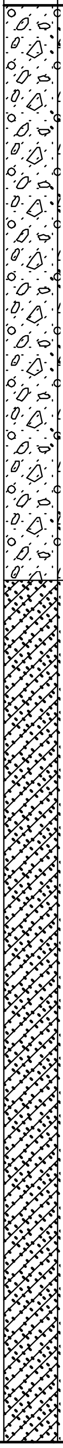
URS Australia Pty Ltd

Monitoring Well AVGW-03-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air / Mud Boring**	Logged By: **MR** Checked By: **AW** Date Started: **13-9-08** Date Finished: **14-9-08**	Relative Level: mAHD Coordinates: 679249 mE 7210597 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				10		sub-angular, resembles conglomerate. Minor high plasticity sandy clay aggregates from 9.6-9.9m.								
				11										
				12		Brown with pale brown and black grains, poorly sorted, gravels are smaller (fg), sub-angular (to max of 12mm), with ~2mm ironstones present.								
				13										
				14		SANDY CLAY: brown mottled grey, medium plasticity, sand is fine to coarse grained, poorly sorted with some quartz grains to ~4mm, sub-rounded, 65% Cl, 25% Sa, 10% Si. Becoming more stiff.						M		
				15										
				16										
				17		Grey with brown and orange mottles, stiff to very stiff (driller), medium to high plasticity, sand is fine grained, 70% Cl, 25% Sa, 5% Si. Clay becoming dominant grain size (~80%).								
				18										
				19		Becoming dark yellow-brown.								





REMARKS:

URS Australia Pty Ltd

Monitoring Well AVGW-03-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

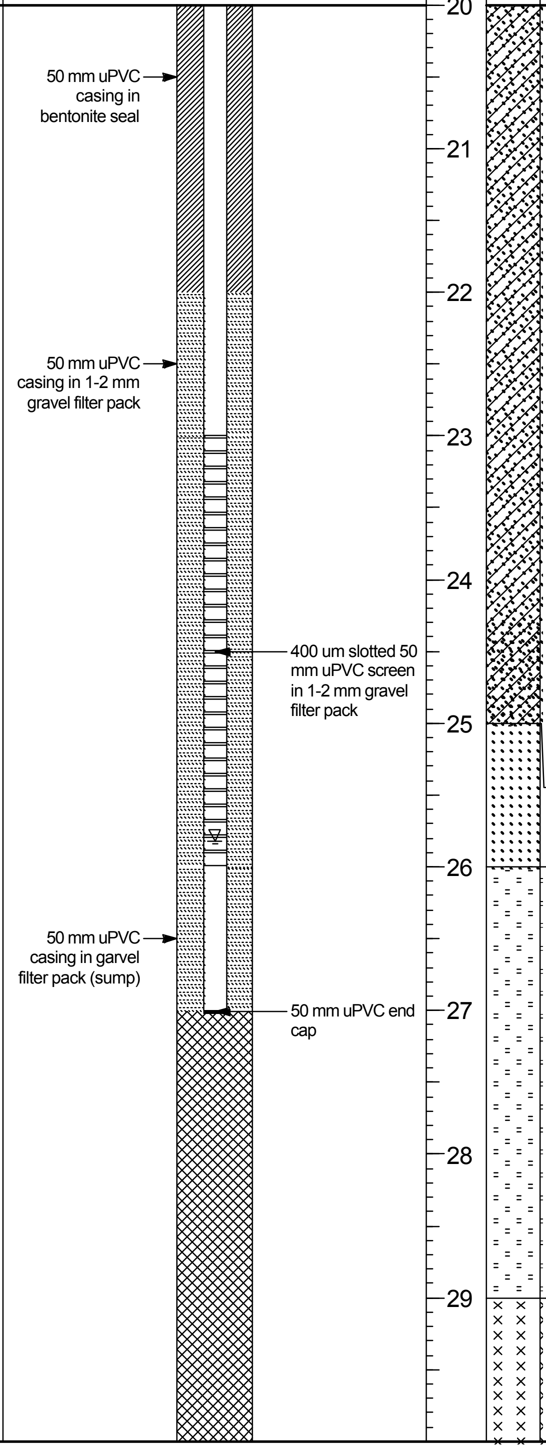
Drilling Method: **Rotary Air / Mud Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **13-9-08**
Date Finished: **14-9-08**

Relative Level: mAHD
Coordinates: 679249 mE
7210597 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS
Sample Type	Sampling and Observations	PID (ppm)	



DESCRIPTION OF STRATA

Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
Green-brown, medium plasticity, stiff, sand is fine grained, 85% Cl, 10% Sa, 5% Si.								
Higher plasticity.								
SANDSTONE: slightly weathered, medium strength, grey/black/white, micaceous (biotite/muscovite (?)), very fine grained, equigranular.			VFG					
MUDSTONE: highly weathered, green-brown, sandstone aggregates present (<4mm), dry.								
Blue grey, slightly more sandy/silty.								
SILTSTONE: highly weathered, weak, blue-grey, very little structure evident.								

REMARKS:

URS Australia Pty Ltd

Monitoring Well AVGW-03-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air / Mud Boring**	Logged By: **MR** Checked By: **AW** Date Started: **13-9-08** Date Finished: **14-9-08**	Relative Level: mAHD Coordinates: 679249 mE 7210597 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				30	× ×									
				31	× ×									
				32	× ×	50% Si, 30% Cl, 20% Sa making up matrix.								
				33	× ×	Blue grey, stiff to very stiff.								
			Hole backfilled with cuttings		× ×									
				34	× ×									
				35	× ×									
				36	× ×	More sand in matrix.								
				37	× ×	Blue grey with increasing green-brown fragments, very fine grained with ~25% very fine grained sand in matrix.								
				38	× ×									
				39	× ×									

REMARKS:

Sheet 5 of 5

URS Australia Pty Ltd

Monitoring Well AVGW-03-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air / Mud Boring**	Logged By: **MR** Checked By: **AW** Date Started: **13-9-08** Date Finished: **14-9-08**	Relative Level: mAHD Coordinates: 679249 mE 7210597 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				40		EOH @ 40.2 mBGL (1650; 13/9/08)								
				41										
				42										
				43										
				44										
				45										
				46										
				47										
				48										
				49										

REMARKS:

Sheet 1 of 7

URS Australia Pty Ltd

Monitoring Well AVGW-04-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **23-9-08**
Date Finished: **23-9-08**

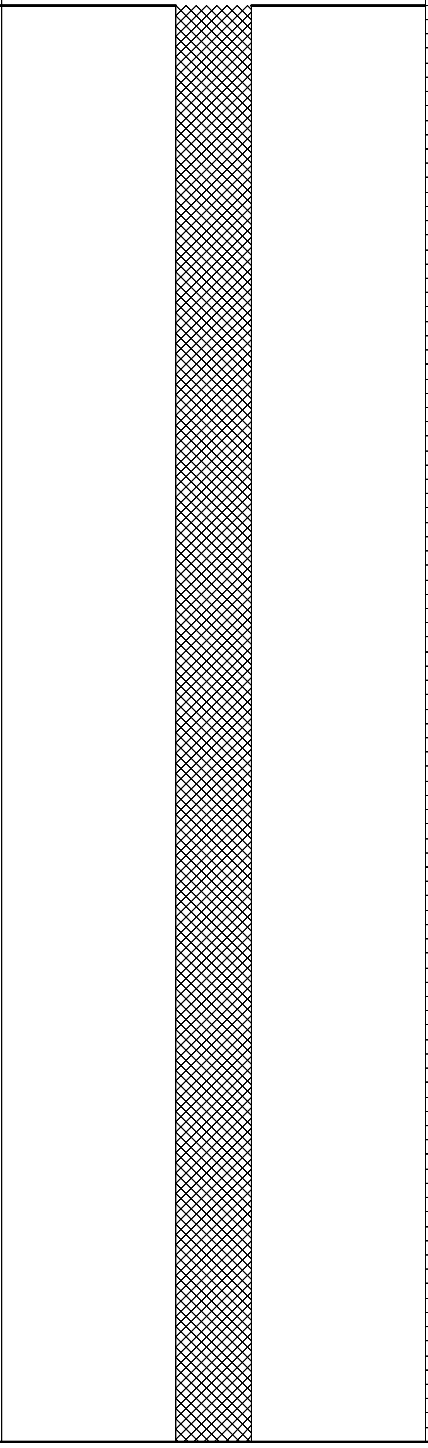
Relative Level: mAHD
Coordinates: 711639 mE
7171230 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0										
1		CLAY: dark brown to black, medium to high plasticity, organic in appearance, some remnant OM present in matrix, shiny/waxy, dry. Red-brown mottled dark brown and pale grey.						M-H		
3		SANDY CLAY: pale grey brown mottled yellow brown, low to medium plasticity, soft to slightly firm, trace red mottles, sand is fine grained (~25%). Dry. ~10% sand.						L-M		
5		SILTY CLAY: pale grey to white, medium plasticity, waxy, trace sand (~5%), ~15% silt.						M		
6		Yellow brown to blue grey, with minor chert-like gravels to 5mm.								
7		Lower plasticity, becoming softer.								
8		Pale grey brown, low to medium plasticity, firm.								
9		Grey brown mottled yellow brown.								

REMARKS:

URS Australia Pty Ltd

Monitoring Well AVGW-04-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **23-9-08**
Date Finished: **23-9-08**

Relative Level: mAHD
Coordinates: 711639 mE
7171230 mN
Permit No:

Client: **Santos Ltd**

Depth (m)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
10	Less silt, grey mottled yellow-brown (minor), high plasticity, firm, slight moisture.								
11	SANDSTONE: dark brown to yellow brown, minor banding, generally mottled, hard, very fine grained.			VF					
12	Slightly weathered, pale yellow to white, fine to medium grained.								
13									
14									
15	Slightly to moderately weathered, white and pale yellow brown.								
16									
17	Becoming very fine grained, slightly moist.								
18									
19	Dry.								

SAMPLING DETAILS: Sample Type | Sampling and Observations | PID (ppm)

WELL CONSTRUCTION DETAILS

REMARKS:

Sheet 3 of 7

URS Australia Pty Ltd

Monitoring Well AVGW-04-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **23-9-08**
Date Finished: **23-9-08**

Relative Level: mAHD
Coordinates: 711639 mE
7171230 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				20	⁙									
				22	⁙	As previous.								
				25	⁙	White/pink/red (minor), fine to coarse grained (to 4mm), very hard, well sorted, sub-angular, dry.								
				26	⁙	Grey, weak, predominantly fine grained, dry.								
				28	×	SILTSTONE: dark grey, highly weathered, very weak, slightly malleable, dry.								
				29	×	More like a SILTY CLAY:, relatively unconsolidated.								

REMARKS:

URS Australia Pty Ltd

Monitoring Well AVGW-04-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **23-9-08**
Date Finished: **23-9-08**

Relative Level: mAHD
Coordinates: 711639 mE
7171230 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			Grout to surface ▨	30	× ×									
			▨	31	× ×	More consolidated, some banding/structure evident, slightly moist.								
			▨	32	× ×	Grey to dark grey-brown, stiff, prominent very thin bands (~1mm), dry.								
			▨	33	× ×									
			▨	34	× ×									
			▨	35	× ×									
			▨	36	× ×									
			▨	37	× ×	Soft, becoming dark blue-grey								
			▨	38	× ×									
			▨	39	× ×									

REMARKS:

Sheet 5 of 7

URS Australia Pty Ltd

Monitoring Well AVGW-04-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **MR** Checked By: **AW** Date Started: **23-9-08** Date Finished: **23-9-08**	Relative Level: mAHD Coordinates: 711639 mE 7171230 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				40										
				41		Slightly lighter in colour, becoming very stiff/hard.								
				42										
				43		Very strong.								
				44										
				45										
				46										
				47										
				48										
				49		As previous, increasing sand content (fine grained, ~15%). Dry								

REMARKS:

URS Australia Pty Ltd

Monitoring Well AVGW-04-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

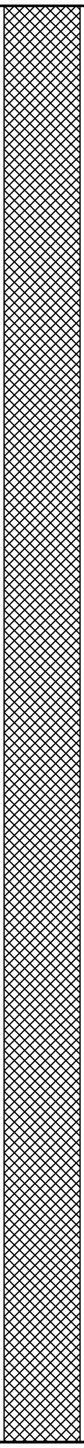
Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **23-9-08**
Date Finished: **23-9-08**

Relative Level: mAHD
Coordinates: 711639 mE
7171230 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			50	× ×									
			51	× ×	Slightly darker grey, softer, prominent fine banded structure (1mm; dark grey/light grey), mainly dark.								
			52	× ×									
			53	× ×									
			54	× ×									
			55	× ×									
			56	× ×	As previous.								
			57	× ×									
			58	× ×									
			59	× ×									

REMARKS:

URS Australia Pty Ltd

Monitoring Well AVGW-04-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**		Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Method: **Rotary Air Boring**	Logged By: **MR** Checked By: **AW** Date Started: **23-9-08** Date Finished: **23-9-08**	Relative Level: mAHD Coordinates: 711639 mE 7171230 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				60		EOH @ 60 mBGL (1500; 23/9/08)								
				61										
				62										
				63										
				64										
				65										
				66										
				67										
				68										
				69										

REMARKS:

Sheet 1 of 6

URS Australia Pty Ltd

Monitoring Well FVGW-02-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **17-9-08**
Date Finished: **17-9-08**

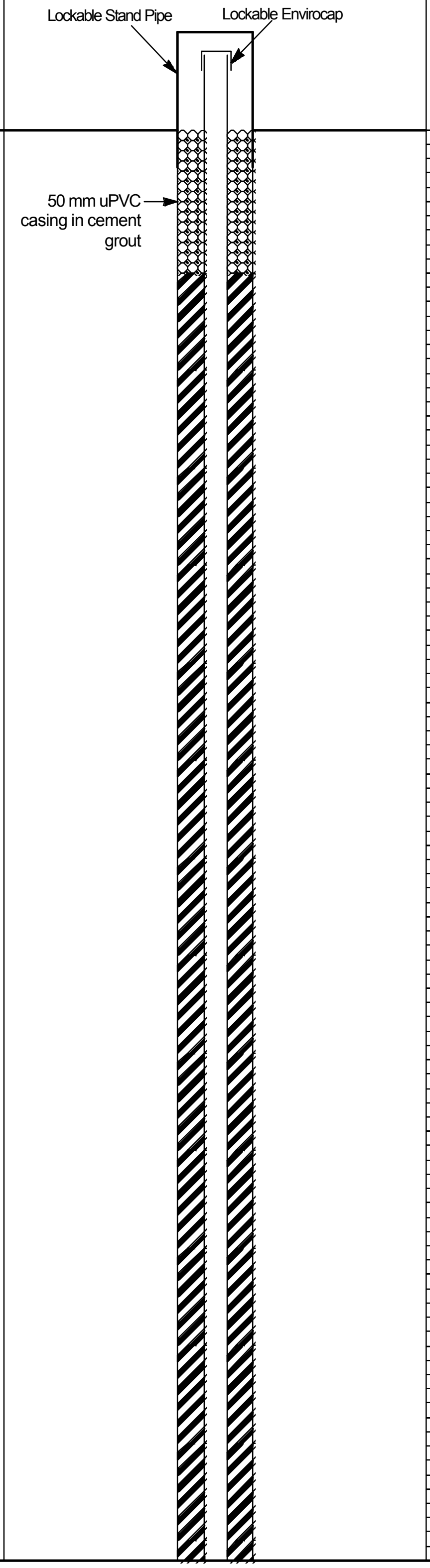
Relative Level: mAHD
Coordinates: 703413 mE
7148344 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type | Sampling and Observations | PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0										
1		SANDY CLAY: dark brown mottled white and red, high plasticity, shiny/waxy, sand is fine grained (~25%), very stiff, dry. Yellow brown, no mottles. Yellow brown mottled red-brown, very stiff (almost claystone).						H		
4		CLAY: yellow brown mottled blue-grey, high plasticity, trace fine grained sand (<5%).						H		
5		SILTSTONE: yellow brown with minor dark grey gravel sized cemented aggregates, medium strength, trace fine grained sand, 85% siltstone, 15% sand.								
6		SANDSTONE: pale yellow brown with light grey band (~200mm), medium strength, fine grained, quartzose. Slightly weaker, no grey bands, slightly moist. Some grey bands containing ferruginous mottles			F					

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-02-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
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Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

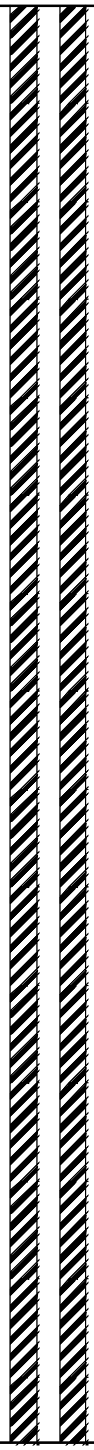
Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **17-9-08**
Date Finished: **17-9-08**

Relative Level: mAHD
Coordinates: 703413 mE
7148344 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | WELL CONSTRUCTION DETAILS | DESCRIPTION OF STRATA



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			10	Higher silt content, becoming grey-brown, comprising 60% fine grained sand, ~35% silt.								
			11 12	Dark yellow brown (khaki), medium strength, very fine grained, well sorted, well structured, slightly weathered. Band of low plasticity grey clay between 11-12 mBGL.								
			13 14	Band of low plasticity grey silty clay between 13-14m (~50mm). Very fine grained, less structure evident.								
			15 16	SILTSTONE: blue grey with grey brown bands, very fine grained, medium strength, very fine banding (~1mm; frequent). Grey to pale yellow brown								
			17	Sandstone aggregates to ~4mm present, predominantly pale grey brown.								
			18	SANDSTONE: pale yellow brown to grey, medium strength, fine to coarse grained, well sorted, dry.			F-C		W		D	
			19	Predominantly grey, with fine bands of dark brown medium plasticity silty clay evident throughout.								

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-02-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **17-9-08**
Date Finished: **17-9-08**

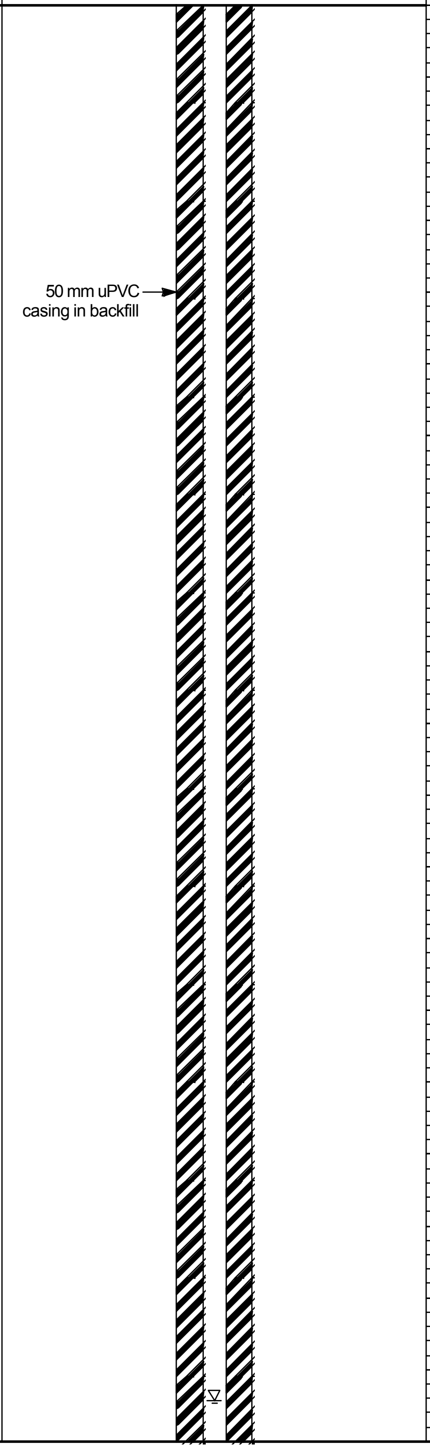
Relative Level: mAHD
Coordinates: 703413 mE
7148344 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
20–25		Silty clay still evident, almost organic in appearance/texture. Becoming very well consolidated, less banding, strong.								
25–27		SILTSTONE: grey to dark grey, medium strength, minor fine grained quartz sand (~10%), dry.								
27–30		SANDSTONE: grey to pale grey, strong, brittle, very fine grained with trace medium grains, poorly sorted, sub-rounded clasts. Dark grey			VF	SR	P			

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-02-08

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Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
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Date Finished: **17-9-08**

Relative Level: mAHD
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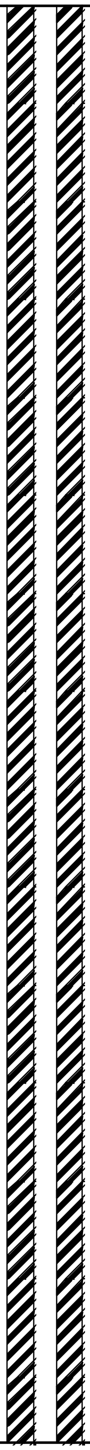
7148344 mN
Permit No:

Client: **Santos Ltd**



SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				30		SILTSTONE: dark grey brown, strong, hard, equigranular with 1mm bands (all uniform colour).								
				31										
				32										
				33		Dark grey brown with fine light grey bands (~1mm).								
				34										
				35										
				36		Very prominent banded structure (~1mm), uniform dark grey colour.								
				37										
				38		Very hard at 38m								
				39										

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-02-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

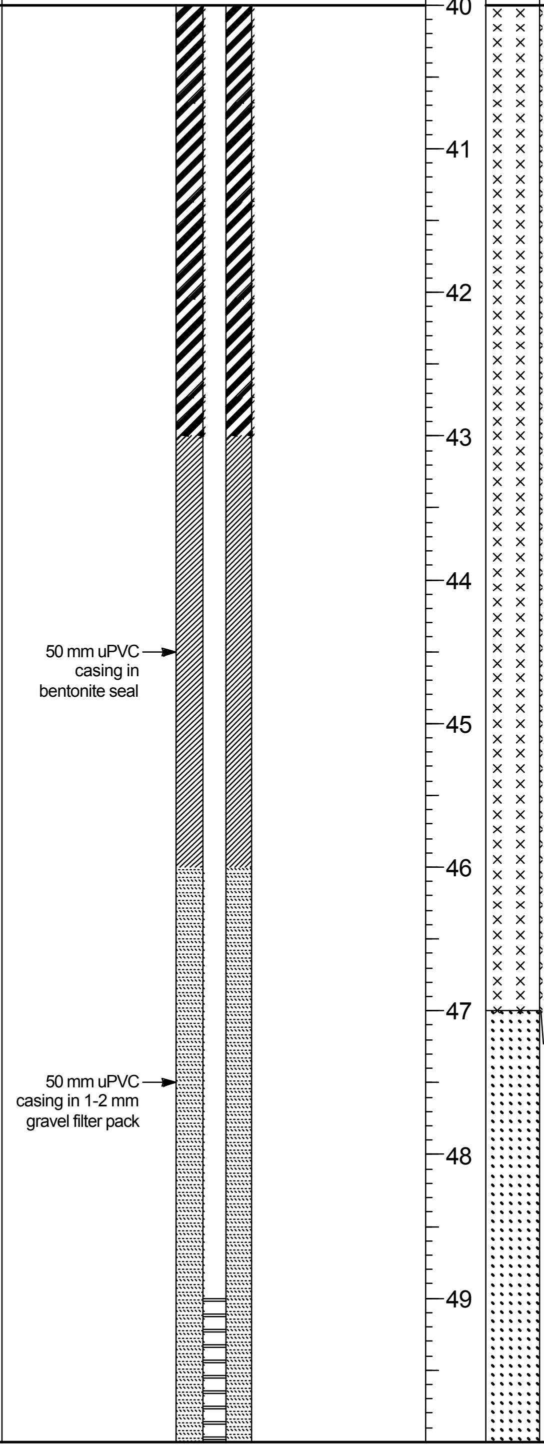
Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **17-9-08**
Date Finished: **17-9-08**

Relative Level: mAHD
Coordinates: 703413 mE
7148344 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification



Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
Dark grey, very stiff to hard, brittle, slightly weathered to fresh.								
Becoming more highly weathered below 43m.								
Minor fine to medium grained sand (5-10%)								
Dark grey with thin dark brown bands (occasional; 1mm), well sorted, strong, hard.								
Becoming moist, sand content increasing, poorly sorted, predominantly fine to medium grained.								
SANDSTONE: dark grey to blue, very fine grained, well sorted, slightly weathered, moist to wet.			VF		W		M-W	
Wet below 48.4 m								
Grey/black/white, strong, brittle, fine grained, micaceous, still rich in quartz, wet.								

REMARKS:

Sheet 6 of 6

URS Australia Pty Ltd

Monitoring Well FVGW-02-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
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Drilling Contractor: **TerraTest**

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Relative Level: mAHD
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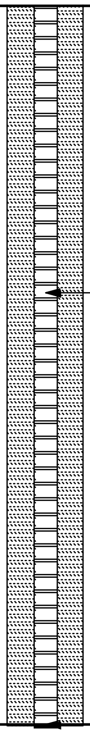
7148344 mN
Permit No:

Client: **Santos Ltd**



SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				50	▨									
				51		Zones/bands (~100mm) of dark grey to black SILTSTONE: equigranular, medium strength to weak, brittle.								
			400 um slotted, 50 mm uPVC screen in 1-2 mm gravel filter pack	52										
				53		As previous								
				54										
			50 mm uPVC end cap	55		EOH @ 55m (1510; 17/9/08)								
				56										
				57										
				58										
				59										

REMARKS:

Sheet 1 of 6

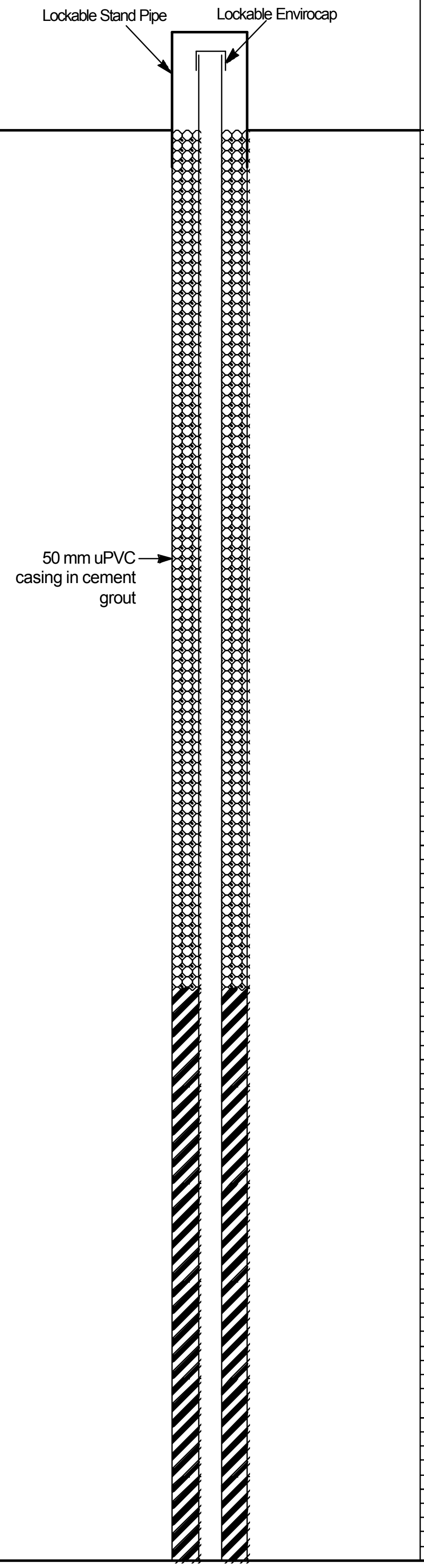
URS Australia Pty Ltd

Monitoring Well FVGW-02-08A

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **MR** Checked By: **AW** Date Started: **17-9-08** Date Finished: **18-9-08**	Relative Level: mAHD Coordinates: 703413 mE 7148341 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS: Sample Type | Sampling and Observations | PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0										
1		SANDY CLAY: dark brown mottled white and red, high plasticity, shiny/waxy, sand is fine grained (~25%), very stiff, dry. Yellow brown, no mottles. Yellow brown mottled red-brown, very stiff (almost claystone).						H		
4		CLAY: yellow brown mottled blue-grey, high plasticity, trace fine grained sand (<5%).						H		
5		SILTSTONE: yellow brown with minor dark grey gravel sized cemented aggregates, medium strength, trace fine grained sand, 85% siltstone, 15% sand.								
6		SANDSTONE: pale yellow brown with light grey band (~200mm), medium strength, fine grained, quartzose. Slightly weaker, no grey bands, slightly moist. Some grey bands containing ferruginous mottles			F					

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-02-08A

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
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Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

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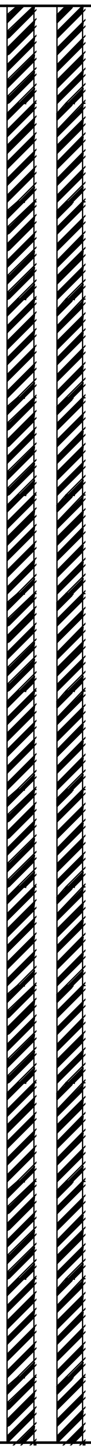
Relative Level: mAHD
Coordinates: 703413 mE
7148341 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
10	∴	Higher silt content, becoming grey-brown, comprising 60% fine grained sand, ~35% silt. Dark yellow brown (khaki), medium strength, very fine grained, well sorted, well structured, slightly weathered. Band of low plasticity grey clay between 11-12 mBGL. Band of low plasticity grey silty clay between 13-14m (~50mm). Very fine grained, less structure evident.								
15	×	SILTSTONE: blue grey with grey brown bands, very fine grained, medium strength, very fine banding (~1mm; frequent). Grey to pale yellow brown Sandstone aggregates to ~4mm present, predominantly pale grey brown.								
18	∴	SANDSTONE: pale yellow brown to grey, medium strength, fine to coarse grained, well sorted, dry. Predominantly grey, with fine bands of dark brown medium plasticity silty clay evident throughout.			F-C		W		D	

REMARKS:

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Monitoring Well FVGW-02-08A

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Drilling Contractor:	**TerraTest**
Project No.:	**42626229**
Project Reference:	**GLNG Gas Field EIS**
Drilling Method:	**Rotary Air Boring**
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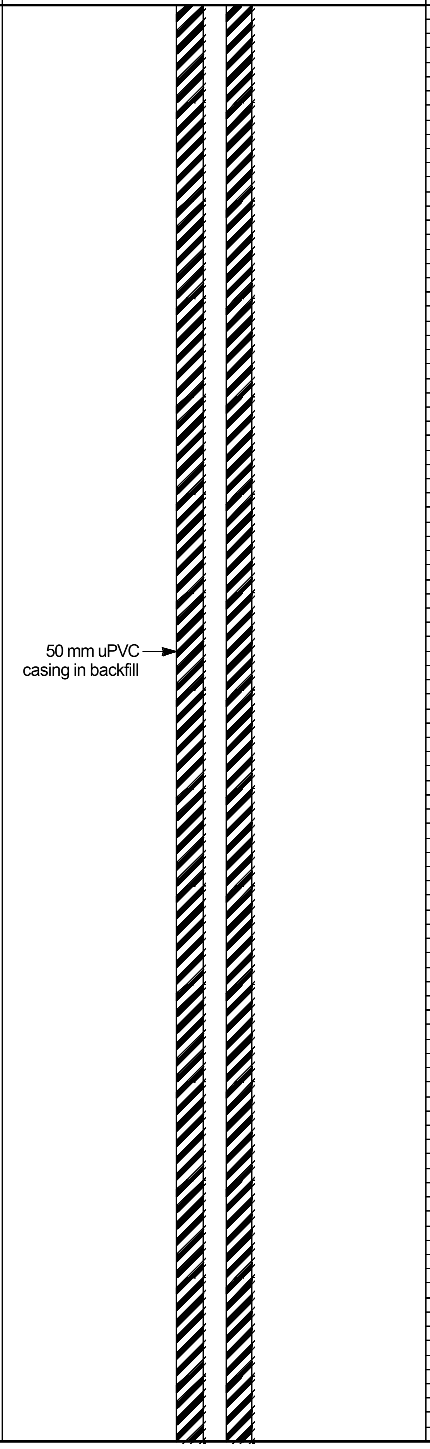
Relative Level:	mAHD
Coordinates:	703413 mE 7148341 mN
Permit No:	
Client:	**Santos Ltd**

SAMPLING DETAILS — Sample Type | Sampling and Observations | PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
20	∷									
21	∷	Silty clay still evident, almost organic in appearance/texture.								
22	∷	Becoming very well consolidated, less banding, strong.								
23	∷									
24	∷									
25	× ×	SILTSTONE: grey to dark grey, medium strength, minor fine grained quartz sand (~10%), dry.								
26	× ×									
27	∷	SANDSTONE: grey to pale grey, strong, brittle, very fine grained with trace medium grains, poorly sorted, sub-rounded clasts.			VF	SR	P			
28	∷	Dark grey								
29	∷									

REMARKS:

Sheet 4 of 6

URS Australia Pty Ltd

Monitoring Well FVGW-02-08A

URS Australia Pty. Ltd.
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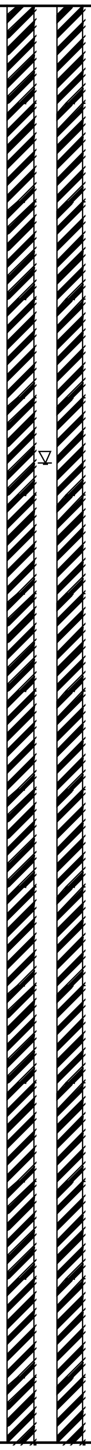
Relative Level: mAHD
Coordinates: 703413 mE
7148341 mN
Permit No:

Client: **Santos Ltd**

WELL CONSTRUCTION DETAILS



SAMPLING DETAILS				DESCRIPTION OF STRATA								
Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			30	SILTSTONE: dark grey brown, strong, hard, equigranular with 1mm bands (all uniform colour).								
			31									
			32									
			33	Dark grey brown with fine light grey bands (~1mm).								
			34									
			35									
			36	Very prominent banded structure (~1mm), uniform dark grey colour.								
			37									
			38	Very hard at 38m								
			39									

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-02-08A

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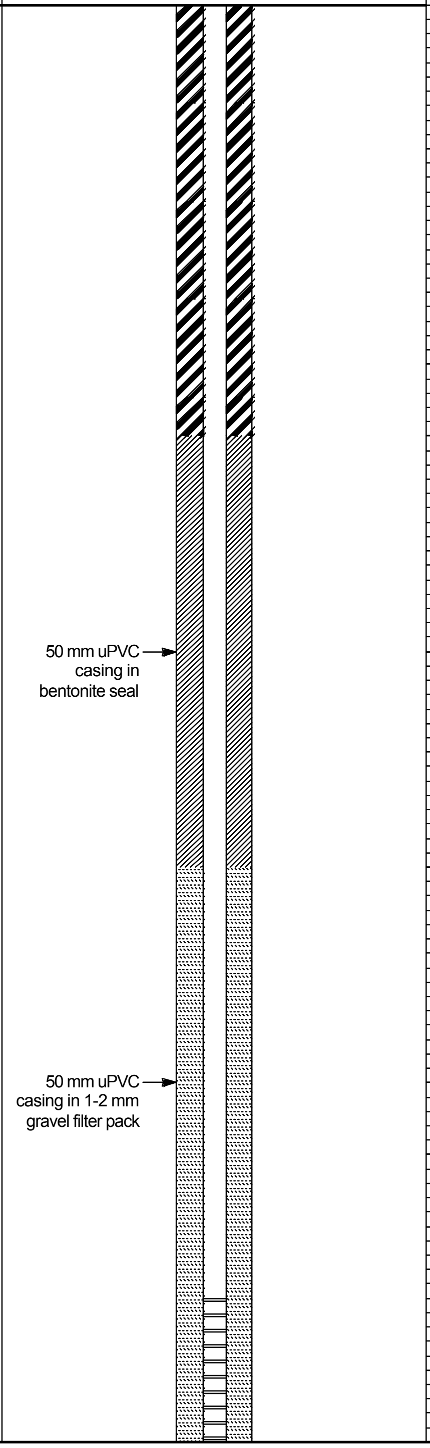
Relative Level: mAHD
Coordinates: 703413 mE
7148341 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS — Sample Type | Sampling and Observations | PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
41	Dark grey, very stiff to hard, brittle, slightly weathered to fresh.								
43	Becoming more highly weathered below 43m.								
44	Minor fine to medium grained sand (5-10%)								
45	Dark grey with thin dark brown bands (occasional; 1mm), well sorted, strong, hard.								
46.5	Becoming moist, sand content increasing, poorly sorted, predominantly fine to medium grained.								
47	SANDSTONE: dark grey to blue, very fine grained, well sorted, slightly weathered, dry			VF		W		D	
48.4	Wet below 48.4 m								
49	Grey/black/white, strong, brittle, fine grained, micaceous, still rich in quartz.								

REMARKS:

Sheet 6 of 6

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Monitoring Well FVGW-02-08A

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
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Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

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Date Started: **17-9-08**
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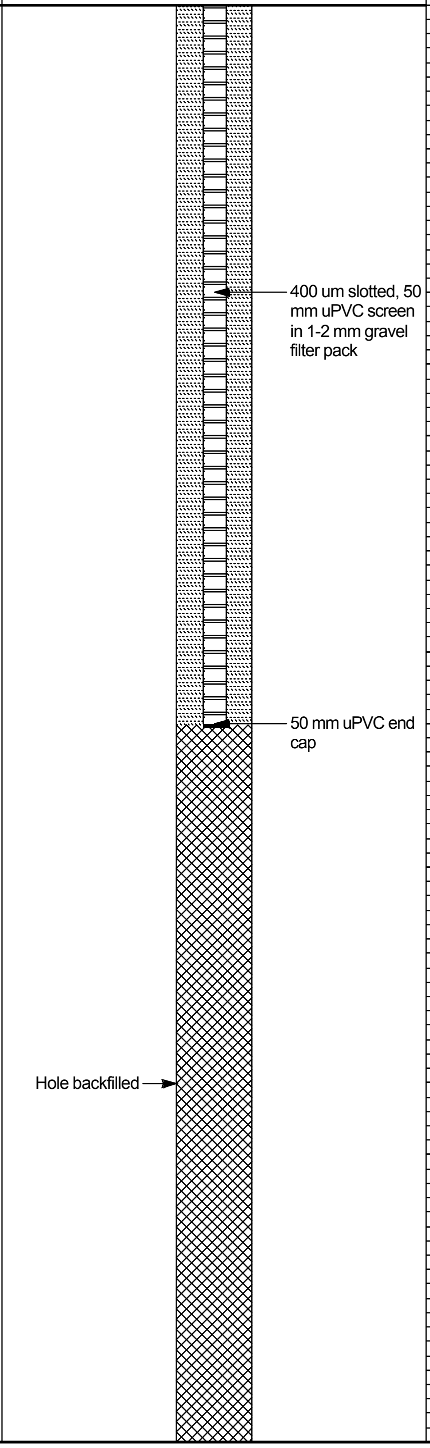
Relative Level: mAHD
Coordinates: 703413 mE
7148341 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | WELL CONSTRUCTION DETAILS | DESCRIPTION OF STRATA



Depth (m)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
50 – 52	Zones/bands (~100mm) of dark grey to black SILTSTONE: equigranular, medium strength to weak, brittle.								
52 – 53	SILTSTONE: dark grey brown, weak to medium strength, banded (frequent; 1mm), dry							D	
53 – 58	SANDSTONE: Grey/black/white, strong, brittle, fine grained, micaceous, still rich in quartz, dry.			F				D	
58 –	SILTSTONE: dark grey, strong, fresh, some thin bands, dry.								

REMARKS:

Sheet 1 of 3

URS Australia Pty Ltd

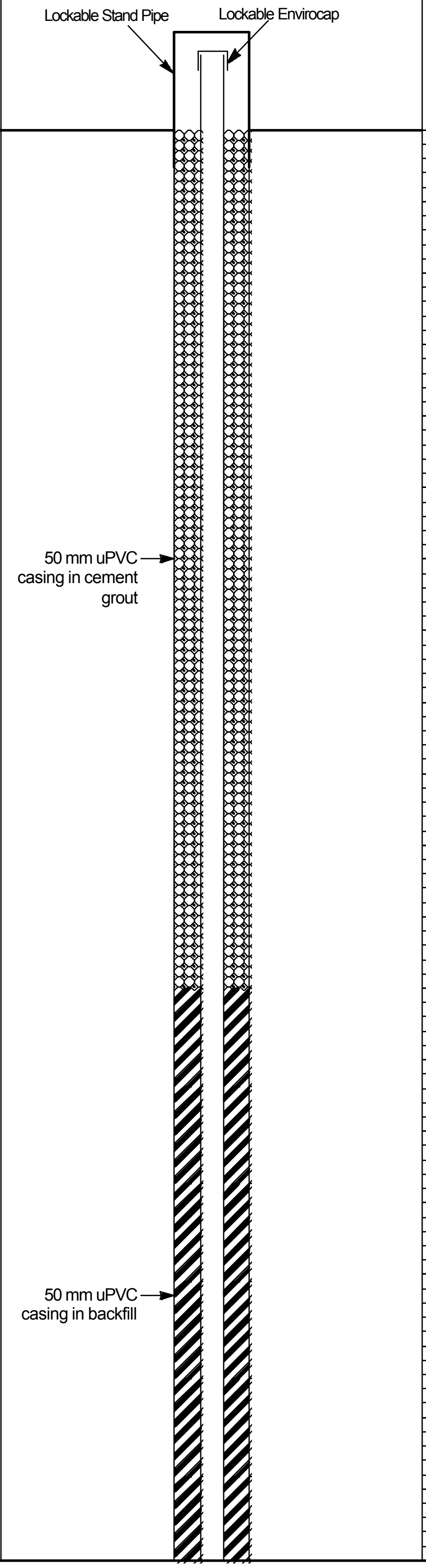
Monitoring Well FVGW-03-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **MR** Checked By: **AW** Date Started: **11-9-08** Date Finished: **12-9-08**	Relative Level: mAHD Coordinates: 692904 mE 7152669 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0		CLAYEY SAND: dark grey-brown, fine to medium grained, poorly sorted, clay is low plasticity, friable. 50% Sa, 30% C, 20% Si. Slightly moist.								
3		SANDY CLAY: dark brown to grey, low plasticity, low strength, friable, sand is fine to medium grained, some occasional cemented inclusions. 40% C, 40 % Sa, 20% Si. Dry to moist Higher clay content. 60% C, 30% Sa, 10% Si. As previous, light brown mottled dark grey-brown, very stiff.						L		
6		CLAYEY SAND: dark yellow brown mottled grey, fine to medium grained with cemented fragments. 60% Sa, 20% C, 20% Si.								
7		SANDY CLAY: dark brown to grey, low to medium plasticity, stiff, sand is fine grained. 60% C, 30% Sa, 10% Si.						L-M		
8		GRAVELLY SAND: pale brown to pink, sand is fine to medium grained, very poorly sorted, gravel is medium to coarse grained (to 50mm), sub-rounded.			F-C	SR	P			
9		SANDSTONE: weak to medium strength, yellow-brown, fine to medium, poorly sorted, gravels to 50 mm			F-M		P		D/M	

REMARKS:

URS Australia Pty Ltd

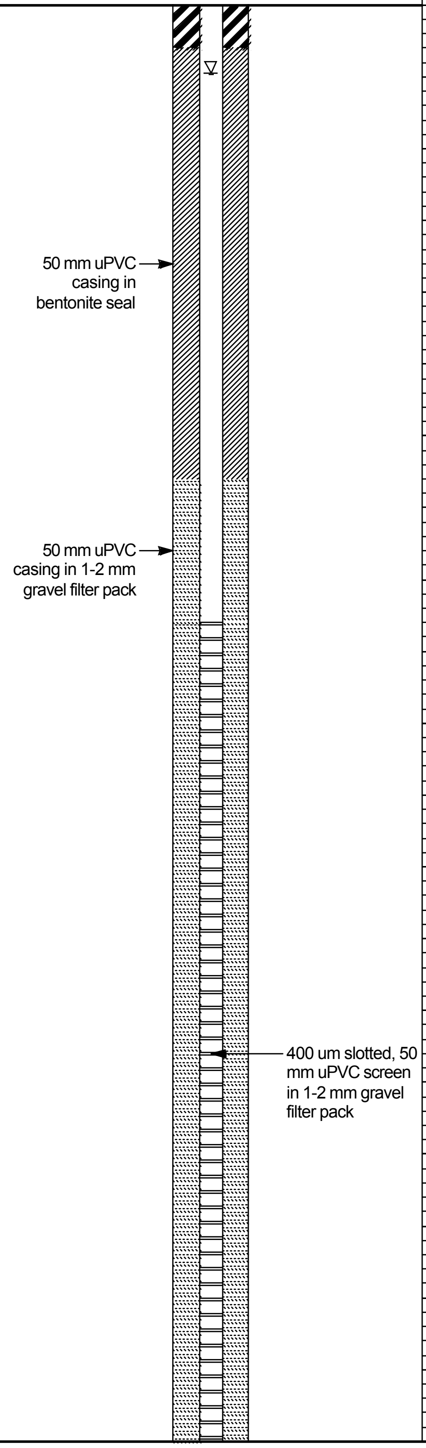
Monitoring Well FVGW-03-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **MR** Checked By: **AW** Date Started: **11-9-08** Date Finished: **12-9-08**	Relative Level: mAHD Coordinates: 692904 mE 7152669 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
10										
11		SANDSTONE (HW): very weak to weak, grey to pale brown, very fine grained, foliated/bedding patterns of bands approximately 1mm thick, moist			VF				M	
12		SANDSTONE (MW-SW): grey to yellow brown, medium grained, well sorted, moist			M				M	
13		SANDSTONE (MW): pale grey, fine to medium grained, well sorted with 20% clay sized aggregations (80 % sandstone, 20% clay), moist			M				M	
14		GRAVELLY CLAY: Grey, mottled, yellow-brown and white, gravel is medium to coarse, angular, comprising weathered sandstone, moist to wet			M-C				M-W	
15		SANDSTONE (CW-HW): grey, very weak, fine to medium, with clay content forming matrix (30%), very wet from > 15 mbgl			F-M				VW	
16										
17										
18										
19										

REMARKS:

Sheet 3 of 3

URS Australia Pty Ltd

Monitoring Well FVGW-03-08

URS Australia Pty. Ltd.
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Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **11-9-08**
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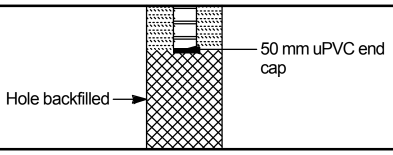
Relative Level: mAHD
Coordinates: 692904 mE
7152669 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				20	▨									
				21		EOH @ 21 mbgl								
				22										
				23										
				24										
				25										
				26										
				27										
				28										
				29										

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-03-08A

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Level 14, 240 Queen Street, Brisbane QLD 4000
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Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

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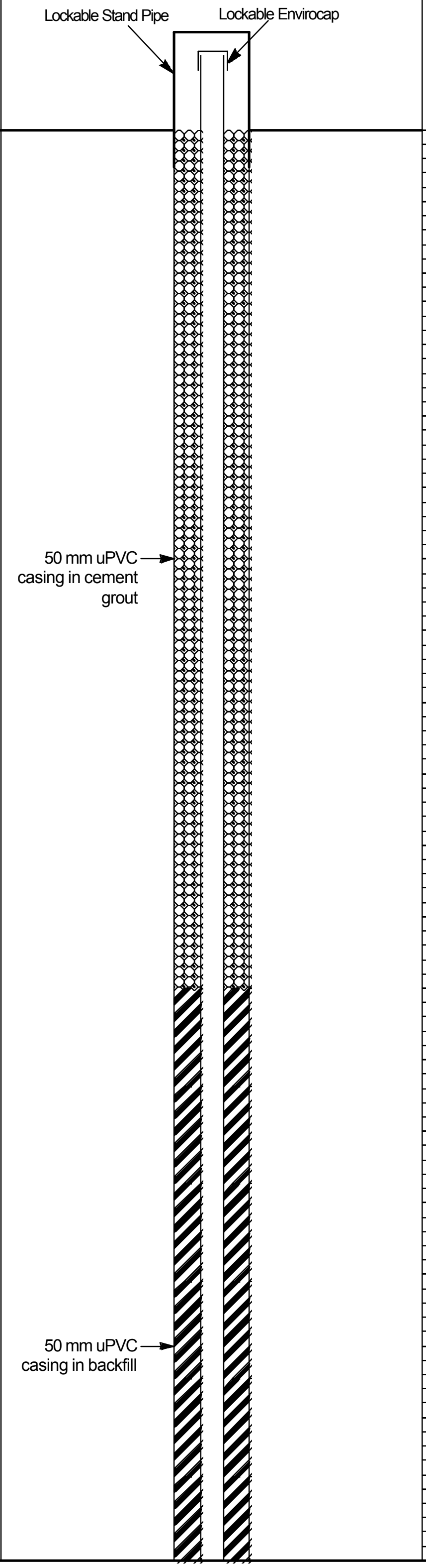
Relative Level: mAHD
Coordinates: 692904 mE
7152665 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | Sample Type | Sampling and Observations | PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0	SILTY SAND with CLAY: dark grey-brown, fine to medium grained, poorly sorted, clay is low plasticity, friable. ~50% Sa, 30% Si, 20% C.			F-M					
2	As previous, slightly higher clay content. "Organic" appearance. Fresh and decayed organic matter evident throughout. 50% Sa, 30% C, 20% Si.								
3	SANDY CLAY: dark brown to black, low plasticity, friable, sticky, with fine to medium grained sand. 50% C, 40% Sa, 10% Si. Becoming moist. Clay content increasing from 4 mBGL.						L		
5	Becoming lighter in colour and more stiff. Slight moisture evident.								
6	CLAYEY SAND: dark yellow-brown, fine to medium grained. 60% Sa, 20% C, 20% Si. Moist								
7	SANDY CLAY: Brown with minor grey mottles, low plasticity, sand is fine grained. 50% C, 30% Sa, 20% Si. Moist.						L		
8	CLAYEY SAND with GRAVEL: brown to pale brown, fine to medium grained, poorly sorted, gravel is fine to coarse grained (to 5mm), sub-angular comprising sandstone aggregates. 50% Sa, 30% C, 20% gravels. Dry to moist			F-C	SA	P			
9	SANDSTONE (MW-HW): Pink to brown, variable			VF					

REMARKS:

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Relative Level: mAHD
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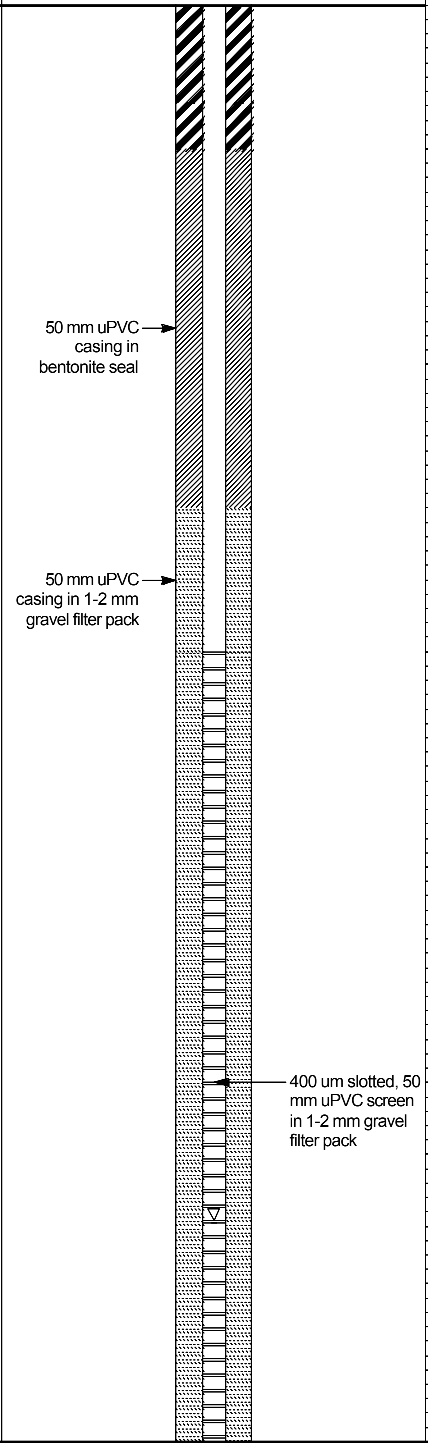
7152665 mN
Permit No:

Client: **Santos Ltd**

WELL CONSTRUCTION DETAILS



SAMPLING DETAILS / **DESCRIPTION OF STRATA**

Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			10	∷	strength, quartzose, very fine grained. As previous, slightly darker in colour, possibly more weathered, with more clay sized particles present. As previous, with angular medium grained gravels. Still significant clay.								
			12	× ×	SILTSTONE (MW-HW): grey/dark grey/brown banding (~1mm; frequent), weak to medium strength, very fine grained, dry to moist.								
			14	∷	SANDSTONE (MW-SW): fine to medium grained, well sorted, minor clay content (~10%), moist.			F-M		W		M	
			15	× ×	SILTSTONE (MW): As per 12 mBGL, dry to moist.								
			16	× ×	Becoming more moist								
			17	∷	SANDSTONE (MW): fine to medium grained, poorly sorted, with ~15% clay. Moist.			F-M				M	
			18	∷									
			19	∷									

REMARKS:

Sheet 3 of 3

URS Australia Pty Ltd

Monitoring Well FVGW-03-08A

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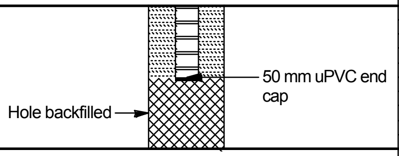
Checked By: **AW**
Date Started: **12-9-08**
Date Finished: **12-9-08**

Relative Level: mAHD
Coordinates: 692904 mE
7152665 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**



Sample Type	Sampling and Observations	PID (ppm)	Well Construction Details	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				20	▨									
				21		EOH @ 21.0 mBGL (1110; 12/9/08)								
				22										
				23										
				24										
				25										
				26										
				27										
				28										
				29										

REMARKS:

Sheet 1 of 7

URS Australia Pty Ltd

Monitoring Well FVGW-04-08

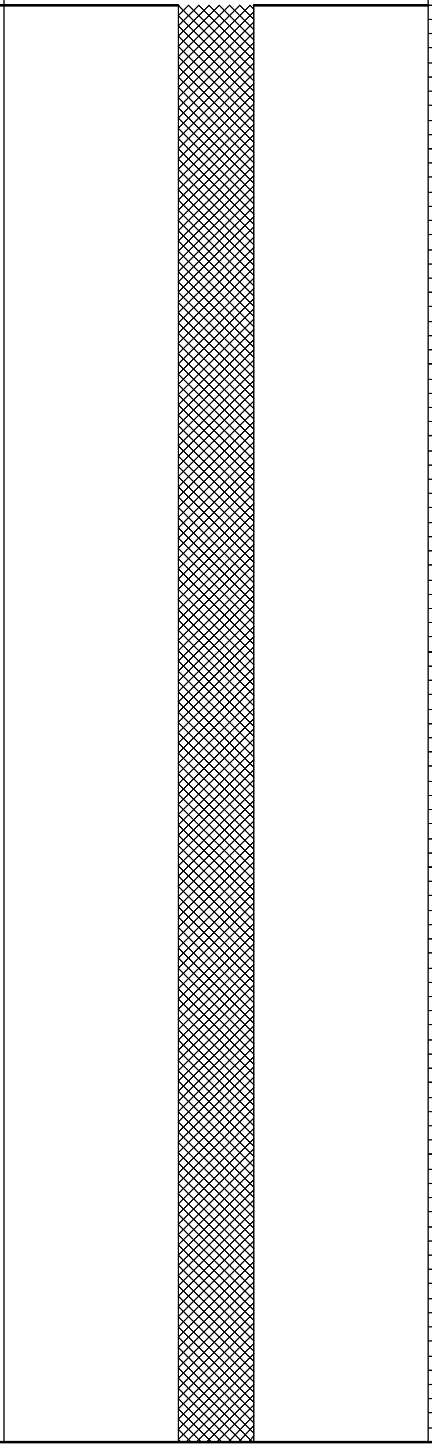
URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.:	**42626229**
Project Reference:	**GLNG Gas Field EIS**
Drilling Contractor:	**TerraTest**
Drilling Method:	**Rotary Air Boring**
Logged By:	**MR**
Checked By:	**AW**
Date Started:	**9-9-08**
Date Finished:	**9-9-08**
Relative Level:	mAHD
Coordinates:	696461 mE 7165645 mN
Permit No:	
Client:	**Santos Ltd**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0	▨	CLAY: dark red-brown, low plasticity, soft with occasional pale brown to white friable aggregatres, dry Weathered sandstone/sand aggregates from 0.9m						L		
2		MUDSTONE: extremely weathered, very weak, brittle, dark green-brown, very fine grained, poorly graded. Paler in colour Pale brown to grey								
5		SANDSTONE: highly weathered, weak, slightly brittle, grey mottled yellow brown, equigranular, very fine grained, dry Brown with grey and green-brown mottles, occasional soft clay-rich black inclusions, fine grained. Dark brown and dark grey with fine black inclusions (organic).			VF				D	

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-04-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **9-9-08**
Date Finished: **9-9-08**

Relative Level: mAHD
Coordinates: 696461 mE
7165645 mN

Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				10										
				11		Finer grained, grading to siltstone.								
				12		SILTSTONE: weak to medium strength, grey and white, very fine grained with trace fine grained sand.								
				13										
				14		Occasional cemented fine grained sandstone fragments in matrix								
				15		SANDSTONE: highly weathered, weak, grey to yellow brown, fine grained, quartzose, well sorted.			F		W			
				16		Dark brown and grey.								
				17										
				18		Extremely weathered, no consolidated aggregates present.								
				19										

REMARKS:

Sheet 3 of 7

URS Australia Pty Ltd

Monitoring Well FVGW-04-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

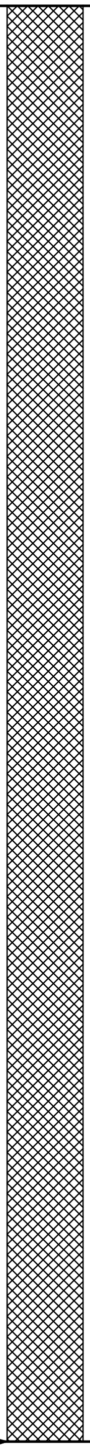
Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **9-9-08**
Date Finished: **9-9-08**

Relative Level: mAHD
Coordinates: 696461 mE
7165645 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			20										
			21										
			22		As previous, present as SILTY SAND, grey brown, very fine grained, poorly graded, dry.								
			23		Some brittle cemented sandstone aggregates, grey to grey-brown, dry.								
			24		Quartz crystals evident in matrix, white to grey brown, very fine grained.								
			25										
			26		SILTSTONE: highly weathered, white to grey, very fine grained, poorly graded, some weakly cemented aggregates, dry.								
			27										
			28		Very little cemented fragments (<5%). Cuttings are powdery silty sand, white to grey.								
			29		Minor yellow-brown fine sands.								

REMARKS:

Sheet 4 of 7

URS Australia Pty Ltd

Monitoring Well FVGW-04-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **MR** Checked By: **AW** Date Started: **9-9-08** Date Finished: **9-9-08**	Relative Level: mAHD Coordinates: 696461 mE 7165645 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			Grout to surface	30	× ×									
				31	× ×	As previous, becoming more sandy (~40% fg sand)								
				32	∷	SANDSTONE: slightly to moderately weathered, weak with some strong aggregates, brown to grey black with black micaceous minerals (biotite) present as fg phenocrysts. Highly weathered, grey-brown, more silt in matrix.								
				33	∷									
				34	∷									
				35	∷									
				36	∷	Dark grey brown, banding/foliated structure evident. Very weak								
				37	∷	Pale yellow to white, very fine grained.								
				38	∷									
				39	∷	Fresh to slightly weathered, very fine grained, quartzose, dry.								

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-04-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **9-9-08**
Date Finished: **9-9-08**

Relative Level: mAHD
Coordinates: 696461 mE
7165645 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				40										
				41		Fresh, becoming pale yellow brown, fine to coarse grained (to 5mm), sub-rounded, dry.								
				42										
				43		Less coarse grains, micas present as medium grains. Predominantly fine grained matrix.								
				44										
				45										
				46										
				47										
				48										
				49										

REMARKS:

Sheet 6 of 7

URS Australia Pty Ltd

Monitoring Well FVGW-04-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
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Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **9-9-08**
Date Finished: **9-9-08**

Relative Level: mAHD
Coordinates: 696461 mE
7165645 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				50		As previous, very fine to medium grained, white to pale yellow, poorly sorted, dry.								
				51										
				52		Medium grained quartz grains to 3mm.								
				53										
				54		Slightly darker in colour, less mg sand.								
				55		Pale grey with trace medium grained sand.								
				56										
				57										
				58		Fine grained and well sorted.								
				59		Very thin lens of grey-blue silty clay at 59.2m. Dry.								

REMARKS:

Sheet 7 of 7

URS Australia Pty Ltd

Monitoring Well FVGW-04-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **MR** Checked By: **AW** Date Started: **9-9-08** Date Finished: **9-9-08**	Relative Level: mAHD Coordinates: 696461 mE 7165645 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				60		EOH @ 60 mBGL (1720; 9/9/08). No water intercepted, no well installed.								
				61										
				62										
				63										
				64										
				65										
				66										
				67										
				68										
				69										

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-05-08

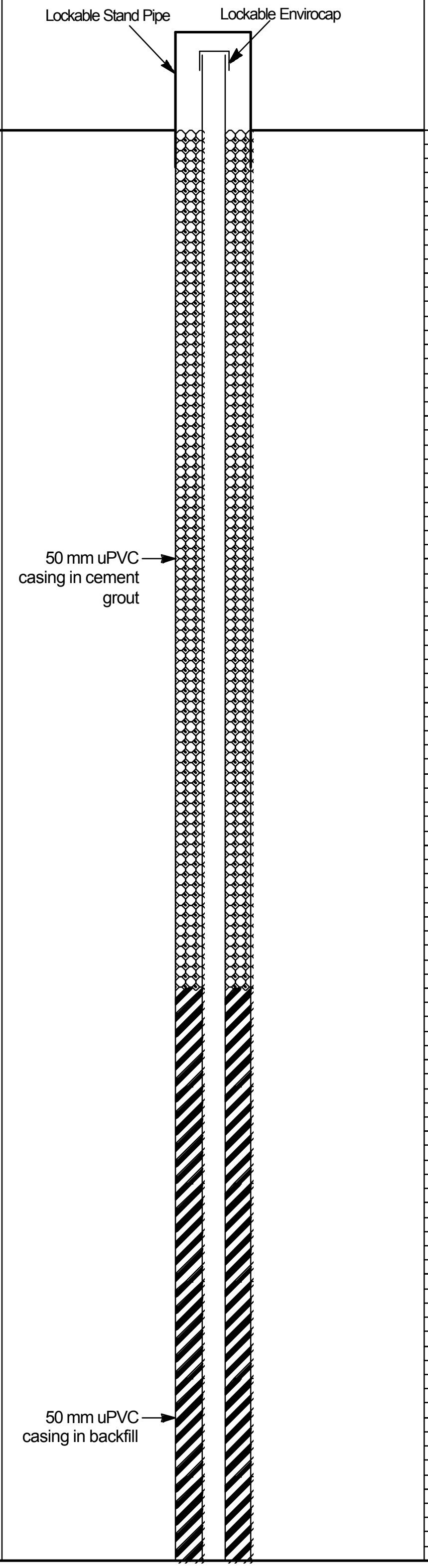
URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**		Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Method: **Rotary Air Boring**	Logged By: **MR** Checked By: **AW** Date Started: **10-9-08** Date Finished: **11-9-08**	Relative Level: mAHD Coordinates: 680714 mE 7167236 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0	▨	CLAY: green-brown mottled red-brown, medium plasticity, trace fine grained sand.						M		
1		MUDSTONE (EW): brown mottled red-brown in fine, frequent bands (1mm), weak, very fine grained, equigranular.								
2		As previous, with grey-green and pale yellow-brown bands.								
3		As previous, higher sand content (~40%), very fine grained.								
4		MUDSTONE (MW-HW): light grey to pale brown, medium strength, very fine grained with trace fine grained sand.								
5		As previous, more highly weathered, predominantly grey-brown, very fine grained.								
6		As previous, grey brown with minor red brown mottles, still has frequent fine banded structure (~1mm).								
7		As previous, grey brown to brown, slightly moist								
8										
9	× ×	SILTSTONE (EW-HW): light grey to grey, very weak, very fine grained, dry.								

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-05-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

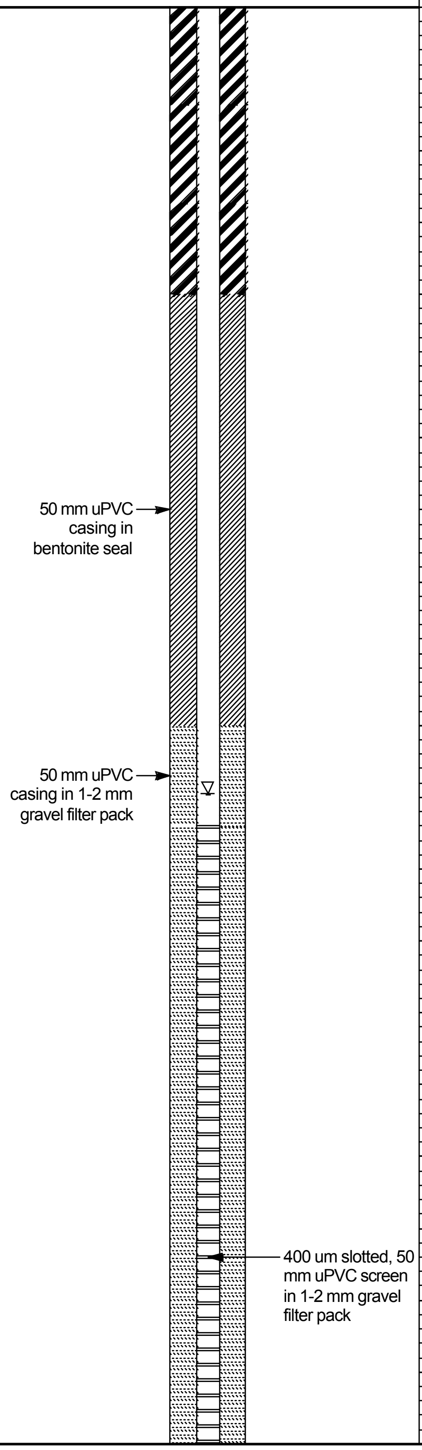
Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **10-9-08**
Date Finished: **11-9-08**

Relative Level: mAHD
Coordinates: 680714 mE
7167236 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS
Sample Type	Sampling and Observations	PID (ppm)	
			

DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
10		As previous, frequent very thin banded structure (~1mm).								
12		As previous, slightly darker in colour. Trace very fine grained sand (~10%).								
13		As previous, some very fine dark red-brown bands. Very weak.								
14		SILTSTONE (HW-MW): dark grey to brown, weak to medium strength, with trace fine grained sand.								
15		As previous, dark grey, moderately to slightly weathered.								
16		As previous, increasing sand content (~25%), slightly moist.								
17		SANDSTONE (SW): grey to pale grey, sand is medium grained, very well sorted, rounded. Moist			M	R	VW		M	
18		SILTSTONE (EW-HW): grey-brown, very weak, with very fine bands (~1mm; frequent), slightly moist, with minor fine grained sand (~10%).								
19		As previous, less moisture								

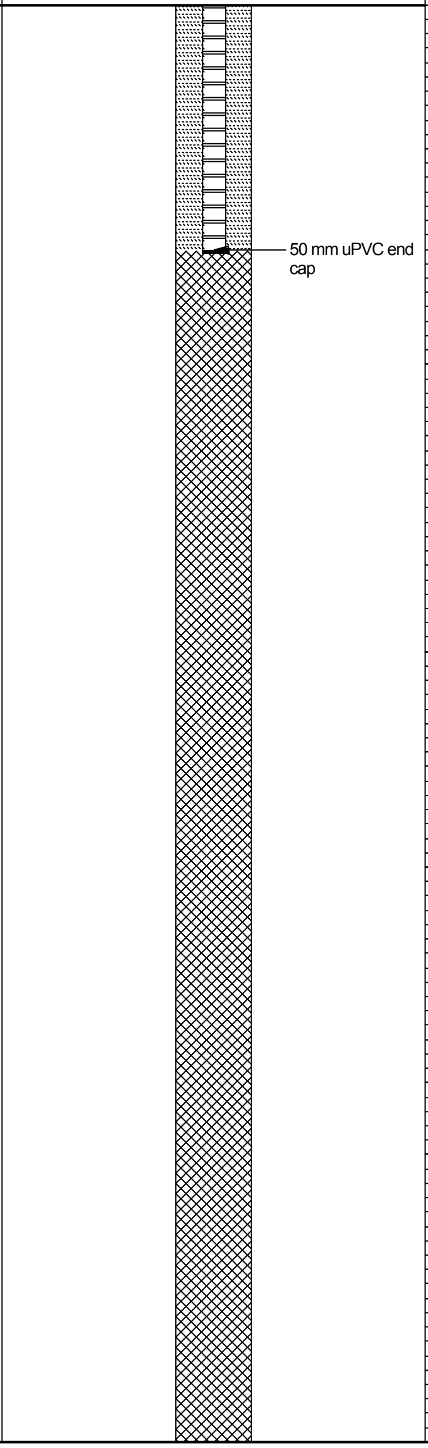
REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-05-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **MR** Checked By: **AW** Date Started: **10-9-08** Date Finished: **11-9-08**	Relative Level: mAHD Coordinates: 680714 mE 7167236 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			20	× ×	As previous, weak, pale grey, trace very fine grained sand (<10%), dry to moist.								
			21	× ×									
			22	× ×	As previous, less sand (<5%).								
			23	× ×	As previous, paler grey, with minor hard bands, still highly weathered.								
			24	× ×									
			25	× ×	As previous, slightly darker, almost grey-brown.								
			26	× ×									
			27	× ×	As previous, pale grey, with ~5% sand.								
			28	× ×	As previous, minor hard bands (unbreakable by hand), est. ~20mm thick.								
			29	× ×									

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-05-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **10-9-08**
Date Finished: **11-9-08**

Relative Level: mAHD
Coordinates: 680714 mE
7167236 mN
Permit No:

Client: **Santos Ltd**

Sample Type	Sampling and Observations	PID (ppm)	Well Construction Details	Depth (m)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				30	SANDSTONE (HW): grey brown, weak with medium strength bands (fine), very fine grained.			VF					
			Hole backfilled										
				31									
				32	As previous, pale grey, minor highly cemented clasts, slightly moist.								
				33	Lighter in colour.								
				34	Becoming very fine grained below 34 m.								
				35	Very fine grained with some minor medium grained sand. No cemented aggregates.								
				36	As previous, slightly darker in colour.								
				37	SANDSTONE/SILTSTONE: very well sorted, loose no cementations, very fine grained sand to silt. Dry.			VF				D	
				38									
				39									

REMARKS:

Sheet 5 of 5

URS Australia Pty Ltd

Monitoring Well FVGW-05-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **MR** Checked By: **AW** Date Started: **10-9-08** Date Finished: **11-9-08**	Relative Level: mAHD Coordinates: 680714 mE 7167236 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				40		EOH @ 40.0 mBGL (1700; 10/9/08)								
				41										
				42										
				43										
				44										
				45										
				46										
				47										
				48										
				49										

REMARKS:

Sheet 1 of 5

URS Australia Pty Ltd

Monitoring Well FVGW-06-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

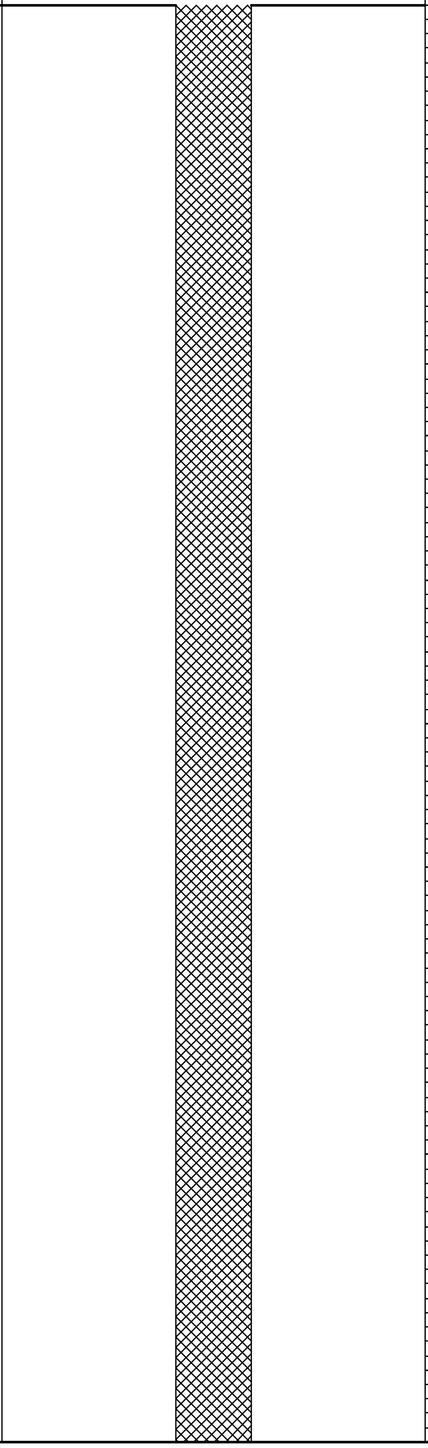
Logged By: **MR**
Checked By: **AW**
Date Started: **16-9-08**
Date Finished: **17-9-08**

Relative Level: mAHD
Coordinates: 688047 mE
7164826 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS — Sample Type | Sampling and Observations | PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0	▨	CLAY: dark grey-brown, medium to high plasticity, stiff, trace fine grained white sand, dry to moist. As previous, dark brown mottled grey, low to medium plasticity, higher sand content (~10%).						M-H	D-M	
2	▧	SILTY CLAY: grey-brown mottled dark brown, medium plasticity, friable, banded structure (fine), 60% Cl, 25% Si, 15% fine sand. Grey brown with yellow-brown bands (~2mm). Predominantly dark grey, waxy, high plasticity, higher clay content, ~80% Cl, 15% Si, 5% Sa.						M		
6	▨	CLAY: dark grey, high plasticity, waxy, stiff, trace silt (~5%).						H		
7	▧	SILTY CLAY: grey brown to yellow brown, medium plasticity, stiff, trace fine grained sand, 75% Cl, 20% Si, 5% fine sand. As previous, higher plasticity, higher clay content (~85%).						M		
9	× ×	SILTSTONE: weak, moderately to highly weathered, cream to yellow-brown (possibly banded), ~20% very fine grained sand.								

REMARKS:

Sheet 2 of 5

URS Australia Pty Ltd

Monitoring Well FVGW-06-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
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Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

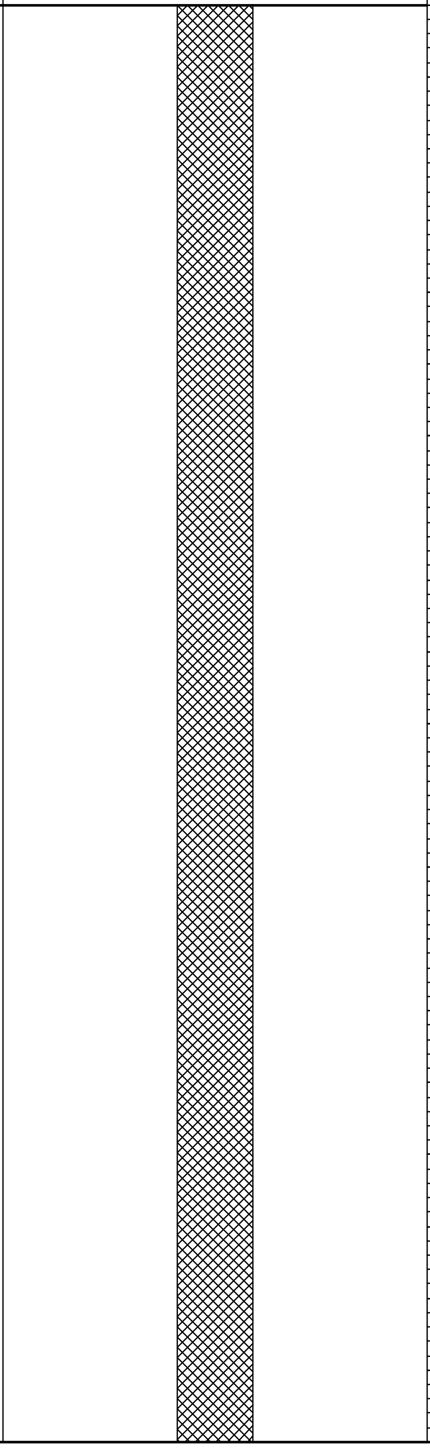
Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **16-9-08**
Date Finished: **17-9-08**

Relative Level: mAHD
Coordinates: 688047 mE
7164826 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				10	× ×	Very weak, soft, very little structure.								
				11	× ×	Slightly harder, grey and brown banding.								
				12	× ×	Soft, grey with yellow brown clay rich bands.								
				13	× ×									
				14	× ×	Prominent clay-rich bands.								
				15	× ×	SILTSTONE/CLAYSTONE: weak, grey to dark grey, very fine grained, well structured, slightly moist.								
				16	× ×									
				17	× ×	Dark grey, firm to stiff, weak, dry.								
				18	× ×									
				19	× ×	Very weak, trace fine grained sand.								



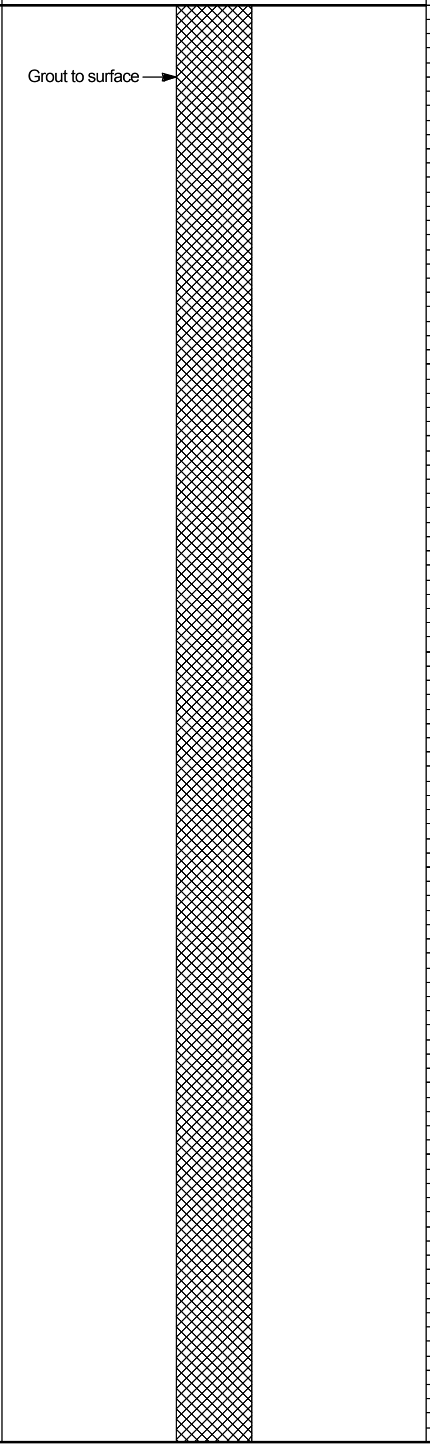
REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-06-08

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **MR** Checked By: **AW** Date Started: **16-9-08** Date Finished: **17-9-08**	Relative Level: mAHD Coordinates: 688047 mE 7164826 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			20	× ×									
			21	× ×	Increased sand content (~15%). Dry.								
			22	× ×	SILTSTONE: weak, blue-grey with dark grey band (~200-300mm), ~40% fine grained siliceous sand, brittle, dry.								
			23	× ×									
			24	× ×	Darter in colour, less sand (~15%).								
			25	⁙	SANDSTONE: pale to dark grey (mottled), medium strength, very brittle, poorly sorted, predominantly fine grained, ~30% medium grained sand, minor silt.			F-M					
			26	× ×	SILTSTONE: Very weak, grey and brown intermixed, minor fine grained sand (~15%), dry.								
			27	× ×	Trace fine to medium grained sandstone aggregates, grey to dk grey, medium strength.								
			28	× ×									
			29	× ×									

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-06-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

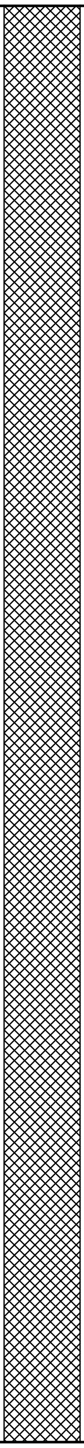
Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **16-9-08**
Date Finished: **17-9-08**

Relative Level: mAHD
Coordinates: 688047 mE
7164826 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				30	× ×	Pale grey, weak to medium strength, banded (fine, frequent), minor fine grained sand (~15%).								
				32	∷	SANDSTONE: weak, grey-blue with grey-brown mottles, brittle, bimodal (very fine grained and fine to medium grained sand) prominent, quartzose, dry.			VF-M					
				36		As previous, mainly very fine grained, almost silt-sized grains.								
				38		Grey-blue, medium strength, bimodal, fine to medium grained and very fine grained, rough texture, 60% fg-mg sand, 40% vfg sand to silt.								



Depth (m): 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

REMARKS:

URS Australia Pty Ltd

Monitoring Well FVGW-06-08

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

Logged By: **MR**
Checked By: **AW**
Date Started: **16-9-08**
Date Finished: **17-9-08**

Relative Level: mAHD
Coordinates: 688047 mE
7164826 mN

Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			▨	40	░									
				41		EOH @ 41mBGL (0751, 17/9/08). No water intercepted. No well installed.								
				42										
				43										
				44										
				45										
				46										
				47										
				48										
				49										

REMARKS:

Sheet 1 of 7

URS Australia Pty Ltd

Monitoring Well RM01

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

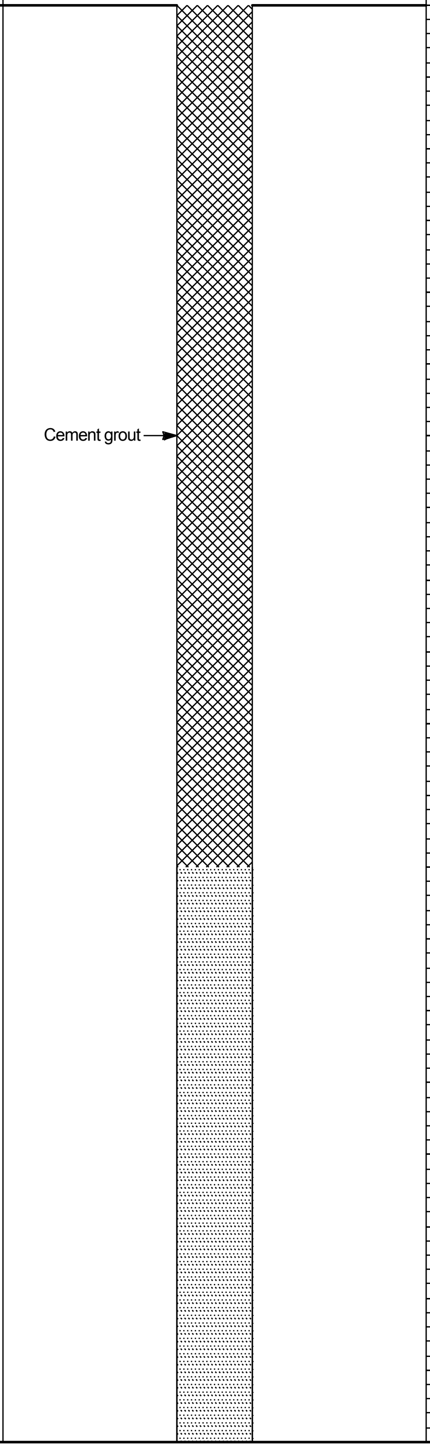
Logged By: **AW**
Checked By: **AW**
Date Started: **2-9-08**
Date Finished: **2-9-08**

Relative Level: mAHD
Coordinates: 716862 mE
7045428 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**

Sample Type | Sampling and Observations | PID (ppm)



Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0	▨	CLAY: light brown, silty, low plasticity, stiff, slightly moist						L	SM	
1	⁚	MUDSTONE: extreemely to highly weathered, light brown, dark yellow, slightly moist							SM	
3	⁚	MUDSTONE: highly weathered, light brown, light grey, dry							D	
4	⁚	MUDSTONE: highly weathered, light grey, light brown, dry							D	
6	⁚	MUDSTONE: highly weathered, dark grey, light brown, dry							D	
7	⁚	MUDSTONE: highly weathered, light brown, dark yellow, dry							D	
8	⁚	MUDSTONE: extreemely to highly weathered, light grey, light brown, slightly moist							SM	
9	⁚	MUDSTONE: highly weathered, light brown, dry							D	

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM01

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **AW** Checked By: **AW** Date Started: **2-9-08** Date Finished: **2-9-08**	Relative Level: mAHD Coordinates: 716862 mE 7045428 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				10	× ×	SILTSTONE: slightly weathered, brown, white, dry							D	
				11	× ×	SILTSTONE: light grey, white, dry							D	
				12	= =	MUDSTONE: extreemely to highly weathered, light brown, dark yellow, dry							D	
				13	× ×	SILTSTONE: highly weathered, light grey, brown, dry							D	
				14	= =	MUDSTONE: extreemely to highly weathered, brown, slightly moist							SM	
				15	× ×	SILTSTONE: highly weathered, brown, dry							D	
				16										
				17	× ×	SILTSTONE: moderately weathered, light brown, dry							D	
				18	× ×	SILTSTONE: moderately weathered, light grey, dry							D	
					= =	MUDSTONE: extreemely to highly weathered, dark grey, slightly moist							SM	
				19										

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM01

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **2-9-08**
Date Finished: **2-9-08**

Relative Level: mAHD
Coordinates: 716862 mE
7045428 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				20		MUDSTONE: dark grey, more firm at 37-38 m, possible small fracture at 41.2 m as rods dropped, dry							D	
				21										
				22										
				23										
				24										
				25										
				26										
				27										
				28										
				29										

REMARKS:

Sheet 4 of 7

URS Australia Pty Ltd

Monitoring Well RM01

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

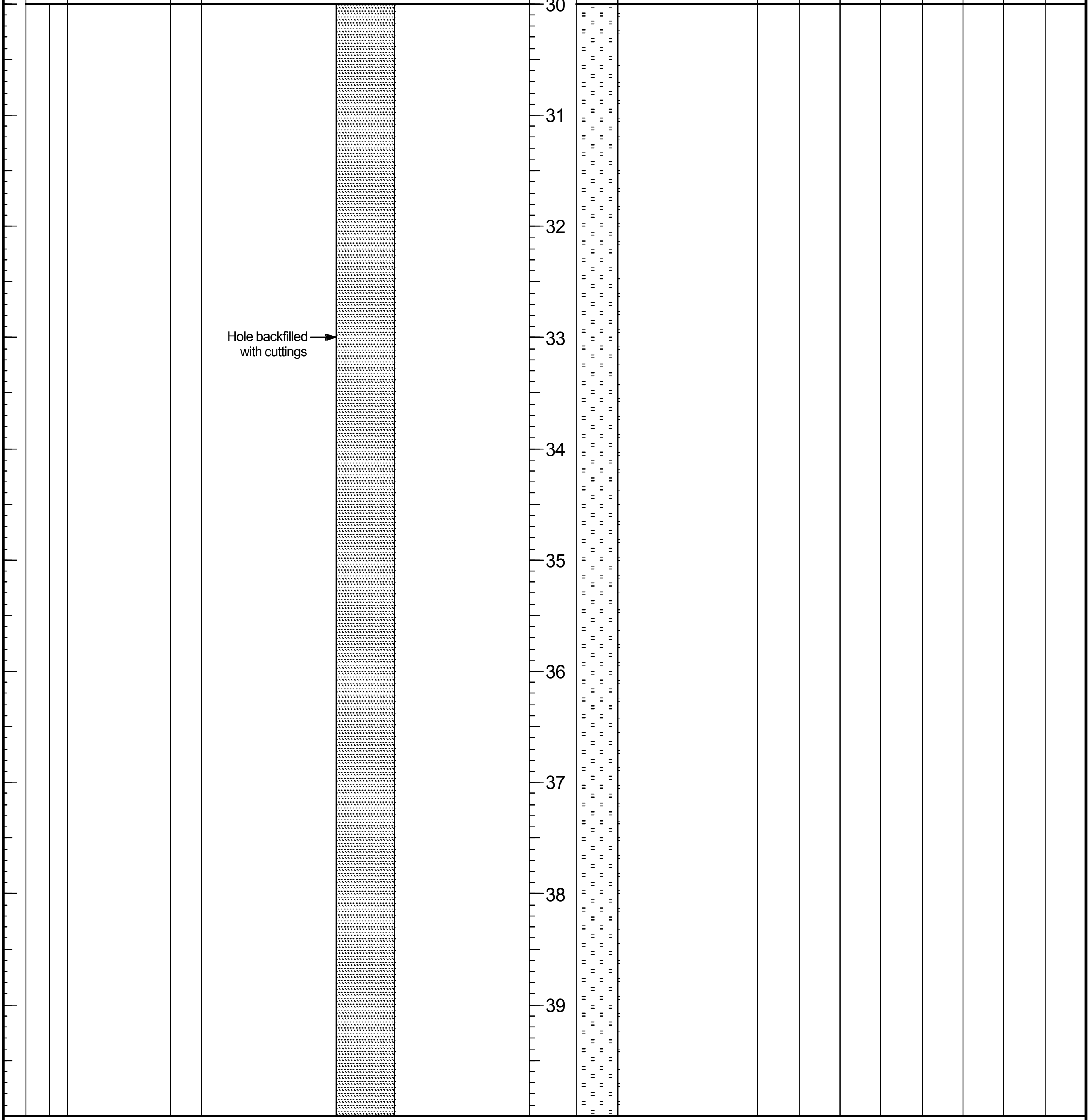
Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **2-9-08**
Date Finished: **2-9-08**

Relative Level: mAHD
Coordinates: 716862 mE
7045428 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification



REMARKS:

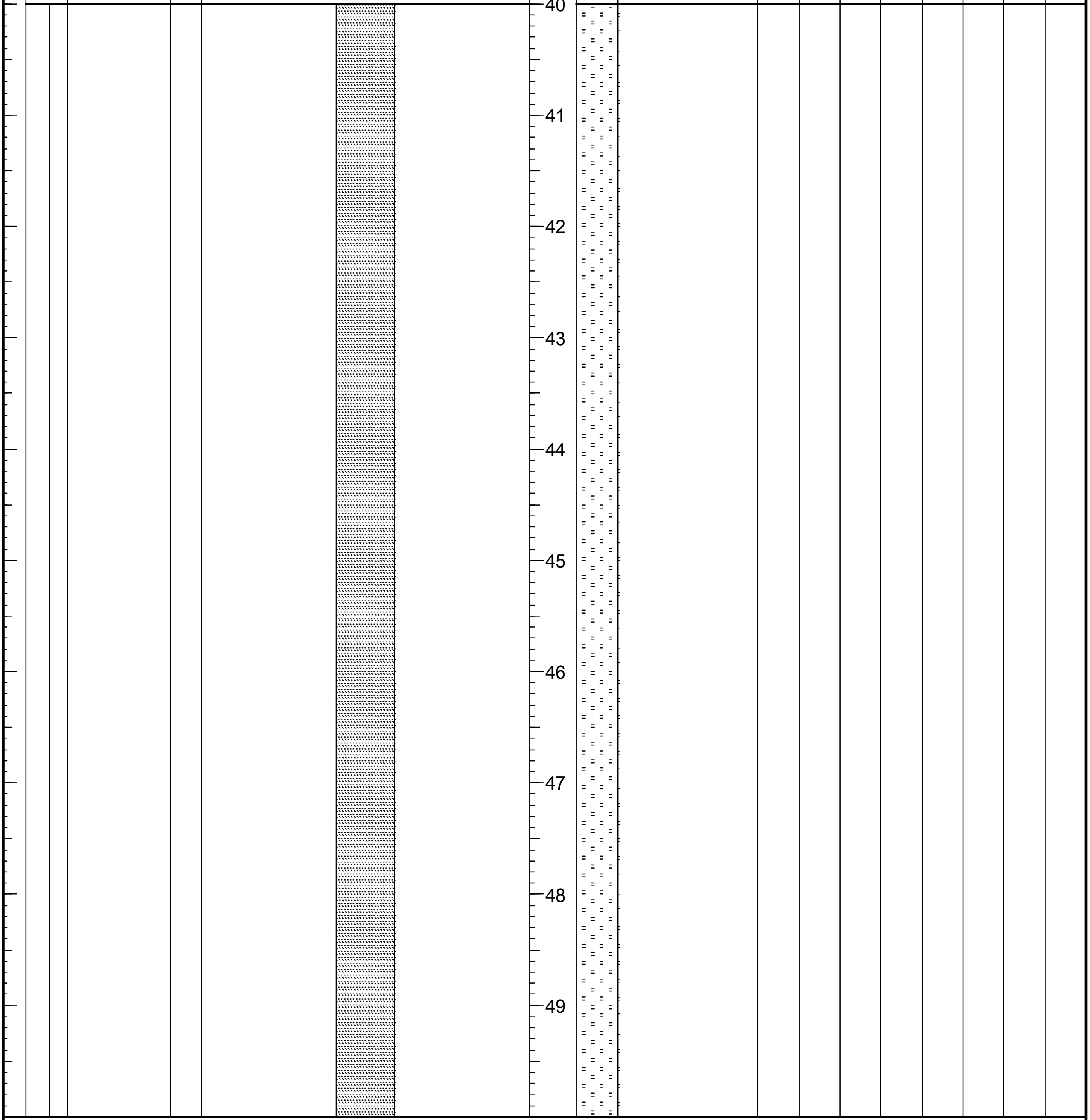
URS Australia Pty Ltd

Monitoring Well RM01

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**		Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Method: **Rotary Air Boring**	Logged By: **AW** Checked By: **AW** Date Started: **2-9-08** Date Finished: **2-9-08**	Relative Level: mAHD Coordinates: 716862 mE 7045428 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification



REMARKS:

URS Australia Pty Ltd

Monitoring Well RM01

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **2-9-08**
Date Finished: **2-9-08**

Relative Level: mAHD
Coordinates: 716862 mE
7045428 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				50										
				51										
				52										
				53										
				54										
				55										
				56		MUDSTONE: light grey, dry							D	
				57		MUDSTONE: dark grey, dry							D	
				58										
				59										

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM01

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **AW** Checked By: **AW** Date Started: **2-9-08** Date Finished: **2-9-08**	Relative Level: mAHD Coordinates: 716862 mE 7045428 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				60		EOH @ 60 mbgl - no water intersected, no well installed								
				61										
				62										
				63										
				64										
				65										
				66										
				67										
				68										
				69										

REMARKS:

Sheet 1 of 6

URS Australia Pty Ltd

Monitoring Well RM02

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **3-9-08**
Date Finished: **4-9-08**

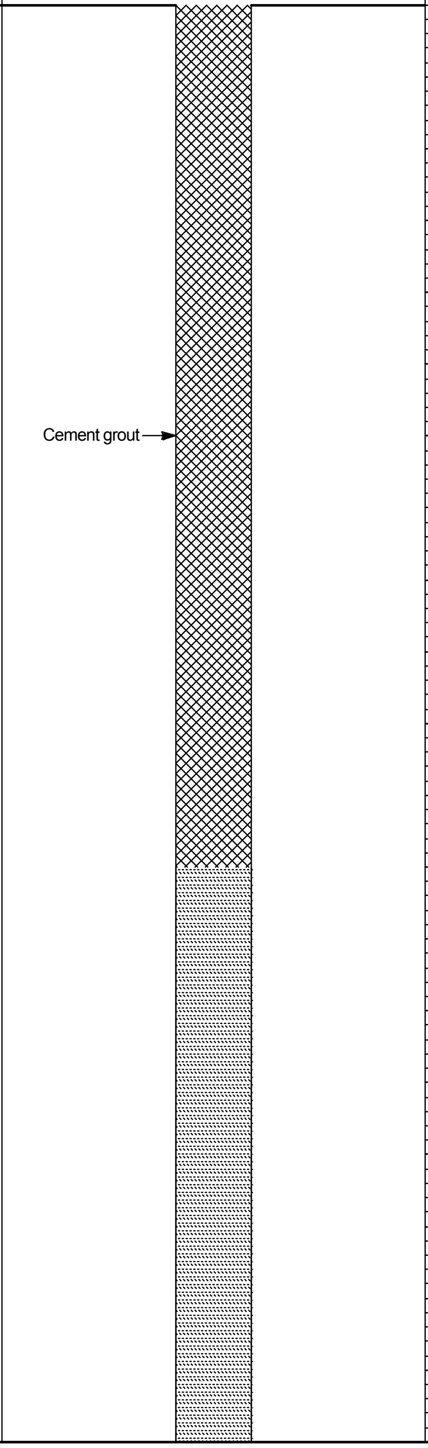
Relative Level: mAHD
Coordinates: 687580 mE
7045052 mN

Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | Sample Type | Sampling and Observations | PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0		MUDSTONE: extreemely weathered, dark yellow, clayey, dry							D	
2		MUDSTONE: extreemely weathered, light grey, dark yellow, dry							D	
3		MUDSTONE: extreemely to highly weathered, grey, dark yellow, dry							D	
6		MUDSTONE: highly weathered, light grey, light brown, dry							D	
8		MUDSTONE: highly weathered, dark grey, light brown							D	

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM02

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **3-9-08**
Date Finished: **4-9-08**

Relative Level: mAHD
Coordinates: 687580 mE
7045052 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				10										
				11		MUDSTONE: highly weathered, dark grey, light brown, with minor chert, dry							D	
				12		MUDSTONE: highly weathered, dark grey, light brown, dry							D	
				13										
				14		MUDSTONE: highly weathered, grey, dry							D	
				15		MUDSTONE: highly weathered, dark grey, light brown, dry							D	
				16		MUDSTONE: highly weathered, grey, light brown, dry							D	
				17		MUDSTONE: moderately weathered, grey, firm, dry							D	
				18										
				19		MUDSTONE: dark grey, dry							D	

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM02

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

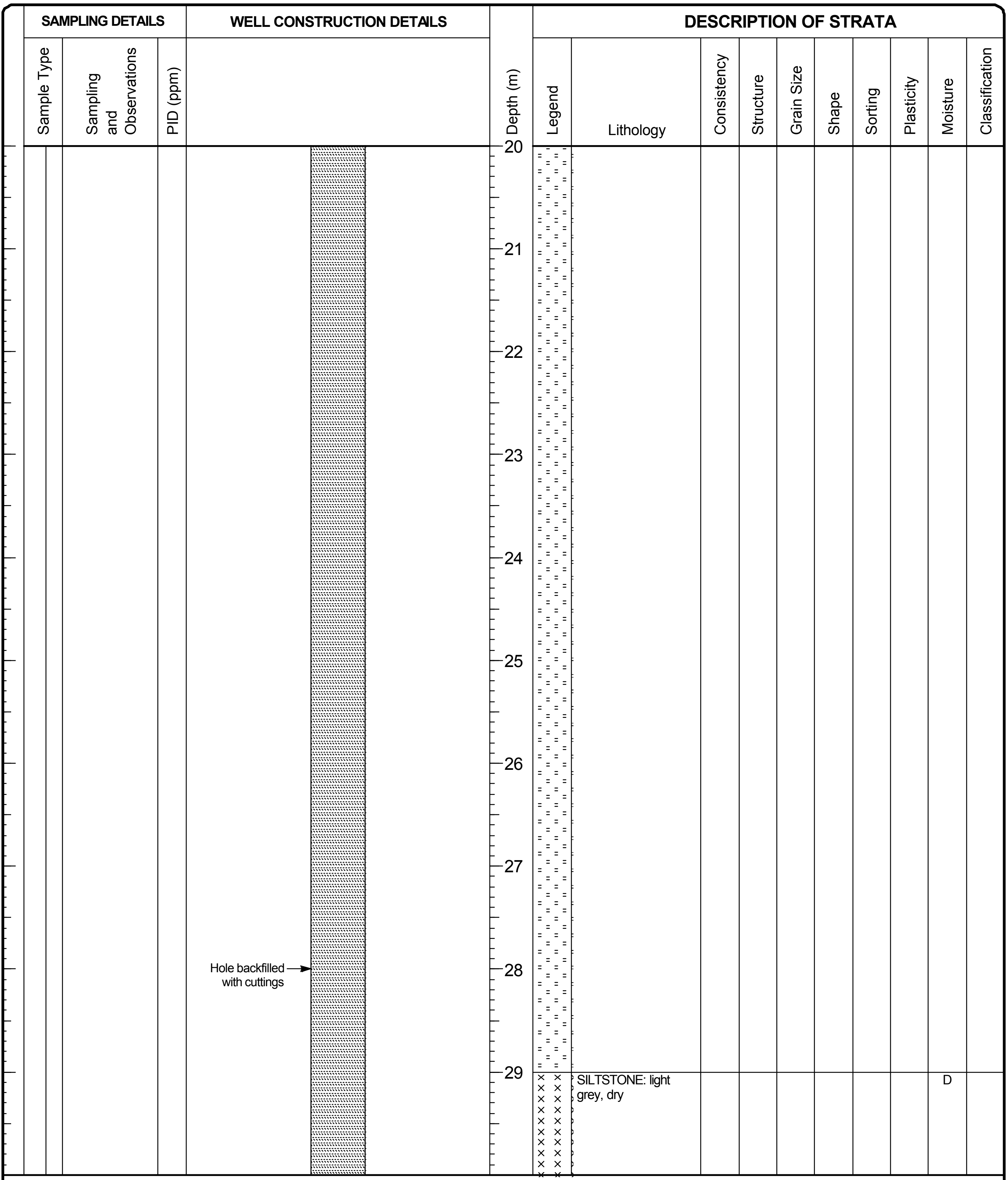
Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **3-9-08**
Date Finished: **4-9-08**

Relative Level: mAHD
Coordinates: 687580 mE
7045052 mN
Permit No:

Client: **Santos Ltd**



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			29	SILTSTONE: light grey, dry							D	

REMARKS:

Sheet 4 of 6

URS Australia Pty Ltd

Monitoring Well RM02

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **3-9-08**
Date Finished: **4-9-08**

Relative Level: mAHD
Coordinates: 687580 mE
7045052 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				30		MUDSTONE: dark grey							D	
				31										
				32										
				33										
				34										
				35										
				36										
				37										
				38										
				39										

REMARKS:

Sheet 5 of 6

URS Australia Pty Ltd

Monitoring Well RM02

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **3-9-08**
Date Finished: **4-9-08**

Relative Level: mAHD
Coordinates: 687580 mE
7045052 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				40										
				41										
				42										
				43										
				44										
				45										
				46										
				47										
				48										
				49										

REMARKS:

Sheet 6 of 6

URS Australia Pty Ltd

Monitoring Well RM02

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **AW** Checked By: **AW** Date Started: **3-9-08** Date Finished: **4-9-08**	Relative Level: mAHD Coordinates: 687580 mE 7045052 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				50		EOH @ 50 mbgl - no water intersected, no well installed								
				51										
				52										
				53										
				54										
				55										
				56										
				57										
				58										
				59										

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM03

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **29-8-08**
Date Finished: **29-8-08**

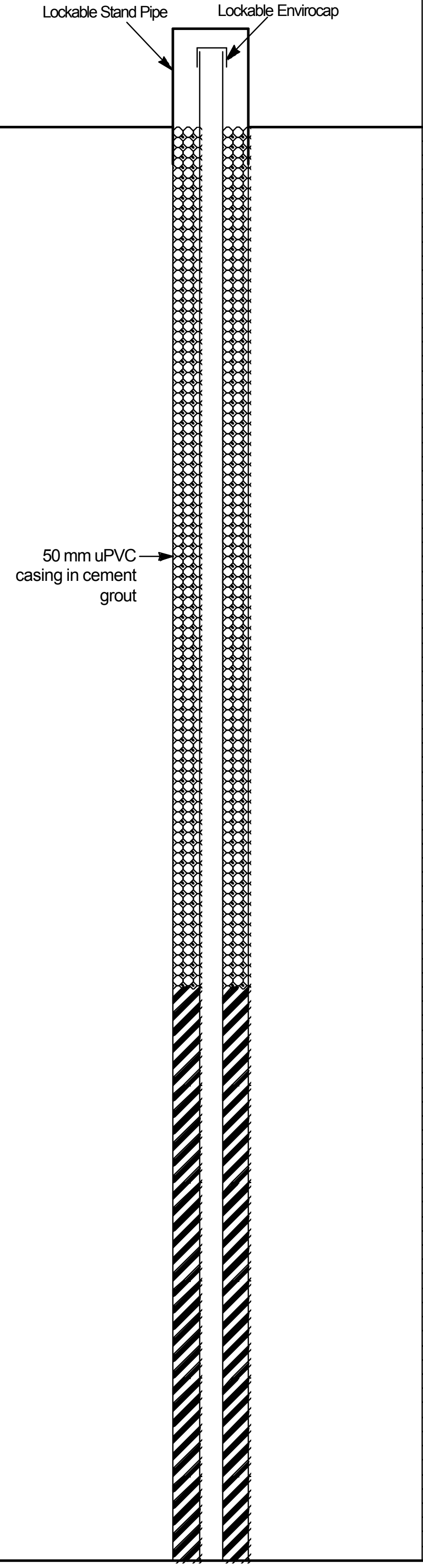
Relative Level: mAHD
Coordinates: 709424 mE
7082756 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0	⁘	SANDSTONE: highly weathered, light brown, dark yellow, clayey, very fine, dry			VF				D	
2	⁘	SANDSTONE: extreemely to highly weathered, brown, clayey, fine, slightly moist			F				SM	
3	⁘	SANDSTONE: extreemely to highly weathered, dark brown, clayey, fine, dry			F				D	
4	⁘	SANDSTONE: extreemely to highly weathered, light brown, clayey, fine to coarse, dry			F-C				D	
5	⁘	SANDSTONE: light brown, medium to coarse with clasts of pink and grey chert, dry			M-C				D	
6	⁘	SANDSTONE: extreemely weathered, light brown, tan, grey, clayey, fine, slightly moist			F				SM	
8	×	SILTSTONE: highly weathered, cream, light brown, dry							D	
9	⁘	SANDSTONE: highly weathered, light brown, tan, fine, slightly moist			F				SM	

REMARKS:

Sheet 2 of 3

URS Australia Pty Ltd

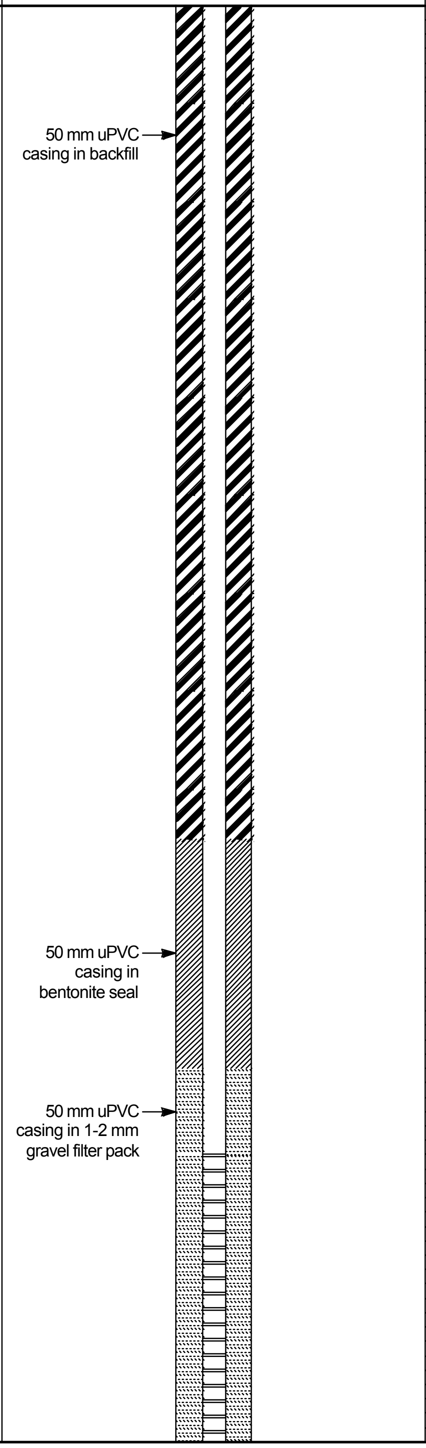
Monitoring Well RM03

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Contractor: **TerraTest**			
Drilling Method: **Rotary Air Boring**	Logged By: **AW** Checked By: **AW** Date Started: **29-8-08** Date Finished: **29-8-08**	Relative Level: mAHD Coordinates: 709424 mE 7082756 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
10	×	SILTSTONE: highly weathered, light brown, light grey							D	
12	⁘	SANDSTONE: light grey, cream, light brown, clean, medium to coarse quartzose, dry			M-C				D	
13	⁘	SNADSTONE: gravelly, light brown, light grey, medium to coarse, sub angular clasts of gravel up to 25 mm, dry, 70% sand, 30% gravel			M-C				D	
14	×	SILTSTONE: highly weathered, light blue, dark grey, dry							D	
15	⁘	SANDSTONE: moderately weathered, light grey, light brown, fine, slightly moist			F				SM	
16	⁘	SANDSTONE: moderately weathered, light brown, dark red, fine, slightly moist			F				SM	
17	⁘	SANDSTONE: moderately weathered, light grey, light blue, fine, dry			F				D	
18	=	MUDSTONE: slightly weathered, light grey, dry							D	
19	×	SILTSTONE: moderately weathered, dark grey, slightly moist							SM	

REMARKS:

Sheet 3 of 3

URS Australia Pty Ltd

Monitoring Well RM03

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

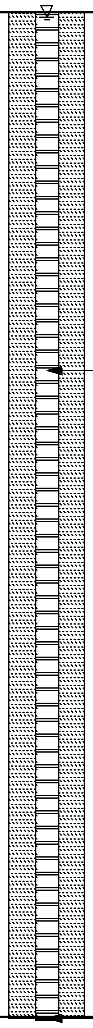
Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **29-8-08**
Date Finished: **29-8-08**

Relative Level: mAHD
Coordinates: 709424 mE
7082756 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**



400 um slotted, 50 mm uPVC screen in 1-2 mm gravel filter pack

50 mm uPVC end cap

Depth (m)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
20	SILTSTONE: moderately weathered, dark grey, very fine sandy, moist							M	
27	EOH @ 27 mbgl								

Depth (m): 20, 21, 22, 23, 24, 25, 26, 27, 28, 29

REMARKS:

URS Australia Pty Ltd

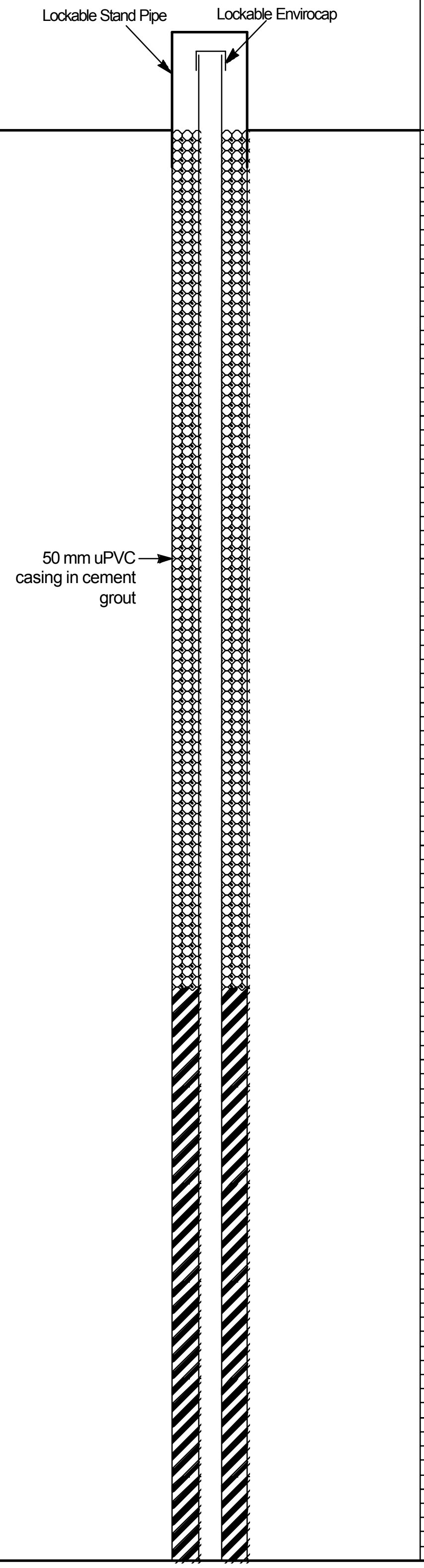
Monitoring Well RM03B

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**		Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Method: **Rotary Air Boring**	Logged By: **AW** Checked By: **AW** Date Started: **30-8-08** Date Finished: **30-8-08**	Relative Level: mAHD Coordinates: mE mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**

Sample Type	Sampling and Observations	PID (ppm)



Depth (m)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0	SANDSTONE: extreemely weathered, dark brown, dark yellow, clayey, fine to medium, dry			F-M				D	
2	SANDSTONE: extreemely weathered, brown, light red, medium, dry			M				D	
3	SANDSTONE: extreemely weathered, light brown, medium, with approximately 30% clay, dry			M				D	
4	SANDSTONE: extreemely weathered, light brown, fine to medium, with approximately 50% clay and minor jasper clasts, dry			F-M				D	
5	SANDSTONE: highly weathered, light brown, medium to coarse, dry			M-C				D	
6	SANDSTONE: highly weathered, light brown, light grey, fine to coarse with minor clasts of ironstone up to 5 mm diameter, clasts of jasper up to 10 mm diameter and clasts of slightly weathered cream volcanics (rhyolite or dacite) up to 25 mm diameter, dry,			M-C				D	
7	MUDSTONE: extreemely to highly weathered, light brown, dark yellow, clayey, slightly moist							SM	
	SILTSTONE: highly weathered, cream, light grey, dry							D	
9	MUDSTONE: highly weathered, light brown, tan, dark yellow, clayey, limonitic?, slightly moist							SM	

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM03B

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **30-8-08**
Date Finished: **30-8-08**

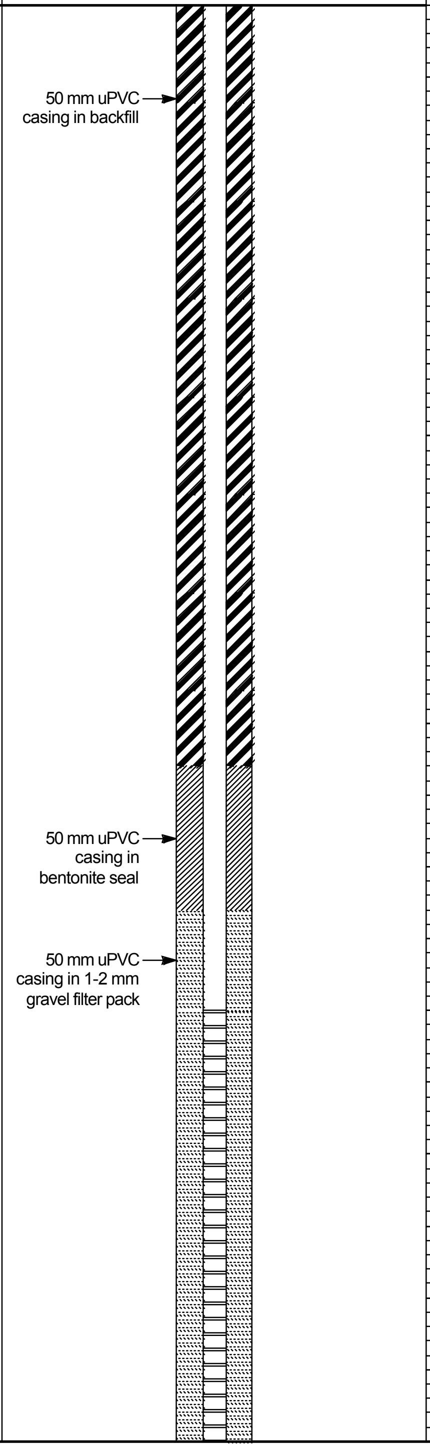
Relative Level: mAHD
Coordinates: mE
mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
10		MUDSTONE: moderately weathered, light grey, light brown, more firm, dry							D	
11		SILTSTONE: highly weathered, light brown with minor light grey, orange, limonitic? mudstone, dry							D	
12		SANDSTONE: highly weathered, light brown, light grey, medium to coarse, very clean, with minor quartz clasts up to 5 mm diameter, sub-angular to sub-round, dry			M-C	SA-SR			D	
13		SANDSTONE: highly weathered, light brown, light grey, medium to coarse, very clean, dry; with lenses of dark grey, light brown mudstone, slightly moist; approximately 70% sandstone, 30% mudstone			M-C				D-SM	
14										
15		SANDSTONE: highly to moderately weathered, light red, light brown, clean, coarse, angular to sub round; with clasts up to 10 mm, sub round, dry			C	A-SR			D	
16		SANDSTONE: highly weathered, light brown, clayey, fine, dry							D	
		SILTSTONE: highly weathered, light grey, blue, dry							D	
17		MUDSTONE: highly weathered, dark grey, dry							D	
18										
19		SILTSTONE: highly weathered, dark grey, dry							D	

REMARKS:

Sheet 3 of 3

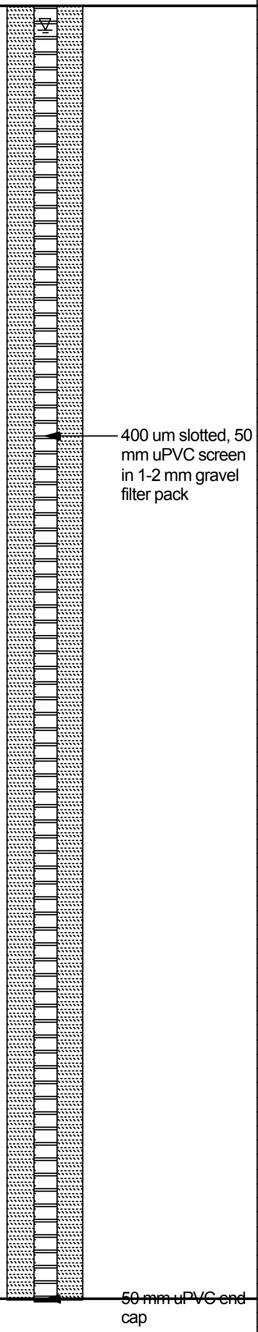
URS Australia Pty Ltd

Monitoring Well RM03B

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**		Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Method: **Rotary Air Boring**	Logged By: **AW** Checked By: **AW** Date Started: **30-8-08** Date Finished: **30-8-08**	Relative Level: mAHD Coordinates: mE mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS · WELL CONSTRUCTION DETAILS · DESCRIPTION OF STRATA



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			20	× ×	SILTSTONE: moderately weathered, dark grey, fine sandy, moist							M	
			21										
			22										
			23										
			24										
			25										
			26										
			27										
			28										
			29		EOH @ 29 mbgl								

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM04

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **31-8-08**
Date Finished: **31-8-08**

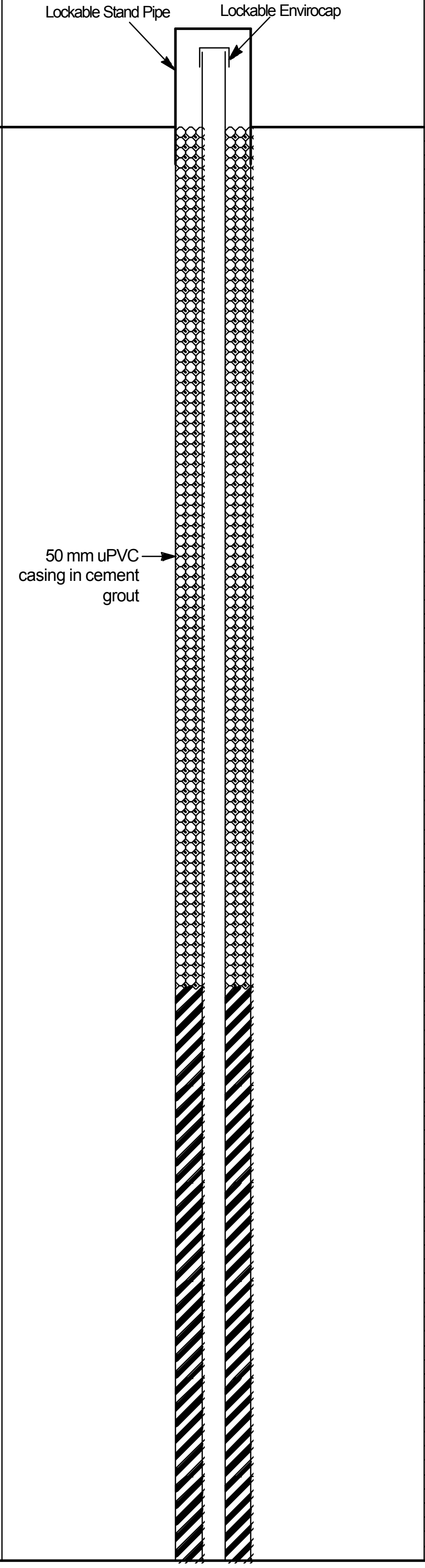
Relative Level: mAHD
Coordinates: 701421 mE
7071383 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type
Sampling and Observations
PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0		CLAY: dark brown, silty, low plasticity, stiff, dry						L	D	
1		SILTSTONE: extreemely to highly weathered, beige, dry							D	
2		CHERT: light grey, dry							D	
		SILTSTONE: highly weathered, light brown, cream, dry							D	
3		SILTSTONE: highly weathered, cream, dry							D	
4		MUDSTONE: highly weathered, dark grey, orange ferruginous?, dry							D	
7		MUDSTONE: highly weathered, dark grey, light brown, dry							D	
8		SILTSTONE: highly weathered, light brown, with chert bands, dry							D	
9		SANDSTONE: highly weathered, light brown, dark yellow, very fine, dry			VF				D	

REMARKS:

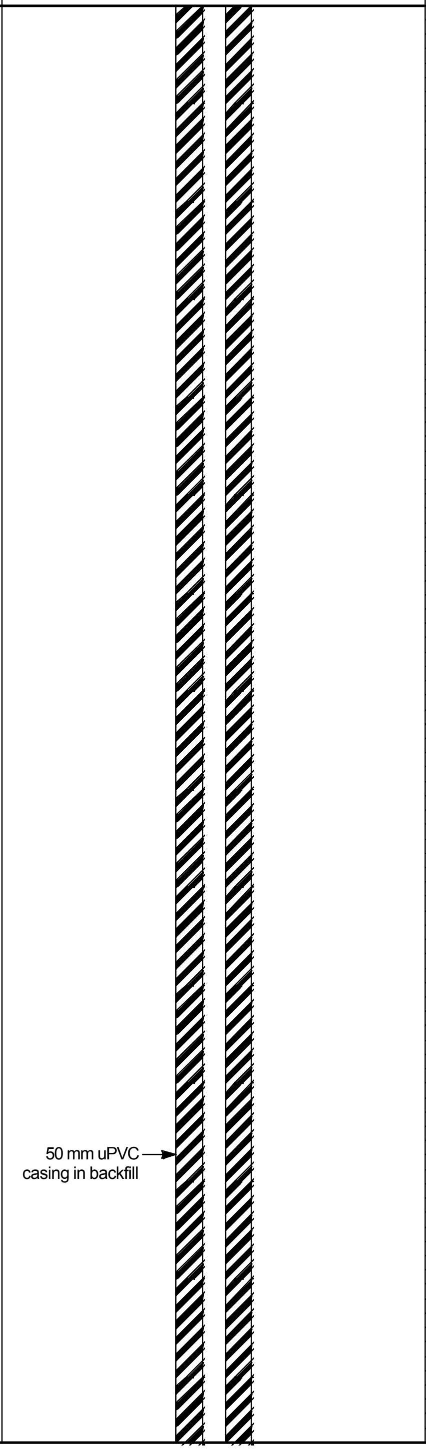
URS Australia Pty Ltd

Monitoring Well RM04

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**		Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Method: **Rotary Air Boring**	Logged By: **AW** Checked By: **AW** Date Started: **31-8-08** Date Finished: **31-8-08**	Relative Level: mAHD Coordinates: 701421 mE 7071383 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			10										
			11		SANDSTONE: highly weathered, light brown, cream, fine, dry			F				D	
			12		SILTSTONE: highly weathered, light brown, dry							D	
			13		SILTSTONE: highly weathered, light grey, light brown, dry							D	
			14		MUDSTONE: highly weathered, dark grey, light brown, dry							D	
			15		MUDSTONE: highly weathered, dark grey, light grey, light blue, dry							D	
			16										
			17										
			18										
			19		SILTSTONE: highly weathered, light brown, dry							D	

REMARKS:

Sheet 3 of 5

URS Australia Pty Ltd

Monitoring Well RM04

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **31-8-08**
Date Finished: **31-8-08**

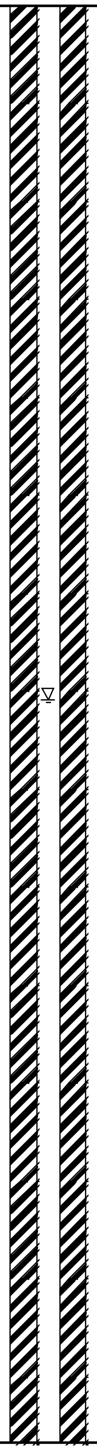
Relative Level: mAHD
Coordinates: 701421 mE
7071383 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type | Sampling and Observations | PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
20	× ×	SILTSTONE: highly weathered, medium brown, light grey, dry							D	
21	× ×	SILTSTONE: highly weathered, dark grey, light grey, some mudstone from 25-26 m, dry							D	
22										
23										
24										
25										
26	∴	SANDSTONE: highly weathered, light brown, light grey, clayey, very fine to fine, slightly moist			VF-F				SM	
27	× ×	SILTSTONE: highly weathered, light grey, slightly moist							SM	
28	× ×	SILTSTONE: highly weathered, dark grey, slightly moist							SM	
29	= =	MUDSTONE: moderately weathered, dark grey, dry							D	

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM04

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Method: **Rotary Air Boring**

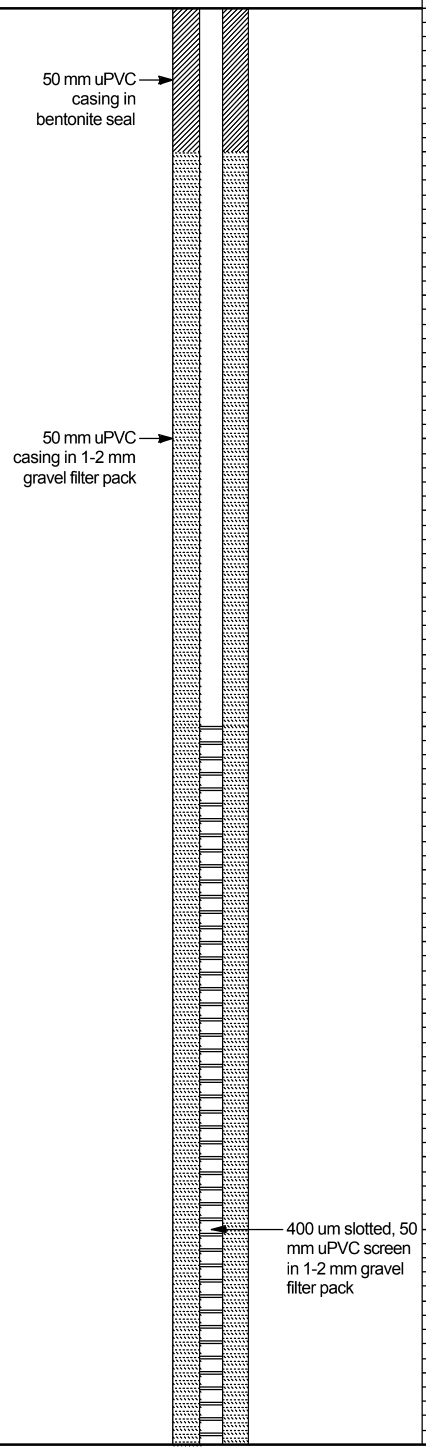
Logged By: **AW**
Checked By: **AW**
Date Started: **31-8-08**
Date Finished: **31-8-08**

Relative Level: mAHD
Coordinates: 701421 mE
7071383 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
30	× ×	SILTSTONE: moderately weathered, dark grey, fine sandy, slightly moist							SM	
31	= =	MUDSTONE: slightly weathered, light grey, dry							D	
32	= =	MUDSTONE: slightly weathered, dark grey, with white chert, dry							D	
33	⁚⁚	SANDSTONE: light grey, white, clean, medium, dry			M				D	
34	⁚⁚	SANDSTONE: light grey, white, light brown, clean, medium to caorse, dry			M-C				D	
35	⁚⁚	SANDSTONE: light grey, white, medium, wet			M				W	
36										
37										
38										
39										

REMARKS:

Sheet 5 of 5

URS Australia Pty Ltd

Monitoring Well RM04

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

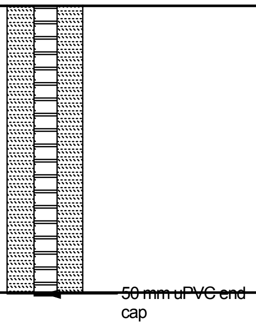
Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **31-8-08**
Date Finished: **31-8-08**

Relative Level: mAHD
Coordinates: 701421 mE
7071383 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				40										
				41										
				42		EOH @ 42 mbgl								
				43										
				44										
				45										
				46										
				47										
				48										
				49										



REMARKS:

MONITORING WELL GLNG GAS FIELD ALL.GPJ WCC_AUS.GDT 21/11/08

URS Australia Pty Ltd

Monitoring Well RM04B

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **1-9-08**
Date Finished: **1-9-08**

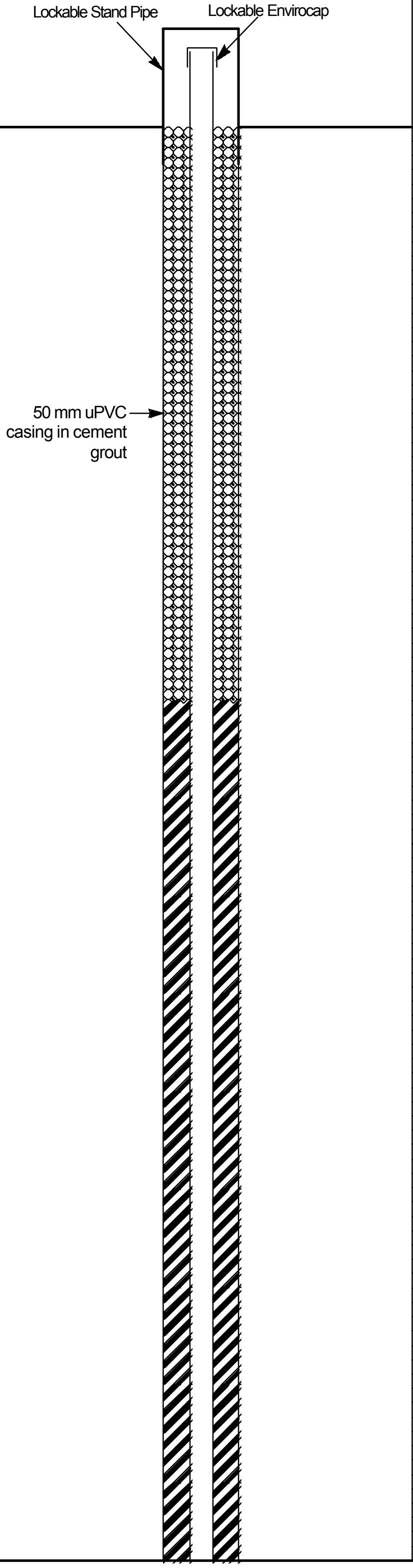
Relative Level: mAHD
Coordinates: mE
mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0		CLAY: dark brown, light brown, silty, low plasticity, stiff, dry						L	D	
1		SILTSTONE: extreemely to highly weathered, beige, light brown, dry							D	
2		SILTSTONE: highly weathered, beige, cream; with some highly weathered, cream, fine sandstone, dry							D	
3		SILTSTONE: highly weathered, light brown; with some light grey chert, dry							D	
4		SANDSTONE: highly weathered, cream, silty, very fine, dry			VF				D	
5		MUDSTONE: highly weathered, light grey, orange, ferruginous, dry							D	
6										
7		MUDSTONE: highly weathered, light grey, light brown, dry							D	
8		MUDSTONE: highly weathered, light brown, dark yellow, silty, dry							D	
9		SANDSTONE: highly weathered, light brown, dark yellow, very fine, dry			VF				D	

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM04B

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

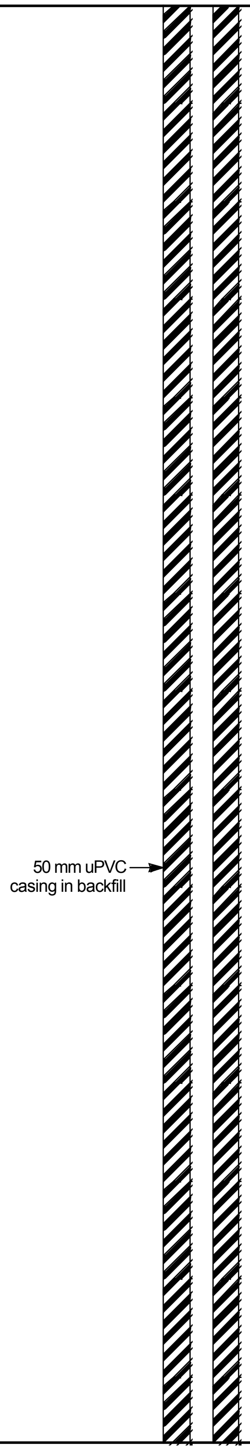
Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **1-9-08**
Date Finished: **1-9-08**

Relative Level: mAHD
Coordinates: mE
mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			10	× ×	SILTSTONE: highly weathered, light brown, dark yellow, very fine sandy, dry							D	
			11	⋯	SANDSTONE: highly weathered, cream, light brown, fine, dry			F				D	
			12	⋯	SANDSTONE: highly weathered, light brown, cream, very fine, dry			VF				D	
			13	× ×	SILTSTONE: highly weathered, light brown, dry							D	
			14	= =	MUDSTONE: highly weathered, light brown, light grey, dry							D	
			15	= =	MUDSTONE: highly weathered, dark grey, light brown, dry							D	
			16	= =	MUDSTONE: highly weathered, dark grey, light grey, blue, dry							D	
			17	= =									
			18	= =									
			19	× ×	SILTSTONE: highly weathered, light brown, light grey, dry							D	

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM04B

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

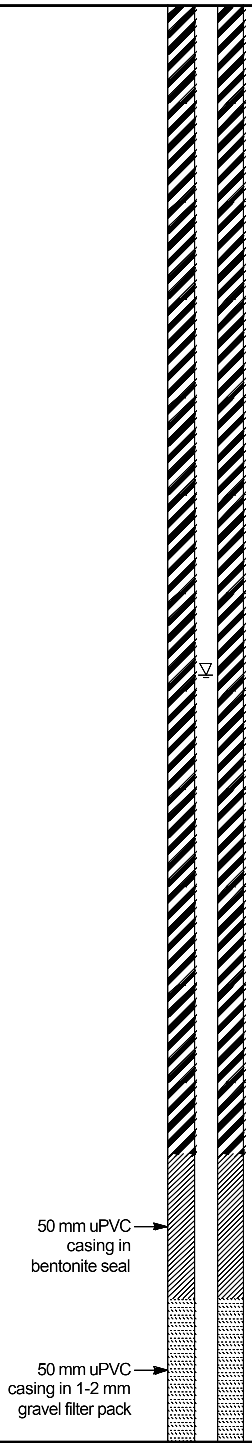
Logged By: **AW**
Checked By: **AW**
Date Started: **1-9-08**
Date Finished: **1-9-08**

Relative Level: mAHD
Coordinates: mE
mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			20		SILTSTONE: highly weathered, brown, light grey, dry							D	
			21		SILTSTONE: highly weathered, dark grey, light grey, dry							D	
			22										
			23										
			24		MUDSTONE: highly weathered, dark grey, light grey, dry							D	
			25										
			26		SANDSTONE: highly weathered, light grey, fine to medium; with black siliceous clasts, wood?, dry			F-M				D	
			27		SANDSTONE: highly weathered, light grey, clayey, fine, slightly moist			F				SM	
			28		MUDSTONE: highly weathered, dark grey, light grey, slightly moist							SM	
			29										

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM04B

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **1-9-08**
Date Finished: **1-9-08**

Relative Level: mAHD
Coordinates: mE
mN

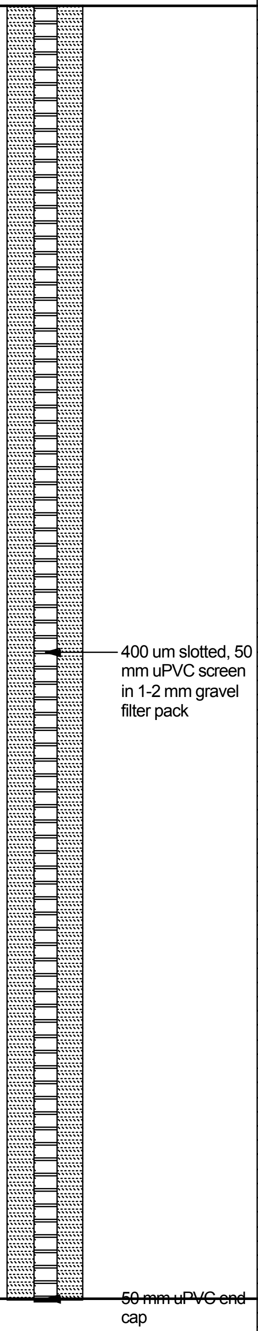
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS

Sample Type | Sampling and Observations | PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
30	MUDSTONE: highly weathered, dark grey, light grey, clayey, moist							M	
31	MUDSTONE: highly to moderately weathered mudstone, light grey, dry							D	
32	SANDSTONE: moderately weathered, grey, very fine to fine, dry			VF-F				D	
33	SANDSTONE: dark grey, very fine to fine, slightly moist			VF-F				SM	
34	SANDSTONE: Dark grey, light grey, fine to medium, slightly moist			F-M				SM	
35	SANDSTONE: light grey, very fine to fine, moist			VF-F				M	
36									
37	SANDSTONE: light grey, fine to medium, moist			F-M				M	
38									
39	EOH @ 39 mbgl								

REMARKS:

Sheet 1 of 6

URS Australia Pty Ltd

Monitoring Well RM05

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

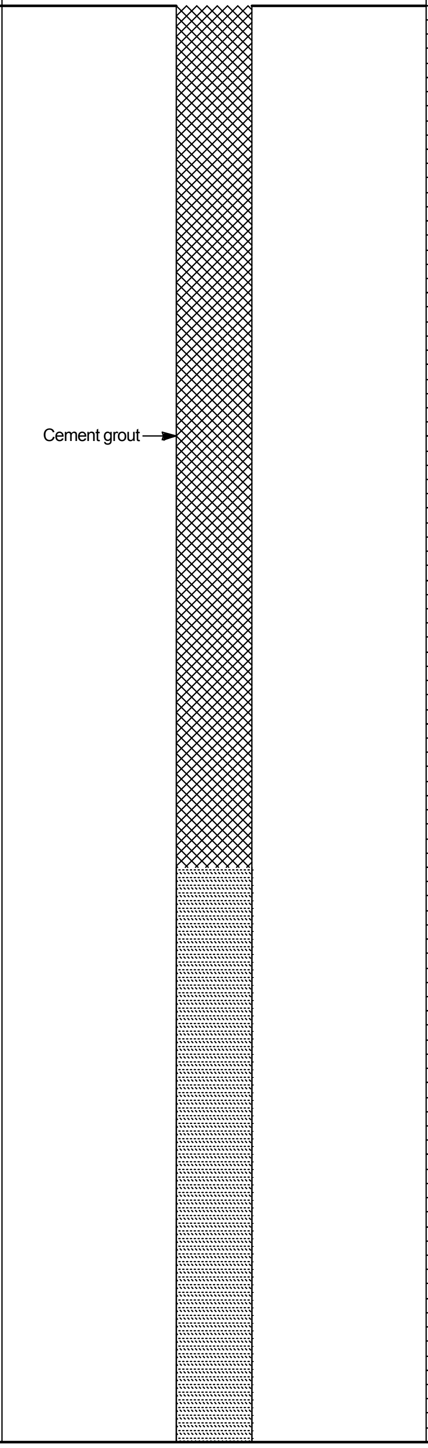
Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **3-9-08**
Date Finished: **3-9-08**

Relative Level: mAHD
Coordinates: 685497 mE
7079033 mN
Permit No:

Client: **Santos Ltd**

WELL CONSTRUCTION DETAILS



SAMPLING DETAILS				DESCRIPTION OF STRATA										
Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			0	▨	CLAY: light red, light brown, low plasticity, stiff, dry						L	D	
			1	×	SILTSTONE: extreemaly to highly weathered, light red, beige, dry							D	
			2	⁚	SANDSTONE: highly weathered,, light grey, white, medium, dry			M				D	
			3	×	SILTSTONE: highly weathered, brown, dry							D	
			4	×	SILTSTONE: highly weathered, light brown, dark yellow, dry							D	
			5										
			6	=	MUDSTONE: highly weathered, light brown, dry							D	
			7	=	MUDSTONE: highly weathered, brown, dry							D	
			8	=	MUDSTONE: highly weathered, light grey, dry							D	
			9	×	SILTSTONE: highly weathered, light brown, dry							D	

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM05

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor:	**TerraTest**
Project No.:	**42626229**
Project Reference:	**GLNG Gas Field EIS**
Drilling Method:	**Rotary Air Boring**
Logged By:	**AW**
Checked By:	**AW**
Date Started:	**3-9-08**
Date Finished:	**3-9-08**
Relative Level:	mAHD
Coordinates:	685497 mE 7079033 mN
Permit No:	
Client:	**Santos Ltd**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**

Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			10		SANDSTONE: highly weathered, beige, cream, fine, dry							D	
			11		SANDSTONE: highly weathered, light brown, tan, very fine, dry			VF				D	
			12		SILTSTONE: moderately weathered, light grey, light blue, firm, dry							D	
			13		SILTSTONE: moderately weathered, light grey, dry							D	
			14										
			15										
			16										
			17										
			18										
			19										

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM05

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

Drilling Contractor: **TerraTest**

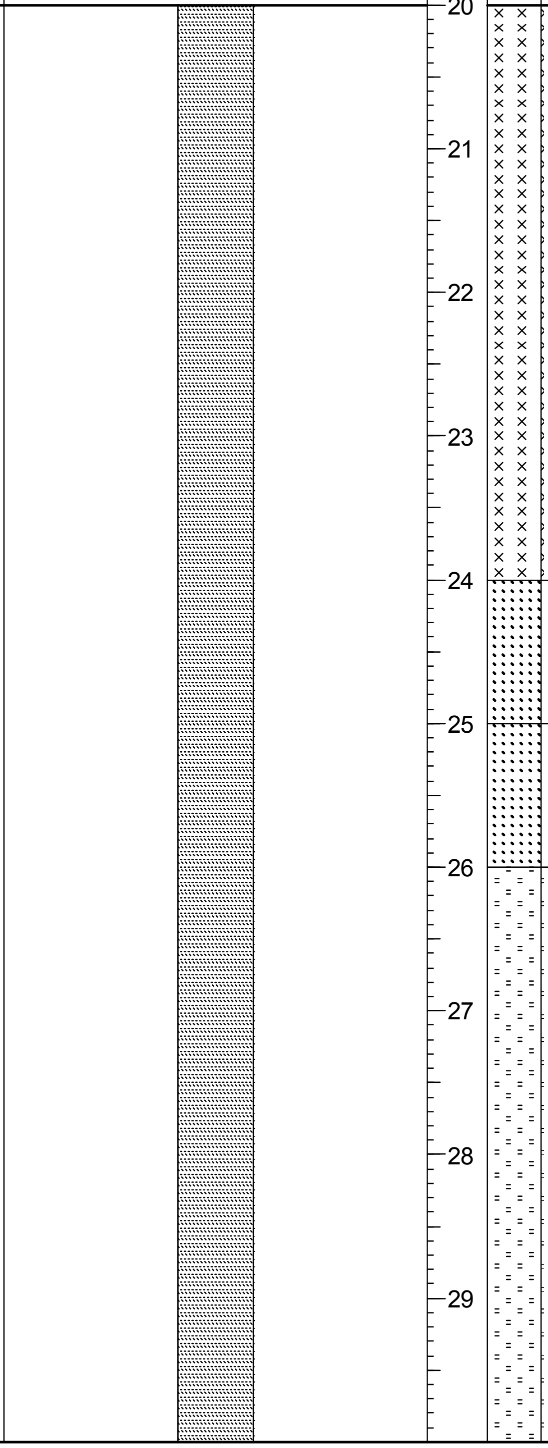
Drilling Method: **Rotary Air Boring**

Logged By: **AW**
Checked By: **AW**
Date Started: **3-9-08**
Date Finished: **3-9-08**

Relative Level: mAHD
Coordinates: 685497 mE
7079033 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				20	× ×									
				24	⁚⁚⁚	SANDSTONE: grey, fine, dry			F				D	
				25	⁚⁚⁚	SANDSTONE: light grey, fine to medium, dry			F-M				D	
				26	= =	MUDSTONE: light grey, dry							D	



REMARKS:

URS Australia Pty Ltd

Monitoring Well RM05

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**

Project No.: **42626229**

Project Reference: **GLNG Gas Field EIS**

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Logged By: **AW**
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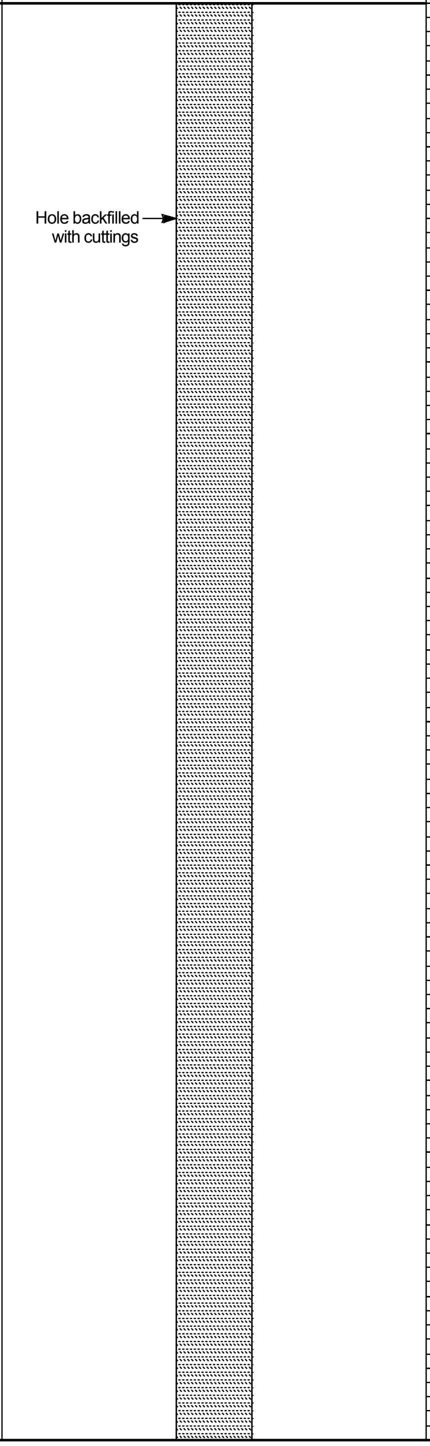
Date Started: **3-9-08**
Date Finished: **3-9-08**

Relative Level: mAHD
Coordinates: 685497 mE
7079033 mN
Permit No:

Client: **Santos Ltd**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			30										
			33		SANDSTONE: grey, very fine, dry			VF				D	
			34		SANDSTONE: light grey, white, clean, fine to medium, dry			F-M				D	
			35		SANDSTONE: grey, very fine, slightly moist			VF				SM	
			37		SILTSTONE: light grey, white, dry							D	
			38		MUDSTONE: dark grey, dry							D	
			39		MUDSTONE: light grey, dry							D	

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM05

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor: **TerraTest**		Project No.: **42626229**	Project Reference: **GLNG Gas Field EIS**
Drilling Method: **Rotary Air Boring**	Logged By: **AW** Checked By: **AW** Date Started: **3-9-08** Date Finished: **3-9-08**	Relative Level: mAHD Coordinates: 685497 mE 7079033 mN Permit No:	Client: **Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				40		SANDSTONE: grey, fine to medium, dry							D	
				41										
				42		MUDSTONE: grey, dry							D	
				43										
				44		MUDSTONE: dark grey, dark brown, hard, carbonaceous, with coal, dry							D	
				45		MUDSTONE: grey, dry							D	
				46		MUDSTONE: dark grey, dark brown, hard, carbonaceous, dry							D	
				47		MUDSTONE: grey, dry							D	
				48										
				49										

REMARKS:

URS Australia Pty Ltd

Monitoring Well RM05

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor:	**TerraTest**
Project No.:	**42626229**
Project Reference:	**GLNG Gas Field EIS**
Drilling Method:	**Rotary Air Boring**
Logged By:	**AW**
Checked By:	**AW**
Date Started:	**3-9-08**
Date Finished:	**3-9-08**
Relative Level:	mAHD
Coordinates:	685497 mE 7079033 mN
Permit No:	
Client:	**Santos Ltd**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				50		MUDSTONE: dark brown, dark grey, carbonaceous, with minor coal, dry							D	
				52		MUDSTONE: grey, dry							D	
				54		MUDSTONE: light grey, dark grey, soft, clayey, slightly moist							SM	
				55.5		SANDSTONE: light grey, dark grey, fine to medium, with clasts of carbonaceous material, dry			F-M				D	
				57		EOH @ 57 mbgl - no water intersected, no well installed								

Depth (m): 50, 51, 52, 53, 54, 55, 56, 57, 58, 59

REMARKS:

Appendix B: CSG Field Aquifer Test Data

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane QLD 4000
Phone: +61 7 3243 2111

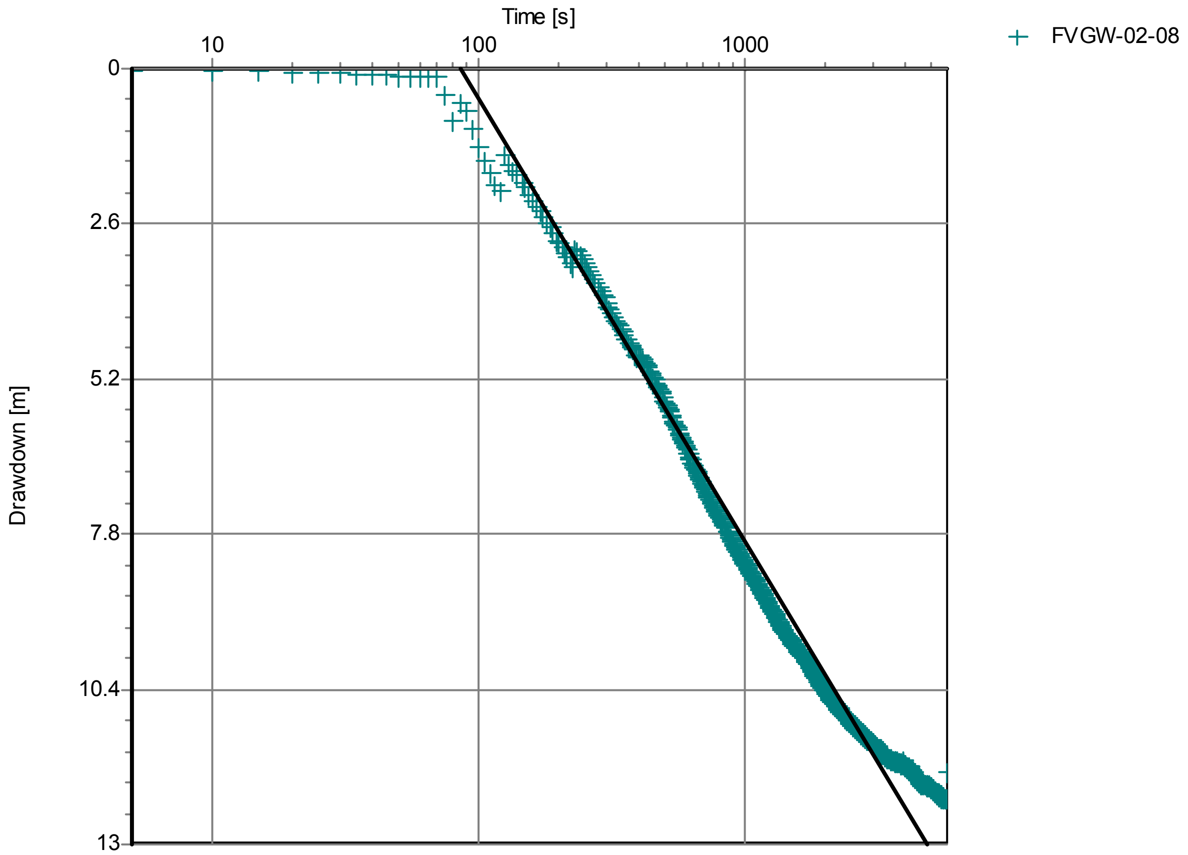
Pumping Test Analysis Report

Project: Santos GLNG Gas Field

Number: 42626229

Client: Santos Ltd

FVGW-02-08 [Cooper-Jacob Time-Drawdown]



Pumping Test: **FVGW-02-08**

Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	8.53E-2 [m²/d]	Conductivity:	1.07E-2 [m/d]

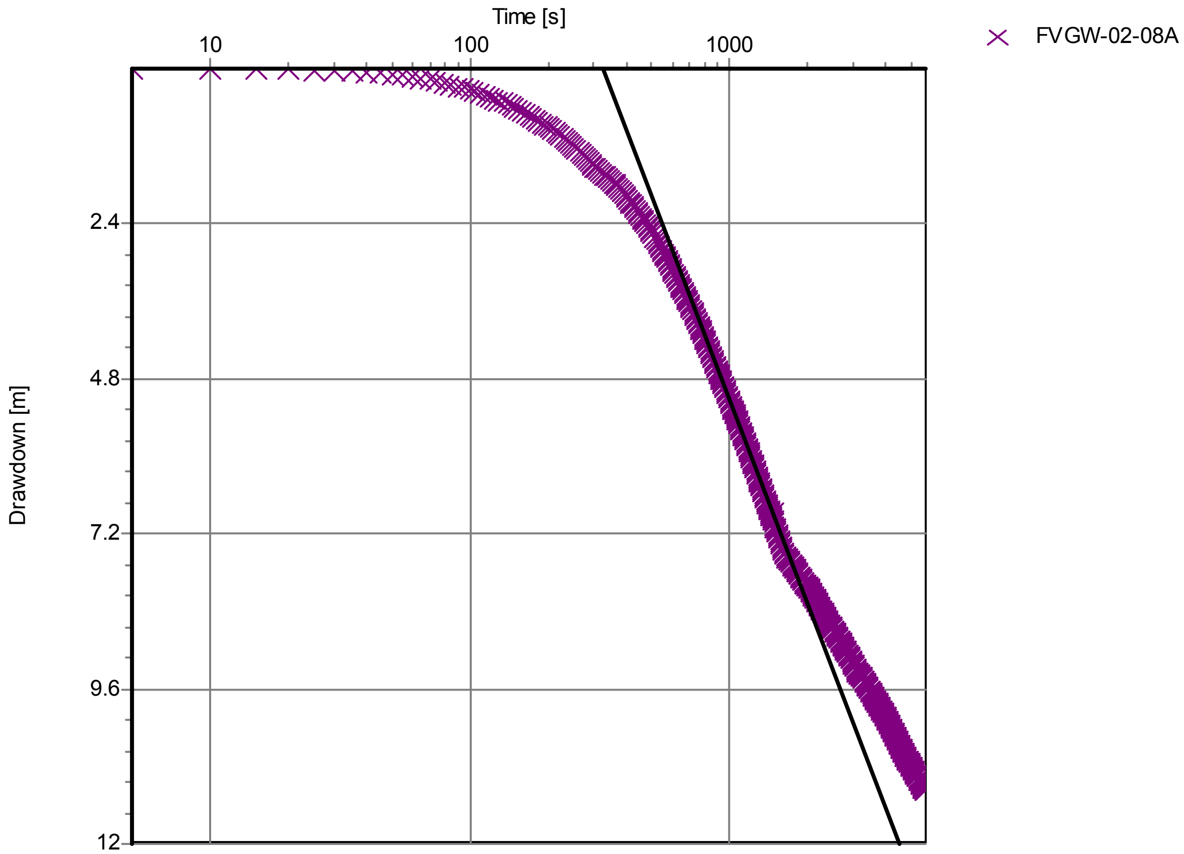
Test parameters:	Pumping Well:	FVGW-02-08	Aquifer Thickness:	8 [m]
	Casing radius:	0.025 [m]	Confined Aquifer	
	Screen length:	6 [m]		
	Boring radius:	0.075 [m]		
	Discharge Rate:	0.04 [l/s]		

Comments:

Evaluated by: AW

Evaluation Date: 5/11/2008

FVGW-02-08A [Cooper-Jacob Time-Drawdown]



Pumping Test: **FVGW-02-08A**

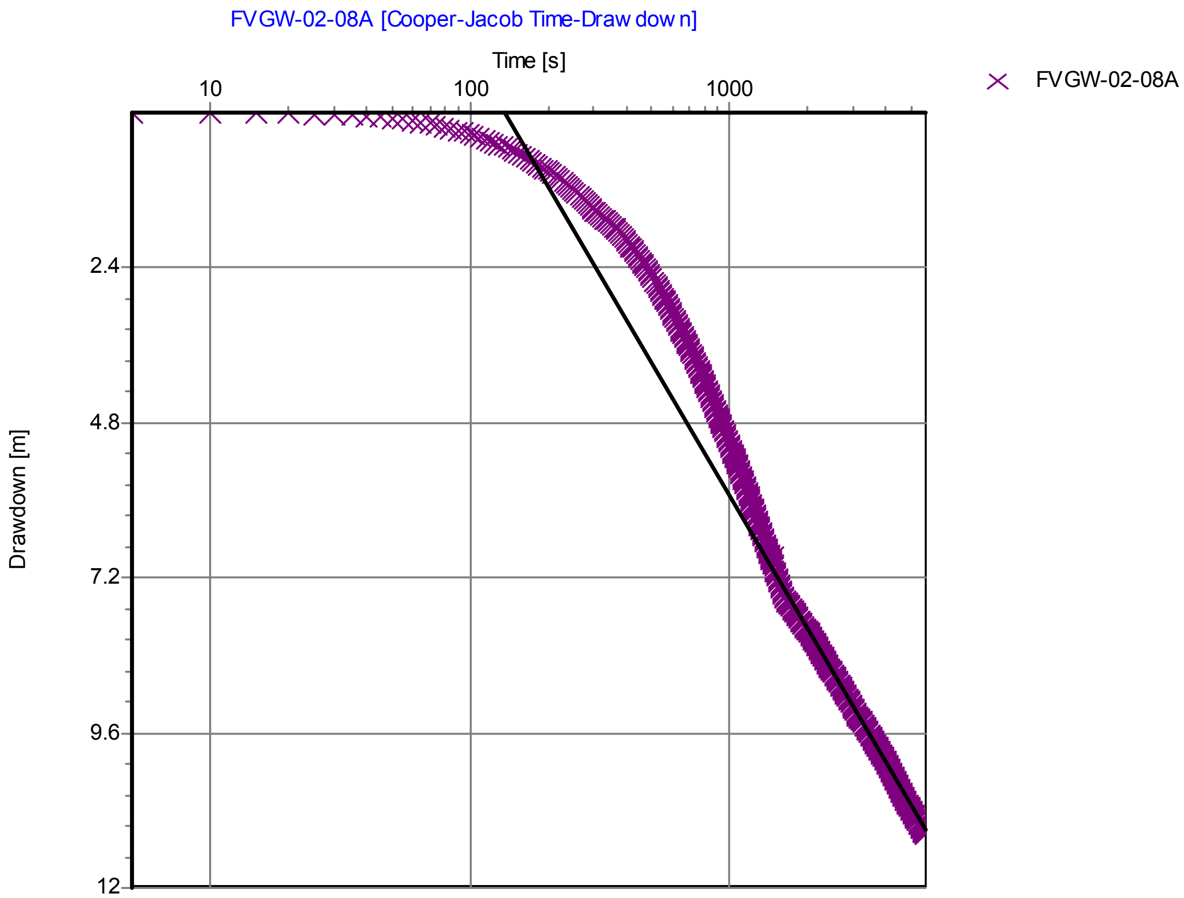
Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	6.02E-2 [m²/d]	Conductivity:	7.52E-3 [m/d]
	Storativity:	2.03E-5		

Test parameters:	Pumping Well:	FVGW-02-08	Aquifer Thickness:	8 [m]
	Casing radius:	0.025 [m]	Confined Aquifer	
	Screen length:	6 [m]		
	Boring radius:	0.075 [m]		
	Discharge Rate:	0.04 [l/s]		

Comments: Distance from pumping well = 5 m

Evaluated by: AW
Evaluation Date: 5/11/2008



Pumping Test:	**FVGW-02-08A**
Analysis Method:	**Cooper-Jacob Time-Drawdown**

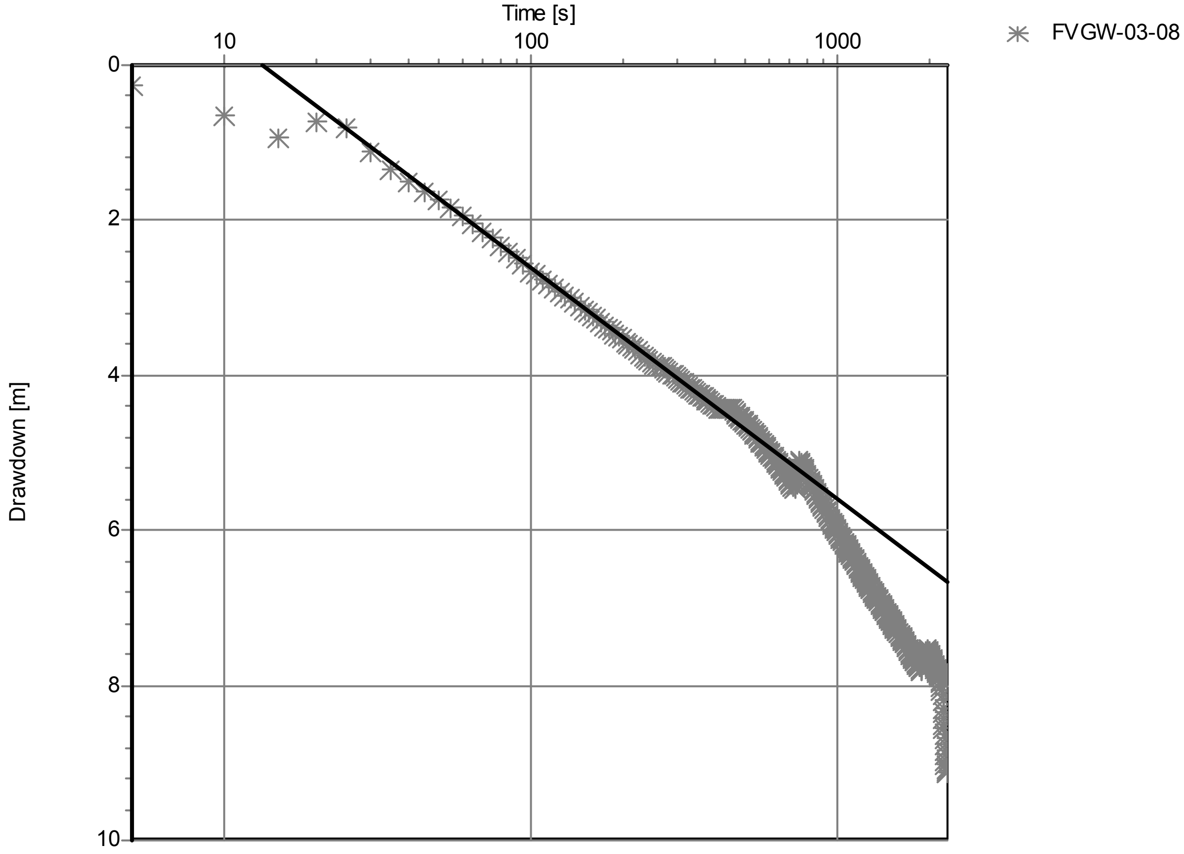
Analysis Results:	Transmissivity:	9.22E-2 [m²/d]	Conductivity:	1.15E-2 [m/d]
	Storativity:	1.31E-5		

Test parameters:	Pumping Well:	FVGW-02-08	Aquifer Thickness:	8 [m]
	Casing radius:	0.025 [m]	Confined Aquifer	
	Screen length:	6 [m]		
	Boring radius:	0.075 [m]		
	Discharge Rate:	0.04 [l/s]		

Comments: Distance from pumping well = 5 m

Evaluated by: AW
Evaluation Date: 5/11/2008

FVGW-03-08 [Cooper-Jacob Time-Draw dow n]



Pumping Test:	**FVGW-03-08**
Analysis Method:	**Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	3.18E-1 [m²/d]	Conductivity:	3.97E-2 [m/d]
Test parameters:	Pumping Well:	FVGW-03-08	Aquifer Thickness:	8 [m]
	Casing radius:	0.025 [m]	Confined Aquifer	
	Screen length:	6 [m]		
	Boring radius:	0.075 [m]		
	Discharge Rate:	0.06 [l/s]		

Comments:

Evaluated by: AW
Evaluation Date: 5/11/2008

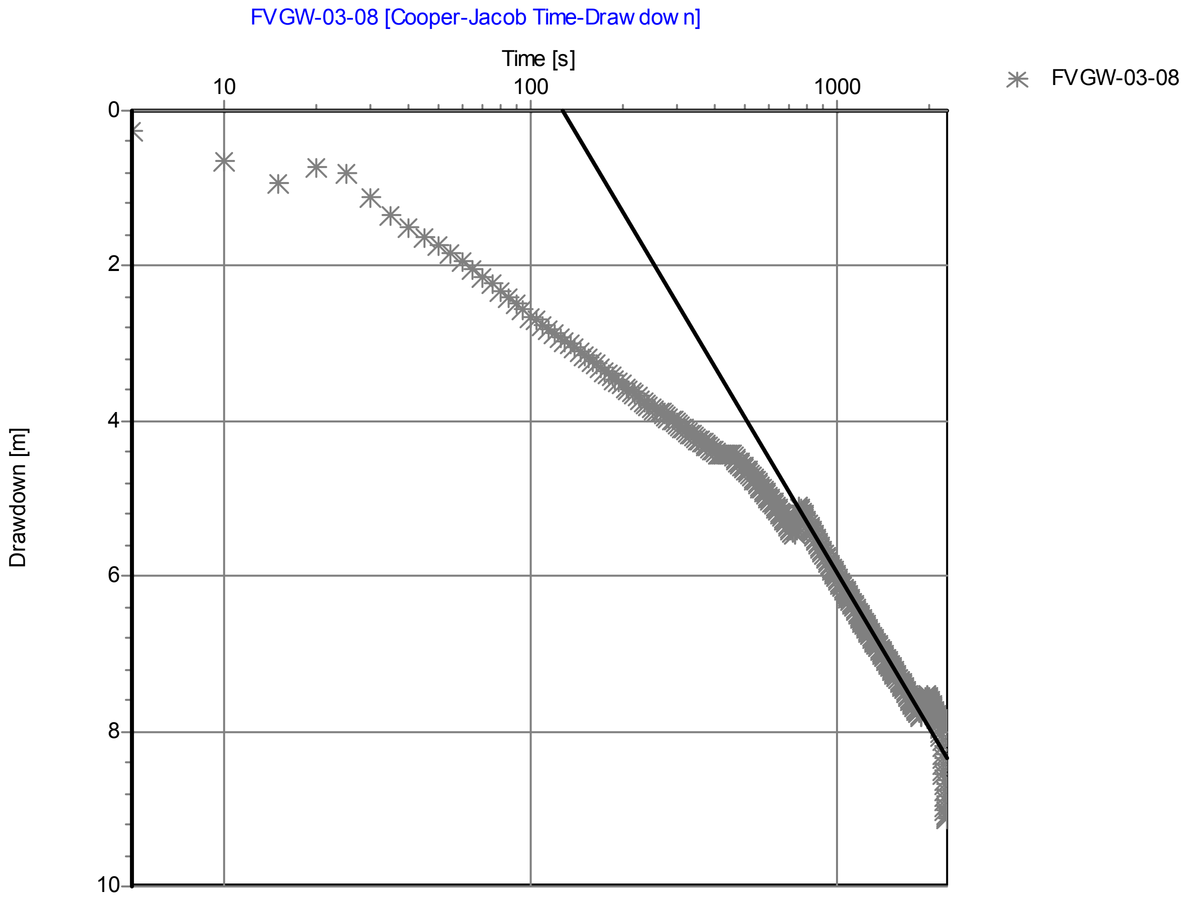
URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane QLD 4000
Phone: +61 7 3243 2111

Pumping Test Analysis Report

Project: Santos GLNG Gas Field

Number: 42626229

Client: Santos Ltd



Pumping Test:	**FVGW-03-08**			
Analysis Method:	**Cooper-Jacob Time-Drawdown**			
Analysis Results:	Transmissivity:	1.42E-1 [m²/d]	Conductivity:	1.78E-2 [m/d]
Test parameters:	Pumping Well:	FVGW-03-08	Aquifer Thickness:	8 [m]
	Casing radius:	0.025 [m]	Confined Aquifer	
	Screen length:	6 [m]		
	Boring radius:	0.075 [m]		
	Discharge Rate:	0.06 [l/s]		

Comments:

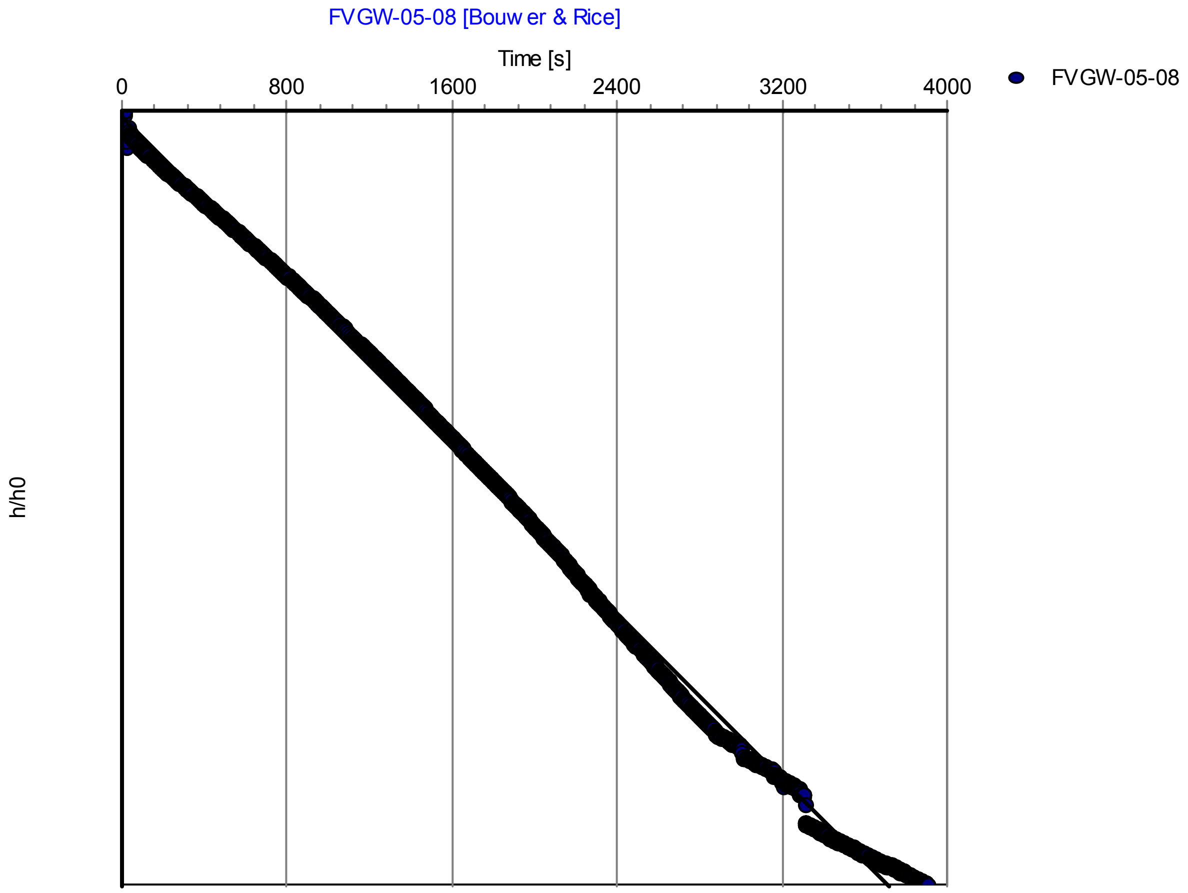
Evaluated by: AW

Evaluation Date: 5/11/2008

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane QLD 4000
Phone: +61 7 3243 2111

Slug Test Analysis Report

Project:	Santos GLNG Gas Field
Number:	42626229
Client:	Santos Ltd



Slug Test: **FVGW-05-08**

Analysis Method: **Bouwer & Rice**

Analysis Results:			Conductivity:	3.23E-3 [m/d]
Test parameters:	Test Well:	FVGW-05-08	Aquifer Thickness:	1 [m]
	Casing radius:	0.025 [m]	Gravel Pack Porosity (%)	25
	Screen length:	6 [m]		
	Boring radius:	0.075 [m]		
	r(eff):	0.043 [m]		

Comments:

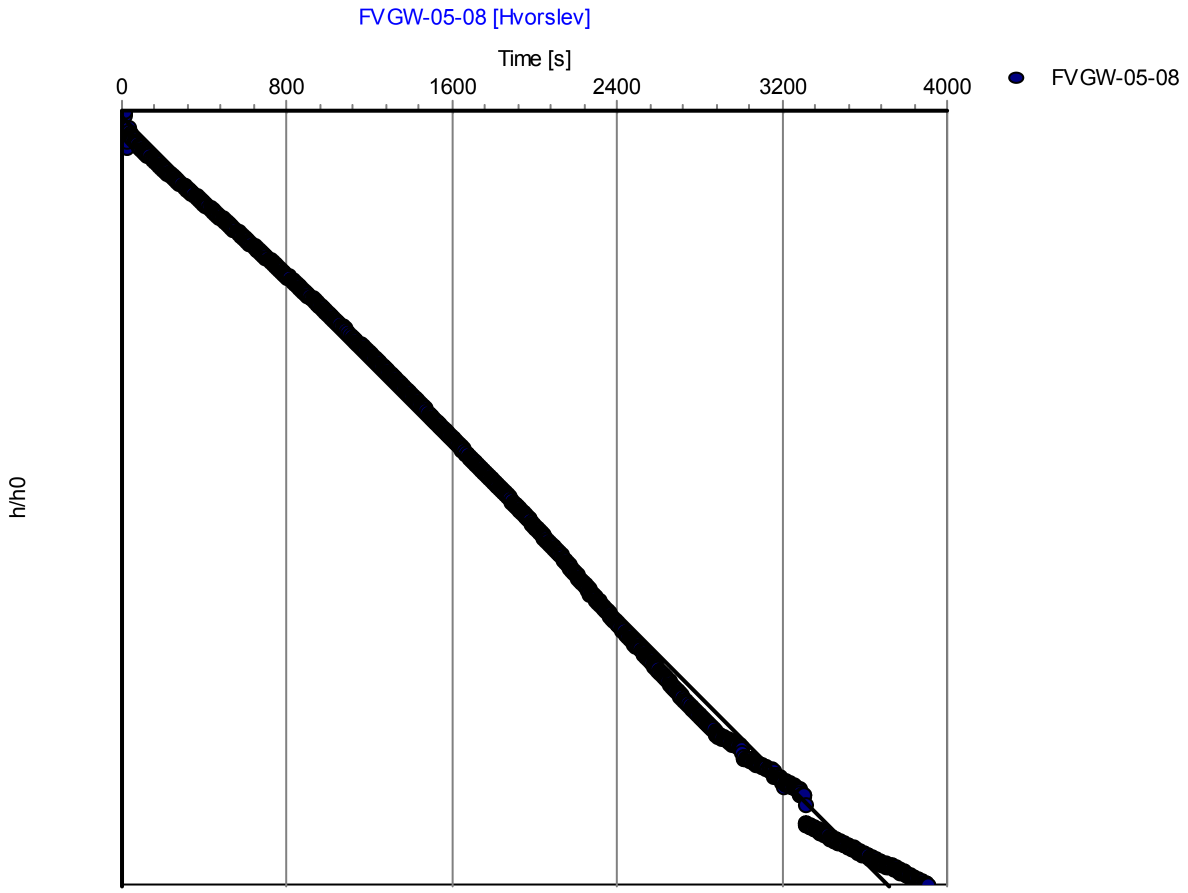
Evaluated by: AW

Evaluation Date: 5/11/2008

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane QLD 4000
Phone: +61 7 3243 2111

Slug Test Analysis Report

Project:	Santos GLNG Gas Field
Number:	42626229
Client:	Santos Ltd



Slug Test: **FVGW-05-08**

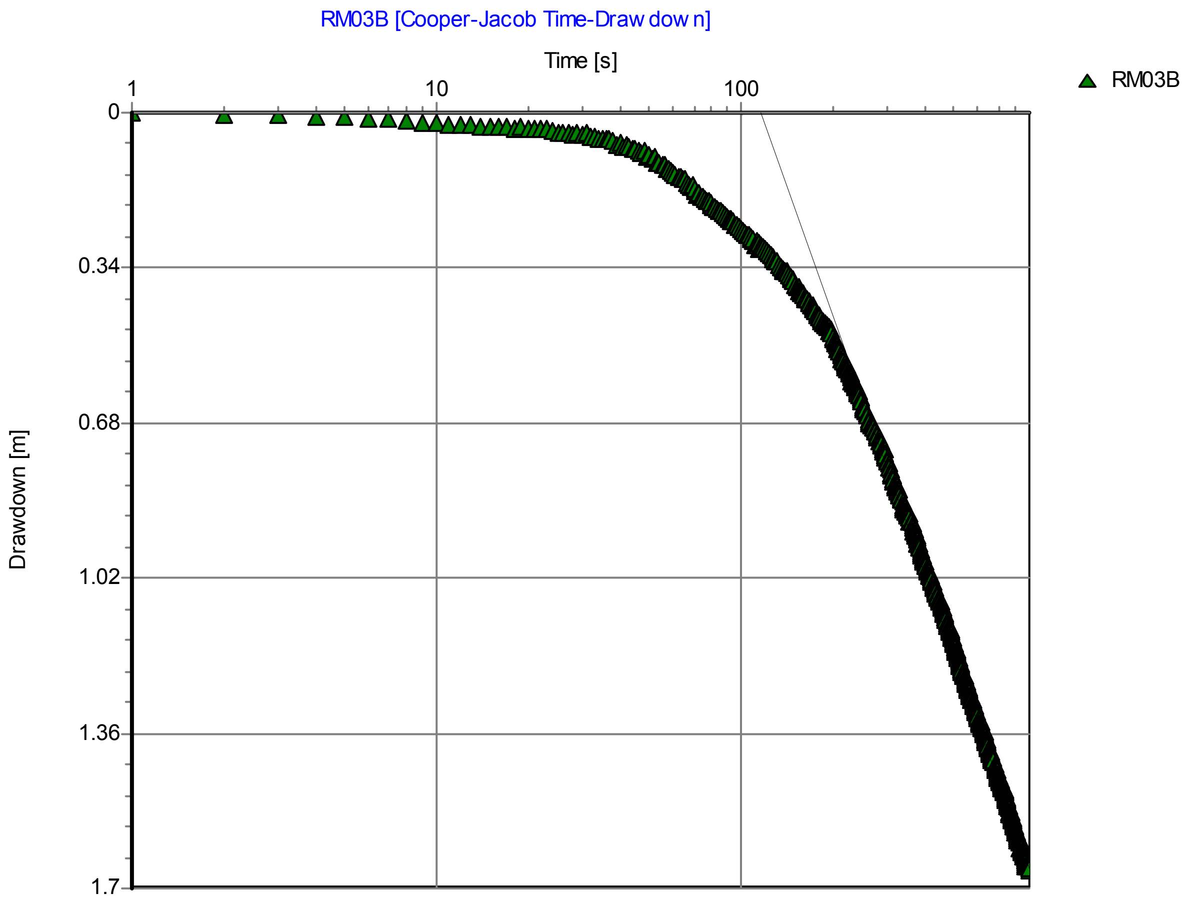
Analysis Method: **Hvorslev**

Analysis Results:	Conductivity:	6.65E-3 [m/d]

Test parameters:	Test Well:	FVGW-05-08	Aquifer Thickness:	1 [m]
	Casing radius:	0.025 [m]		
	Screen length:	6 [m]		
	Boring radius:	0.075 [m]		

Comments:

Evaluated by: AW
Evaluation Date: 5/11/2008



Pumping Test: **RM03B**

Analysis Method: **Cooper-Jacob Time-Drawdown**

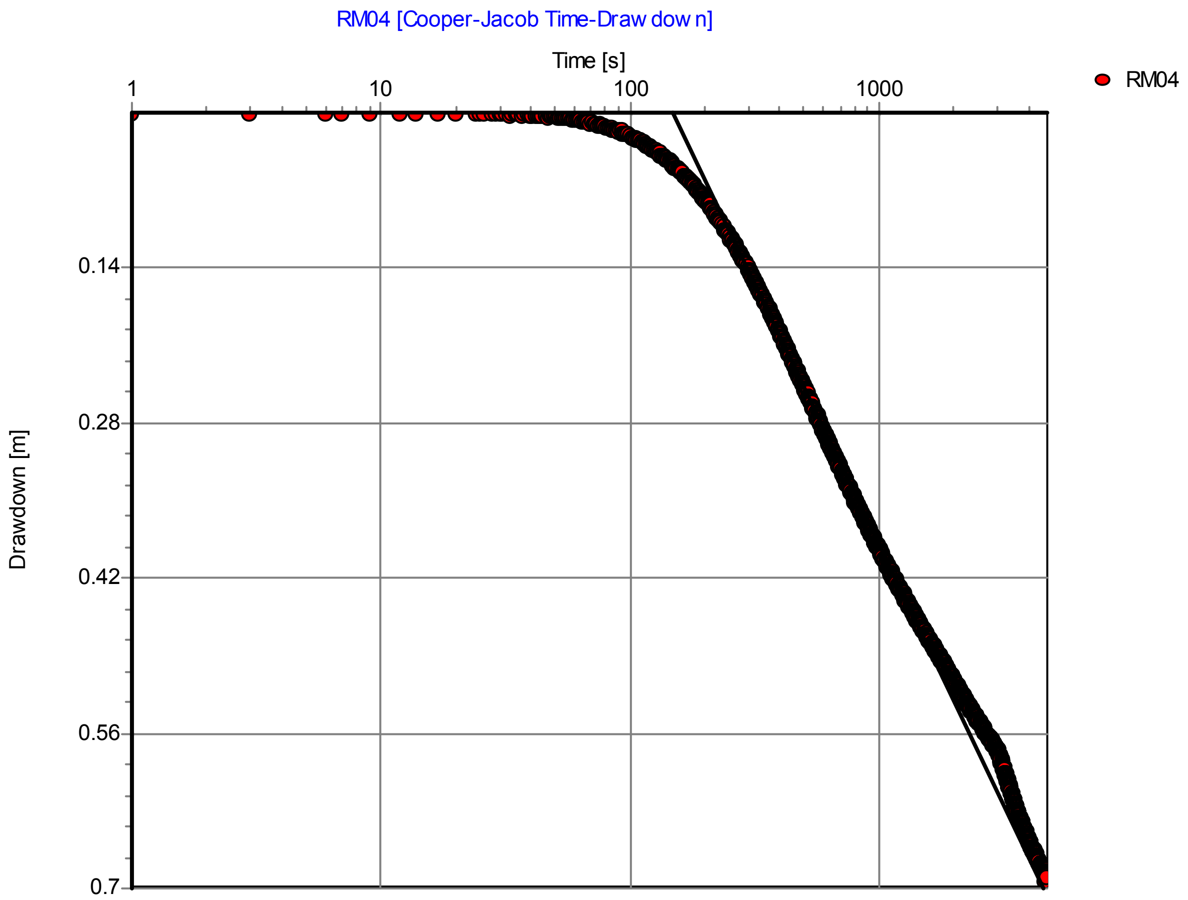
Analysis Results:	Transmissivity:	2.54E-1 [m²/d]	Conductivity:	2.82E-2 [m/d]
Test parameters:	Pumping Well:	RM03B	Aquifer Thickness:	9 [m]
	Casing radius:	0.025 [m]	Confined Aquifer	
	Screen length:	12 [m]		
	Boring radius:	0.075 [m]		
	Discharge Rate:	0.03 [l/s]		

Comments: Test terminated early due to pump failure

Evaluated by: AW
Evaluation Date: 5/11/2008

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane QLD 4000
Phone: +61 7 3243 2111

Pumping Test Analysis Report
Project: Santos GLNG Gas Field
Number: 42626229
Client: Santos Ltd



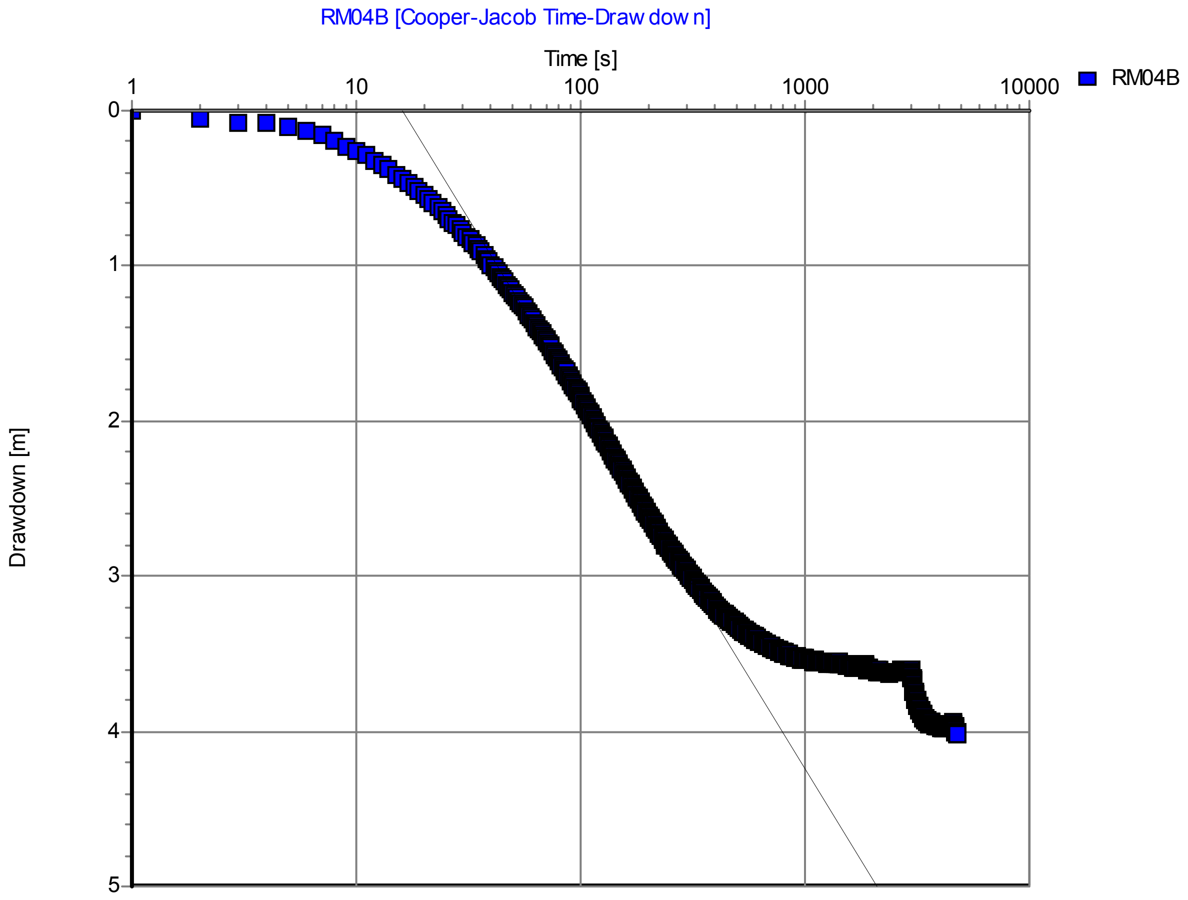
Pumping Test:	**RM04**
Analysis Method:	**Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	1.68E+0 [m²/d]	Conductivity:	2.41E-1 [m/d]
	Storativity:	2.59E-4		

Test parameters:	Pumping Well:	RM04B	Aquifer Thickness:	7 [m]
	Casing radius:	0.025 [m]	Confined Aquifer	
	Screen length:	9 [m]		
	Boring radius:	0.075 [m]		
	Discharge Rate:	0.05 [l/s]		

Comments: Distance from pumping well = 5 m

Evaluated by: AW
Evaluation Date: 5/11/2008



Pumping Test: **RM04B**

Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	3.35E-1 [m²/d]	Conductivity:	5.59E-2 [m/d]

Test parameters:	Pumping Well:	RM04B	Aquifer Thickness:	6 [m]
	Casing radius:	0.025 [m]	Confined Aquifer	
	Screen length:	9 [m]		
	Boring radius:	0.075 [m]		
	Discharge Rate:	0.05 [l/s]		

Comments:

Evaluated by: AW
Evaluation Date: 5/11/2008

Appendix C: CSG Field Hydrochemistry

CHAIN OF CUSTODY FORM

Sheet 1 of 1

THIS COLUMN FOR LAB USE ONLY

Job Code:

Due Date:

FROM:
URS (AUSTRALIA)
Level 14, 240 Queen Street
BRISBANE QLD 4000
PO Box 302, BBN QLD 4001
Ph: 07 3243 2111

DATE: 10/10/08

Fax: 07 3243 2199

TO: ALS
32 SHAND ST
STAFFORD
QLD 4056

Project No: 42626229 [redacted]
Project Manager: Stephen Denner [redacted]
Agreement No:

Sampler(s): AW
Signature(s): AW
Checked:

Custody seal intact? ☐ YES ☐ NO

Sample cold? ☐ YES ☐ NO

Released for URS by: AW
Date: 10/10/08 Time: 12:00

Received for Laboratory by: D. Kang of ALS
Date: 14/10/08 Time: 8:35

Container Size, Type, Preservative and Analysis

	Container Identification						
Size							
Type*							
Preservative Code							
Analytes	NT1	NT2	W3 (Dissolved)	W3 (Total)			

Lab identification	Date	Time	Matrix	Sample Number	Comments	Total no	Tick required analytes						
①	7/10	PM	WATER	RM03B	P	2	✓	✓	✓				
②	7/10	PM	WATER	QC01	P	1				✓			

Environmental Division
Brisbane
Work Order
EB0814158
Telephone : +61-7-3243 7222

Remarks:

TOTAL

Courier Job No:

* Container Type and Preservative Codes: P = Neutral Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar; S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS = Sulfuric

Specify Turnaround Time:

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

SAMPLE RECEIPT NOTIFICATION (SRN)

Comprehensive Report

Work Order : **EB0814158**

Client	: **URS AUSTRALIA PTY LTD (QLD)**	Laboratory	: Environmental Division Brisbane
Contact	: MR STEPHEN DENNER	Contact	: Tim Kilmister
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4001	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: stephen_denner@urscorp.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 32432111	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32432199	Facsimile	: +61-7-3243 7218
Project	: 42626229	Page	: 1 of 2
Order number	: ----		
C-O-C number	: ----	Quote number	: ES2008URSQLD0041 (EN/001/08)
Site	: ----		
Sampler	: AW	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Dates

Date Samples Received	: 14-OCT-2008	Issue Date	: 15-OCT-2008 11:03
Client Requested Due Date	: 21-OCT-2008	Scheduled Reporting Date	: **21-OCT-2008**

Delivery Details

Mode of Delivery	: Carrier	Temperature	: 21.2 C - Ice bricks present
No. of coolers/boxes	: 1 SMALL	No. of samples received	: 2
Sercurity Seal	: Intact.	No. of samples analysed	: 2

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Requested Deliverables
- **Samples received in appropriately pretreated and preserved containers.**
- **Sample(s) have been received within recommended holding times.**
- Please direct any turn around / technical queries to the laboratory contact designated above.
- Please direct any queries related to sample condition / numbering / breakages to Maggie Kahi.
- Analytical work for this work order will be conducted at ALS Brisbane.
- Sample Disposal - Aqueous (14 days), Solid (90 days) from date of completion of work order.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exist.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process neccessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.
When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing

Matrix: **WATER**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	WATER - EN055 Ionic Balance	WATER - NT-01 Major Cations (Ca, Mg, Na, K)	WATER - NT-02 (EB/PCT) Major Anions (Cl, SO4, Alkalinity)	WATER - W-03 13 Metals (NEPM Suite)	WATER - W-03T 13 Metals (Total) (NEPM)
EB0814158-001	07-OCT-2008 12:00	RM03B	✓	✓	✓	✓	
EB0814158-002	07-OCT-2008 12:00	QC01					✓

Requested Deliverables

MR STEPHEN DENNER		
- *AU Certificate of Analysis - NATA	Email	stephen_denner@urscorp.com
- A4 - AU Sample Receipt Notification - Environmental	Email	stephen_denner@urscorp.com
- AU Interpretive QC Report (Anon QCI Not Rep)	Email	stephen_denner@urscorp.com
- AU QC Report (Anon QC Not Rep) - NATA	Email	stephen_denner@urscorp.com
- Default - Chain of Custody	Email	stephen_denner@urscorp.com
- EDI Format - MRED	Email	stephen_denner@urscorp.com
RESULTS ADDRESS		
- *AU Certificate of Analysis - NATA	Email	brisbane@urscorp.com
- A4 - AU Sample Receipt Notification - Environmental	Email	brisbane@urscorp.com
- AU Interpretive QC Report (Anon QCI Not Rep)	Email	brisbane@urscorp.com
- AU QC Report (Anon QC Not Rep) - NATA	Email	brisbane@urscorp.com
- Default - Chain of Custody	Email	brisbane@urscorp.com
- EDI Format - MRED	Email	brisbane@urscorp.com
THE ACCOUNTS BRISBANE		
- A4 - AU Tax Invoice	Email	brisbane_accounts@urscorp.com

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EB0814158**	Page	: 1 of 4
Client	: **URS AUSTRALIA PTY LTD (QLD)**	Laboratory	: Environmental Division Brisbane
Contact	: MR STEPHEN DENNER	Contact	: Tim Kilmister
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4001	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: stephen_denner@urscorp.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 32432111	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32432199	Facsimile	: +61-7-3243 7218
Project	: 42626229	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 14-OCT-2008
Sampler	: AW	Issue Date	: 21-OCT-2008
Site	: ----		
		No. of samples received	: 2
Quote number	: EN/001/08	No. of samples analysed	: 2

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

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Inorganics

General Comments

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

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

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

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

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = Chemistry Abstract Services number
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **LCS recovery for EG020T (Total Metals) fall outside Dynamic Control Limits. They are however within ALS Static Control Limits and hence deemed acceptable.**

Analytical Results

Sub-Matrix: **WATER**			*Client sample ID*	**RM03B**	**QC01**	----	----	----
			Client sampling date / time	07-OCT-2008 12:00	07-OCT-2008 12:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB0814158-001**	**EB0814158-002**	**----**	**----**	**----**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**396**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**396**	----	----	----	----
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	**92**	----	----	----	----
ED045P: Chloride by PC Titrator								
Chloride	16887-00-6	1	mg/L	**292**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**67**	----	----	----	----
Magnesium	7439-95-4	1	mg/L	**25**	----	----	----	----
Sodium	7440-23-5	1	mg/L	**307**	----	----	----	----
Potassium	7440-09-7	1	mg/L	**6**	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.011**	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Barium	7440-39-3	0.001	mg/L	**0.036**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	**0.001**	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.001**	----	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.003**	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.021**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.002**	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.006**	----	----	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	----	<0.001	----	----	----
Beryllium	7440-41-7	0.001	mg/L	----	<0.001	----	----	----
Barium	7440-39-3	0.001	mg/L	----	<0.001	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	----	<0.0001	----	----	----
Chromium	7440-47-3	0.001	mg/L	----	<0.001	----	----	----
Cobalt	7440-48-4	0.001	mg/L	----	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	----	<0.001	----	----	----
Lead	7439-92-1	0.001	mg/L	----	<0.001	----	----	----
Manganese	7439-96-5	0.001	mg/L	----	<0.001	----	----	----
Nickel	7440-02-0	0.001	mg/L	----	<0.001	----	----	----

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	**RM03B**	**QC01**	----	----	----
			Client sampling date / time	07-OCT-2008 12:00	07-OCT-2008 12:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB0814158-001**	**EB0814158-002**	**----**	**----**	**----**
EG020T: Total Metals by ICP-MS - Continued								
Vanadium	7440-62-2	0.01	mg/L	----	<0.01	----	----	----
Zinc	7440-66-6	0.005	mg/L	----	<0.005	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	----	<0.0001	----	----	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**18.1**	----	----	----	----
^ Total Cations	----	0.01	meq/L	**18.9**	----	----	----	----
^ Ionic Balance	----	0.01	%	**2.29**	----	----	----	----

QUALITY CONTROL REPORT

Work Order	: **EB0814158**	Page	: 1 of 7
Client	: **URS AUSTRALIA PTY LTD (QLD)**	Laboratory	: Environmental Division Brisbane
Contact	: MR STEPHEN DENNER	Contact	: Tim Kilmister
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4001	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: stephen_denner@urscorp.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 32432111	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32432199	Facsimile	: +61-7-3243 7218
Project	: 42626229	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: ----		
C-O-C number	: ----	Date Samples Received	: 14-OCT-2008
Sampler	: AW	Issue Date	: 21-OCT-2008
Order number	: ----		
		No. of samples received	: 2
Quote number	: EN/001/08	No. of samples analysed	: 2

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

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

NATA
WORLD RECOGNISED
ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in
accordance with NATA
accreditation requirements.

Accredited for compliance with
ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Inorganics

General Comments

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

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

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

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

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = Chemistry Abstract Services number
LOR = Limit of reporting
RPD = Relative Percentage Difference
\# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR:- No Limit; Result between 10 and 20 times LOR:- 0% - 50%; Result > 20 times LOR:- 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
ED037P: Alkalinity by PC Titrator (QC Lot: 788783)									
EB0814137-002	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
ED040F: Dissolved Major Anions (QC Lot: 784619)									
EB0814087-009	Anonymous	ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EB0814135-011	Anonymous	ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
ED045P: Chloride by PC Titrator (QC Lot: 788784)									
EB0814137-003	Anonymous	ED045-P: Chloride	16887-00-6	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
ED093F: Dissolved Major Cations (QC Lot: 784620)									
EB0814087-009	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Magnesium	7439-95-4	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Sodium	7440-23-5	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Potassium	7440-09-7	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EB0814135-011	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Magnesium	7439-95-4	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Sodium	7440-23-5	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Potassium	7440-09-7	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EG020F: Dissolved Metals by ICP-MS (QC Lot: 786306)									
EB0814071-010	Anonymous	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Barium	7440-39-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Cobalt	7440-48-4	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Copper	7440-50-8	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Lead	7439-92-1	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EB0814071-021	Anonymous	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Barium	7440-39-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EG020F: Dissolved Metals by ICP-MS (QC Lot: 786306) - continued									
EB0814071-021	Anonymous	EG020A-F: Cobalt	7440-48-4	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Copper	7440-50-8	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Lead	7439-92-1	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EG020T: Total Metals by ICP-MS (QC Lot: 784764)									
EB0814133-005	Anonymous	EG020A-T: Cadmium	7440-43-9	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Arsenic	7440-38-2	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Beryllium	7440-41-7	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Barium	7440-39-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Chromium	7440-47-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Cobalt	7440-48-4	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Copper	7440-50-8	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Lead	7439-92-1	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Manganese	7439-96-5	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Nickel	7440-02-0	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Zinc	7440-66-6	0.005	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Vanadium	7440-62-2	0.01	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EB0814161-004	Anonymous	EG020A-T: Cadmium	7440-43-9	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Arsenic	7440-38-2	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Beryllium	7440-41-7	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Barium	7440-39-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Chromium	7440-47-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Cobalt	7440-48-4	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Copper	7440-50-8	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Lead	7439-92-1	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Manganese	7439-96-5	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Nickel	7440-02-0	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Zinc	7440-66-6	0.005	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Vanadium	7440-62-2	0.01	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EG035F: Dissolved Mercury by FIMS (QC Lot: 787606)									
EB0814136-002	Anonymous	EG035F: Mercury	7439-97-6	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EB0814178-001	Anonymous	EG035F: Mercury	7439-97-6	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 789122)									
EB0814137-001	Anonymous	EG035T: Mercury	7439-97-6	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

Method: Compound	*CAS Number*	*LOR*	*Unit*	*Method Blank (MB) Report*	*Laboratory Control Spike (LCS) Report*			
					Spike	*Spike Recovery (%)*	*Recovery Limits (%)*	
				Result	*Concentration*	*LCS*	*Low*	*High*
ED037P: Alkalinity by PC Titrator (QCLot: 788783)								
ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	----	200 mg/L	91.9	77.5	112
ED040F: Dissolved Major Anions (QCLot: 784619)								
ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	<1	----	----	----	----
ED045P: Chloride by PC Titrator (QCLot: 788784)								
ED045-P: Chloride	16887-00-6	1	mg/L	<1	1000 mg/L	100	88.4	110
ED093F: Dissolved Major Cations (QCLot: 784620)								
ED093F: Calcium	7440-70-2	1	mg/L	<1	----	----	----	----
ED093F: Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
ED093F: Sodium	7440-23-5	1	mg/L	<1	----	----	----	----
ED093F: Potassium	7440-09-7	1	mg/L	<1	----	----	----	----
EG020F: Dissolved Metals by ICP-MS (QCLot: 786306)								
EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.100 mg/L	108	79.6	115
EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	0.100 mg/L	124	80.8	130
EG020A-F: Barium	7440-39-3	0.001	mg/L	<0.001	----	----	----	----
EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.100 mg/L	110	86.6	113
EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	0.100 mg/L	122	84.4	128
EG020A-F: Cobalt	7440-48-4	0.001	mg/L	<0.001	0.100 mg/L	112	86.6	117
EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	0.200 mg/L	107	85	117
EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	0.100 mg/L	109	85.4	117
EG020A-F: Manganese	7439-96-5	0.001	mg/L	<0.001	0.100 mg/L	104	84.1	122
EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	0.100 mg/L	109	86.3	118
EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	0.100 mg/L	97.3	76.9	117
EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	0.200 mg/L	122	84.2	130
EG020T: Total Metals by ICP-MS (QCLot: 784764)								
EG020A-T: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.100 mg/L	93.2	75.7	110
EG020A-T: Beryllium	7440-41-7	0.001	mg/L	<0.001	0.100 mg/L	104	76.7	130
EG020A-T: Barium	7440-39-3	0.001	mg/L	<0.001	----	----	----	----
EG020A-T: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.100 mg/L	98.7	81.8	111
EG020A-T: Chromium	7440-47-3	0.001	mg/L	<0.001	0.100 mg/L	94.8	80.9	125
EG020A-T: Cobalt	7440-48-4	0.001	mg/L	<0.001	0.100 mg/L	96.7	81.3	117
EG020A-T: Copper	7440-50-8	0.001	mg/L	<0.001	0.200 mg/L	# 124	80.9	115
EG020A-T: Lead	7439-92-1	0.001	mg/L	<0.001	0.100 mg/L	104	84.4	113
EG020A-T: Manganese	7439-96-5	0.001	mg/L	<0.001	0.100 mg/L	96.5	76.8	123
EG020A-T: Nickel	7440-02-0	0.001	mg/L	<0.001	0.100 mg/L	96.0	81.5	117

Sub-Matrix: **WATER**

				Method Blank (MB) Report	*Laboratory Control Spike (LCS) Report*			
					Spike	*Spike Recovery (%)*	*Recovery Limits (%)*	
Method: Compound	*CAS Number*	*LOR*	*Unit*	*Result*	*Concentration*	*LCS*	*Low*	*High*
EG020T: Total Metals by ICP-MS (QCLot: 784764) - continued								
EG020A-T: Vanadium	7440-62-2	0.01	mg/L	<0.01	0.100 mg/L	93.8	70.5	119
EG020A-T: Zinc	7440-66-6	0.005	mg/L	<0.005	0.200 mg/L	100	81	127
EG035F: Dissolved Mercury by FIMS (QCLot: 787606)								
EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.010 mg/L	93.5	85.3	117
EG035T: Total Recoverable Mercury by FIMS (QCLot: 789122)								
EG035T: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.0100 mg/L	92.9	84.2	118

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report Spike Concentration	Spike Recovery (%) MS	Recovery Limits (%) Low	High
ED045P: Chloride by PC Titrator (QCLot: 788784)							
EB0814158-001	RM03B	ED045-P: Chloride	16887-00-6	80 mg/L	100	70	130
EG020T: Total Metals by ICP-MS (QCLot: 784764)							
EB0814137-001	Anonymous	EG020A-T: Arsenic	7440-38-2	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Beryllium	7440-41-7	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Barium	7440-39-3	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Cadmium	7440-43-9	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Chromium	7440-47-3	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Cobalt	7440-48-4	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Copper	7440-50-8	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Lead	7439-92-1	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Manganese	7439-96-5	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Nickel	7440-02-0	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Vanadium	7440-62-2	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-T: Zinc	7440-66-6	Anonymous	Anonymous	Anonymous	Anonymous
EG035F: Dissolved Mercury by FIMS (QCLot: 787606)							
EB0814136-002	Anonymous	EG035F: Mercury	7439-97-6	Anonymous	Anonymous	Anonymous	Anonymous
EG035T: Total Recoverable Mercury by FIMS (QCLot: 789122)							
EB0814137-001	Anonymous	EG035T: Mercury	7439-97-6	Anonymous	Anonymous	Anonymous	Anonymous

INTERPRETIVE QUALITY CONTROL REPORT

Work Order	: **EB0814158**	Page	: 1 of 5
Client	: URS AUSTRALIA PTY LTD (QLD)	Laboratory	: Environmental Division Brisbane
Contact	: MR STEPHEN DENNER	Contact	: Tim Kilmister
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4001	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: stephen_denner@urscorp.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 32432111	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32432199	Facsimile	: +61-7-3243 7218
Project	: 42626229	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: ----		
C-O-C number	: ----	Date Samples Received	: 14-OCT-2008
Sampler	: AW	Issue Date	: 21-OCT-2008
Order number	: ----		
		No. of samples received	: 2
Quote number	: EN/001/08	No. of samples analysed	: 2

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

This Interpretive Quality Control Report contains the following information:

- Analysis Holding Time Compliance
- Quality Control Parameter Frequency Compliance
- Brief Method Summaries
- Summary of Outliers

Analysis Holding Time Compliance

The following report summarises extraction / preparation and analysis times and compares with recommended holding times. Dates reported represent first date of extraction or analysis and precludes subsequent dilutions and reruns. Information is also provided re the sample container (preservative) from which the analysis aliquot was taken. Elapsed period to analysis represents number of days from sampling where no extraction / digestion is involved or period from extraction / digestion where this is present. For composite samples, sampling date is assumed to be that of the oldest sample contributing to the composite. Sample date for laboratory produced leachates is assumed as the completion date of the leaching process. Outliers for holding time are based on USEPA SW 846, APHA, AS and NEPM (1999). A listing of breaches is provided in the Summary of Outliers.

Holding times for leachate methods (excluding elutriates) vary according to the analytes being determined on the resulting solution. For non -volatile analytes, the holding time compliance assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These soil holding times are: Organics (14 days); Mercury (28 days) & other metals (180 days). A recorded breach therefore does not guarantee a breach for all non-volatile parameters.

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method	***Sample Date***	*Extraction / Preparation*			*Analysis*		
***Container** / Client Sample ID(s)*		***Date extracted***	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
ED037P: Alkalinity by PC Titrator							
Clear Plastic Bottle - Natural RM03B	**07-OCT-2008**	**---**	---	----	**20-OCT-2008**	21-OCT-2008	✓
ED040F: Dissolved Major Anions							
Clear Plastic Bottle - Natural RM03B	**07-OCT-2008**	**---**	---	----	**15-OCT-2008**	04-NOV-2008	✓
ED045P: Chloride by PC Titrator							
Clear Plastic Bottle - Natural RM03B	**07-OCT-2008**	**---**	---	----	**20-OCT-2008**	04-NOV-2008	✓
ED093F: Dissolved Major Cations							
Clear Plastic Bottle - Natural RM03B	**07-OCT-2008**	**---**	---	----	**15-OCT-2008**	04-NOV-2008	✓
EG020F: Dissolved Metals by ICP-MS							
Clear Plastic Bottle - Filtered; Lab-acidified RM03B	**07-OCT-2008**	**---**	---	----	**16-OCT-2008**	05-APR-2009	✓
EG020T: Total Metals by ICP-MS							
Clear Plastic Bottle - Unfiltered; Lab-acidified QC01	**07-OCT-2008**	**15-OCT-2008**	05-APR-2009	✓	**15-OCT-2008**	05-APR-2009	✓
EG035F: Dissolved Mercury by FIMS							
Clear Plastic Bottle - Filtered; Lab-acidified RM03B	**07-OCT-2008**	**----**	----	----	**17-OCT-2008**	04-NOV-2008	✓
EG035T: Total Recoverable Mercury by FIMS							
Clear Plastic Bottle - Unfiltered; Lab-acidified QC01	**07-OCT-2008**	**----**	----	----	**20-OCT-2008**	04-NOV-2008	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(where) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Alkalinity by PC Titrator	ED037-P	1	3	**33.3**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Chloride by PC Titrator	ED045-P	1	8	**12.5**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	2	19	**10.5**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	2	18	**11.1**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Anions - Filtered	ED040F	2	20	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Cations - Filtered	ED093F	2	20	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	6	**16.7**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite A	EG020A-T	2	19	**10.5**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Laboratory Control Samples (LCS)							
Alkalinity by PC Titrator	ED037-P	1	3	**33.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Chloride by PC Titrator	ED045-P	1	8	**12.5**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	1	19	**5.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	18	**5.6**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	6	**16.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite A	EG020A-T	1	19	**5.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Method Blanks (MB)							
Chloride by PC Titrator	ED045-P	1	8	**12.5**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	1	19	**5.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	18	**5.6**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Anions - Filtered	ED040F	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Cations - Filtered	ED093F	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	6	**16.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite A	EG020A-T	1	19	**5.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)							
Chloride by PC Titrator	ED045-P	1	8	**12.5**	**5.0**	✓	ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	1	19	**5.3**	**5.0**	✓	ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	18	**5.6**	**5.0**	✓	ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	6	**16.7**	**5.0**	✓	ALS QCS3 requirement
Total Metals by ICP-MS - Suite A	EG020A-T	1	19	**5.3**	**5.0**	✓	ALS QCS3 requirement

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Alkalinity by PC Titrator	ED037-P	WATER	APHA 21st ed., 2320 B This procedure determines alkalinity by both manual measurement and automated measurement (e.g. PC Titrate) using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Major Anions - Filtered	ED040F	WATER	APHA 21st ed., 3120 Sulfur and/or Silcon content is determined by ICP/AES and reported as Sulfate and/or Silica after conversion by gravimetric factor.
Chloride by PC Titrator	ED045-P	WATER	APHA 21st ed., 4500 Cl - B. Automated Silver Nitrate titration.
Major Cations - Filtered	ED093F	WATER	APHA 21st ed., 3120; USEPA SW 846 - 6010 The ICPAES technique ionises filtered sample atoms emitting a characteristic spectrum. This spectrum is then compared against matrix matched standards for quantification. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Dissolved Metals by ICP-MS - Suite A	EG020A-F	WATER	(APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Total Metals by ICP-MS - Suite A	EG020A-T	WATER	(APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Dissolved Mercury by FIMS	EG035F	WATER	AS 3550, APHA 21st ed. 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the filtered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Total Mercury by FIMS	EG035T	WATER	AS 3550, APHA 21st ed. 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the unfiltered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Ionic Balance by PCT and ICPAES	EN055	WATER	APHA 21st Ed. 1030F. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
Digestion for Total Recoverable Metals	EN25	WATER	USEPA SW846-3005 Method 3005 is a Nitric/Hydrochloric acid digestion procedure used to prepare surface and ground water samples for analysis by ICPAES or ICPMS. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)

Summary of Outliers

Outliers : Quality Control Samples

The following report highlights outliers flagged in the Quality Control (QC) Report. Surrogate recovery limits are static and based on USEPA SW846 or ALS-QWI/EN/38 (in the absence of specific USEPA limits). This report displays QC Outliers (breaches) only.

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: **WATER**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Laboratory Control Spike (LCS) Recoveries							
EG020T: Total Metals by ICP-MS	888612-029	----	**Copper**	7440-50-8	124 %	80.9-115%	**Recovery greater than upper control limit**

- **For all matrices, no Method Blank value outliers occur.**
- **For all matrices, no Duplicate outliers occur.**
- **For all matrices, no Matrix Spike outliers occur.**

Regular Sample Surrogates

- **For all regular sample matrices, no surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

This report displays Holding Time breaches only. Only the respective Extraction / Preparation and/or Analysis component is/are displayed.

- **No Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

The following report highlights breaches in the Frequency of Quality Control Samples.

- **No Quality Control Sample Frequency Outliers exist.**

CHAIN OF CUSTODY DOCUMENTATION

114912

ALS Environmental

CLIENT: URS AUSTRALIA

POSTAL ADDRESS: GPO BOX 302, BRISBANE 4001 QLD

SEND REPORT TO: A. STANNARD SEND INVOICE TO: S. DENNER

DATA NEEDED BY: REPORT NEEDED BY:

PROJECT ID: SANTOS GLNG QUOTE NO.:

P.O. NO.: COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

RED/GREEN ~~[illegible]~~ 125mL provided for metals analysis : no preservative . dissolved metals please (field filtered).

FOR LAB USE ONLY

COOLER SEAL

Yes .... No ....

Broken............. Intact ....

COOLER TEMP. deg. C

LABORATORY BATCH NO.:

SAMPLERS: A. STANNARD

PHONE: 32432[illegible] FAX: 32432199 EMAIL: Andrew-Stannard@ urscorp.com

REPORT FORMAT: HARD: ☐ FAX: ☐ E-MAIL: ☑

QC LEVEL: QCS1: ☐ QCS2: ☐ QCS3: ☐ QCS4: ☐

SAMPLE DATA				*CONTAINER DATA			ANALYSIS REQUIRED			
SAMPLE ID	MATRIX	DATE	TIME	TYPE & PRESERVATIVE	NO.	pH	MAJOR IONS	MAJOR ALKALOIDS	NEPM 13 METALS (DISSOLVED)	NOTES
1 CCDAM	LIQUID	21/10/08		1 x 500mL P, 1x RG	2	6-7	x	x	x	
2 RM03		"			2		x	x	x	
3 FVGW02		22/10/08			2		x	x	x	
4 FVGW03		"			2		x	x	x	
5 FVGW05		23/10/08			2		x	x	x	
6 AVGW03		"			2		x	x	x	
7 QC01		21/10/08			2		x	x	x	
8 QC02		22/10/08			2		x	x	x	
9 QC03		"			2		x	x	x	
10 QC04		23/10/08			2		x	x	x	

Environmental Division
Brisbane
Work Order
EB0814729
Telephone : + 61-7-3243 7222

RELINQUISHED BY		RECEIVED BY		METHOD OF SHIPMENT
NAME: A. STANNARD OF: URS	DATE: 24/10/08 TIME: 1100.	NAME: Bruce Lee OF: ALS	DATE: 27/10/08 TIME: 08:00	CONSIGNMENT NOTE NO.
NAME: OF:	DATE: TIME:	NAME: OF:	DATE: TIME:	TRANSPORT CO. NAME

*Container Type and Preservative Codes: **P** = Natural Plastic; **N** = Nitric Acid Preserved; **C** = Sodium Hydroxide Preserved; **J** = Solvent Washed Acid Rinsed Jar; **S** = Solvent Washed Acid Rinsed Glass Bottle; **V** = Vial; **VC** = Hydrochloric Acid Preserved Vial; **VS** = Sulphuric Acid Preservative Vial; **BS** = Sulphuric Acid Preserved Glass Bottle; **PS** = Sulphuric Acid Preserved Plastic Bottle; **Z** = Zinc Acetate Preserved Bottle; **E** = EDTA Preserved Bottle; **H** = Hydrochloric Acid Preserved Plastic Bottle; **F** = Formaldehyde Preserved; **ST** = Sterile Bottle; **B** = Plastic Bag; **O** = Other

AUSTRALIAN LABORATORY SERVICES P/L

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YELLOW - CUSTOMER COPY
PINK - BOOK COPY

SAMPLE RECEIPT NOTIFICATION (SRN)

Comprehensive Report

Work Order : **EB0814729**

Client	: **URS AUSTRALIA PTY LTD (QLD)**	Laboratory	: Environmental Division Brisbane
Contact	: MR ANDREW STANNARD	Contact	: Tim Kilmister
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4001	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: andrew_stannard@urscorp.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 32432145	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32432199	Facsimile	: +61-7-3243 7218
Project	: SANTOS GLNG	Page	: 1 of 2
Order number	: ----		
C-O-C number	: 114912	Quote number	: ES2008URSQLD0041 (EN/001/08)
Site	: ----		
Sampler	: A. STANNARD	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Dates

Date Samples Received	: 27-OCT-2008	Issue Date	: 27-OCT-2008 16:49
Client Requested Due Date	: 05-NOV-2008	Scheduled Reporting Date	: **03-NOV-2008**

Delivery Details

Mode of Delivery	: Carrier	Temperature	: 19.4 C - Ice present
No. of coolers/boxes	: 1 MEDIUM	No. of samples received	: 10
Sercurity Seal	: Intact.	No. of samples analysed	: 10

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Requested Deliverables
- **Samples received in appropriately pretreated and preserved containers.**
- **Sample(s) have been received within recommended holding times.**
- Please direct any turn around / technical queries to the laboratory contact designated above.
- Please direct any queries related to sample condition / numbering / breakages to Maggie Kahi.
- Analytical work for this work order will be conducted at ALS Brisbane.
- Sample Disposal - Aqueous (14 days), Solid (90 days) from date of completion of work order.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exist.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process neccessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.
When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing

Matrix: **WATER**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	WATER - EN055 Ionic Balance	WATER - Major Anions Cl, SO4, Alkalinity PCT	WATER - Major Cations Ca, Mg, Na, K	WATER - W-03 13 Metals (NEPM Suite)
EB0814729-001	21-OCT-2008 15:00	CCDAM	✓	✓	✓	✓
EB0814729-002	21-OCT-2008 15:00	RM03	✓	✓	✓	✓
EB0814729-003	22-OCT-2008 15:00	FVGW02	✓	✓	✓	✓
EB0814729-004	22-OCT-2008 15:00	FVGW03	✓	✓	✓	✓
EB0814729-005	23-OCT-2008 15:00	FVGW05	✓	✓	✓	✓
EB0814729-006	23-OCT-2008 15:00	AVGW03	✓	✓	✓	✓
EB0814729-007	21-OCT-2008 15:00	QC01	✓	✓	✓	✓
EB0814729-008	22-OCT-2008 15:00	QC02	✓	✓	✓	✓
EB0814729-009	22-OCT-2008 15:00	QC03	✓	✓	✓	✓
EB0814729-010	23-OCT-2008 15:00	QC04	✓	✓	✓	✓

Requested Deliverables

MR ANDREW STANNARD		
- *AU Certificate of Analysis - NATA	Email	andrew_stannard@urscorp.com
- A4 - AU Sample Receipt Notification - Environmental	Email	andrew_stannard@urscorp.com
- AU Interpretive QC Report (Anon QCI Not Rep)	Email	andrew_stannard@urscorp.com
- AU QC Report (Anon QC Not Rep) - NATA	Email	andrew_stannard@urscorp.com
- Default - Chain of Custody	Email	andrew_stannard@urscorp.com
- EDI Format - MRED	Email	andrew_stannard@urscorp.com
MR STEPHEN DENNER		
- A4 - AU Tax Invoice	Email	stephen_denner@urscorp.com
RESULTS ADDRESS		
- *AU Certificate of Analysis - NATA	Email	brisbane@urscorp.com
- A4 - AU Sample Receipt Notification - Environmental	Email	brisbane@urscorp.com
- AU Interpretive QC Report (Anon QCI Not Rep)	Email	brisbane@urscorp.com
- AU QC Report (Anon QC Not Rep) - NATA	Email	brisbane@urscorp.com
- Default - Chain of Custody	Email	brisbane@urscorp.com
- EDI Format - MRED	Email	brisbane@urscorp.com
THE ACCOUNTS BRISBANE		
- A4 - AU Tax Invoice	Email	brisbane_accounts@urscorp.com

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order : **EB0814729**

Client : **URS AUSTRALIA PTY LTD (QLD)**
Contact : MR ANDREW STANNARD
Address : GPO BOX 302
BRISBANE QLD, AUSTRALIA 4001

E-mail : andrew_stannard@urscorp.com
Telephone : +61 32432145
Facsimile : +61 07 32432199

Project : SANTOS GLNG
Order number : ----
C-O-C number : 114912
Sampler : A. STANNARD
Site : ----

Quote number : EN/001/08

Page : 1 of 4

Laboratory : Environmental Division Brisbane
Contact : Tim Kilmister
Address : 32 Shand Street Stafford QLD Australia 4053

E-mail : Services.Brisbane@alsenviro.com
Telephone : +61-7-3243 7222
Facsimile : +61-7-3243 7218

QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 27-OCT-2008
Issue Date : 03-NOV-2008

No. of samples received : 10
No. of samples analysed : 10

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

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED
ACCREDITATION

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Inorganics
Stephen Hislop	Senior Inorganic Chemist	Inorganics

General Comments

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

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

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

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

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = Chemistry Abstract Services number
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Ionic Balance out of acceptable limits for sample AVGW03 due to analytes not quantified in this report.**
- **Ionic balances are within acceptable limits as detailed in the 20th Ed. APHA "Standard Methods for the Examination of Water and Wastewater".**

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	**CCDAM**	**RM03**	**FVGW02**	**FVGW03**	**FVGW05**
			Client sampling date / time	21-OCT-2008 15:00	21-OCT-2008 15:00	22-OCT-2008 15:00	22-OCT-2008 15:00	23-OCT-2008 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB0814729-001**	**EB0814729-002**	**EB0814729-003**	**EB0814729-004**	**EB0814729-005**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	**77**	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**865**	**230**	**16**	**285**	**345**
Total Alkalinity as CaCO3	----	1	mg/L	**942**	**230**	**16**	**285**	**345**
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	**9**	**93**	**18**	**36**	**16**
ED045P: Chloride by PC Titrator								
Chloride	16887-00-6	1	mg/L	**529**	**70**	**1360**	**109**	**26**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**8**	**20**	**344**	**73**	**66**
Magnesium	7439-95-4	1	mg/L	**6**	**9**	**3**	**21**	**33**
Sodium	7440-23-5	1	mg/L	**701**	**149**	**511**	**101**	**45**
Potassium	7440-09-7	1	mg/L	**29**	**5**	**5**	**5**	**6**
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.001	**0.002**	**0.005**	**0.018**	**0.011**
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L	**0.093**	**0.022**	**3.20**	**0.126**	**0.467**
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	**0.003**	**0.002**	<0.001	**0.002**	**0.001**
Cobalt	7440-48-4	0.001	mg/L	<0.001	**0.004**	<0.001	**0.022**	**0.009**
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	**0.001**	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	<0.001	**0.118**	**0.072**	**1.22**	**0.379**
Nickel	7440-02-0	0.001	mg/L	<0.001	**0.029**	<0.001	**0.020**	**0.010**
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	<0.005	**0.006**	**0.005**	**0.046**	**0.012**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**33.9**	**8.51**	**39.1**	**9.52**	**7.95**
^ Total Cations	----	0.01	meq/L	**32.1**	**8.38**	**39.8**	**9.85**	**8.10**
^ Ionic Balance	----	0.01	%	**2.76**	**0.81**	**0.87**	**1.65**	**0.90**

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	**AVGW03**	**QC01**	**QC02**	**QC03**	**QC04**
			Client sampling date / time	23-OCT-2008 15:00	21-OCT-2008 15:00	22-OCT-2008 15:00	22-OCT-2008 15:00	23-OCT-2008 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB0814729-006**	**EB0814729-007**	**EB0814729-008**	**EB0814729-009**	**EB0814729-010**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**526**	<1	<1	**312**	<1
Total Alkalinity as CaCO3	----	1	mg/L	**526**	<1	<1	**312**	<1
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	**5**	**4**	**4**	**34**	**4**
ED045P: Chloride by PC Titrator								
Chloride	16887-00-6	1	mg/L	**97**	**24**	**23**	**116**	**23**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**48**	**1**	<1	**69**	**1**
Magnesium	7439-95-4	1	mg/L	**15**	**4**	**4**	**20**	**4**
Sodium	7440-23-5	1	mg/L	**277**	**11**	**11**	**106**	**11**
Potassium	7440-09-7	1	mg/L	**9**	<1	<1	**5**	<1
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.014**	<0.001	<0.001	**0.014**	<0.001
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L	**0.230**	<0.001	<0.001	**0.127**	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	**0.001**	<0.001	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	**0.023**	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	**1.46**	**0.001**	<0.001	**1.30**	**0.001**
Nickel	7440-02-0	0.001	mg/L	**0.002**	<0.001	<0.001	**0.022**	<0.001
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	**0.048**	<0.005
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**13.3**	**0.76**	**0.73**	**10.2**	**0.73**
^ Total Cations	----	0.01	meq/L	**15.9**	**0.90**	**0.85**	**9.88**	**0.92**
^ Ionic Balance	----	0.01	%	**8.70**	----	----	**1.71**	----

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

QUALITY CONTROL REPORT

Work Order	: **EB0814729**	Page	: 1 of 7
Client	: **URS AUSTRALIA PTY LTD (QLD)**	Laboratory	: Environmental Division Brisbane
Contact	: MR ANDREW STANNARD	Contact	: Tim Kilmister
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4001	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: andrew_stannard@urscorp.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 32432145	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32432199	Facsimile	: +61-7-3243 7218
Project	: SANTOS GLNG	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: ----		
C-O-C number	: 114912	Date Samples Received	: 27-OCT-2008
Sampler	: A. STANNARD	Issue Date	: 03-NOV-2008
Order number	: ----		
		No. of samples received	: 10
Quote number	: EN/001/08	No. of samples analysed	: 10

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

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

NATA
WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Inorganics
Stephen Hislop	Senior Inorganic Chemist	Inorganics

General Comments

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

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

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

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

Key :
Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = Chemistry Abstract Services number
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR:- No Limit; Result between 10 and 20 times LOR:- 0% - 50%; Result > 20 times LOR:- 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
ED037P: Alkalinity by PC Titrator (QC Lot: 799177)									
EB0814729-001	CCDAM	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	77		0.0	0% - 20%
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	865	865	0.0	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	942	942	0.0	0% - 20%
EB0814729-010	QC04	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	<1		0.0	No Limit
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	<1		0.0	No Limit
ED040F: Dissolved Major Anions (QC Lot: 798580)									
EB0814644-004	Anonymous	ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EB0814720-003	Anonymous	ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
ED040F: Dissolved Major Anions (QC Lot: 798582)									
EB0814729-006	AVGW03	ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	1	1	0.0	No Limit
EB0814748-005	Anonymous	ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
ED045P: Chloride by PC Titrator (QC Lot: 799178)									
EB0814729-001	CCDAM	ED045-P: Chloride	16887-00-6	1	mg/L	529	512	3.3	0% - 20%
EB0814729-010	QC04	ED045-P: Chloride	16887-00-6	1	mg/L	23		4.2	0% - 20%
ED093F: Dissolved Major Cations (QC Lot: 798581)									
EB0814644-004	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Magnesium	7439-95-4	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Sodium	7440-23-5	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Potassium	7440-09-7	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EB0814720-003	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Magnesium	7439-95-4	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Sodium	7440-23-5	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Potassium	7440-09-7	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
ED093F: Dissolved Major Cations (QC Lot: 798583)									
EB0814729-006	AVGW03	ED093F: Calcium	7440-70-2	1	mg/L	10		0.0	0% - 50%
		ED093F: Magnesium	7439-95-4	1	mg/L	3	3	0.0	No Limit
		ED093F: Sodium	7440-23-5	1	mg/L	54	56	2.6	0% - 20%
		ED093F: Potassium	7440-09-7	1	mg/L	2	2	0.0	No Limit
EB0814748-005	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Magnesium	7439-95-4	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Sodium	7440-23-5	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Potassium	7440-09-7	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EG020F: Dissolved Metals by ICP-MS (QC Lot: 797913)									
EB0814720-001	Anonymous	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Barium	7440-39-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Cobalt	7440-48-4	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Copper	7440-50-8	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Lead	7439-92-1	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EB0814729-002	RM03	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	0.0	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	0.002		0.0	No Limit
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Barium	7440-39-3	0.001	mg/L	0.022		0.0	0% - 20%
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	0.002	0.002	48.6	No Limit
		EG020A-F: Cobalt	7440-48-4	0.001	mg/L	0.004	0.004	0.0	No Limit
		EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001		0.0	No Limit
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	0.118		2.7	0% - 20%
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	0.029	0.031	4.7	0% - 20%
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	0.006		0.0	No Limit
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01		0.0	No Limit
EG035F: Dissolved Mercury by FIMS (QC Lot: 799207)									
EB0814632-001	Anonymous	EG035F: Mercury	7439-97-6	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EB0814676-001	Anonymous	EG035F: Mercury	7439-97-6	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EG035F: Dissolved Mercury by FIMS (QC Lot: 799208)									
EB0814729-003	FVGW02	EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001		0.0	No Limit
EB0814734-033	Anonymous	EG035F: Mercury	7439-97-6	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
ED037P: Alkalinity by PC Titrator (QCLot: 799177)								
ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	----	500 mg/L	96.4	77.5	112
ED040F: Dissolved Major Anions (QCLot: 798580)								
ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	<1	----	----	----	----
ED040F: Dissolved Major Anions (QCLot: 798582)								
ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	<1	----	----	----	----
ED045P: Chloride by PC Titrator (QCLot: 799178)								
ED045-P: Chloride	16887-00-6	1	mg/L	<1	1000 mg/L	105	88.4	110
ED093F: Dissolved Major Cations (QCLot: 798581)								
ED093F: Calcium	7440-70-2	1	mg/L	<1	----	----	----	----
ED093F: Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
ED093F: Sodium	7440-23-5	1	mg/L	<1	----	----	----	----
ED093F: Potassium	7440-09-7	1	mg/L	<1	----	----	----	----
ED093F: Dissolved Major Cations (QCLot: 798583)								
ED093F: Calcium	7440-70-2	1	mg/L	<1	----	----	----	----
ED093F: Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
ED093F: Sodium	7440-23-5	1	mg/L	<1	----	----	----	----
ED093F: Potassium	7440-09-7	1	mg/L	<1	----	----	----	----
EG020F: Dissolved Metals by ICP-MS (QCLot: 797913)								
EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.100 mg/L	94.3	79.6	115
EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	0.100 mg/L	123	80.8	130
EG020A-F: Barium	7440-39-3	0.001	mg/L	<0.001	----	----	----	----
EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.100 mg/L	102	86.6	113
EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	0.100 mg/L	113	84.4	128
EG020A-F: Cobalt	7440-48-4	0.001	mg/L	<0.001	0.100 mg/L	101	86.6	117
EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	0.200 mg/L	103	85	117
EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	0.100 mg/L	99.3	85.4	117
EG020A-F: Manganese	7439-96-5	0.001	mg/L	<0.001	0.100 mg/L	99.6	84.1	122
EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	0.100 mg/L	104	86.3	118
EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	0.100 mg/L	94.1	76.9	117
EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	0.200 mg/L	110	84.2	130
EG035F: Dissolved Mercury by FIMS (QCLot: 799207)								
EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.010 mg/L	102	85.3	117
EG035F: Dissolved Mercury by FIMS (QCLot: 799208)								

Sub-Matrix: **WATER**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
				Result	Concentration	LCS	Low	High
EG035F: Dissolved Mercury by FIMS (QCLot: 799208) - continued								
EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.010 mg/L	102	85.3	117

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

				Matrix Spike (MS) Report			
				Spike	Spike Recovery (%)	Recovery Limits (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
ED045P: Chloride by PC Titrator (QCLot: 799178)							
EB0814729-002	RM03	ED045-P: Chloride	16887-00-6	40 mg/L	115	70	130
EG020F: Dissolved Metals by ICP-MS (QCLot: 797913)							
EB0814720-002	Anonymous	EG020A-F: Arsenic	7440-38-2	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Beryllium	7440-41-7	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Barium	7440-39-3	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Cadmium	7440-43-9	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Chromium	7440-47-3	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Cobalt	7440-48-4	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Copper	7440-50-8	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Lead	7439-92-1	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Manganese	7439-96-5	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Nickel	7440-02-0	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Vanadium	7440-62-2	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Zinc	7440-66-6	Anonymous	Anonymous	Anonymous	Anonymous
EG035F: Dissolved Mercury by FIMS (QCLot: 799207)							
EB0814632-001	Anonymous	EG035F: Mercury	7439-97-6	Anonymous	Anonymous	Anonymous	Anonymous
EG035F: Dissolved Mercury by FIMS (QCLot: 799208)							
EB0814729-003	FVGW02	EG035F: Mercury	7439-97-6	0.01 mg/L	75.9	70	130

INTERPRETIVE QUALITY CONTROL REPORT

Work Order	: **EB0814729**	Page	: 1 of 6
Client	: URS AUSTRALIA PTY LTD (QLD)	Laboratory	: Environmental Division Brisbane
Contact	: MR ANDREW STANNARD	Contact	: Tim Kilmister
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4001	Address	: 32 Shand Street Stafford QLD Australia 4053
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Telephone	: +61 32432145	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32432199	Facsimile	: +61-7-3243 7218
Project	: SANTOS GLNG	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: ----		
C-O-C number	: 114912	Date Samples Received	: 27-OCT-2008
Sampler	: A. STANNARD	Issue Date	: 03-NOV-2008
Order number	: ----		
		No. of samples received	: 10
Quote number	: EN/001/08	No. of samples analysed	: 10

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

This Interpretive Quality Control Report contains the following information:

- Analysis Holding Time Compliance
- Quality Control Parameter Frequency Compliance
- Brief Method Summaries
- Summary of Outliers

Analysis Holding Time Compliance

The following report summarises extraction / preparation and analysis times and compares with recommended holding times. Dates reported represent first date of extraction or analysis and precludes subsequent dilutions and reruns. Information is also provided re the sample container (preservative) from which the analysis aliquot was taken. Elapsed period to analysis represents number of days from sampling where no extraction / digestion is involved or period from extraction / digestion where this is present. For composite samples, sampling date is assumed to be that of the oldest sample contributing to the composite. Sample date for laboratory produced leachates is assumed as the completion date of the leaching process. Outliers for holding time are based on USEPA SW 846, APHA, AS and NEPM (1999). A listing of breaches is provided in the Summary of Outliers.

Holding times for leachate methods (excluding elutriates) vary according to the analytes being determined on the resulting solution. For non -volatile analytes, the holding time compliance assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These soil holding times are: Organics (14 days); Mercury (28 days) & other metals (180 days). A recorded breach therefore does not guarantee a breach for all non-volatile parameters.

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method *Container / Client Sample ID(s)*	*Sample Date*	*Extraction / Preparation*			*Analysis*		
		Date extracted	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
ED037P: Alkalinity by PC Titrator							
Clear Plastic Bottle - Natural CCDAM, RM03, QC01	**21-OCT-2008**	**---**	---	----	**30-OCT-2008**	04-NOV-2008	✓
Clear Plastic Bottle - Natural FVGW02, FVGW03, QC02, QC03	**22-OCT-2008**	**---**	---	----	**30-OCT-2008**	05-NOV-2008	✓
Clear Plastic Bottle - Natural FVGW05, AVGW03, QC04	**23-OCT-2008**	**---**	---	----	**30-OCT-2008**	06-NOV-2008	✓
ED040F: Dissolved Major Anions							
Clear Plastic Bottle - Natural CCDAM, RM03, QC01	**21-OCT-2008**	**---**	---	----	**30-OCT-2008**	18-NOV-2008	✓
Clear Plastic Bottle - Natural FVGW02, FVGW03, QC02, QC03	**22-OCT-2008**	**---**	---	----	**30-OCT-2008**	19-NOV-2008	✓
Clear Plastic Bottle - Natural FVGW05, AVGW03, QC04	**23-OCT-2008**	**---**	---	----	**30-OCT-2008**	20-NOV-2008	✓
ED045P: Chloride by PC Titrator							
Clear Plastic Bottle - Natural CCDAM, RM03, QC01	**21-OCT-2008**	**---**	---	----	**30-OCT-2008**	18-NOV-2008	✓
Clear Plastic Bottle - Natural FVGW02, FVGW03, QC02, QC03	**22-OCT-2008**	**---**	---	----	**30-OCT-2008**	19-NOV-2008	✓
Clear Plastic Bottle - Natural FVGW05, AVGW03, QC04	**23-OCT-2008**	**---**	---	----	**30-OCT-2008**	20-NOV-2008	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method	***Sample Date***	*Extraction / Preparation*			*Analysis*		
Container */ Client Sample ID(s)*		***Date extracted***	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
ED093F: Dissolved Major Cations							
Clear Plastic Bottle - Natural CCDAM, RM03, QC01	**21-OCT-2008**	**---**	---	----	**30-OCT-2008**	18-NOV-2008	✓
Clear Plastic Bottle - Natural FVGW02, FVGW03, QC02, QC03	**22-OCT-2008**	**---**	---	----	**30-OCT-2008**	19-NOV-2008	✓
Clear Plastic Bottle - Natural FVGW05, AVGW03, QC04	**23-OCT-2008**	**---**	---	----	**30-OCT-2008**	20-NOV-2008	✓
EG020F: Dissolved Metals by ICP-MS							
Clear Plastic Bottle - Filtered; Lab-acidified CCDAM, RM03, QC01	**21-OCT-2008**	**---**	---	----	**29-OCT-2008**	19-APR-2009	✓
Clear Plastic Bottle - Filtered; Lab-acidified FVGW02, FVGW03, QC02, QC03	**22-OCT-2008**	**---**	---	----	**29-OCT-2008**	20-APR-2009	✓
Clear Plastic Bottle - Filtered; Lab-acidified FVGW05, AVGW03, QC04	**23-OCT-2008**	**---**	---	----	**29-OCT-2008**	21-APR-2009	✓
EG035F: Dissolved Mercury by FIMS							
Clear Plastic Bottle - Filtered; Lab-acidified CCDAM, RM03, QC01	**21-OCT-2008**	**----**	----	----	**30-OCT-2008**	18-NOV-2008	✓
Clear Plastic Bottle - Filtered; Lab-acidified FVGW02, FVGW03, QC02, QC03	**22-OCT-2008**	**----**	----	----	**30-OCT-2008**	19-NOV-2008	✓
Clear Plastic Bottle - Filtered; Lab-acidified FVGW05, AVGW03, QC04	**23-OCT-2008**	**----**	----	----	**30-OCT-2008**	20-NOV-2008	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(where) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Alkalinity by PC Titrator	ED037-P	2	15	**13.3**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Chloride by PC Titrator	ED045-P	2	15	**13.3**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	4	36	**11.1**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	2	20	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Anions - Filtered	ED040F	4	40	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Cations - Filtered	ED093F	4	39	**10.3**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Laboratory Control Samples (LCS)							
Alkalinity by PC Titrator	ED037-P	1	15	**6.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Chloride by PC Titrator	ED045-P	1	15	**6.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	2	36	**5.6**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Method Blanks (MB)							
Chloride by PC Titrator	ED045-P	1	15	**6.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	2	36	**5.6**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Anions - Filtered	ED040F	2	40	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Cations - Filtered	ED093F	2	39	**5.1**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)							
Chloride by PC Titrator	ED045-P	1	15	**6.7**	**5.0**	✓	ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	2	36	**5.6**	**5.0**	✓	ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	20	**5.0**	**5.0**	✓	ALS QCS3 requirement

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Alkalinity by PC Titrator	ED037-P	WATER	APHA 21st ed., 2320 B This procedure determines alkalinity by both manual measurement and automated measurement (e.g. PC Titrate) using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Major Anions - Filtered	ED040F	WATER	APHA 21st ed., 3120 Sulfur and/or Silcon content is determined by ICP/AES and reported as Sulfate and/or Silica after conversion by gravimetric factor.
Chloride by PC Titrator	ED045-P	WATER	APHA 21st ed., 4500 Cl - B. Automated Silver Nitrate titration.
Major Cations - Filtered	ED093F	WATER	APHA 21st ed., 3120; USEPA SW 846 - 6010 The ICPAES technique ionises filtered sample atoms emitting a characteristic spectrum. This spectrum is then compared against matrix matched standards for quantification. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Dissolved Metals by ICP-MS - Suite A	EG020A-F	WATER	(APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Dissolved Mercury by FIMS	EG035F	WATER	AS 3550, APHA 21st ed. 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the filtered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Ionic Balance by PCT and ICPAES	EN055	WATER	APHA 21st Ed. 1030F. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)

Summary of Outliers

Outliers : Quality Control Samples

The following report highlights outliers flagged in the Quality Control (QC) Report. Surrogate recovery limits are static and based on USEPA SW846 or ALS-QWI/EN/38 (in the absence of specific USEPA limits). This report displays QC Outliers (breaches) only.

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

- **For all matrices, no Method Blank value outliers occur.**
- **For all matrices, no Duplicate outliers occur.**
- **For all matrices, no Laboratory Control outliers occur.**
- **For all matrices, no Matrix Spike outliers occur.**

Regular Sample Surrogates

- **For all regular sample matrices, no surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

This report displays Holding Time breaches only. Only the respective Extraction / Preparation and/or Analysis component is/are displayed.

- **No Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

The following report highlights breaches in the Frequency of Quality Control Samples.

- **No Quality Control Sample Frequency Outliers exist.**

Appendix D: LNG Facility Borehole Logs

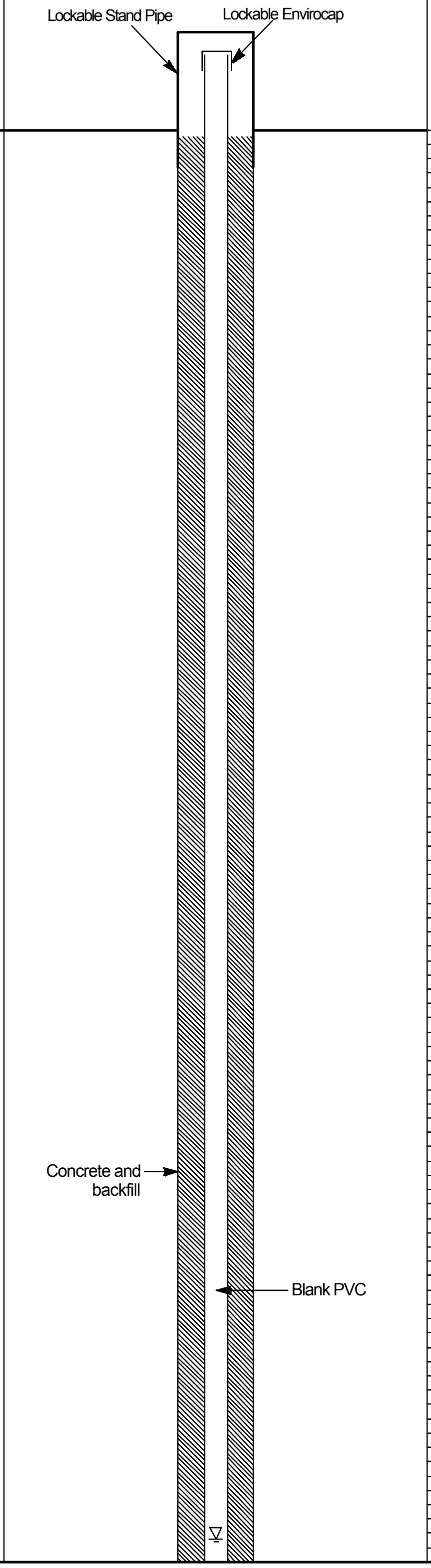
URS Australia Pty Ltd

Monitoring Well GW1

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.:	**42626224**
Project Reference:	**GLNG**
Drilling Contractor:	
Drilling Method:	
Logged By:	**Tom Silverman**
Checked By:	
Date Started:	**5-11-08**
Date Finished:	**5-11-08**
Relative Level:	8.908 mAHD
Coordinates:	317537.803 mE 7369428.566 mN
Permit No:	
Client:	**Santos**

SAMPLING DETAILS — **WELL CONSTRUCTION DETAILS** — **DESCRIPTION OF STRATA**



Sample Type	Sampling and Observations	PID (ppm)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			CLAY with 10-25% fine sand, 5-10% silt, dark yellow/brown, dry, low plasticity, very stiff, no odour	VS					L	D	CL
☒	u50		increasing sand and gravel with depth								CL
☒	30 blows/140mm		SAND with 10-30% clay and minor gravel. Yellow brown with black, orange and white staining, no odour, dry, very dense	VD						D	SC
			SAND with 20-30% gravel and 10-20% clay. Very hard drilling								SC
			Decreasing gravel size below 4m. (Too hard for SPT & u50.)								SC
			White MUDSTONE.Decreasing sand and gravel.Very hard drilling								
☒	60 blows/110mm		White MUDSTONE with 5-10% sand, gravel, very stiff-hard								
			White MUDSTONE with 10-30% sand and gravel								

REMARKS:

Sheet 2 of 3

URS Australia Pty Ltd

Monitoring Well GW1

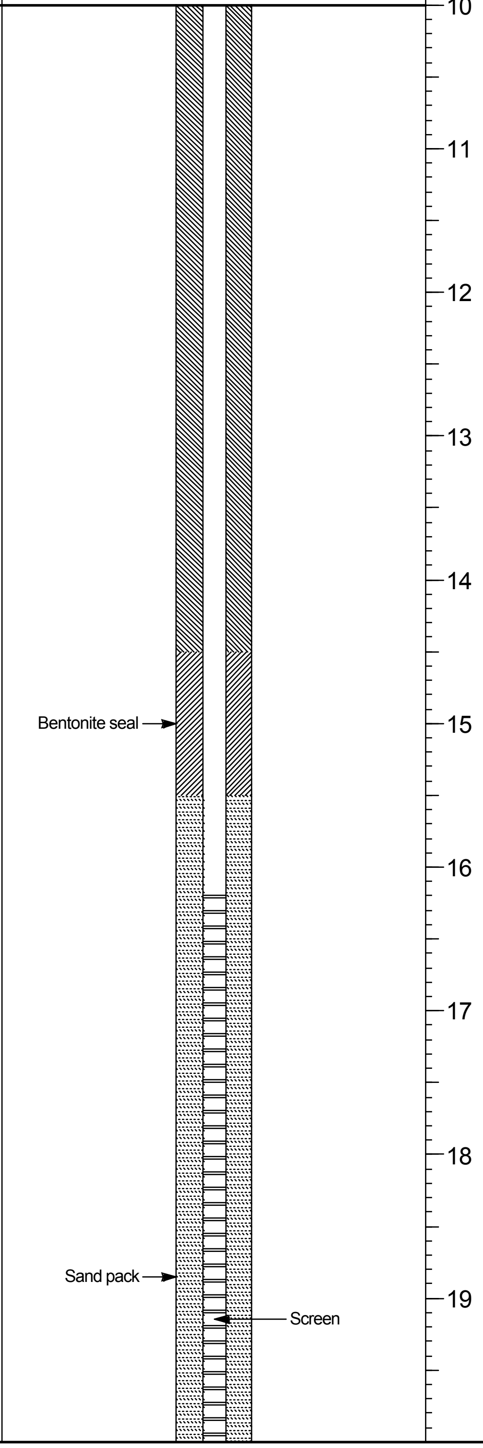
URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor:		Project No.: **42626224**	Project Reference: **GLNG**
Drilling Method:	Logged By: **Tom Silverman** Checked By: Date Started: **5-11-08** Date Finished: **5-11-08**	Relative Level: 8.908 mAHD Coordinates: 317537.803 mE 7369428.566 mN Permit No:	Client: **Santos**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
10		White MUDSTONE with 10-30% sand and gravel (losing water to formation 11-12m)								
16		White MUDSTONE with sand and gravel lenses (up to 0.5 m).Likely a fractured conglomerate								
17		Fractured CONGLOMERATE with 10-20% gravel and brown silt, quartz-rich angular gravel (broken by drilling)								
19		Fractured CONGLOMERATE with 10-20% quartz-rich angular gravel and fine brown silt.								

REMARKS:

Sheet 3 of 3

URS Australia Pty Ltd

Monitoring Well GW1

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor:

Project No.: **42626224**

Project Reference: **GLNG**

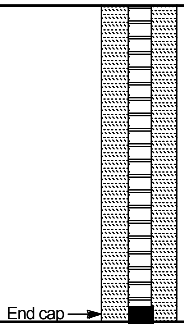
Drilling Method:

Logged By: **Tom Silverman**
Checked By:
Date Started: **5-11-08**
Date Finished: **5-11-08**

Relative Level: 8.908 mAHD
Coordinates: 317537.803 mE
7369428.566 mN
Permit No:

Client: **Santos**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				20		GRAVEL and sand								
				21										
				22		Refusal end of bore								
				23										
				24										
				25										
				26										
				27										
				28										
				29										



REMARKS:

URS Australia Pty Ltd

Monitoring Well GW2D

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor:

Project No.: **42626224**

Project Reference: **GLNG**

Drilling Method:

Logged By: **Tom Silverman**
Checked By:
Date Started: **5-9-08**
Date Finished: **5-9-08**

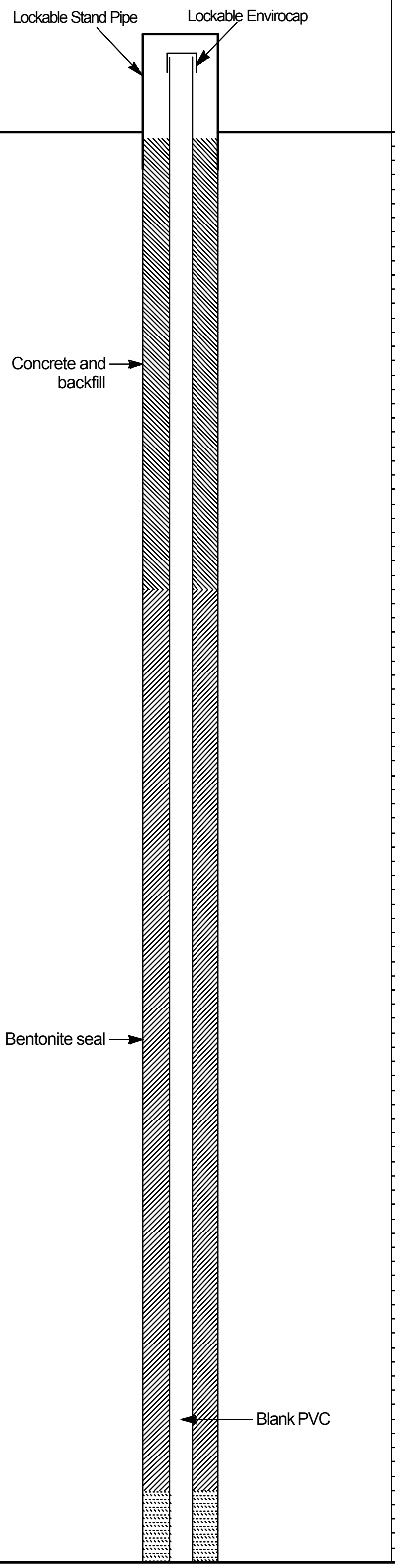
Relative Level: 19.686 mAHD
Coordinates: 318196.392 mE
7369336.355 mN
Permit No:

Client: **Santos**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)
☒	4/06/2006	
☒	30 blows/150mm	
☒	7/16/21	

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
	Poorly graded SAND, 20-30% silt, dark red/brown, no odor, dry, dense								SM
	SAND with gravel, 20-40% silt and clay, dark red brown, no odor, very dense								SP
	Fine SAND with gravel, 20-40% silty clay, dark red brown, no odor, very dense								SP
	Silty clay with 20-40% fine sand and gravel. Red brown grading to white clayey silt								
	Clayey SILT with fine sand and gravel								
	Yellow/brown CLAY								CL
	CLAY (likely mudstone) with 10-20% sand and gravel								SC

REMARKS:

Sheet 2 of 3

URS Australia Pty Ltd

Monitoring Well GW2D

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626224**

Project Reference: **GLNG**

Drilling Contractor:

Drilling Method:

Logged By: **Tom Silverman**

Checked By:

Date Started: **5-9-08**

Date Finished: **5-9-08**

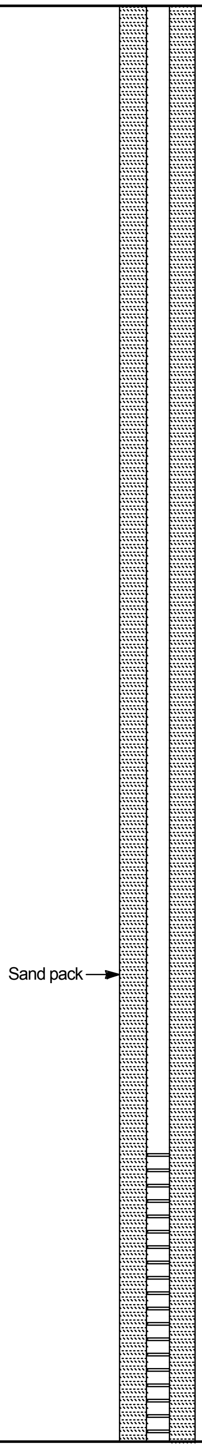
Relative Level: 19.686 mAHD

Coordinates: 318196.392 mE
7369336.355 mN

Permit No:

Client: **Santos**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				10	▨									
				18	▨	CLAY (likely mudstone) with 20-40% sand and gravel								CL



Depth (m): 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

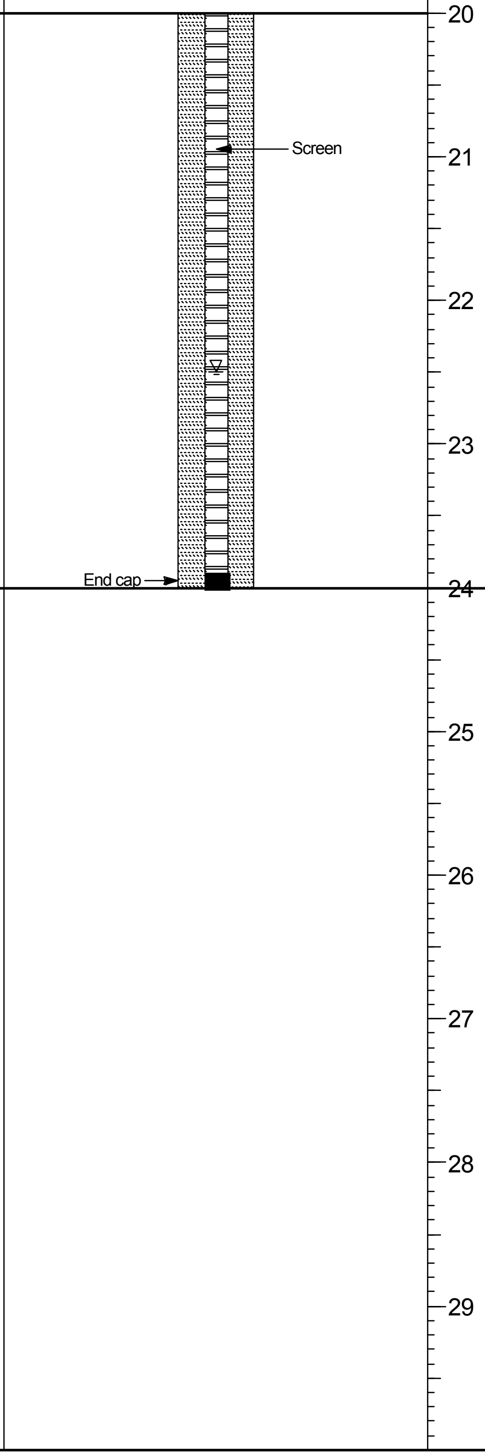
REMARKS:

URS Australia Pty Ltd

Monitoring Well GW2D

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626224**	Project Reference: **GLNG**
Drilling Contractor:			
Drilling Method:	Logged By: **Tom Silverman** Checked By: Date Started: **5-9-08** Date Finished: **5-9-08**	Relative Level: 19.686 mAHD Coordinates: 318196.392 mE 7369336.355 mN Permit No:	Client: **Santos**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS
Sample Type	Sampling and Observations	PID (ppm)	



DESCRIPTION OF STRATA

Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
▨									
▨	Weathered CONGLOMERATE with 50% sand, 30-50% silt, and 5-10% gravel								
▨	Competent CONGLOMERATE,difficult drilling								CL
	Refusal with roller-bit. End of bore.								

REMARKS:

Sheet 1 of 1

URS Australia Pty Ltd

Monitoring Well GW2S

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor:

Drilling Method:

Project No.: **42626224**

Project Reference: **GLNG**

Logged By: **Tom Silverman**
Checked By:
Date Started: **20-5-08**
Date Finished: **20-5-08**

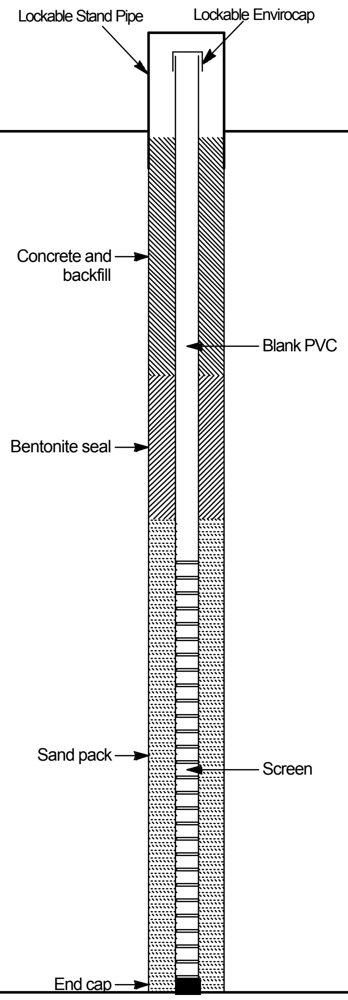
Relative Level: 19.874 mAHD
Coordinates: 318197.964 mE
7369337.488 mN
Permit No:

Client: **Santos**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0		Poorly graded SAND, 20-30% silt, dark red/brown, no odor, dry, dense								SM
		Silty clayey fine SAND with gravel, 20-40% silty clay, dark red brown, no odor, very dense								SM
4		Silty sandy CLAY (20-40% sand) with gravel. Red brown grading to white clayey SILT								CL
5		Clayey SILT with sand and gravel								
		Yellow/brown CLAY								SC
6		End of bore								

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

REMARKS:

Sheet 1 of 1

URS Australia Pty Ltd

Monitoring Well GW3

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor:

Project No.: **42626224**

Project Reference: **GLNG**

Drilling Method:

Logged By: **Tom Silverman**
Checked By:
Date Started: **5-11-08**
Date Finished: **5-11-08**

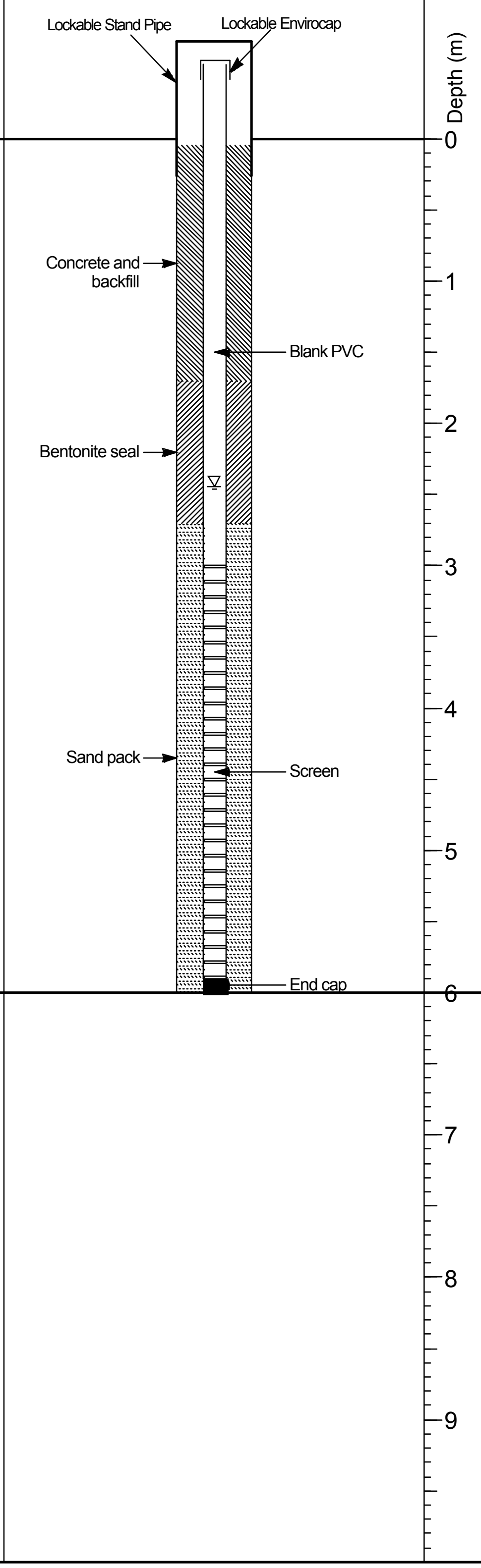
Relative Level: 3.362 mAHD
Coordinates: 317411.82 mE
7369164.126 mN
Permit No:

Client: **Santos**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)
☒	6/18/15	
☒	7/07/2007	
☒	30 blows/120mm	

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
▨	Grey CLAY with brown/orange mottling, 5-10% sand and gravel, medium plasticity, dry, stiff to very stiff	ST-VS					M	D	CL
▨	CLAY with 20-30% sand, 5-15% gravel, non plastic, dry							D	CL
▩	SAND with 20-40% clay and 5-10% gravel, dark yellow brown with orange mottling								
▨	Yellow brown CLAY with 5-10% sand, 5-10% gravel, med plasticity, moist, stiff	ST					M	M	CL
▨	Grey CLAY with orange brown mottling, lenses of fine sand								CL
▩	White/grey weathered MUDSTONE								CL
⁘	Fractured CONGLOMERATE, garvel, sand and silt								SP
	End of bore	VD							

REMARKS:

Sheet 1 of 3

URS Australia Pty Ltd

Monitoring Well GW4D

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor:

Drilling Method:

Project No.: **42626224**

Project Reference: **GLNG**

Logged By: **Tom Silverman**
Checked By:
Date Started: **19-5-08**
Date Finished: **19-5-08**

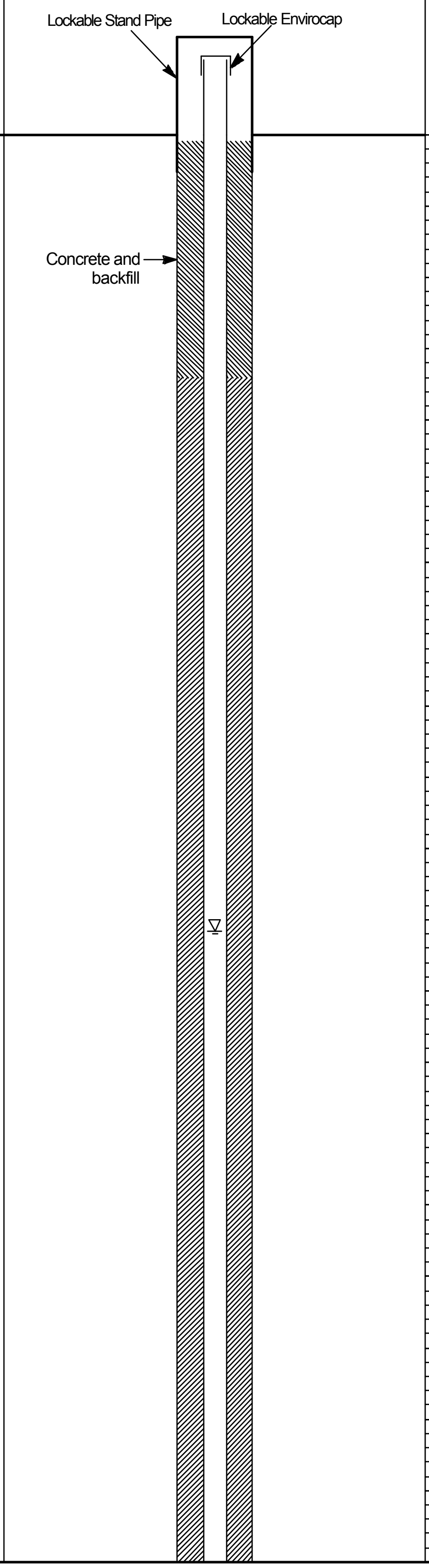
Relative Level: 2.696 mAHD
Coordinates: 318551.245 mE
7368755.536 mN
Permit No:

Client: **Santos**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0		Loose brown GRAVEL, sand, dry, no odour								GR
1		Yellow brown CLAY with 20-40% sand, dry, stiff, no odour, low plasticity								CL
2		CLAY with 10% gravel, 10-20% firm sand, moist, plastic							M	CL
		CLAY with 20-40% sand, low plasticity						L		CL
3		Wash boring begins. CLAY with angular gravel (10 to 40%), 10 - 30% sand								CL
4										
5		White and brown weathered MUDSTONE with 10% fine sand, wet, stiff, low plasticity								CL
6										
7		White MUDSTONE with traces of fine sand and gravel								CL
8										
9										

REMARKS:

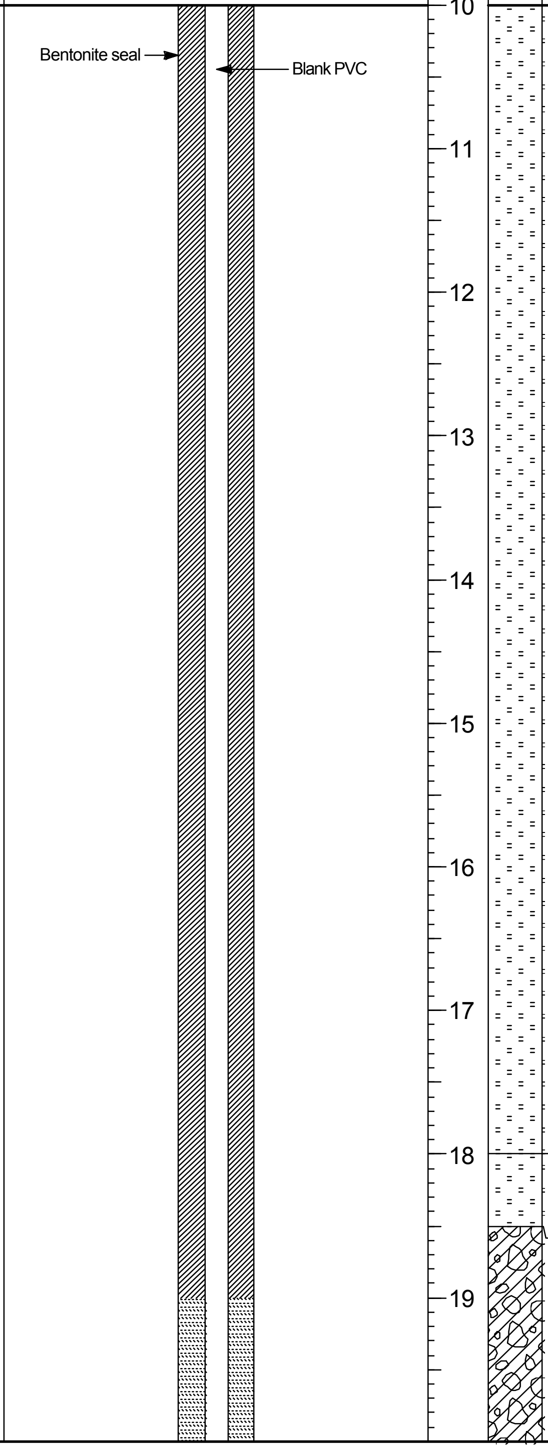
Sheet 2 of 3

URS Australia Pty Ltd

Monitoring Well GW4D

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626224**	Project Reference: **GLNG**
Drilling Contractor:			
Drilling Method:	Logged By: **Tom Silverman** Checked By: Date Started: **19-5-08** Date Finished: **19-5-08**	Relative Level: 2.696 mAHD Coordinates: 318551.245 mE 7368755.536 mN Permit No:	Client: **Santos**

SAMPLING DETAILS | **WELL CONSTRUCTION DETAILS** | **DESCRIPTION OF STRATA**



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			18	Very difficult drilling, MUDSTONE with 25-45% sand and gravel								
				CONGLOMERATE with increasing sand and gravel with depth								GC

REMARKS:

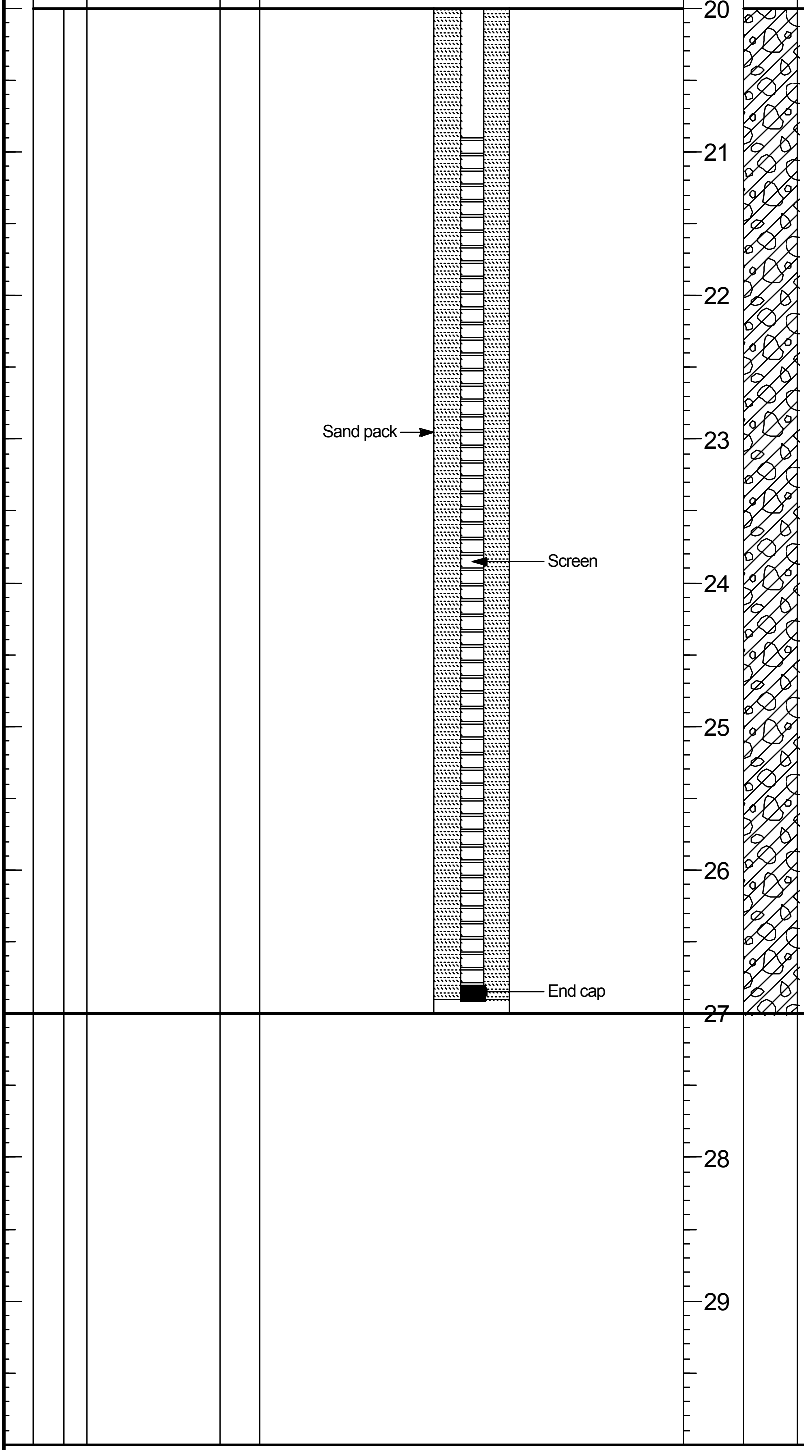
Sheet 3 of 3

URS Australia Pty Ltd

Monitoring Well GW4D

URS Australia Pty. Ltd. Level 14, 240 Queen Street, Brisbane QLD 4000	Phone +61 7 3243 2111 Fax +61 7 3243 2199	Project No.: **42626224**	Project Reference: **GLNG**
Drilling Contractor:			
Drilling Method:	Logged By: **Tom Silverman** Checked By: Date Started: **19-5-08** Date Finished: **19-5-08**	Relative Level: 2.696 mAHD Coordinates: 318551.245 mE 7368755.536 mN Permit No:	Client: **Santos**

SAMPLING DETAILS			WELL CONSTRUCTION DETAILS		DESCRIPTION OF STRATA									
Sample Type	Sampling and Observations	PID (ppm)		Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
				27		End of bore								



REMARKS:

Sheet 1 of 1

URS Australia Pty Ltd

Monitoring Well GW4S

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor:

Project No.: **42626224**

Project Reference: **GLNG**

Drilling Method:

Logged By: **Tom Silverman**
Checked By:
Date Started: **5-8-08**
Date Finished: **5-8-08**

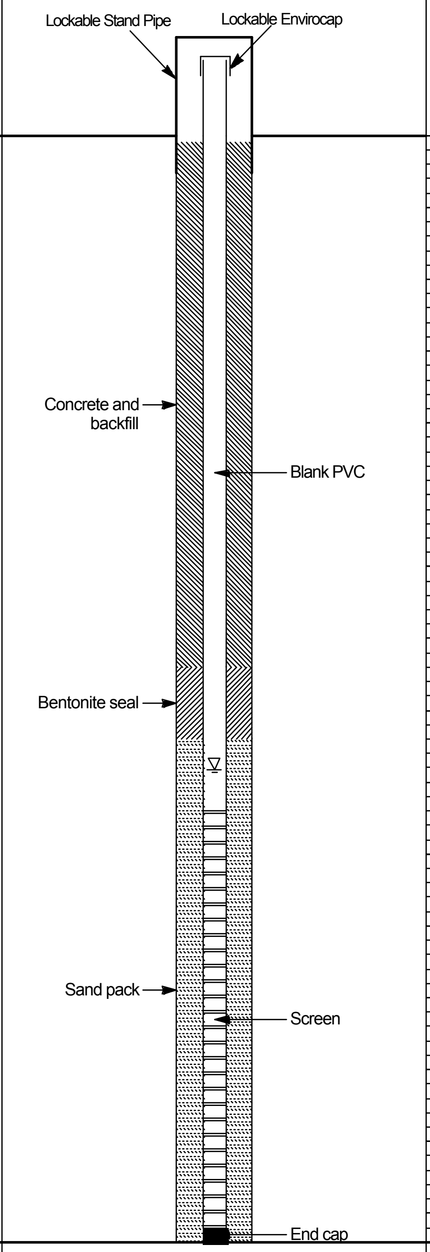
Relative Level: 2.572 mAHD
Coordinates: 318547.849 mE
7368757.635 mN
Permit No:

Client: **Santos**

SAMPLING DETAILS

Depth (m)	Sample Type	Sampling and Observations	PID (ppm)
1.35	☒	2/02/2004	
3	☒	21/18/10	
6	☒	5/10/2012	

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
0		Loose dry brown GRAVEL and sand								GR
1.2	▨	Yellow brown CLAY with 20-40% sand, dry, stiff, no odour, low plasticity								CL
2	▨	CLAY with 10% gravel, 10-20% firm sand, moist, plastic							M	CL
2.3	▨	CLAY with 20-40% sand, low plasticity						L		CL
3	▨	Wash boring begins. CLAY with angular gravel (10 to 40%), 10 - 30% sand								CL
5	▨	Weathered MUDSTONE with 10% fine sand, white with brown pockets, wet, stiff, low plasticity, continuous until ~7.7 m								CL
7.7		End of bore							w	

Depth (m): 0 1 2 3 4 5 6 7 8 9

REMARKS:

Sheet 1 of 1

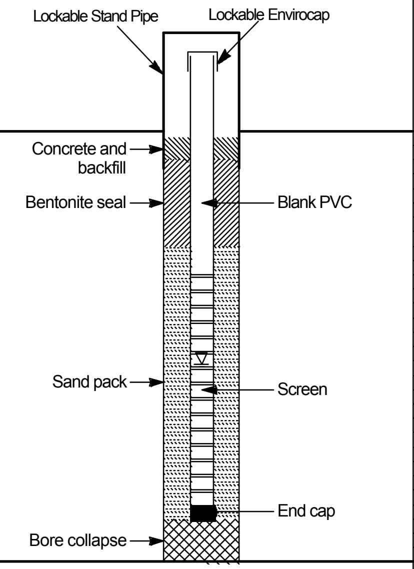
URS Australia Pty Ltd

Monitoring Well GW5

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.:	**42626224**	Project Reference:	**GLNG**
Drilling Contractor:			
Drilling Method:		Client:	**Santos**
Logged By:	**Tom Silverman**	Relative Level:	2.534 mAHD
Checked By:		Coordinates:	319699.331 mE 7368502.67 mN
Date Started:	**5-8-08**	Permit No:	
Date Finished:	**5-8-08**		

WELL CONSTRUCTION DETAILS



SAMPLING DETAILS / DESCRIPTION OF STRATA

Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			0		Brown/grey CLAY with 10% sand and gravel, very plastic, stiff, moist								SP
☒	30 blows/120mm				Red brown sandy CLAY (30-50% sand), non plastic, moist, stiff								CL
			2		Grey sandy weathered SILTSTONE. Very difficult to auger through								SP
			3		Refusal, very hard. End of bore								

REMARKS:

Sheet 1 of 1

URS Australia Pty Ltd

Monitoring Well GW6

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Project No.: **42626224**

Project Reference: **GLNG**

Drilling Contractor:

Drilling Method:

Logged By: **Tom Silverman**
Checked By:
Date Started: **5-9-08**
Date Finished: **5-9-08**

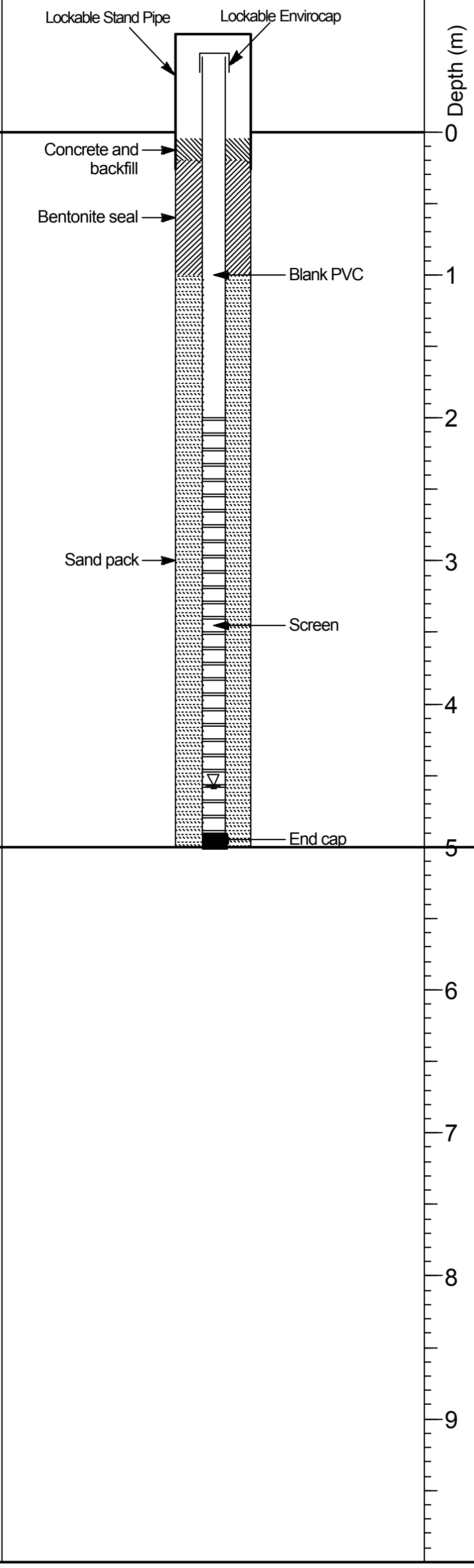
Relative Level: 5.643 mAHD
Coordinates: 318789.577 mE
7368334.003 mN
Permit No:

Client: **Santos**

SAMPLING DETAILS

Sample Type	Sampling and Observations	PID (ppm)
☒	u50	
☒	18/22/15	
☒	30 blows/100mm	

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA

Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
▨	Yellow/brown to grey sandy CLAY (30-40% sand),mod plasticity, dry, no odour, more stiff								CL
░	Light yellow brown poorly graded fine sand with 10-20% silt to clay, dry, no odour, loose								SP
▨	Yellow/brown CLAY, dry, no odour, very stiff to hard								CL
░	CLAY with 20-30% fine sand. yellow/brown, dry, no odour, very stiff to hard								SP
	End of bore								

REMARKS:

Sheet 1 of 1

URS Australia Pty Ltd

Monitoring Well GW8

URS Australia Pty. Ltd.
Level 14, 240 Queen Street, Brisbane QLD 4000
Phone +61 7 3243 2111
Fax +61 7 3243 2199

Drilling Contractor:

Project No.: **42626224**

Project Reference: **GLNG**

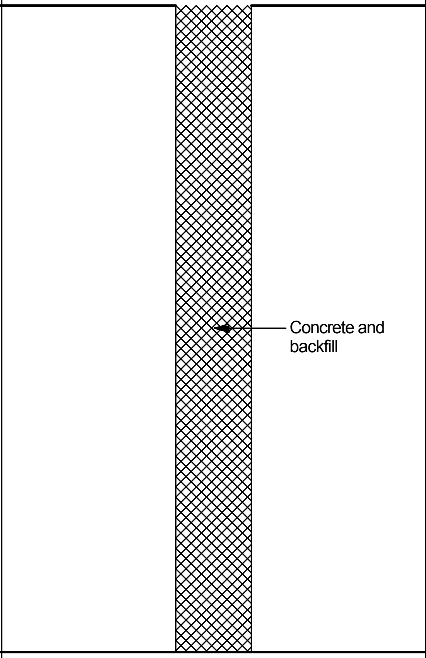
Drilling Method:

Logged By: **Tom Silverman**
Checked By:
Date Started:
Date Finished:

Relative Level: mAHD
Coordinates: mE
mN
Permit No:

Client: **Santos**

SAMPLING DETAILS / WELL CONSTRUCTION DETAILS / DESCRIPTION OF STRATA



Sample Type	Sampling and Observations	PID (ppm)	Depth (m)	Legend	Lithology	Consistency	Structure	Grain Size	Shape	Sorting	Plasticity	Moisture	Classification
			0		Dark red brown fine SAND, with <15% silty/clay, dry medium dense								
			1		Dark red brown silty clayey fine SAND with gravel pieces, dry medium dense								GP
☒	6/10/2021				Fine SAND with 20-40% silt and clay, with large pieces of gravel								GC
					Silty CLAY with 10-25% fine sand, brown, mod plasticity								CL
			3		Silty clayey fine SAND with gravel very dense								SP
☒	30 blows/140mm				End of bore								

Depth (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

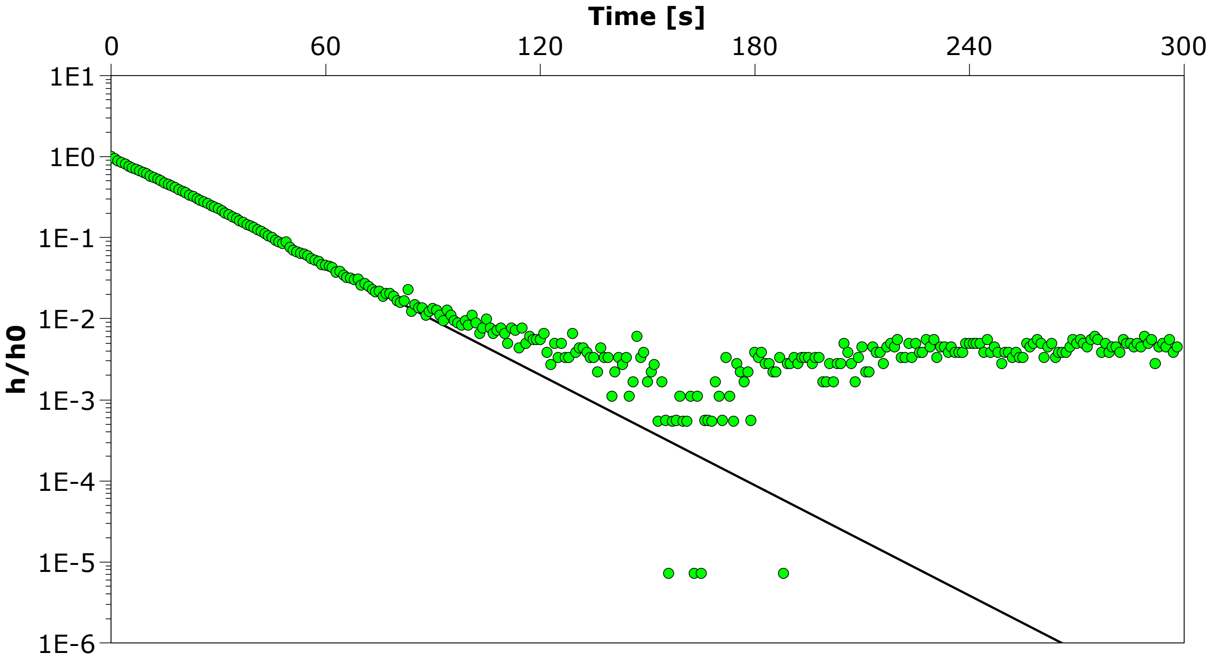
REMARKS:

Appendix E: LNG Facility Variable Head Test Data

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane, QLD, 4000
Phone: +61 7 3243 2111

Slug Test Analysis Report
Project: Santos GLNG EIS
Number: 42626229
Client: Santos

Location: Curtis Island QLD	Slug Test: GW1	Test Well: GW1
Test conducted by: AW		Test date: 18/06/2008
Analysis performed by: AW	GW1 Bouwer & Rice	Date: 1/07/2008
Aquifer Thickness: 5.20 m		



Calculation after Bouwer && Rice

Observation well	K [m/d]	
GW1	1.03×10^{0}	

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane, QLD, 4000
Phone: +61 7 3243 2111

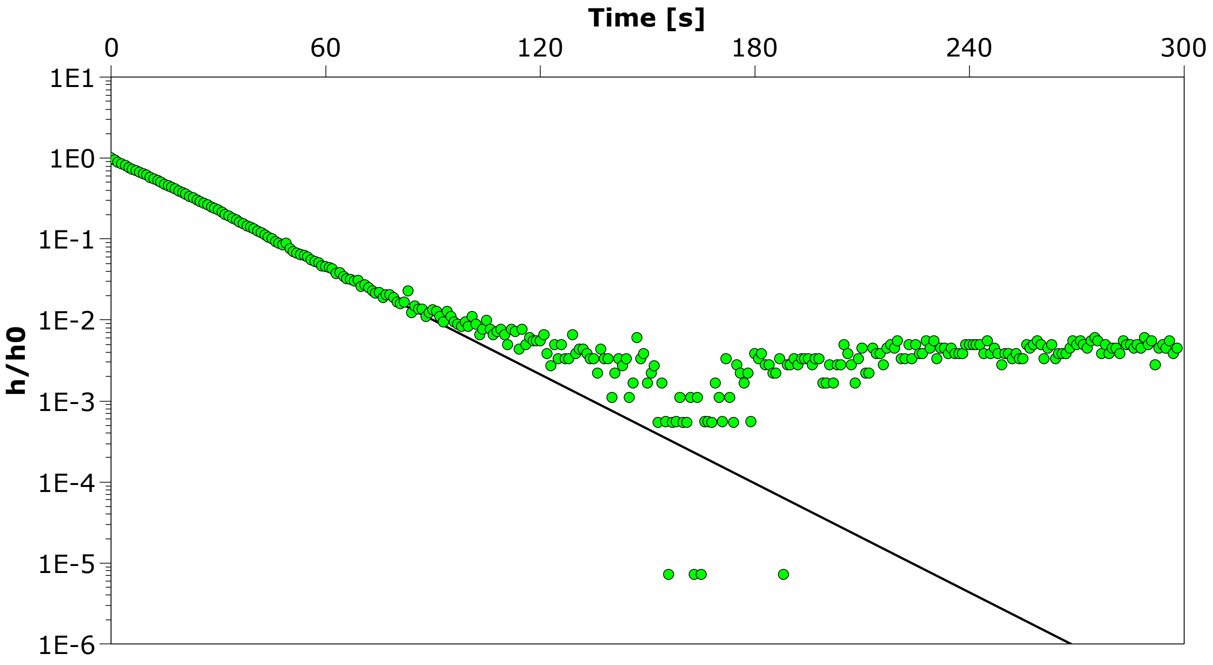
Slug Test Analysis Report

Project: Santos GLNG EIS

Number: 42626229

Client: Santos

Location: Curtis Island QLD	Slug Test: GW1	Test Well: GW1
Test conducted by: AW		Test date: 18/06/2008
Analysis performed by: AW	GW1 Hvorslev	Date: 1/07/2008
Aquifer Thickness: 5.20 m		

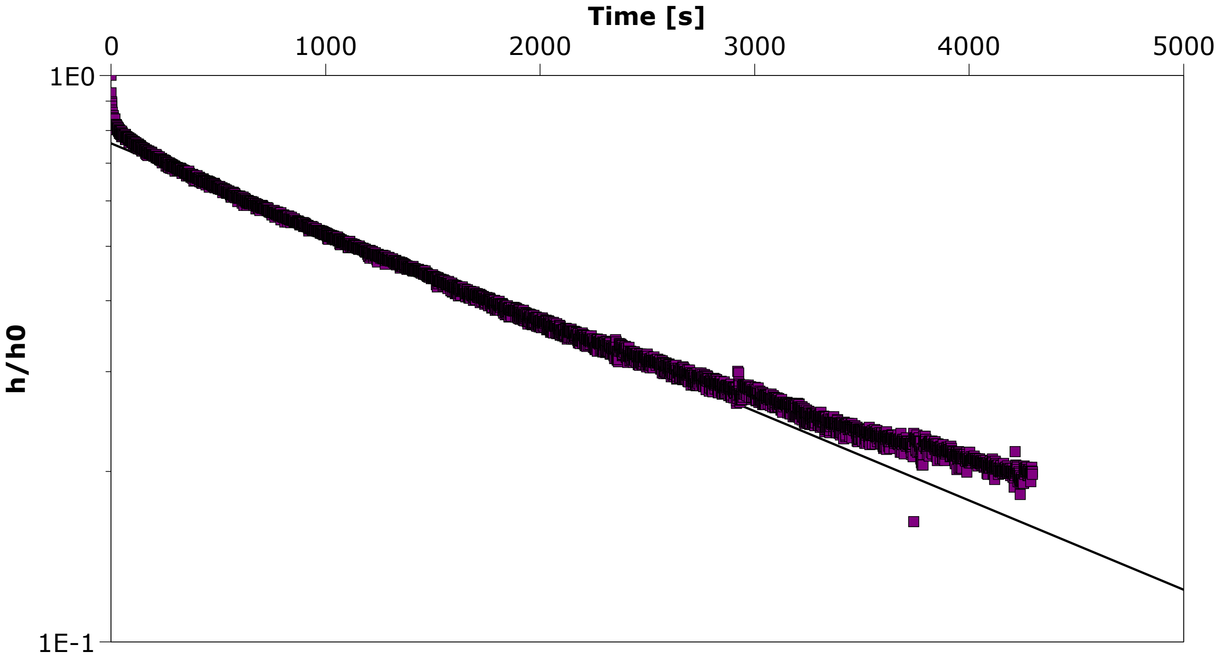


Calculation after Hvorslev

Observation well	K [m/d]	
GW1	1.30×10^{0}	

URS Australia Pty Ltd **Level 14, 240 Queen St** **Brisbane, QLD, 4000** **Phone: +61 7 3243 2111**	**Slug Test Analysis Report** Project: Santos GLNG EIS Number: 42626229 Client: Santos

Location: Curtis Island QLD	Slug Test: GW2D	Test Well: GW2D
Test conducted by: AW		Test date: 18/06/2008
Analysis performed by: AW	GW2D Bouwer & Rice	Date: 1/07/2008
Aquifer Thickness: 2.00 m		



Calculation after Bouwer && Rice

Observation well	K [m/d]	
GW2D	1.55×10^{-2}	

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane, QLD, 4000
Phone: +61 7 3243 2111

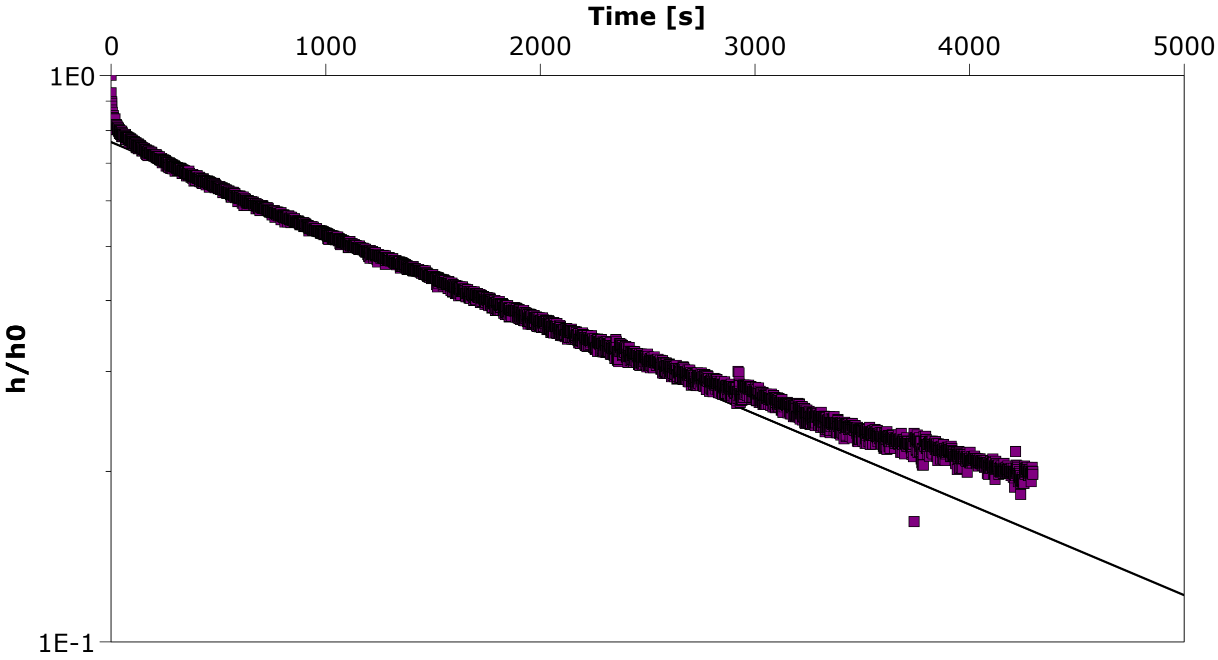
Slug Test Analysis Report

Project: Santos GLNG EIS

Number: 42626229

Client: Santos

Location: Curtis Island QLD	Slug Test: GW2D	Test Well: GW2D
Test conducted by: AW		Test date: 18/06/2008
Analysis performed by: AW	GW2D Hvorslev	Date: 1/07/2008
Aquifer Thickness: 2.00 m		



Calculation after Hvorslev

Observation well	K [m/d]	
GW2D	2.05×10^{-2}	

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane, QLD, 4000
Phone: +61 7 3243 2111

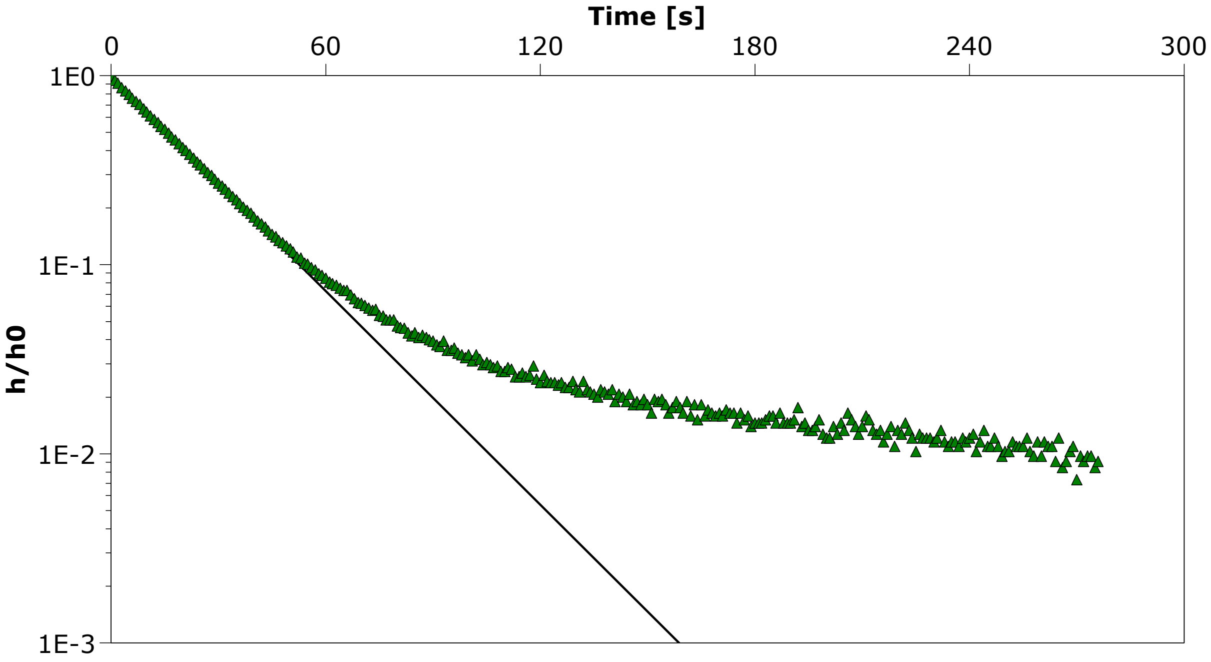
Slug Test Analysis Report

Project: Santos GLNG EIS

Number: 42626229

Client: Santos

Location: Curtis Island QLD	Slug Test: GW4D	Test Well: GW4D
Test conducted by: AW		Test date: 18/06/2008
Analysis performed by: AW	GW4D Bouwer & Rice	Date: 1/07/2008
Aquifer Thickness: 7.50 m		



Calculation after Bouwer && Rice

Observation well	K [m/d]	
GW4D	8.45×10^{-1}	

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane, QLD, 4000
Phone: +61 7 3243 2111

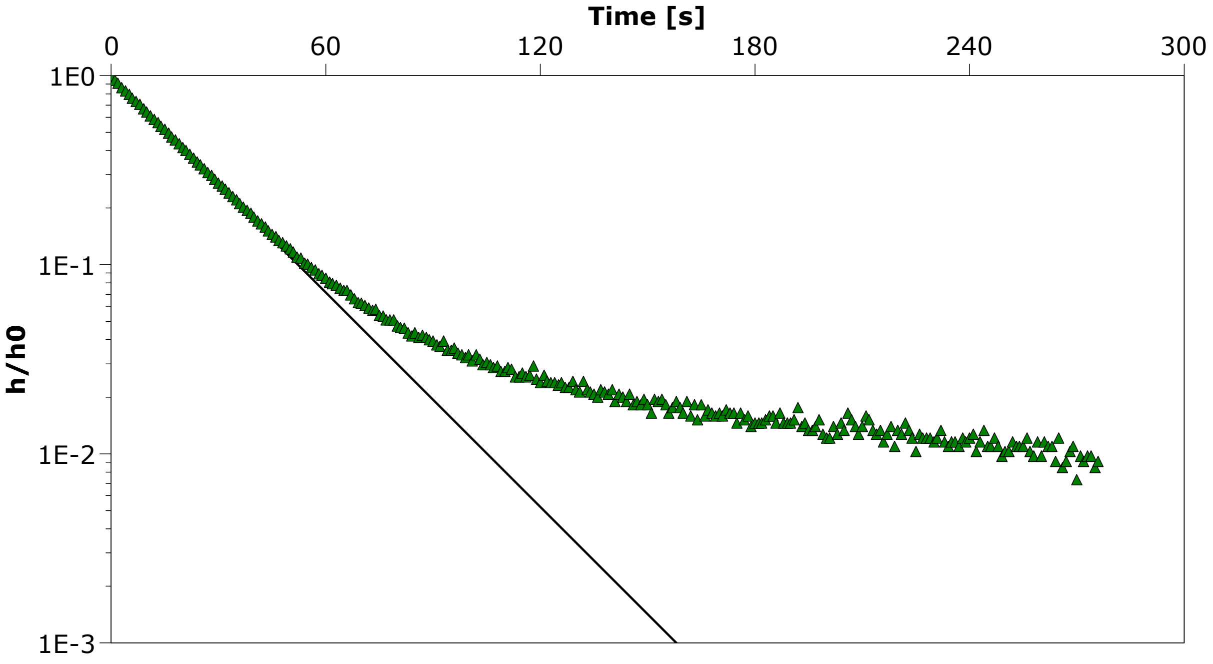
Slug Test Analysis Report

Project: Santos GLNG EIS

Number: 42626229

Client: Santos

Location: Curtis Island QLD	Slug Test: GW4D	Test Well: GW4D
Test conducted by: AW		Test date: 18/06/2008
Analysis performed by: AW	GW4D Hvorslev	Date: 1/07/2008
Aquifer Thickness: 7.50 m		



Calculation after Hvorslev

Observation well	K [m/d]	
GW4D	1.08×10^0	

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane, QLD, 4000
Phone: +61 7 3243 2111

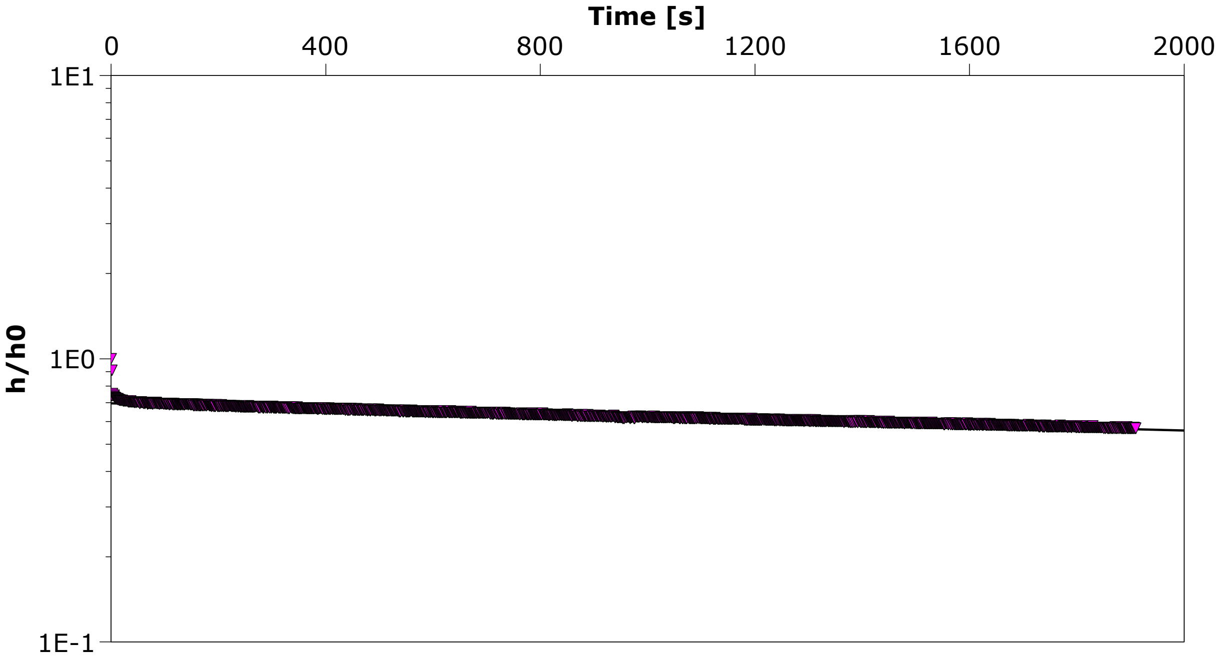
Slug Test Analysis Report

Project: Santos GLNG EIS

Number: 42626229

Client: Santos

Location: Curtis Island QLD	Slug Test: GW4S	Test Well: GW4S
Test conducted by: AW		Test date: 18/06/2008
Analysis performed by: AW	GW4S Bouwer & Rice	Date: 1/07/2008
Aquifer Thickness: 1.70 m		

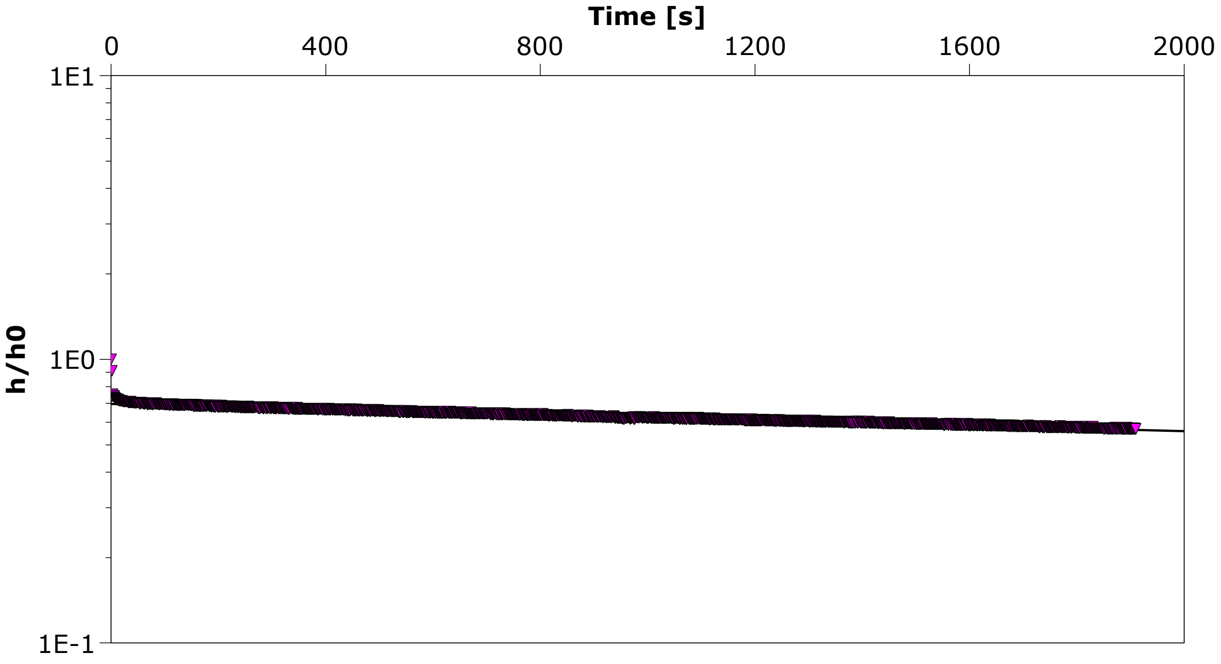


Calculation after Bouwer && Rice

Observation well	K [m/d]	
GW4S	3.82×10^{-3}	

URS Australia Pty Ltd Level 14, 240 Queen St Brisbane, QLD, 4000 Phone: +61 7 3243 2111	**Slug Test Analysis Report**
	Project: Santos GLNG EIS
	Number: 42626229
	Client: Santos

Location: Curtis Island QLD	Slug Test: GW4S	Test Well: GW4S
Test conducted by: AW		Test date: 18/06/2008
Analysis performed by: AW	GW4S Hvorslev	Date: 1/07/2008
Aquifer Thickness: 1.70 m		



Calculation after Hvorslev

Observation well	K [m/d]	
GW4S	4.94×10^{-3}	

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane, QLD, 4000
Phone: +61 7 3243 2111

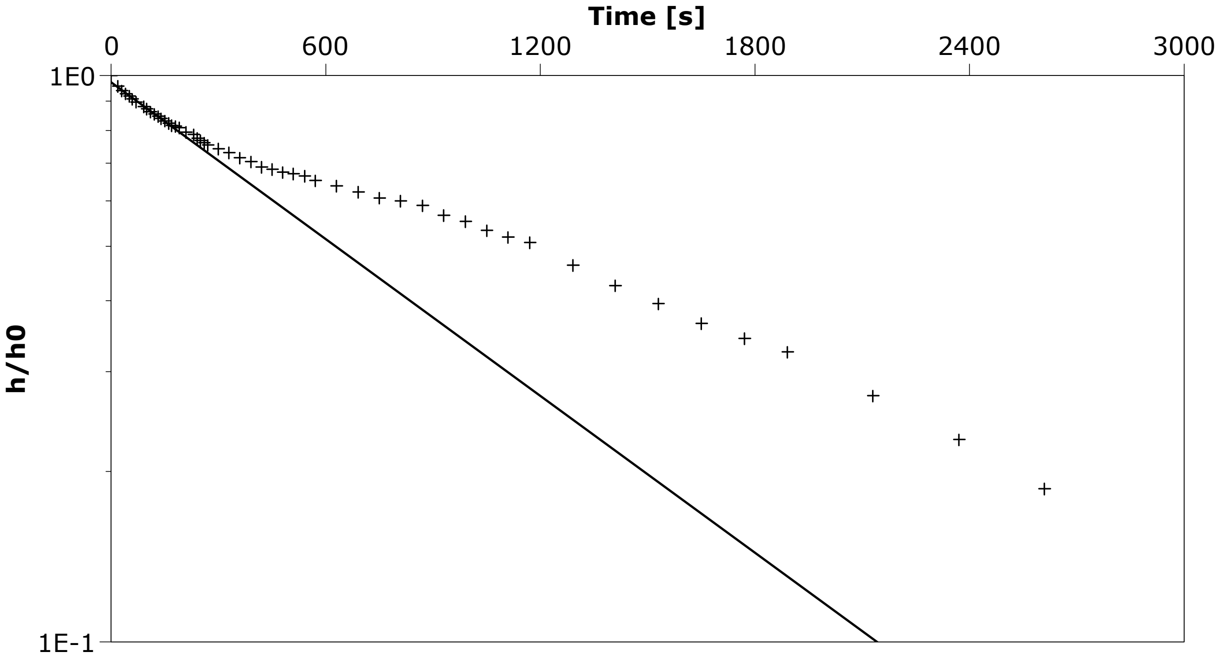
Slug Test Analysis Report

Project: Santos GLNG EIS

Number: 42626229

Client: Santos

Location: Curtis Island QLD	Slug Test: GW5	Test Well: GW5
Test conducted by: AW		Test date: 19/06/2008
Analysis performed by: AW	GW5 Bouwer & Rice	Date: 1/07/2008
Aquifer Thickness: 1.50 m		



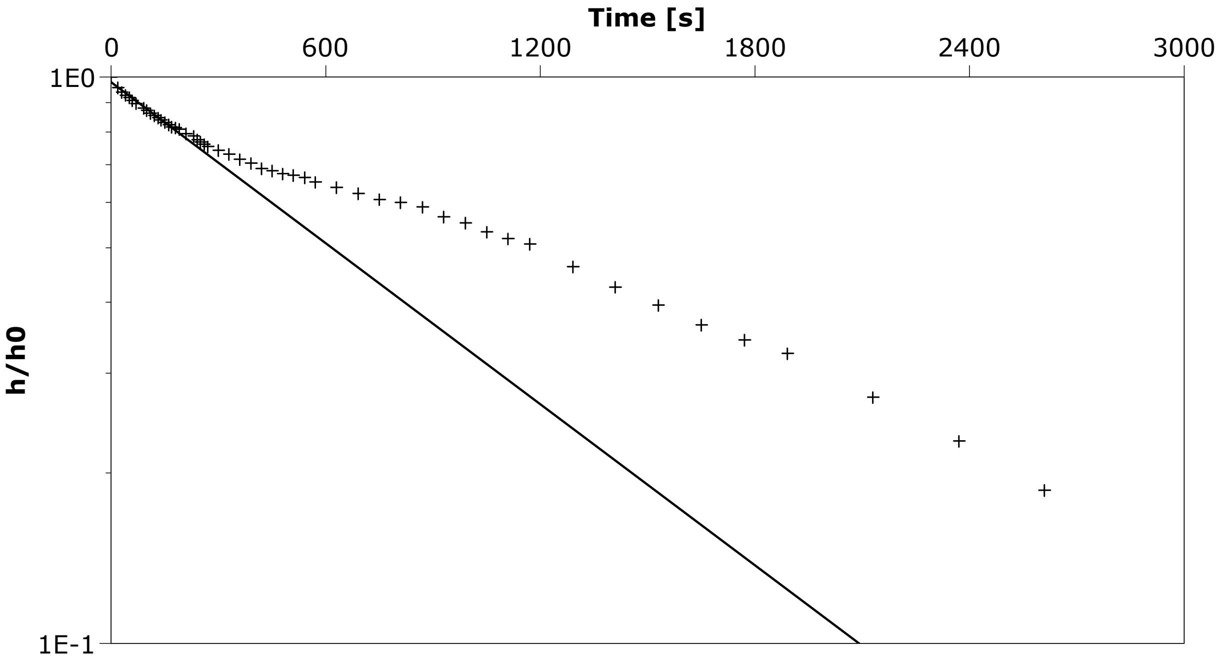
Calculation after Bouwer && Rice

Observation well	K [m/d]	
GW5	5.50×10^{-2}	

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane, QLD, 4000
Phone: +61 7 3243 2111

Slug Test Analysis Report	
Project:	Santos GLNG EIS
Number:	42626229
Client:	Santos

Location: Curtis Island QLD	Slug Test: GW5	Test Well: GW5
Test conducted by: AW		Test date: 19/06/2008
Analysis performed by: SW	GW5 Hvorslev	Date: 1/07/2008
Aquifer Thickness: 1.50 m		

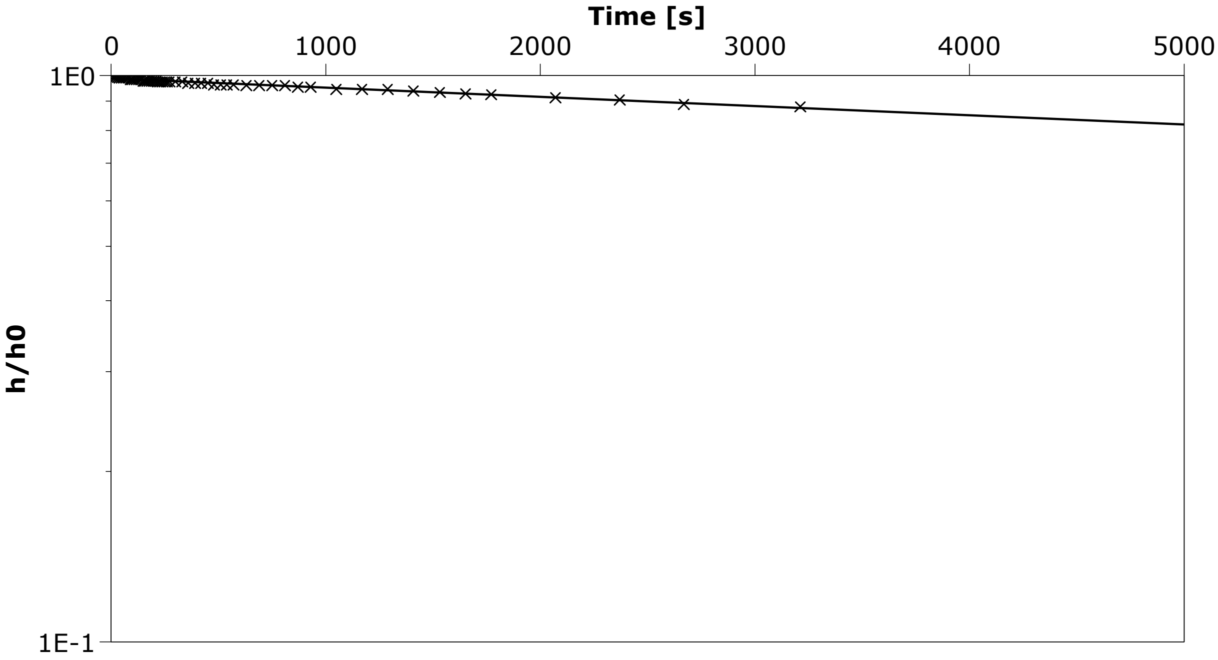


Calculation after Hvorslev

Observation well	K [m/d]	
GW5	7.35×10^{-2}	

URS Australia Pty Ltd **Level 14, 240 Queen St** **Brisbane, QLD, 4000** **Phone: +61 7 3243 2111**	**Slug Test Analysis Report** Project: Santos GLNG EIS Number: 42626229 Client: Santos

Location: Curtis Island QLD	Slug Test: GW6	Test Well: GW6
Test conducted by: AW		Test date: 19/06/2008
Analysis performed by: AW	GW6 Bouwer & Rice	Date: 1/07/2008
Aquifer Thickness: 1.00 m		

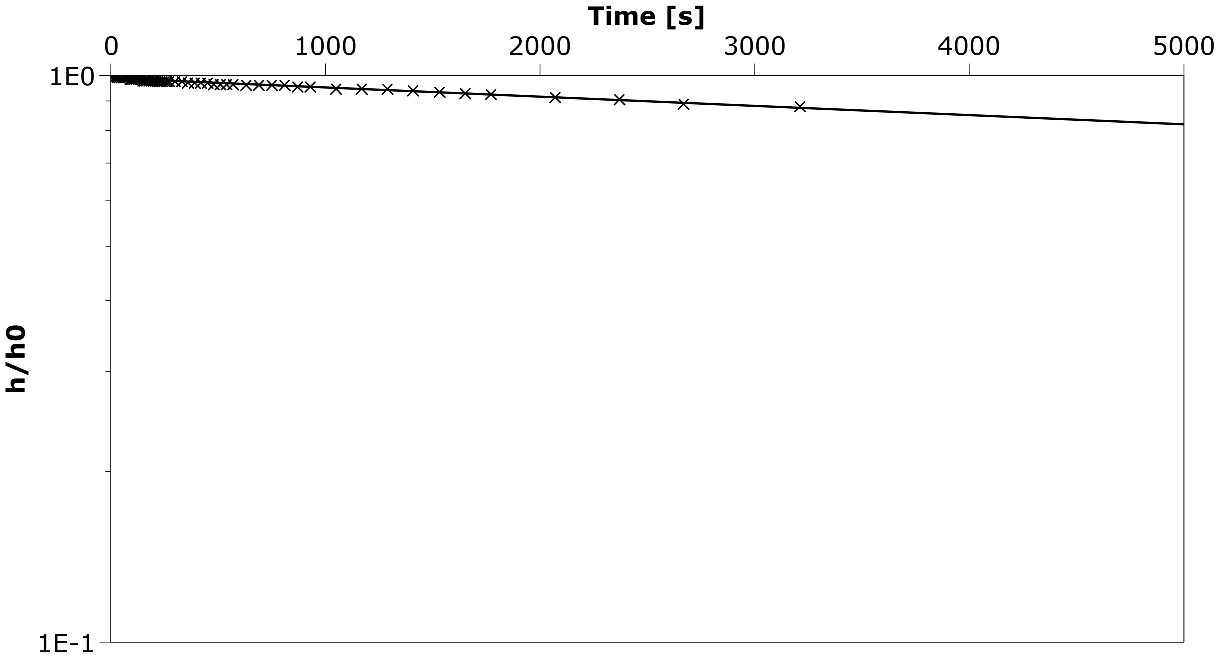


Calculation after Bouwer && Rice

Observation well	K [m/d]	
GW6	2.64×10^{-3}	

URS Australia Pty Ltd **Level 14, 240 Queen St** **Brisbane, QLD, 4000** **Phone: +61 7 3243 2111**	**Slug Test Analysis Report** Project: Santos GLNG EIS Number: 42626229 Client: Santos

Location: Curtis Island QLD	Slug Test: GW6	Test Well: GW6
Test conducted by: AW		Test date: 19/06/2008
Analysis performed by: AW	GW6 Hvorslev	Date: 1/07/2008
Aquifer Thickness: 1.00 m		



Calculation after Hvorslev

Observation well	K [m/d]	
GW6	3.47×10^{-3}	

Appendix F: LNG Facility Hydrochemistry

CHAIN OF CUSTODY FORM

Sheet 1 of 1

HIS COLUMN
OR LAB USE ONLY

ob Code:

ue Date:

FROM:
URS (AUSTRALIA)
Level 14, 240 Queen Street
BRISBANE QLD 4000
PO Box 302, BBN QLD 4001
Ph: 07 3243 2111

DATE: 20/6/08

Fax: 07 3243 2199

TO: ALS
32 Shand St
Stafford QLD
4053

Project No: 42626229 [redacted]
Project Manager: Tom Silverman
Agreement No:

Sampler(s): AW
Signature(s): AW
Checked:

Container Size, T
and A
Container I

Environmental Division
Brisbane
Work Order
EB0808250

Telephone : + 61-7-3243 7222

ustody seal intact?
YES NO
Sample cold?
YES NO

Released for URS by: AW
Date: 20/6/08 Time: 7:30

Received for Laboratory by: L.NDWAN
Date: 23/06 Time: 13.40

						Size							
						Type*							
						Preservative Code							
						Analytes	NT1	NT2	W3	PH			
ab identification	Date	Time	Matrix	Sample Number	Comments	Total no	Tick required analytes						
1	17/6	AM	Water	GW4S	P, N	2	✓	✓	✓	✓			
2	17/6	AM		GW4D	P, N	2	✓	✓	✓	✓			
3	17/6	PM		GW2D	P, N	2	✓	✓	✓	✓			
4	17/6	PM		GW5	P, N	2	✓	✓	✓	✓			
5	17/6	PM		GW6	P, N	2	✓	✓	✓	✓			
6	18/6	AM		GW1	P, N	2	✓	✓	✓	✓			
7	19/6	PM		GW3	P, N	2	✓	✓	✓	✓			
8	17/6	AM		QC01	P, N	2	✓	✓	✓	✓			
9	17/6	AM		QC02	N	1			✓				
10	17/6	AM		QC03	N	1			✓				
emarks:					TOTAL								

* Container Type and Preservative Codes: P = Neutral Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar; S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS = Sulfuric

ourier Job No:

Specify Turnaround Time:

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

Chain of Custody/May 00

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EB0808250**	Page	: 1 of 5
Client	: **URS AUSTRALIA PTY LTD (QLD)**	Laboratory	: Environmental Division Brisbane
Contact	: ALL RESULTS BRISBANE	Contact	: Tim Kilmister
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4001	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: brisbane@urscorp.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 32432111	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32432199	Facsimile	: +61-7-3243 7218
Project	: 42626229	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 23-JUN-2008
Sampler	: AW	Issue Date	: 30-JUN-2008
Site	: ----		
		No. of samples received	: 10
Quote number	: EN/001/08	No. of samples analysed	: 10

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

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Inorganics

General Comments

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

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

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

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

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key :
CAS Number = Chemistry Abstract Services number
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Analytical Results

Sub-Matrix: **LIQUID**

			Client sample ID	**GW4S**	**GW4D**	**GW2D**	**GW5**	**GW6**
			Client sampling date / time	17-JUN-2008 11:00	17-JUN-2008 11:00	17-JUN-2008 15:00	17-JUN-2008 15:00	17-JUN-2008 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB0808250-001**	**EB0808250-002**	**EB0808250-003**	**EB0808250-004**	**EB0808250-005**
EA005: pH								
pH Value	----	0.01	pH Unit	**5.71**	**7.36**	**6.58**	**3.59**	**6.66**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**390**	**156**	**315**	<1	**255**
Total Alkalinity as CaCO3	----	1	mg/L	**390**	**156**	**315**	<1	**255**
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	**26**	**592**	**8**	**2110**	**541**
ED045P: Chloride by PC Titrator								
Chloride	16887-00-6	1	mg/L	**3830**	**8040**	**550**	**12800**	**8280**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**541**	**1350**	**86**	**443**	**544**
Magnesium	7439-95-4	1	mg/L	**583**	**1180**	**125**	**1070**	**828**
Sodium	7440-23-5	1	mg/L	**946**	**1500**	**184**	**6030**	**3510**
Potassium	7440-09-7	1	mg/L	**10**	**5**	**2**	**146**	**7**
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.060**	**0.018**	**0.078**	<0.001	**0.094**
Beryllium	7440-41-7	0.001	mg/L	**0.002**	<0.001	<0.001	**0.022**	**0.001**
Barium	7440-39-3	0.001	mg/L	**2.31**	**0.517**	**0.163**	**0.126**	**0.631**
Cadmium	7440-43-9	0.0001	mg/L	**0.0001**	**0.0002**	<0.0001	**0.0010**	**0.0004**
Chromium	7440-47-3	0.001	mg/L	**0.002**	<0.001	<0.001	**0.013**	**0.002**
Cobalt	7440-48-4	0.001	mg/L	**0.400**	**0.029**	**0.044**	**0.485**	**0.112**
Copper	7440-50-8	0.001	mg/L	**0.002**	**0.001**	<0.001	**0.012**	**0.002**
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	**0.063**	<0.001
Manganese	7439-96-5	0.001	mg/L	**33.1**	**11.5**	**39.9**	**16.0**	**27.8**
Nickel	7440-02-0	0.001	mg/L	**0.028**	**0.035**	**0.013**	**0.534**	**0.086**
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	**0.023**	**0.019**	**0.010**	**0.590**	**0.040**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**116**	**242**	**22.0**	**404**	**250**
^ Total Cations	----	0.01	meq/L	**116**	**230**	**22.7**	**376**	**248**
^ Ionic Balance	----	0.01	%	<0.01	**2.52**	**1.55**	**3.63**	**0.34**

Analytical Results

Sub-Matrix: **LIQUID**			*Client sample ID*	**GW1**	**GW3**	**QC01**	**QC02**	**QC03**
			Client sampling date / time	18-JUN-2008 11:00	19-JUN-2008 15:00	17-JUN-2008 11:00	17-JUN-2008 11:00	17-JUN-2008 11:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB0808250-006**	**EB0808250-007**	**EB0808250-008**	**EB0808250-009**	**EB0808250-010**
EA005: pH								
pH Value	----	0.01	pH Unit	**6.54**	**6.86**	**6.38**	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**217**	**826**	**154**	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**217**	**826**	**154**	----	----
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	**71**	**482**	**589**	----	----
ED045P: Chloride by PC Titrator								
Chloride	16887-00-6	1	mg/L	**1080**	**8900**	**7800**	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**142**	**305**	**1350**	----	----
Magnesium	7439-95-4	1	mg/L	**136**	**620**	**1190**	----	----
Sodium	7440-23-5	1	mg/L	**474**	**4200**	**1480**	----	----
Potassium	7440-09-7	1	mg/L	**2**	**103**	**5**	----	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.047**	**0.083**	**0.016**	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	**0.001**	<0.001	----	----
Barium	7440-39-3	0.001	mg/L	**0.153**	**0.780**	**0.532**	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0003**	**0.0002**	**0.0003**	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.030**	**0.033**	**0.029**	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	**0.001**	**0.001**	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Manganese	7439-96-5	0.001	mg/L	**17.4**	**59.9**	**11.6**	----	----
Nickel	7440-02-0	0.001	mg/L	**0.141**	**0.094**	**0.037**	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Zinc	7440-66-6	0.005	mg/L	**0.201**	**0.018**	**0.415**	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	----	----	----	<0.001	<0.001
Beryllium	7440-41-7	0.001	mg/L	----	----	----	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L	----	----	----	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	----	----	----	**0.0001**	**0.0003**
Chromium	7440-47-3	0.001	mg/L	----	----	----	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	----	----	----	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	----	----	----	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	----	----	----	<0.001	<0.001

Analytical Results

Sub-Matrix: **LIQUID**			Client sample ID	**GW1**	**GW3**	**QC01**	**QC02**	**QC03**
			Client sampling date / time	18-JUN-2008 11:00	19-JUN-2008 15:00	17-JUN-2008 11:00	17-JUN-2008 11:00	17-JUN-2008 11:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB0808250-006**	**EB0808250-007**	**EB0808250-008**	**EB0808250-009**	**EB0808250-010**
EG020T: Total Metals by ICP-MS - Continued								
Manganese	7439-96-5	0.001	mg/L	----	----	----	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	----	----	----	<0.001	<0.001
Vanadium	7440-62-2	0.01	mg/L	----	----	----	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	----	----	----	<0.005	**0.021**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	----	----	----	<0.0001	**0.0001**
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**36.3**	**278**	**235**	----	----
^ Total Cations	----	0.01	meq/L	**38.9**	**251**	**230**	----	----
^ Ionic Balance	----	0.01	%	**3.43**	**4.99**	**1.22**	----	----

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

QUALITY CONTROL REPORT

Work Order	: **EB0808250**	Page	: 1 of 7
Client	: **URS AUSTRALIA PTY LTD (QLD)**	Laboratory	: Environmental Division Brisbane
Contact	: ALL RESULTS BRISBANE	Contact	: Tim Kilmister
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4001	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: brisbane@urscorp.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 32432111	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32432199	Facsimile	: +61-7-3243 7218
Project	: 42626229	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: ----		
C-O-C number	: ----	Date Samples Received	: 23-JUN-2008
Sampler	: AW	Issue Date	: 30-JUN-2008
Order number	: ----		
		No. of samples received	: 10
Quote number	: EN/001/08	No. of samples analysed	: 10

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

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

WORLD RECOGNISED
ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Inorganics

General Comments

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

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

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

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

Key :
Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = Chemistry Abstract Services number
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR:- No Limit; Result between 10 and 20 times LOR:- 0% - 50%; Result > 20 times LOR:- 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA005: pH (QC Lot: 689369)									
EB0808222-001	Anonymous	EA005: pH Value	----	0.01	pH Unit	Anonymous	Anonymous	Anonymous	Anonymous
EB0808224-004	Anonymous	EA005: pH Value	----	0.01	pH Unit	Anonymous	Anonymous	Anonymous	Anonymous
EA005: pH (QC Lot: 689370)									
EB0808250-003	GW2D	EA005: pH Value	----	0.01	pH Unit	6.58	6.57	0.2	0% - 20%
ED037P: Alkalinity by PC Titrator (QC Lot: 690167)									
EB0808250-001	GW4S	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	390	390	0.0	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	390	390	0.0	0% - 20%
EB0808261-002	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
ED040F: Dissolved Major Anions (QC Lot: 689330)									
EB0808199-014	Anonymous	ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EB0808199-023	Anonymous	ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
ED045P: Chloride by PC Titrator (QC Lot: 690168)									
EB0808250-001	GW4S	ED045-P: Chloride	16887-00-6	1	mg/L	3830	3730	2.5	0% - 20%
EB0808261-002	Anonymous	ED045-P: Chloride	16887-00-6	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
ED093F: Dissolved Major Cations (QC Lot: 689331)									
EB0808199-014	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Magnesium	7439-95-4	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Sodium	7440-23-5	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Potassium	7440-09-7	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EB0808199-023	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Magnesium	7439-95-4	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Sodium	7440-23-5	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		ED093F: Potassium	7440-09-7	1	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EG020F: Dissolved Metals by ICP-MS (QC Lot: 689424)									
EB0808199-014	Anonymous	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Barium	7440-39-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Cobalt	7440-48-4	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EG020F: Dissolved Metals by ICP-MS (QC Lot: 689424) - continued									
EB0808199-014	Anonymous	EG020A-F: Copper	7440-50-8	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Lead	7439-92-1	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EB0808199-040	Anonymous	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Barium	7440-39-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Cobalt	7440-48-4	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Copper	7440-50-8	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Lead	7439-92-1	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EG020T: Total Metals by ICP-MS (QC Lot: 689149)									
EB0808250-009	QC02	EG020A-T: Cadmium	7440-43-9	0.0001	mg/L	0.0001	<0.0001	0.0	No Limit
		EG020A-T: Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-T: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-T: Barium	7440-39-3	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-T: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-T: Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-T: Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-T: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-T: Manganese	7439-96-5	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-T: Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-T: Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	0.0	No Limit
		EG020A-T: Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	0.0	No Limit
EG035F: Dissolved Mercury by FIMS (QC Lot: 693408)									
EB0808250-001	GW4S	EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.0	No Limit
EB0808262-003	Anonymous	EG035F: Mercury	7439-97-6	0.0001	mg/L	Anonymous	Anonymous	Anonymous	Anonymous
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 693413)									
EB0808250-009	QC02	EG035T: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.0001	0.0	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	*Laboratory Control Spike (LCS) Report*			
					Spike	*Spike Recovery (%)*	*Recovery Limits (%)*	
Method: Compound	*CAS Number*	*LOR*	*Unit*	*Result*	*Concentration*	*LCS*	*Low*	*High*
EA005: pH (QCLot: 689369)								
EA005: pH Value	----	0.01	pH Unit	----	7.00 pH Unit	100	98.3	118
EA005: pH (QCLot: 689370)								
EA005: pH Value	----	0.01	pH Unit	----	7.00 pH Unit	100	98.3	118
ED037P: Alkalinity by PC Titrator (QCLot: 690167)								
ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	----	500 mg/L	101	77.5	112
ED040F: Dissolved Major Anions (QCLot: 689330)								
ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	<1	----	----	----	----
ED045P: Chloride by PC Titrator (QCLot: 690168)								
ED045-P: Chloride	16887-00-6	1	mg/L	<1	1000 mg/L	99.6	88.4	110
ED093F: Dissolved Major Cations (QCLot: 689331)								
ED093F: Calcium	7440-70-2	1	mg/L	<1	----	----	----	----
ED093F: Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
ED093F: Sodium	7440-23-5	1	mg/L	<1	----	----	----	----
ED093F: Potassium	7440-09-7	1	mg/L	<1	----	----	----	----
EG020F: Dissolved Metals by ICP-MS (QCLot: 689424)								
EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.100 mg/L	100	79.6	115
EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	0.100 mg/L	110	80.8	130
EG020A-F: Barium	7440-39-3	0.001	mg/L	<0.001	----	----	----	----
EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.100 mg/L	101	86.6	113
EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	0.100 mg/L	104	84.4	128
EG020A-F: Cobalt	7440-48-4	0.001	mg/L	<0.001	0.100 mg/L	104	86.6	117
EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	0.200 mg/L	106	85	117
EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	0.100 mg/L	100	85.4	117
EG020A-F: Manganese	7439-96-5	0.001	mg/L	<0.001	0.100 mg/L	102	84.1	122
EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	0.100 mg/L	107	86.3	118
EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	0.100 mg/L	104	76.9	117
EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	0.200 mg/L	108	84.2	130
EG020T: Total Metals by ICP-MS (QCLot: 689149)								
EG020A-T: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.100 mg/L	97.2	75.7	110
EG020A-T: Beryllium	7440-41-7	0.001	mg/L	<0.001	0.100 mg/L	105	76.7	130
EG020A-T: Barium	7440-39-3	0.001	mg/L	<0.001	----	----	----	----
EG020A-T: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.100 mg/L	99.4	81.8	111
EG020A-T: Chromium	7440-47-3	0.001	mg/L	<0.001	0.100 mg/L	107	80.9	125

Sub-Matrix: **WATER**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
				Result	Concentration	LCS	Low	High
EG020T: Total Metals by ICP-MS (QCLot: 689149) - continued								
EG020A-T: Cobalt	7440-48-4	0.001	mg/L	<0.001	0.100 mg/L	102	81.3	117
EG020A-T: Copper	7440-50-8	0.001	mg/L	<0.001	0.200 mg/L	100	80.9	115
EG020A-T: Lead	7439-92-1	0.001	mg/L	<0.001	0.100 mg/L	96.8	84.4	113
EG020A-T: Manganese	7439-96-5	0.001	mg/L	<0.001	0.100 mg/L	99.1	76.8	123
EG020A-T: Nickel	7440-02-0	0.001	mg/L	<0.001	0.100 mg/L	101	81.5	117
EG020A-T: Vanadium	7440-62-2	0.01	mg/L	<0.01	0.100 mg/L	104	70.5	119
EG020A-T: Zinc	7440-66-6	0.005	mg/L	<0.005	0.200 mg/L	101	81	127
EG035F: Dissolved Mercury by FIMS (QCLot: 693408)								
EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.010 mg/L	106	85.3	117
EG035T: Total Recoverable Mercury by FIMS (QCLot: 693413)								
EG035T: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.0100 mg/L	108	84.2	118

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

				Matrix Spike (MS) Report			
				Spike Concentration	Spike Recovery (%)	Recovery Limits (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number		MS	Low	High
ED045P: Chloride by PC Titrator (QCLot: 690168)							
EB0808250-002	GW4D	ED045-P: Chloride	16887-00-6	4000 mg/L	96.9	70	130
EG020F: Dissolved Metals by ICP-MS (QCLot: 689424)							
EB0808199-015	Anonymous	EG020A-F: Arsenic	7440-38-2	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Beryllium	7440-41-7	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Barium	7440-39-3	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Cadmium	7440-43-9	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Chromium	7440-47-3	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Cobalt	7440-48-4	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Copper	7440-50-8	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Lead	7439-92-1	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Manganese	7439-96-5	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Nickel	7440-02-0	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Vanadium	7440-62-2	Anonymous	Anonymous	Anonymous	Anonymous
		EG020A-F: Zinc	7440-66-6	Anonymous	Anonymous	Anonymous	Anonymous
EG020T: Total Metals by ICP-MS (QCLot: 689149)							
EB0808250-010	QC03	EG020A-T: Arsenic	7440-38-2	1.000 mg/L	98.8	70	130
		EG020A-T: Beryllium	7440-41-7	0.100 mg/L	96.5	70	130
		EG020A-T: Barium	7440-39-3	1.000 mg/L	99.0	70	130
		EG020A-T: Cadmium	7440-43-9	0.500 mg/L	93.7	70	130
		EG020A-T: Chromium	7440-47-3	1.000 mg/L	103	70	130
		EG020A-T: Cobalt	7440-48-4	1.000 mg/L	99.2	70	130
		EG020A-T: Copper	7440-50-8	1.000 mg/L	100	70	130
		EG020A-T: Lead	7439-92-1	1.000 mg/L	98.1	70	130
		EG020A-T: Manganese	7439-96-5	1.000 mg/L	102	70	130
		EG020A-T: Nickel	7440-02-0	1.000 mg/L	99.0	70	130
		EG020A-T: Vanadium	7440-62-2	1.000 mg/L	101	70	130
		EG020A-T: Zinc	7440-66-6	1.000 mg/L	100	70	130
EG035F: Dissolved Mercury by FIMS (QCLot: 693408)							
EB0808250-001	GW4S	EG035F: Mercury	7439-97-6	0.01 mg/L	80.4	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 693413)							
EB0808250-009	QC02	EG035T: Mercury	7439-97-6	0.0100 mg/L	107	70	130

INTERPRETIVE QUALITY CONTROL REPORT

Work Order	: **EB0808250**	Page	: 1 of 7
Client	: URS AUSTRALIA PTY LTD (QLD)	Laboratory	: Environmental Division Brisbane
Contact	: ALL RESULTS BRISBANE	Contact	: Tim Kilmister
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4001	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: brisbane@urscorp.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 32432111	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32432199	Facsimile	: +61-7-3243 7218
Project	: 42626229	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: ----		
C-O-C number	: ----	Date Samples Received	: 23-JUN-2008
Sampler	: AW	Issue Date	: 30-JUN-2008
Order number	: ----		
		No. of samples received	: 10
Quote number	: EN/001/08	No. of samples analysed	: 10

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

This Interpretive Quality Control Report contains the following information:

- Analysis Holding Time Compliance
- Quality Control Parameter Frequency Compliance
- Brief Method Summaries
- Summary of Outliers

Analysis Holding Time Compliance

The following report summarises extraction / preparation and analysis times and compares with recommended holding times. Dates reported represent first date of extraction or analysis and precludes subsequent dilutions and reruns. Information is also provided re the sample container (preservative) from which the analysis aliquot was taken. Elapsed period to analysis represents number of days from sampling where no extraction / digestion is involved or period from extraction / digestion where this is present. For composite samples, sampling date is assumed to be that of the oldest sample contributing to the composite. Sample date for laboratory produced leachates is assumed as the completion date of the leaching process. Outliers for holding time are based on USEPA SW 846, APHA, AS and NEPM (1999). A listing of breaches is provided in the Summary of Outliers.

Holding times for leachate methods (excluding elutriates) vary according to the analytes being determined on the resulting solution. For non -volatile analytes, the holding time compliance assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These soil holding times are: Organics (14 days); Mercury (28 days) & other metals (180 days). A recorded breach therefore does not guarantee a breach for all non-volatile parameters.

Matrix: **WATER**

Evaluation: ✗ = Holding time breach ; ✓ = Within holding time.

Method	*Sample Date*	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)		*Date extracted*	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
EA005: pH							
Clear Plastic Bottle - Natural GW4S, GW4D, GW2D, GW5, GW6, QC01	**17-JUN-2008**	**----**	----	----	**24-JUN-2008**	17-JUN-2008	✗
Clear Plastic Bottle - Natural GW1	**18-JUN-2008**	**----**	----	----	**24-JUN-2008**	18-JUN-2008	✗
Clear Plastic Bottle - Natural GW3	**19-JUN-2008**	**----**	----	----	**24-JUN-2008**	19-JUN-2008	✗
ED037P: Alkalinity by PC Titrator							
Clear Plastic Bottle - Natural GW4S, GW4D, GW2D, GW5, GW6, QC01	**17-JUN-2008**	**---**	---	----	**25-JUN-2008**	01-JUL-2008	✓
Clear Plastic Bottle - Natural GW1	**18-JUN-2008**	**---**	---	----	**25-JUN-2008**	02-JUL-2008	✓
Clear Plastic Bottle - Natural GW3	**19-JUN-2008**	**---**	---	----	**25-JUN-2008**	03-JUL-2008	✓
ED040F: Dissolved Major Anions							
Clear Plastic Bottle - Natural GW4S, GW4D, GW2D, GW5, GW6, QC01	**17-JUN-2008**	**---**	---	----	**24-JUN-2008**	15-JUL-2008	✓
Clear Plastic Bottle - Natural GW1	**18-JUN-2008**	**---**	---	----	**24-JUN-2008**	16-JUL-2008	✓
Clear Plastic Bottle - Natural GW3	**19-JUN-2008**	**---**	---	----	**24-JUN-2008**	17-JUL-2008	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method ***Container*** */ Client Sample ID(s)*	***Sample Date***	*Extraction / Preparation*			*Analysis*		
		Date extracted	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
ED045P: Chloride by PC Titrator							
Clear Plastic Bottle - Natural GW4S, GW4D, GW2D, GW5, GW6, QC01	**17-JUN-2008**	**---**	---	----	**25-JUN-2008**	15-JUL-2008	✓
Clear Plastic Bottle - Natural GW1	**18-JUN-2008**	**---**	---	----	**25-JUN-2008**	16-JUL-2008	✓
Clear Plastic Bottle - Natural GW3	**19-JUN-2008**	**---**	---	----	**25-JUN-2008**	17-JUL-2008	✓
ED093F: Dissolved Major Cations							
Clear Plastic Bottle - Natural GW4S, GW4D, GW2D, GW5, GW6, QC01	**17-JUN-2008**	**---**	---	----	**24-JUN-2008**	15-JUL-2008	✓
Clear Plastic Bottle - Natural GW1	**18-JUN-2008**	**---**	---	----	**24-JUN-2008**	16-JUL-2008	✓
Clear Plastic Bottle - Natural GW3	**19-JUN-2008**	**---**	---	----	**24-JUN-2008**	17-JUL-2008	✓
EG020F: Dissolved Metals by ICP-MS							
Clear Plastic Bottle - Nitric Acid; Filtered GW4S, GW4D, GW2D, GW5, GW6, QC01	**17-JUN-2008**	**---**	---	----	**24-JUN-2008**	14-DEC-2008	✓
Clear Plastic Bottle - Nitric Acid; Filtered GW1	**18-JUN-2008**	**---**	---	----	**24-JUN-2008**	15-DEC-2008	✓
Clear Plastic Bottle - Nitric Acid; Filtered GW3	**19-JUN-2008**	**---**	---	----	**24-JUN-2008**	16-DEC-2008	✓
EG020T: Total Metals by ICP-MS							
Clear Plastic Bottle - Nitric Acid; Unfiltered QC02, QC03	**17-JUN-2008**	**24-JUN-2008**	14-DEC-2008	✓	**24-JUN-2008**	14-DEC-2008	✓
EG035F: Dissolved Mercury by FIMS							
Clear Plastic Bottle - Nitric Acid; Filtered GW4S, GW4D, GW2D, GW5, GW6, QC01	**17-JUN-2008**	**----**	----	----	**30-JUN-2008**	15-JUL-2008	✓
Clear Plastic Bottle - Nitric Acid; Filtered GW1	**18-JUN-2008**	**----**	----	----	**30-JUN-2008**	16-JUL-2008	✓
Clear Plastic Bottle - Nitric Acid; Filtered GW3	**19-JUN-2008**	**----**	----	----	**30-JUN-2008**	17-JUL-2008	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method	***Sample Date***	*Extraction / Preparation*			*Analysis*		
***Container** / Client Sample ID(s)*		***Date extracted***	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
EG035T: Total Recoverable Mercury by FIMS							
Clear Plastic Bottle - Nitric Acid; Unfiltered							
QC02, QC03	**17-JUN-2008**	**----**	----	----	**30-JUN-2008**	15-JUL-2008	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(where) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Alkalinity by PC Titrator	ED037-P	2	20	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Chloride by PC Titrator	ED045-P	2	20	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	2	19	**10.5**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	2	19	**10.5**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Anions - Filtered	ED040F	2	19	**10.5**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Cations - Filtered	ED093F	2	19	**10.5**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
pH	EA005	3	26	**11.5**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	2	**50.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite A	EG020A-T	1	2	**50.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Laboratory Control Samples (LCS)							
Alkalinity by PC Titrator	ED037-P	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Chloride by PC Titrator	ED045-P	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	1	19	**5.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	19	**5.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
pH	EA005	4	26	**15.4**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	2	**50.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite A	EG020A-T	1	2	**50.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Method Blanks (MB)							
Chloride by PC Titrator	ED045-P	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	1	19	**5.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	19	**5.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Anions - Filtered	ED040F	1	19	**5.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Cations - Filtered	ED093F	1	19	**5.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	2	**50.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite A	EG020A-T	1	2	**50.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)							
Chloride by PC Titrator	ED045-P	1	20	**5.0**	**5.0**	✓	ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	1	19	**5.3**	**5.0**	✓	ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	19	**5.3**	**5.0**	✓	ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	2	**50.0**	**5.0**	✓	ALS QCS3 requirement
Total Metals by ICP-MS - Suite A	EG020A-T	1	2	**50.0**	**5.0**	✓	ALS QCS3 requirement

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
pH	EA005	WATER	APHA 21st ed. 4500 H+ B. pH of water samples is determined by ISE either manually or by automated pH meter. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Alkalinity by PC Titrator	ED037-P	WATER	APHA 21st ed., 2320 B This procedure determines alkalinity by both manual measurement and automated measurement (e.g. PC Titrate) using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Major Anions - Filtered	ED040F	WATER	APHA 21st ed., 3120 Sulfur and/or Silcon content is determined by ICP/AES and reported as Sulfate and/or Silica after conversion by gravimetric factor.
Chloride by PC Titrator	ED045-P	WATER	APHA 21st ed., 4500 Cl - B. Automated Silver Nitrate titration.
Major Cations - Filtered	ED093F	WATER	APHA 21st ed., 3120; USEPA SW 846 - 6010 The ICPAES technique ionises filtered sample atoms emitting a characteristic spectrum. This spectrum is then compared against matrix matched standards for quantification. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Dissolved Metals by ICP-MS - Suite A	EG020A-F	WATER	(APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Total Metals by ICP-MS - Suite A	EG020A-T	WATER	(APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Dissolved Mercury by FIMS	EG035F	WATER	AS 3550, APHA 21st ed. 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the filtered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Total Mercury by FIMS	EG035T	WATER	AS 3550, APHA 21st ed. 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the unfiltered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Ionic Balance	EN055	WATER	APHA 21st Ed. 1030F. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
Digestion for Total Recoverable Metals	EN25	WATER	USEPA SW846-3005 Method 3005 is a Nitric/Hydrochloric acid digestion procedure used to prepare surface and ground water samples for analysis by ICPAES or ICPMS. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)

Summary of Outliers

Outliers : Quality Control Samples

The following report highlights outliers flagged in the Quality Control (QC) Report. Surrogate recovery limits are static and based on USEPA SW846 or ALS-QWI/EN/38 (in the absence of specific USEPA limits). This report displays QC Outliers (breaches) only.

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

- **For all matrices, no Method Blank value outliers occur.**
- **For all matrices, no Duplicate outliers occur.**
- **For all matrices, no Laboratory Control outliers occur.**
- **For all matrices, no Matrix Spike outliers occur.**

Regular Sample Surrogates

- **For all regular sample matrices, no surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

This report displays Holding Time breaches only. Only the respective Extraction / Preparation and/or Analysis component is/are displayed.

Matrix: **WATER**

Method	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)	*Date extracted*	*Due for extraction*	***Days overdue***	*Date analysed*	*Due for analysis*	***Days overdue***
EA005: pH						
Clear Plastic Bottle - Natural GW4S, GW4D, GW2D, GW5, GW6, QC01	----	----	----	24-JUN-2008	17-JUN-2008	**7**
Clear Plastic Bottle - Natural GW1	----	----	----	24-JUN-2008	18-JUN-2008	**6**
Clear Plastic Bottle - Natural GW3	----	----	----	24-JUN-2008	19-JUN-2008	**5**

Outliers : Frequency of Quality Control Samples

The following report highlights breaches in the Frequency of Quality Control Samples.

- **No Quality Control Sample Frequency Outliers exist.**

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