Draft environmental management plan

Environmental monitoring and reporting

Y-C

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Appendix C – Environmental Monitoring and Reporting

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1. Introduction

Santos Gladstone Liquefied Natural Gas (GLNG) has a robust monitoring framework that ensures the integrity of its monitoring practices and data..

Monitoring and reporting conditions included the GFD Environmental Management Plan (EM Plan) are based on current management plans and procedures, and demonstrates how Santos GLNG undertakes monitoring within the Santos GLNG Upstream Project Area. .

This appendix includes specific monitoring and reporting considerations required under the *Water Act* 2000 and the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) that fall outside the Queensland *Environmental Protection Act 1994* (EP Act). Such monitoring requirements include the following:

Water Act (Queensland)

- Regional baseline bore assessments
- Office of Groundwater Impact Assessment (OGIA) Underground Water Impact Report (UWIR) water quality and pressure monitoring
- OGIA UWIR springs monitoring
- Trigger levels and response
- Reporting.

EPBC Act (Commonwealth)

- Monitoring of subsidence
- Early warning monitoring for EPBC Act listed springs
- Monitoring associated with hydraulic fracturing
- Aquifer connectivity monitoring
- Significant / listed Species
- EPBC trigger levels and exceedance response
- Notification and reporting.

The Queensland Government's regulatory framework for coal seam gas development includes the management of impacts to groundwater caused by gas extraction. This function is delivered by the OGIA an independent entity established under the Water Act. The OGIA is required to prepare cumulative assessments of the impacts of gas extraction in regions defined by the Queensland Government as Cumulative Management Areas (CMA).

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2. Water Act

2.1. Regional Baseline Bore Assessments

Since 2008, Santos GLNG has implemented and operated a regional groundwater monitoring program to establish background groundwater conditions and monitor potential impact to Great Artesian Basin aquifers resulting from the extraction activities in the coal seams. The program involves monitoring three types of infrastructure:

- Dedicated groundwater monitoring bores targeting specific aquifers, monitoring water pressure and water quality.
- Private bores identified in the extensive bore inventory undertaken by Santos GLNG, as suitable for groundwater quality and/or groundwater level monitoring. These bores have been selected as they target a single known aquifer.
- Multi-level vibrating wire piezometers (VWP) or, quartz or sapphire pressure gauges, measuring the pressure of the surrounding formation at their installed depth. Multi-level installations allow for monitoring of water levels in various units within the same borehole. The piezometers, in the case of VWPs, are cement grouted during installation; therefore, no water sample can be collected from VWPs.

The current network extends across Santos GLNG's approved gas fields, as well as a number of the proposed GFD Project tenements. A summary of the current network, including target formation, is provided in the table below.

Table 2-1 Summary of regional groundwater monitoring locations

Formation	Private bores (including telemetered farm bores)	Santos GLNG vibrating wire piezometers	Santos GLNG groundwater monitoring bores	Total
Bungil Formation	5	-	-	5
Mooga Sandstone	27	9	4	40
Orallo Formation	20	-	3	23
Gubberamunda Sandstone	14	15	14	43
Westbourne Formation	-	4	-	4
Springbok Sandstone	-	5	-	5
Walloon Coal Measures	10	38	-	48
Hutton Sandstone	8	-	-	8
Precipice Sandstone	-	8	5	13
Clematis Sandstone	1	-	-	1
Bandanna Formation	-	21	-	21
TOTAL	**85**	**100**	**26**	**211**

Further development of the regional monitoring network is ongoing to meet the requirements of the UWIR 2012 Water Monitoring Strategy. Existing and currently planned groundwater monitoring in the vicinity of GFD Project tenements will provide an initial baseline as well as early warning of unexpected impacts, and will allow appropriate groundwater management actions to be taken to manage and mitigate potential adverse impacts. Following future updates to the UWIR, Santos GLNG's regional groundwater monitoring network will be adapted if necessary to ensure appropriate monitoring for the GFD Project area.

2.2. UWIR Water Monitoring Strategy

The UWIR includes a Water Monitoring Strategy (WMS), which requires petroleum tenure holders to:

- Install groundwater monitoring locations to form a regional groundwater monitoring network for the Surat Cumulative Management Area (CMA).
- Conduct ongoing monitoring and reporting of groundwater pressure and quality.
- Collect and report water production data from petroleum and gas wells and water quality and bottom hole pressure in selected wells.

Santos GLNG is currently installing the monitoring network required by the WMS, which includes 120 water pressure monitoring points and 24 water quality monitoring points in various formations of the Surat CMA. Water quality parameters are required only at key locations, primarily to assist in understanding hydrogeological processes and establishing water quality trends in response to groundwater extraction. Santos GLNG regularly submits updates of the implementation plan to the OGIA.

Table 2-2 Monitoring locations to meet UWIR Water Monitoring Strategy requirements

UWIR target unit	Water pressure monitoring points	Water quality monitoring points
Mooga Sandstone	6	3
Orallo Formation	2	1
Gubberamunda Sandstone	14	4
Westbourne Formation	2	0
Springbok Sandstone	10	3
Walloon Coal Measures	43	0
Hutton Sandstone	7	2
Evergreen Formation (=Boxvale SST)	2	0
Precipice Sandstone	12	4
Clematis Sandstone	7	2
Bandanna Formation	15	5
Total	**120**	**24**

The WMS requires water level data to be collected at a minimum frequency of once a fortnight. For water quality monitoring points, field electrical conductivity and temperature should be measured on a fortnightly basis, and detailed laboratory analysis is to be undertaken annually for analytes including:

- Field parameters: pH, temperature, electrical conductivity, redox potential, free gas at wellhead (methane).
- Major ions: total alkalinity, carbonate, bicarbonate, calcium, magnesium, sodium, potassium, sulphate, chloride.
- Dissolved metals: As, Ba, B, Cd, Cr, Co, Cu, Fe, Hg, Mn, Ni, Pb, Se, Sr and Zn.
- Fluoride, total dissolved solids.
- Dissolved gas (methane).

More frequent water sampling for detailed laboratory analysis might be necessary if analysis of the trends in field parameters or water pressure suggests a material shift in water quality could occur.

Santos GLNG will comply with updates to the Water Monitoring Strategy that may be required by future updates to the UWIR.

2.3. UWIR Springs Monitoring

The UWIR requires petroleum tenure holders in the Surat CMA to monitor springs according to the spring monitoring program. The spring monitoring program aims to collect information on springs above an aquifer that could be affected by water extraction for petroleum and gas activities. The objective of the spring monitoring program is to identify changes in the volume and chemistry of water flowing to a spring and changes to the general character of springs, such that the potential for change to environmental values at the spring can be assessed.

The locations and details of springs that Santos GLNG is currently monitoring in accordance with the spring monitoring program are provided in the tables below. All of the UWIR springs monitoring sites are located within or nearby the Santos GLNG Fairview gas field.

Table 2-3 Spring vents currently monitored by Santos GLNG

Spring complex name	Spring complex number	Vent number(s)	Location of spring
Abyss	592	Selected: 286, 286.1, 286.2, 286.3, 682	On and off Santos GLNG tenements
Lucky Last	230	All: 287, 340, 686, 687, 687.1, 687.2, 687.3, 687.4, 687.5, 687.6, 688, 689	On Santos GLNG tenement
Ponies	229	All: 284	On Santos GLNG tenement
Spring Rock Creek	561	All: 285	On Santos GLNG tenement
Yebna 2	591	All: 534	On Santos GLNG tenement
311	311	Selected: 535, 536, 537, 704	On Santos GLNG tenement

Table 2-4 Watercourse springs currently monitored by Santos GLNG

Watercourse spring site number	Start Latitude	Start Longitude	Finish Latitude	Finish Longitude	Location of watercourse spring
W40	-25.6795	149.1373	-25.6848	149.0665	On Santos GLNG tenement
W80	-25.7434	148.6857	-25.6977	148.4273	Off-tenure
W81*	-25.7127	149.0837	-25.7151	149.0283	On Santos GLNG tenement
W82*	-25.8038	148.7799	-25.8119	148.7327	On Santos GLNG tenement

* Field studies indicate these locations are dry and do not receive baseflow - ongoing monitoring may not be required.

2.4. Trigger Levels and Responses

Groundwater monitoring data is managed in the Santos GLNG EQuIS database, which facilitates data interpretation such as trend analysis and comparison of data against baseline information and trigger levels. Exceedance above trigger levels results in an automated alert. Continuous water pressure and water production data is managed in ENVAULT, and mirrored in the Santos GLNG in-house database, Historian. ENVAULT is an environmental data collection and presentation service provided by Greenspan.

Santos GLNG, in collaboration with Australia Pacific Liquefied Natural Gas (APLNG) and Queensland Gas Company (QGC), has developed a statistical methodology to enable removal of natural variability from the water pressure data sets. The methodology relies on statistical techniques to assist in the removal of non-gas effect. Santos GLNG is developing these techniques further by developing a method for estimation and subsequent removal of localised and regional “non-gas” water pressure variations. The methodology also ensures compliance with the Australian and New Zealand Environment and Conservation Council (2000) and Queensland Water Quality Guidelines (2009).

3. EPBC Act

The EPBC Act was amended in June 2013 related to coal seam gas and large coal mining development, which designated water resources as Matters of National Environmental Significance (MNES).

Specific requirements for groundwater monitoring and reporting are contained in each publication of the UWIR for the Surat CMA. This includes requirements for groundwater level and quality monitoring, baseline assessments of landholder bores and springs monitoring. If required following future updates and publication of the UWIR, Santos GLNG's existing regional groundwater monitoring program will be adapted to ensure appropriate monitoring for the GFD Project activities. Targeted groundwater monitoring will also be undertaken in association with the GFD Project and can include:

- Monitoring of EPBC springs in accordance with the Joint Industry Plan (JIP)
- Monitoring associated with coal seam water / brine management and storage activities (including seepage monitoring) in accordance with Environmental Authority (EA) conditions
- Monitoring of subsidence in accordance with the Ground Deformation Monitoring and Management Plan
- Monitoring associated with hydraulic fracturing activities in accordance with the stimulation impact monitoring plan and EA conditions
- Managed Aquifer Recharge activities in accordance with EA conditions.

3.1. Subsidence Monitoring

Santos GLNG currently conducts baseline and ongoing geodetic monitoring programs to quantify deformation at the land surface.

This monitoring is undertaken together with QGC, Arrow and APLNG through the engaged Altamira Information to use interferometric synthetic aperture radar (InSAR), a radar technology used in geodesy and remote sensing, to establish a baseline of ground surface motion across the gas fields (including the GFD Project tenements) prior to significant development of gas. The baseline assessment, undertaken between Q4 2011 and Q2 2012, did not detect large-scale ground deformation, although several areas with local patterns of deformation related to various natural or anthropogenic factors were detected.

Santos GLNG's plan for ongoing geodetic monitoring is detailed in the Ground Deformation Monitoring and Management Plan. Santos GLNG, QGC, Arrow and APLNG have engaged Altamira Information to collect satellite images every 24 to 48 days over a spatial coverage, which includes the GFD Project tenements. The data is then processed using Geographic Information System (GIS) software.

3.2. Early Warning Monitoring (for EPBC Act Listed Springs)

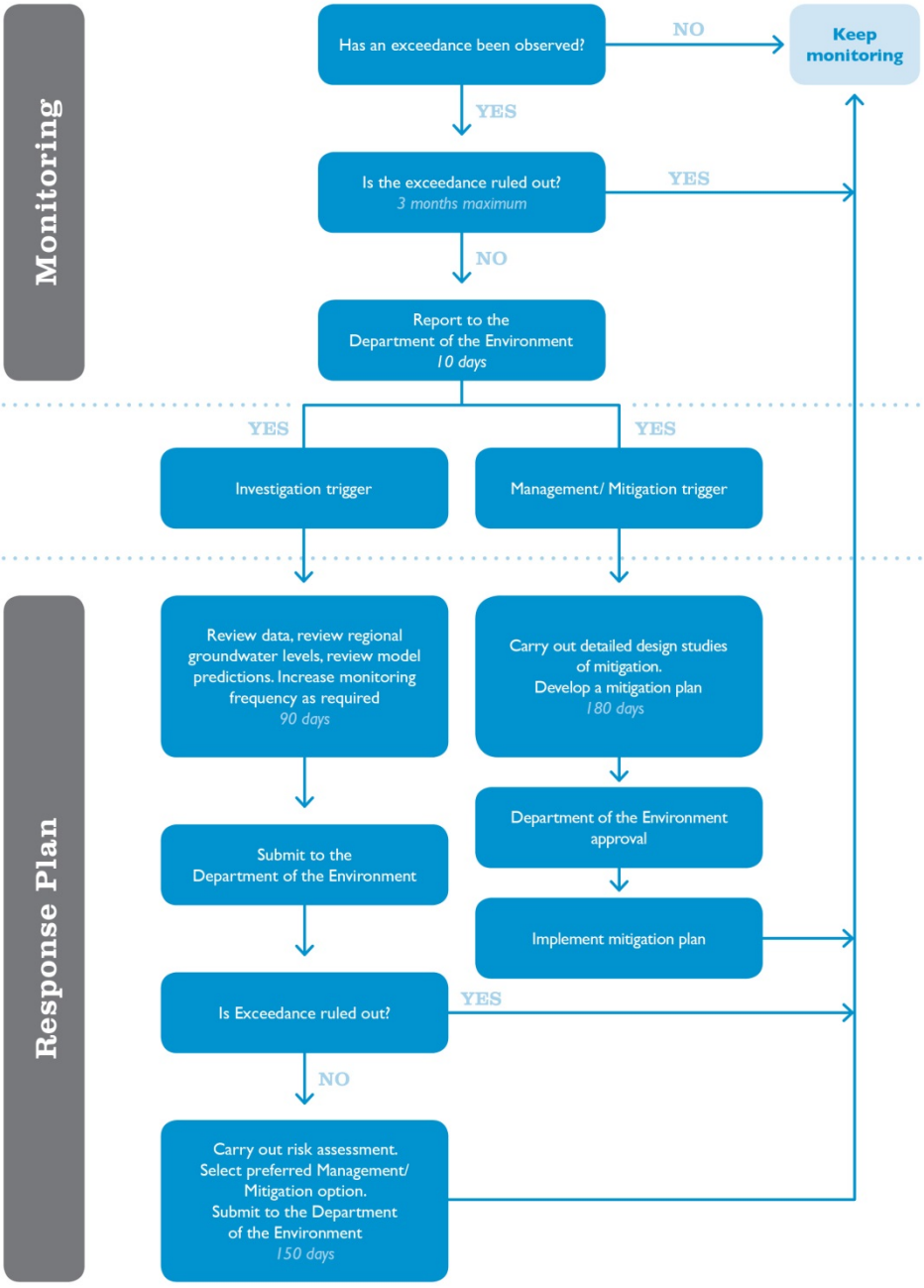
The JIP establishes an early warning system (EWS), which involves the use of groundwater level variations as a proxy for early warning of impact to the ecosystem supported by the spring. Santos GLNG is responsible for a number of installations across the Surat CMA, which are not limited to the monitoring of those EPBC springs located on Santos tenements. The network includes Early Warning Monitoring Installations close to the area of coal seam water extraction or between the extraction areas and the spring, as well as Trigger Monitoring Points located within close proximity of the spring.

The JIP includes monitoring the springs on a quarterly basis to match the frequency in the UWIR. Groundwater monitoring bores of the EWS are monitored daily for water level and six-monthly for water quality. Santos initiated the first year of spring quarterly monitoring in February 2013 for its on-tenements springs, and a joint industry spring baseline for the EPBC and Surat UWIR springs of the CMA was started in October 2013 for a one year of baseline period. The baseline monitoring includes assessing fauna, flora and macro-invertebrates and collecting samples for isotope analysis in addition to water quality.

The proponents for EWS monitoring has developed a Springs Quality Plan, which standardises:

- Field procedures for springs and groundwater sampling.
- Field quality assurance/quality control (QA/QC) procedures.
- Data management processes.
- Data control processes.

The monitoring and response plan associated with the investigation and management/mitigation triggers is shown in **Figure 1** below.



Source: URS, 2014b (Figure 2-6)

Figure 1 Monitoring and Response Flow Chart

3.3. Hydraulic Fracturing Monitoring

Santos GLNG undertakes monitoring prior to and during hydraulic fracturing activities according to the Stimulation Impact Monitoring Plan. The Stimulation Impact Monitoring Plan requires a baseline bore assessment to be completed prior to undertaking a stimulation activity to assess the quality of:

- Active landholders' groundwater bores (subject to access being permitted by the landholder) in an aquifer that is within 200 metres above or below the target gas producing formation and is spatially located with a two kilometre radius from the location of the stimulation initiation point.
- Other bores that could potentially be adversely impacted by the stimulation activities in accordance with the findings of the risk assessment required by conditions.

Ongoing monitoring of the well where hydraulic stimulation occurs is also undertaken.

3.4. Aquifer Connectivity Monitoring

Santos GLNG has assessed the hydraulic connectivity between formations to characterise the level of hydraulic connectivity between the gas producing coal beds and the overlying and underlying aquifers.

Santos GLNG is also further assessing potential horizontal pathways for impact propagation, i.e. assessing the horizontal variability of formation characteristics. This includes characterisation of the formations considered as aquitards.

The studies carried out to date include:

- Monitoring of water pressures at a number of multi-level pressure monitoring bores and vibrating wire piezometers to inform on horizontal and vertical groundwater gradients
- Monitoring water quality including isotopes (12C and 13C) at landholder bores, monitoring bores and gas wells to define the chemical signature of formations
- A deep aquifer monitoring program involving conversion of eight conventional gas wells into monitoring wells
- Fitting of existing landholder bores with pressure gauges and automatic recording loggers to observe response to pumping from nearby production activities
- A field coring program involving in-situ and laboratory testing of hydraulic conductivity
- The Managed Aquifer Recharge (MAR) trials at Hermitage (within the Roma gas field), which comprised injection and pumping tests and the assessment of the hydraulic responses
- Ongoing testing of hydraulic conductivity for the major coal seams of the Walloon Coal Measures.

The results of the hydraulic connectivity program demonstrate that under natural conditions, there is limited hydraulic connectivity between the formations. Ongoing studies will provide further characterisation on the level of connectivity between the formations as coal seam water extractions continue. These studies comprise groundwater monitoring activities, hydrogeological investigations and assessment of field data to inform refinement and calibration of the OGIA numerical groundwater model. Table 3-1 provides a status update on progress of current Santos GLNG hydraulic connectivity programs (Santos GLNG, 2014).

Table 3-1 Status of Santos GLNG hydraulic connectivity studies

Hydraulic connectivity study	Current status
Hutton - Wallumbilla Fault Program-Roma	In progress. Expected completion end of 2014
Contact Zone Program - Fairview	In progress. Program to be defined in August 2014 in view of field results for activities carried out Q1 and Q2 2014
Installation of deep monitoring bores	As per Surat UWIR requirements, not further developed in this report
Multi-level groundwater pressure monitoring	All wells expected to be completed by end 2014
Geological hydraulic conductivity mapping	An OGIA Connectivity Project, no longer to be investigated and developed by Santos GLNG
Aquifer geochemical and isotopic signature	To be updated 2014-2015
Aquifer response – private bores	Expected completion by end 2014
Aquifer response – monitoring bores	Ongoing, and undertake as required, as events occur
Groundwater modelling	Completed by the OGIA, no longer to be investigated and developed by Santos GLNG

3.5. Significant/Listed Species

Santos' GFD Significant Species Management Plan describes the strategy, methods and controls implemented by Santos GLNG to manage adverse impacts on significant species and their habitats listed in the EPBC Act and Threatened Ecological Communities. In areas where threatened species have been recorded, monitoring will be conducted during the construction and operation phases and will be comprised of targeted surveys for threatened individuals and/or breeding places.

Specific monitoring requirements from GFD impacts on species and/or habitats include the following:

- Where there are negative impacts, monitoring will be part of the general project monitoring program.
- Where mitigation measure is likely, a targeted monitoring program will be required.
- Where alternative actions should be considered and/or mitigation measures applied, a targeted monitoring program is necessary.

3.6. EPBC Trigger Levels and Exceedance Response

The JIP establishes the following triggers and drawdown levels for EPBC Act springs:

- Investigation triggers – a nominated value at an Early Warning Monitoring Installation and Trigger Monitoring Point that triggers an action such as data review, model review, increased monitoring frequency, increased monitoring parameters
- Management/mitigation triggers – a nominated value at a Trigger Monitoring Point that triggers some action to be taken to prevent an impact occurring at an EPBC Act spring
- Drawdown Limit – a nominated value at a Trigger Monitoring Point that, if exceeded, would be taken to represent a breach of the Commonwealth Approval Conditions. This value has been estimated to correspond to greater than 0 +/- 0.2 m impact in a source aquifer at an EPBC spring.

A groundwater level exceedance is defined as a value of the water level exceeding the defined drawdown levels for a continuous period of three months.

4. Reporting

Reporting requirements will vary across the GFD Project for protection of identified surface water and groundwater resources. Santos GLNG operators should refer to site-specific EAs for reporting requirements in the first instance, and the Draft EM Plan for general procedures.

In general, Santos GLNG will report to government in compliance with:

- The terms of environmental approvals issued by Department of the Environment and the Department of Environment and Heritage Protection (DEHP), including requirements for:
  - Duty to notify, and reporting for notifiable activities
  - Reporting for emergency environmental incidents
  - Annual reports for monitoring programs targeted at specific environmental receptors
  - Document management (for example, keeping project-related documents for a specific number of years).
- The terms of beneficial use approvals issued by DEHP
- UWIR requirements for the WMS:
  - WMS network implementation report every six months; the first report to be submitted to OGIA within two months of approval of the final UWIR
  - Required groundwater monitoring data submitted to OGIA every six months
  - Results of completed groundwater baseline assessment reported to OGIA within 12 months of the UWIR being approved.
- UWIR requirements for the Spring Impact Management Strategy:
  - Evaluation of Mitigation Options Report prepared for each spring identified as being within GFD Project area in the most recent UWIR; provided to OGIA within nine months of UWIR approval by DEHP. A project plan for the preparation of this report will also be provided to OGIA within two months of final UWIR approval.
- JIP EWS commitments, which include simple reporting of data every year (data and plots of data against trigger as appropriate, trend analysis after collection of baseline) and a consolidated report every three years.

In addition to the regulatory reporting outlined above, Santos GLNG also releases publicly available monitoring data to uphold commitments to the community for openness and transparency. Groundwater and surface water monitoring data can be viewed by the public via the Santos Water Portal at http://www.santoswaterportal.com.au/.

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5. References

Australian and New Zealand Environment and Conservation Council, 2000. Water Quality Guidelines for Protection of Fresh and Marine Water Quality.

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Department of Environment and Heritage Protection. 2009. *Queensland Water Quality Guidelines*.

URS Australia Pty, 2014 (URS 2014a). *Santos GLNG Gas Field Development Project Environmental Impact Statement Report on Matters of National Environmental Significance (Water Resources).* 16 May 2014, Rev. A.

URS Australia Pty, 1 May 2014 (URS 2014b). *Santos GLNG Gas Field Development Project Water Resources Management Plan.*

6. Abbreviations and Units

Acronym	Description
APLNG	Australia Pacific Liquefied Natural Gas
CMA	Cumulative Management Area
DEHP	Department of Environment and Heritage Protection
EA	Environmental Authority
EP Act	Environmental Protection Act 1994
EPBC Act	Environment Protection and Biodiversity Act 1999
EM Plan	Environmental Management Plan
EWS	Early Warning System
GFD	Gas Field Development
GIS	Geographic Information System
GLNG	Gladstone Liquefied Natural Gas
InSAR	Interferometric synthetic aperture radar
JIP	Joint Industry Plan
m	metre
MNES	Matters of National Environmental Significance
OGIA	Office of Groundwater Impact Assessment
QA/QC	Quality Assurance/Quality Control
QGC	Queensland Gas Company
UWIR	Underground Water Impact Report
VMP	Vibrating wire piezometers
WMS	Water Monitoring Strategy