# Groundwater 14

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# 14 Groundwater

## 14.1 Introduction

This section describes the groundwater values of the GFD Project area and surrounds, the potential groundwater impacts arising from the GFD Project activities and outlines appropriate mitigation measures.

Groundwater in the GFD Project area has been and continues to be used extensively for stock, agricultural, domestic, town, and industry uses. The Underground Water Impact Report (UWIR) identified 21,200 registered water bores within the Surat Cumulative Management Area (CMA) and their total water extraction is about 215,000 ML per year (QWC 2012). Water is generally produced from a number of regional aquifers in the Great Artesian Basin (GAB) hydrogeological system and from locally important alluvial systems and volcanic rocks of the Surat Basin and the upper Bowen Basin. Water quality in most aquifers is generally fresh to brackish. Natural discharge from the GAB aquifers also supplies both watercourse springs and spring vents in the GFD Project area.

This section has been prepared in accordance with section 4.6 of the *Terms of reference for an environmental impact statement* issued March 2013. The index to locate where each ToR requirement is met within this EIS is included in Appendix B: Terms of reference cross-reference. Full details of the groundwater assessment are provided in Appendix O: Groundwater.

## 14.2 Regulatory Context

This EIS as a whole has been prepared in accordance with the State and Commonwealth regulatory context as provided within Appendix C: Regulatory framework. The legislation, policies and guidelines that apply to the groundwater values and potential impacts of the GFD Project are outlined within Table 14-1.

Table 14-1 Regulatory context of the GFD Project - groundwater

| Legislation, policy or guideline | Relevance to the GFD Project |
|---|---|
| *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act)<br>This Act is the central piece of environmental legislation at the Commonwealth level. It provides for the protection of environmental values, including matters of national environmental significance (MNES). | Actions that are likely to have a significant impact on MNES are subject to the assessment and approval process under the EPBC Act. Recent amendments to the EPBC Act have made water resources a MNES in relation to the impacts of coal seam gas and large coal mining development on water resources. This means that projects such as the GFD Project that have potential for significant impacts on water resources must be referred to the Department of the Environment for assessment under the EPBC Act. Projects that have potential for significant impact on nationally threatened plants and animals, including GAB spring communities, must also be referred for assessment.<br>The controlling provisions for the GFD Project are detailed in section 1.6.1 of Section 1: Introduction. |

| Legislation, policy or guideline | Relevance to the GFD Project |
|---|---|
| *Petroleum Act 1923* (Qld) (Petroleum Act) *and Petroleum and Gas (Production and Safety) Act 2004* (Qld) (P&G Act)<br>Petroleum tenure was granted under the Petroleum Act prior to the development of the P&G Act. Petroleum leases may still be granted under this Act for holders of existing tenure (authority to prospect) granted under this Act. However, prospecting tenure cannot be applied for under the Petroleum Act.<br>The P&G Act regulates petroleum activities with the aim of developing a safe, efficient and viable petroleum and fuel gas industry in Queensland. Petroleum tenure is granted under the Act. | The Petroleum Act and P&G Act provide the rights to tenure holders to take or interfere with groundwater as part of petroleum activities and to use the water for carrying out authorised activities. |
| *Water Act 2000* (Qld) (Water Act)<br>The Act regulates the development of water resource plans (WRPs) and resource operations plans (ROPs) for major river catchments in Queensland.<br>WRPs establish a framework for sharing water between human consumptive needs and environmental values. ROPs are developed in parallel with WRPs and provide a framework for implementing WRPs. | The Water Act regulates groundwater impacts caused by petroleum tenure holders by setting out monitoring and reporting requirements, groundwater drawdown trigger levels, and make-good obligations if the extraction of coal seam water adversely affects groundwater supply to a third-party water bore or a natural spring.<br>The monitoring requirements under the Water Act include petroleum tenure holders undertaking baseline assessments of private water bores in areas where gas production testing or production has commenced. Where impacts to a bore occur and make-good obligations apply, a petroleum tenure holder is required to:<br>• Undertake a bore assessment<br>• Enter into a make-good agreement with the owner of the bore<br>• Comply with the make-good agreement<br>• Negotiate a variation of the make-good agreement if asked to do so. |
| *Environmental Protection Act 1994* (Qld) (EP Act) and *Environmental Protection Regulation 2008* (EP Regulation)<br>The EP Act is the principal legislation for the protection and management of environmental values within Queensland. The Act aims to protect the natural environment and associated ecological systems and processes, while allowing for sustainable development.<br>The EP Regulation prescribes the regulatory framework for managing the impacts of industrial, agricultural and resource development projects on the environment. This includes the definition and approvals processes for environmental impact statements and environmentally relevant activities. | The EP Act addresses the management of coal seam water. Once coal seam water is extracted, it is classified as a waste under the EP Act and either an environmental authority that specifically provides for the management of the water, or a beneficial use approval (under the *Waste Reduction and Recycling Act 2011* (Qld)), is required.<br>Regulated waste is defined in Schedule 7 of the EP<br>The EP Regulation has been amended so that better quality coal seam water is exempt from the definition of regulated waste. This change applies where coal seam water has a pH between 6 -10.5 and an electrical conductivity less than 15,000 micro-Siemens per centimetre (µS/cm). |

| Legislation, policy or guideline | Relevance to the GFD Project |
|---|---|
| *Environmental Protection (Water) Policy 2009* (Qld) (EPP Water)<br>EPP Water aims to protect Queensland's waters while allowing for ecologically sustainable development. It provides a framework for identifying environmental values for aquatic ecosystems and human uses, and determining water quality guidelines and objectives to enhance or protect the environmental values. | The EPP Water sets out the relevant environmental values and water quality objectives for water, and the relevant water quality guidelines and indicators for protecting these values. The environmental values and water quality objectives for surface water and groundwater are listed in Schedule 1 of the EPP Water. |
| *Waste Reduction and Recycling Act 2011*(Qld) (WRR Act)<br>The Act aims to promote waste avoidance and reduction and to encourage resource recovery and efficiency. The Act provides a strategic framework for managing wastes by establishing a waste and resource management hierarchy. | The WRR Act authorises beneficial uses of coal seam water and what would otherwise be wastes from the production of gas. The granting of a beneficial use approval changes the status of coal seam water from a waste under the EP Act to a resource that is to be used for a beneficial purpose. |
| *Nature Conservation Act 1992* (Qld) (NC Act)<br>The NC Act provides for the conservation and protection of native flora and fauna species in Queensland and a framework for establishing, managing and the use of protected areas. | The NC Act lists and protects individual species and ecological communities associated with groundwater-dependent springs. |
| *Coal Seam Gas Water Management Policy 2012*<br>This policy guides operators in managing coal seam water, including beneficial use in a way that protects the environment and maximises its productive use as a valuable resource. | The policy requires that coal seam water be used for a purpose that is beneficial to the environment, existing or new water users, and/or existing or new water-dependent industries. If beneficial use options have been considered and are not feasible, treating and disposing of coal seam water must be undertaken in a way that firstly avoids, and then minimises and mitigates impacts on environmental values. |
| *Sustainable Planning Act 2009* (Qld) (SP Act)<br>The Act seeks to achieve ecologically sustainable development by managing the process and effects of planning and development in a coordinated and integrated manner. The SP Act provides the overarching framework for Queensland's planning and development assessment system. | Works for taking or interfering with groundwater in the GAB are assessable development under the SP Act and require a development permit. |

This EIS seeks to obtain primary approvals for the project including the Queensland Government Coordinator-Generals Report and Commonwealth Government EPBC Act approval.

Application for or amendments to existing environmental authorities will occur subsequent to this EIS process. Other subsequent approvals required after the EIS process has been completed, corresponding triggers and legislative frameworks applicable to the GFD Project are identified in Section 2: Project approvals.

Approval of this EIS will trigger a number of subsequent approvals required for the GFD Project to proceed. Approvals will be required on tenure and off-tenure. Section 2: Project approvals summarises the key approvals necessary for the planning, construction, operations and decommissioning of the GFD Project. The triggers for each approval, the relevant administering authority and application details are provided. Consultation on the subsequent approvals will be ongoing with the administering authorities.

### 14.2.1 Underground Water Impact Report for the Surat Cumulative Management Area

#### 14.2.1.1 Regulatory framework

The Queensland Government has implemented a legislative regime to ensure the petroleum and gas industry develops in a responsible way. The regime applies to conventional petroleum and gas production as well as non-conventional (coal seam) gas production.

Under the regime, petroleum tenure holders have the right to extract groundwater in the process of petroleum and gas production (P&G Act), but are required to monitor and manage the impacts on springs and water supplies (Water Act). This includes a requirement to 'make good' impairment (due to changes in pressure or water quality) of private bore supplies caused by the exercise of these rights. Make good requirements ensure that existing users of groundwater such as agricultural businesses can continue to operate as usual.

In areas where gas fields are being developed by multiple companies, the impacts of water extraction on groundwater levels may overlap. In these situations a cumulative approach is required to assess and manage impacts and a CMA may be declared. The Office of Groundwater Impact Assessment (OGIA) is responsible for assessing cumulative impacts in these areas and establishing integrated management arrangements through the preparation of an UWIR.

With the Surat and southern Bowen basins undergoing expansion in conventional petroleum and gas production as well as non-conventional (including coal seam) gas production in 2011 by multiple proponents, this led to declaration of the Surat CMA.

The UWIR for the Surat CMA was released in 2012 and is a statutory instrument under the Water Act. The report assesses the cumulative impacts of water extraction by conventional petroleum and gas production as well as non-conventional (including coal seam) gas production on groundwater in the Surat CMA, and establishes integrated management arrangements.

In preparing the UWIR, the OGIA undertook numerical groundwater modelling to predict potential impacts of petroleum and gas production on groundwater pressure. The assessment included the currently approved operations of Santos Limited, its subsidiaries and joint venture partners, as well as development by:

- Origin Energy, its subsidiaries and joint venture partners, such as Asia Pacific LNG
- Queensland Gas Company, its subsidiaries and joint venture partners
- Arrow Energy, its subsidiaries and joint venture partners
- Other petroleum tenure holders (as detailed in the UWIR).

The Water Act regulates groundwater impacts caused by petroleum tenure holders by setting out monitoring and reporting requirements, groundwater drawdown trigger threshold levels, and make good obligations if the extraction of coal seam water adversely affects groundwater supply to a third-party water bore or a natural spring.

The monitoring requirements include petroleum tenure holders undertaking baseline assessments of private water bores in areas where gas production testing or production has commenced. Baseline assessments are required to assist with proposed make good agreements and involve obtaining information about bores, including:

- The level and quality of groundwater in the bore
- How the bore is constructed
- The type of infrastructure used to pump water from the bore.

The groundwater drawdown trigger thresholds in the Water Act include:

- Bore trigger thresholds, where there is a decline in the water level in the aquifer that is:
  - Prescribed by regulation
  - For a consolidated aquifer - 5 m
  - For an unconsolidated aquifer - 2 m.
- Spring trigger thresholds, where there is a decline in the water level of the aquifer that is:
  - Prescribed by regulation
  - 0.2 m or greater.

An Immediately Affected Area (IAA) is defined under the Water Act as the area of an aquifer where the water level is predicted to decline, due to water extraction by petroleum tenure holders, by more than the bore trigger threshold within three years of the UWIR. An IAA bore is a bore located within this area.

A Long-term Affected Area (LAA) is defined under the Water Act as the area of an aquifer where the water level is predicted to decline, due to water extraction by petroleum tenure holders, by more than the bore trigger threshold at some time in the future.

A potentially affected spring is defined under the Water Act as a spring overlying an aquifer where the water level is predicted to decline by more than the spring trigger threshold at the location of the spring at some time in the future. The potentially affected aquifer is not necessarily the spring source aquifer. The UWIR includes springs within 10 km of the spring trigger threshold as potentially affected, to allow for the limitations of modelling small changes in water level/pressure (QWC, 2012a).

Where impacts to a bore occur and make good obligations apply, a petroleum tenure holder is required to:

- Undertake a bore assessment
- Enter into a make good agreement with the owner of the bore
- Comply with the make good agreement
- If asked to vary the make good agreement, negotiate a variation of the make good agreement.

#### 14.2.1.2 Assessment Results, and Management

In preparing the UWIR (QWC, 2012a), QWC undertook groundwater flow modelling to predict impacts on water levels and found that 85 registered water bores would experience water level declines by more than the trigger threshold within three years, and a total of 528 bores would be affected at some time in the future (i.e. an additional 443 bores). Under the Water Act, petroleum tenure holders are required to ‘make good’ the impairment of private bore supplies that may result from petroleum and gas activities. The UWIR identifies which petroleum tenure holder is responsible as more than one tenure holder could be contributing to the impact.

The Annual Report 2013 for the Surat Underground Water Impact Report (OGIA, 2013b) outlines a number of changes to the industry development profile and available information about private water bores since the UWIR was prepared. Gas development in the Surat CMA has not commenced as early as planned, bore assessments conducted by tenure holders have found that the source aquifer for some bores is a shallower aquifer than the aquifer identified in the DNRM groundwater database and some unregistered bores have been identified. This has resulted in changes to the short term impacts described in the UWIR.

The UWIR found that 85 registered water bores in the Surat CMA would experience water level declines of more than 5 m within 3 years (by 2015). Based on the new development profile and updated bore data, the Annual Report assessed that 65 registered water bores would experience water level declines of more than 5 m within 3 years (by 2015) (OGIA, 2013b).

There are five spring complexes in the Surat CMA where the predicted decline in groundwater level in the source aquifer is more than 0.2 metres at the location of the spring (QWC, 2012a). The Spring Impact Management Strategy in the UWIR requires petroleum tenure holders to evaluate and submit a report to OGIA on potential mitigation options at these locations. Petroleum tenure holders are also required to monitor conditions in springs and submit the results to OGIA. The regulatory framework requires that the OGIA reviews and replaces the UWIR at least every three years. The new UWIR for the Surat CMA is due to be prepared in 2015.

#### 14.2.1.3 Current UWIR mitigation and monitoring requirements

The UWIR includes a Water Monitoring Strategy, an integrated regional water monitoring network to collect data on groundwater levels and basic groundwater quality in the Surat CMA. The network includes 498 water pressure monitoring points at 142 locations and 120 water quality monitoring points. There are already networks of monitoring bores in place, and the remaining monitoring points are being constructed by petroleum tenure holders. Santos GLNG has already installed 120 water pressure monitoring and 24 water quality monitoring points required by the UWIR. Santos GLNG has installed further monitoring not specifically required by UWIR (refer section 9.1.1 of Appendix O: Groundwater). Santos GLNG regularly submits updates of the implementation plan to the OGIA.

The UWIR has assigned Santos GLNG as responsible for impacts to one bore. Santos GLNG has entered into a make good agreement with the owner of this bore.

Section 397 of the Water Act requires petroleum tenure holders to carry out baseline assessments of water bores on their tenures before production commences. The baseline assessments must be carried out in accordance with a baseline assessment plan approved by EHP and the Guideline for Baseline Assessments. Santos GLNG has completed baseline assessments of 793 bores associated with the Santos GLNG tenures (Golder, 2012b; URS, 2013c).

The UWIR has also assigned Santos GLNG as the tenure holder responsible for preparing Spring Impact Mitigation Strategies for three spring vent complexes in the Surat CMA. The UWIR requires that investigations be undertaken to assess potential options to prevent or mitigate predicted impacts to EVs at each site. Spring Impact Mitigation Strategies are not yet required to include actions to directly prevent or mitigate predicted impacts on springs. This is because detailed investigations are required to understand the conceptual hydrogeology and the risks posed to EVs before potential mitigation options and their effectiveness can be adequately evaluated.

The springs identified in the UWIR as requiring development of a Spring Impact Mitigation Strategy are those where an impact of more than 0.2 m is predicted in the source aquifer of the spring. The applicability of these measures to Lucky Last, Spring Rock Creek and 311/Yebna 2 have been investigated by Santos GLNG and an Evaluation of Prevention or Mitigation Options Report (EPMOR) (Golder, 2014) has been prepared and submitted to the OGIA for consideration.

The mitigation options identified in the EPMOR will be implemented when risks to the EVs of a spring are imminent. A program of monitoring the aquifer systems has commenced to ensure that potential impacts to groundwater pressure in the source aquifers of springs and impact propagation are detected in advance of reaching the spring areas.

The UWIR requires petroleum tenure holders in the Surat CMA to monitor springs in accordance with the spring monitoring program. The spring monitoring program aims to collect information on springs above an aquifer that may at some future time be affected by water extraction for petroleum and gas activities. The locations and details of springs that are currently being monitored by Santos GLNG in accordance with the spring monitoring program are provided in section 9.1.3 of Appendix O: Groundwater. All of the UWIR springs monitoring sites are located within or nearby the Santos GLNG Fairview gas field.

### 14.2.2 Joint Industry Plan for an Early Warning System for the Monitoring and Protection of EPBC Springs

The project approval for the GLNG project under the EPBC Act requires CSG activities to have "no adverse impacts" to EPBC springs. Santos GLNG and three other proponents of already approved projects have developed a Joint Industry Plan (JIP) for an Early Warning System for the Monitoring and Protection of EPBC Springs (Santos GLNG, 2013b). The plan has been developed in consultation with Geoscience Australia, the Commonwealth Department of the Environment, and the Expert Panel for Major Coal Seam Gas Projects. The plan aligns with the spring monitoring and mitigation requirements in the UWIR. A summary of the key points of the plan are to establish:

- Consistent monitoring and management across the CMA to manage the risk of the impacts, combined with a defined network of monitoring bores for each proponent
- Use of the UWIR cumulative model to assess the risk to the springs
- To measure groundwater drawdown at locations and times prior to adverse impact to EPBC springs
- Single proponent responsibility for EPBC springs aligning with the UWIR
- Alignment on exceedance response processes and timing.

The JIP establishes an Early Warning System (EWS) to provide adequate time for assessment and implementation of management measures prior to potential adverse impacts on the EVs of springs associated with an EPBC Act listing. The EWS involves the concept of impact propagation pathways and the use of groundwater level variations as an early warning proxy for impact to the ecosystem supported by the spring. A groundwater monitoring bore network that focuses on the primary source aquifers of springs associated with an EPBC Act listing (primarily the Hutton Sandstone and Precipice Sandstone) is currently being installed and includes:

- Early Warning Monitoring Installations (EWMI) close to the area of coal seam water extraction or between the extraction areas and the spring. These early warning bores are located to provide initial drawdown data, and secondary data in support of interpretation of observations made closer to springs
- Trigger Monitoring Points (TMP) located within close proximity of the spring.

The JIP establishes drawdown triggers that instigate actions commensurate with increasing risk to springs associated with an EPBC Act listing:

- Investigation triggers – a nominated value that triggers an action such as data review, model review, increased monitoring frequency, increased monitoring parameters
- Management/mitigation triggers – a nominated value at a TMP that triggers some action to be taken to prevent an impact occurring at a spring associated with an EPBC Act listing.

#### 14.2.2.1 Current JIP monitoring requirements and implementation

There are 11 springs (complexes and watercourse) that are currently being monitored by Santos GLNG in accordance with the JIP (refer to section 9.1.3 of Appendix O: Groundwater). The JIP includes the monitoring of 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. The baseline monitoring includes assessment of fauna, flora and macro-invertebrates and collection of samples for isotope analysis in addition to water quality.

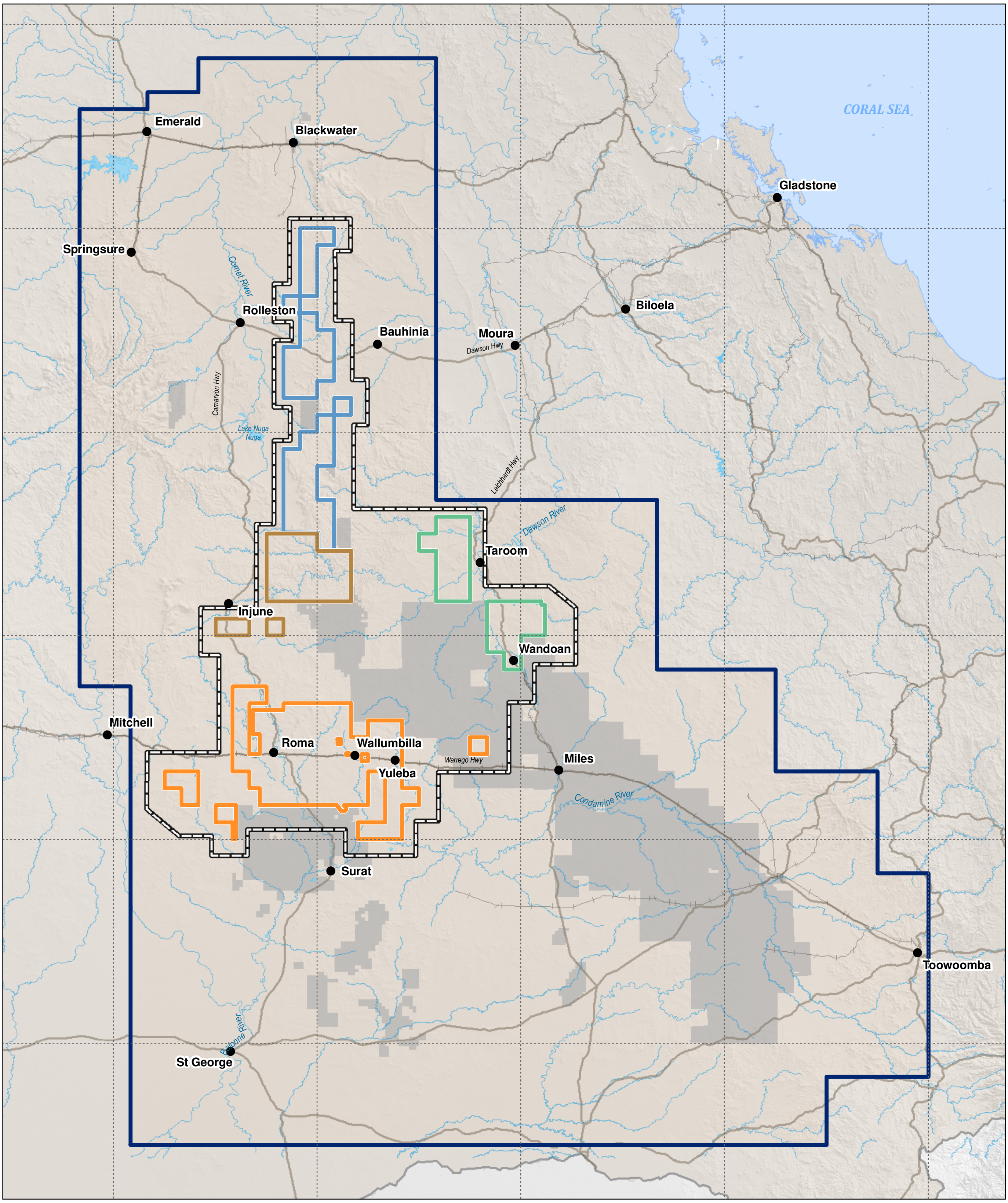
## 14.3 Assessment methodology

This assessment describes the groundwater values within the GFD Project area and assesses the GFD Project's potential impacts on these values.

A quantitative assessment of cumulative depressurisation impacts due to the production of conventional oil and gas production as well as non-conventional (coal seam) gas production by multiple proponents has been undertaken using the Office of Groundwater Impact Assessment (OGIA) numerical groundwater model for the Surat Cumulative Management Area (Surat CMA). The Surat CMA is shown in Figure 14-1. Further details on the numerical groundwater flow modelling results and cumulative impacts are provided in section 7 of Appendix O: Groundwater.

Other impacts to groundwater values have been assessed qualitatively using the significance assessment methodology which considers the sensitivity of the underlying environment and the magnitude of a potential impact to assess its level of significance. This methodology is used it is known that some impact will occur and the significance of that impact is determined by considering its magnitude and the sensitivity to change of the environmental value that will be affected. A summary of the impact assessment is shown in section 14.7.

Assessment of the groundwater environment within the GFD Project area has been undertaken using data from Santos GLNG, government agencies and reports in the public domain to determine or identify existing groundwater resources, associated environmental values (EVs) and sensitive receptors.

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Source:Data supplied by client and by Parsons Brickenhoff

Other coal seam gas proponents production tenures

Surat cumulative management area

**GFD Project area**

- Arcadia gas field
- Fairview gas field
- Roma gas field
- Scotia gas field
- Possible area for supporting infrastructure

- Towns
- Railways
- Major roads
- Major drainage

BNE



Santos GLNG Project

GFD PROJECT EIS

**COAL SEAM GAS PRODUCTION AREAS IN THE SURAT CMA**

URS

**GROUNDWATER**

Figure: **14-1**

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### 14.3.1 Numerical groundwater modelling assessment

An integral part of the production of gas is the extraction of groundwater to depressurise the coal seam to enable gas to flow. The numerical groundwater flow model for the Surat CMA was developed to assess potential cumulative depressurisation impacts associated with water extraction for petroleum and gas production by Santos, QGC, Origin, Arrow and other proponents (QWC, 2012a). The initial model simulation informed the UWIR (QWC, 2012a) included Santos GLNG's approved production activity.

Since the UWIR was released in 2012, and for the purpose of determining potential groundwater impact from the proposed GFD Project, the numerical groundwater flow model has been refined and run twice. The first simulation provided a baseline scenario, referred to as 'the UWIR Scenario'. This regional groundwater flow model for the Surat CMA included Santos GLNG's production activities, as well as other production developments including all petroleum tenure holders.

In mid-2013 the OGIA modelled the regional groundwater flow for the Surat CMA to simulate development changes associated with the GFD Project and more development proposed by another proponent. This second simulation is referred to as 'the EIS Scenario'.

To account for the inherent uncertainties relating to key model parameter estimates, predictive model runs were undertaken using the null-space Monte Carlo approach. In this approach, the model is run multiple (200) times to derive a suite of parameter values, all of which result in acceptable calibration of the model. Model predictions from all calibrated runs are then aggregated to provide a probabilistic estimate of impacts. For instance, estimates of groundwater depressurisation at each model cell can be expressed in terms of the 50th percentile (median) and 95th percentile of all 200 calibrated model predictions.

The actual impacts are likely to be less than what is presented in this section for the following reasons:

- The EIS scenario is a maximum development scenario
- The impacts presented are the 95$^{th}$ percentile of 200 model runs. This means that 95% of predictions result in impacts that are less than or equal to the impacts presented here
- The groundwater model does not simulate the effects of dual phase flow (i.e. water and gas flow) and represents only the flow of groundwater. This is expected to lead to an overestimation of impacts to groundwater, particularly within the extent of the project tenures.

The UWIR groundwater model is widely recognised as the most up to date and comprehensive model for cumulative groundwater impact predictions for the Surat CMA.

The production areas for Santos GLNG and other proponents under the UWIR and EIS scenarios are shown on Figure 14-1.

Results of the modelling of the EIS Scenario have been compared to the results of the UWIR Scenario to enable assessment of the change in cumulative impacts due to the additional production proposed by Santos GLNG and another proponent.

Further details on the numerical groundwater flow modelling results and cumulative impacts are provided in section 7 of Appendix O: Groundwater.

### 14.3.2 Significance assessment

An assessment of the groundwater environment within the GFD Project area, in terms of the existing groundwater resources, associated environmental values (EVs) and sensitive receptors has been undertaken using data available from Santos GLNG, as well as from government agencies and reports in the public domain, and analysis of the data from hydrogeological maps and cross-sections.

A significance assessment methodology was then applied to assess the impacts of the GFD Project on groundwater EVs. There are no quantitative guidelines available for assessment of groundwater. Potential impact was assessed based on the sensitivity or vulnerability of the environmental value and the magnitude of the potential impact. For these activities and related impacts, a significance assessment methodology was applied. The methodology is described in detail within section 5.6.3 of Section 5 Assessment framework. The management framework and associated mitigation measures that may be used to reduce the risks associated with potential groundwater impacts on the surface water environment have also been identified.

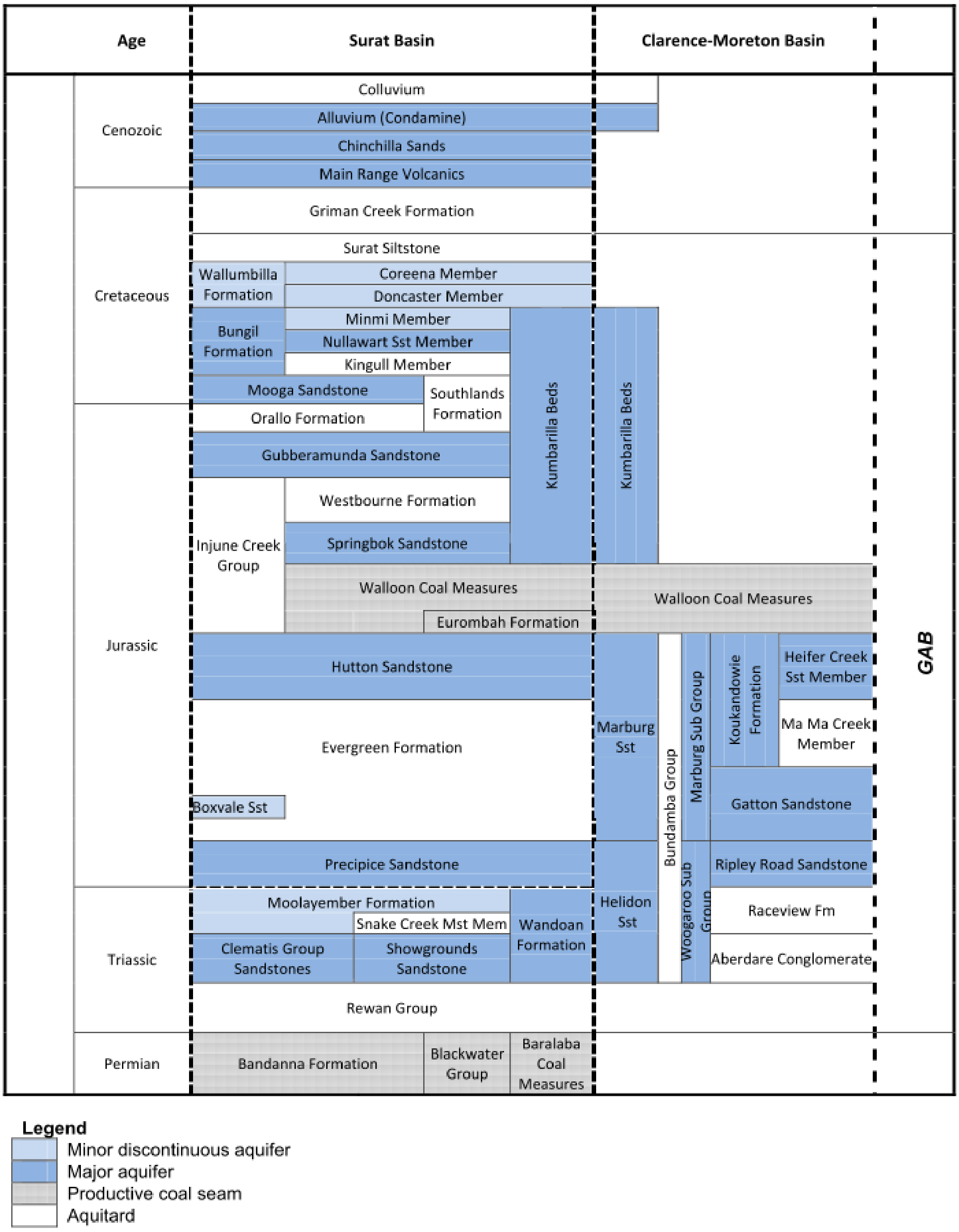
## 14.4 Environmental values

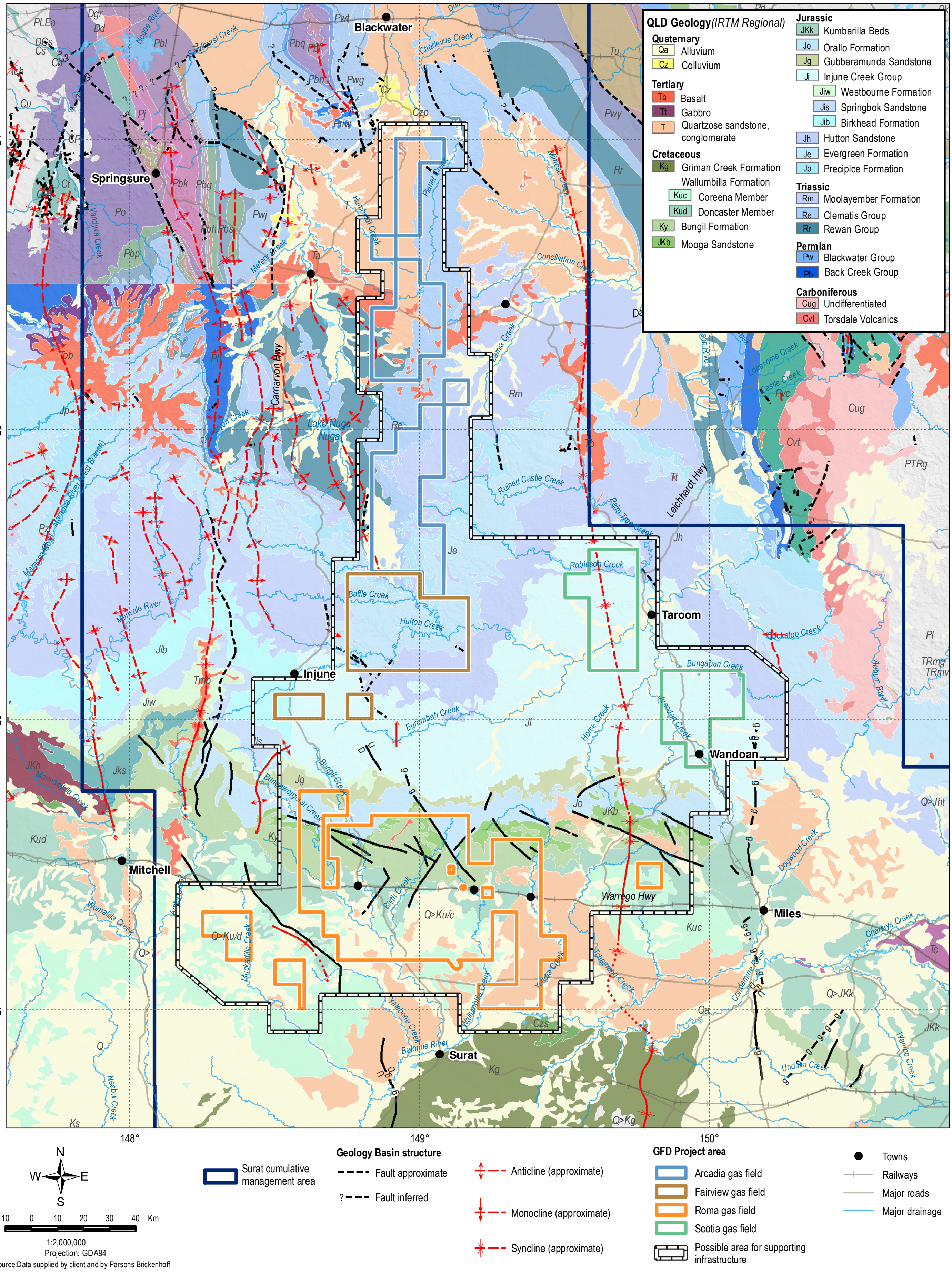
### 14.4.1 Existing hydrogeological environment

The GFD Project tenures are located within the Surat and Bowen basins. Figure 14-2 shows the sequence of aquifers and aquitards within this region of the GAB and Figure 14-3 shows the regional geology of the GFD Project area. The main productive water bearing formations in the GFD Project area include:

- Quaternary alluvial aquifer systems associated with the unconsolidated sediments of the Condamine-Balonne River, the Dawson River and the Comet River systems
- Minor aquifers within Tertiary fractured basalt and sediments caps
- Water bearing formations of the GAB. These include the Clematis Sandstone, Precipice Sandstone, Hutton Sandstone, Springbok Sandstone, Gubberamunda Sandstone, Mooga Sandstone and Bungil Formation.

Figure 14-2 Regional hydrostratigraphy (QWC, 2012)






Source: Data supplied by client and by Parsons Brickenhoff



Santos GLNG Project

GFD PROJECT EIS

**REGIONAL GEOLOGY**

URS

**GROUNDWATER**

Figure: **14-3**

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An overview of the main hydrogeological units for water supply in the GFD Project area is presented in Table 14-2. The Bungil and Orallo formations are generally not considered to be aquifers, but are used for water supply in the GFD Project area and have therefore been included in Table 14-2. The alluvial systems and Tertiary fractured basalts are not connected across the GFD Project areas; however, these formations are still targeted for water supply.

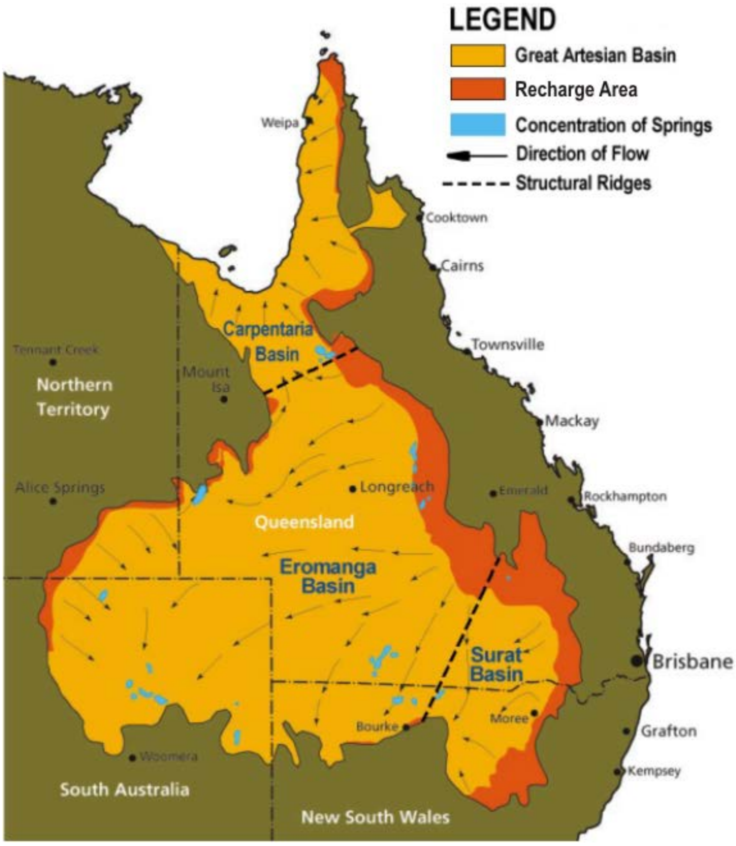
**Table 14-2 Main hydrogeological units for water supply in the GFD Project tenures**

| Aquifer | Outcrop area (Gas field) | Aquifer type | Thickness* (m) | Depth | Use/ Development |
|---|---|---|---|---|---|
| Alluvium | Arcadia, Roma, Scotia, Fairview | Unconfined | | At surface | Limited, stock, seasonal |
| Tertiary fractured basalts and sediments | Arcadia, Roma | Unconfined | 10 to 30 | At surface | Limited, Stock/domestic |
| Bungil Formation | Roma | Minor aquifer/ water bearing formation | up to 200 | At surface north of Roma, dips south | Limited Stock/domestic |
| Mooga Sandstone | Roma | Important aquifer | 25 to 200 | At surface north of Roma, dips south | Stock/domestic, town water supplies, baseflow |
| Orallo Formation | Roma | Aquitard | 140 to 270 | At surface north of Roma, dips south | Limited, Stock/domestic |
| Gubberamunda Sandstone | Roma | Important aquifer | 45 to 300 | At surface north of Roma, dips south | Important GAB aquifer, town water supply, stock |
| Springbok Sandstone | Scotia, Fairview | Important aquifer | up to 70 | At surface south of Injune, dips south | Limited, discontinuous, stock |
| Hutton Sandstone | Scotia, Fairview | Important aquifer | up to 700 | At surface north of Injune and Taroom, dips south | Important GAB aquifer, drinking water, town water supplies, stock, baseflow |
| Precipice Sandstone | Fairview | Important aquifer | averaging 80 | At surface north of Injune and Taroom, dips south | Important GAB aquifer, drinking water, town water supplies, stock, baseflow |
| Clematis Sandstone | Fairview, Arcadia | Important aquifer | up to130 | At surface south and west of Rolleston | Important GAB aquifer, town water supplies, stock, baseflow |

*Santos GLNG (2013c)

Figure 14-4 shows the main recharge areas and the dominant (regional) flow directions within the GAB. The GFD Project area is located in the recharge area of the GAB. Most recharge occurs along the outcrop areas in the north, northwest, northeast and east along the Great Dividing Range. Recharge occurs predominantly by rainfall, either by direct infiltration into the outcrop areas or indirectly via leakage from streams or overlying aquifers. Calibrated recharge rates estimated from OGIA's regional groundwater model give recharge rates into the GAB aquifers ranging geographically from 1 to 30 mm per year with a median of 2.8 mm per year (QWC, 2012).

Figure 14-4 Great artesian basin




Recharge water flows primarily along the bedding planes and fractures of aquifers and aquitards from the recharge areas to the south, southwest and west, though there is a minor northward flow component in some aquifers (Hodgkinson et al., 2009), e.g. near Taroom. Groundwater moves very slowly and flow velocities in the GAB have been estimated to range from 1 to 5 m per year (Habermehl, 1980). Groundwater movement within the GAB is dominated by sub-horizontal flow in the aquifers, with vertical leakage from the aquifers through the low permeability aquitards occurring throughout the basin at a much slower rate.

Natural discharge from aquifers in GFD Project tenures occurs through vent springs, baseflow to rivers (watercourse springs), vertical leakage between aquifers, and subsurface flow into adjoining areas. Extraction of groundwater in GFD Project tenures occurs via bores used for stock and domestic supply or agriculture, uncontrolled artesian bores, and petroleum and gas production.

### 14.4.2 Groundwater quality

Groundwater quality in the GFD Project tenures was assessed using the following data:

- Groundwater baseline assessment data, provided by Santos GLNG in June 2013 (Baseline Assessment Manager) (Santos GLNG, 2013a)
- Groundwater monitoring network data, provided by Santos GLNG in June 2013 (Envirosys) (Santos GLNG, 2013a)
- Available groundwater quality data in the DNRM database, provided by DNRM in May 2013 (DNRM, 2013a).

The use of these three datasets provides representative groundwater quality data for the relevant hydrogeological units in the GFD Project tenures. Groundwater quality data were compared to the ANZECC (2000) *Guidelines for Fresh and Marine Water Quality*, the ANZECC (2000) *Guidelines for Primary Industry and the Australian Drinking Water Guidelines* (Australia National Health and Medical Research Council, and Natural Resource Management Ministerial Council, 2011) *Australian Drinking Water Guidelines* (ADWG). These guidelines were selected to assess the environmental values of groundwater, including suitability for livestock watering and drinking water and support of instream environments where groundwater discharges as a watercourse spring. Groundwater quality in the GFD Project tenures is further discussed in section 5.7 of Appendix O: Groundwater. A summary of groundwater quality characteristics of the relevant hydrogeological units in the GFD Project tenures is provided in Table 14-3 below.

Table 14-3 Groundwater quality summary for each of the relevant hydrogeological units in the GFD Project tenures (median (range))

| Parameter | Unit | Alluvium | Tertiary Basalts* | Bungil Formation | Mooga Sandstone | Gubberamunda Sandstone | Injune Creek Group | Walloon Coal Measures | Hutton Sandstone |
|---|---|---|---|---|---|---|---|---|---|
| **pH** | pH units | 7.5 (7.5-8.3) | 7.4-7.6 | 8.3 (5.8-9.0) | 8.4 (6.3-9.9) | 8.3 (7.3-9.4) | 8.1 (7.4-9.1) | 7.7 (6.6-8.6) | 8.1 (7.0-9.2) |
| **Conductivity** | µS/cm | 1,530 (955-2,500) | 2,100-7,510 | 1,650 (1,161-8,000) | 1,550 (121-10,000) | 1,195 (542-2,700) | 6,460 (2,700-9,000) | 3,700 (935-23,400) | 1,090 (367-16,000) |
| **Fe** | mg/L | na | <0.05^ | 0.08 (0.01-4.00) | 0.04 (0.01-1.15) | 0.06 (0.01-6.09) | 0.35^ | 0.04 (0.02-0.05) | 0.04 (0.02-5.06) |
| **Mn** | mg/L | na | 0.002^ | 0.010 (0.002-0.14) | 0.010 (0.002-0.053) | 0.010 (0.002-0.172) | 0.043^ | 0.065 (0.02-0.11) | 0.022 (0.01-0.758) |
| **Parameter** | **Unit** | **Precipice Sandstone** | **Clematis Sandstone** | **Wallumbilla Formation** | **Orallo Formation** | **Eurombah Formation** | **Evergreen Formation** | **Rewan Group*** | **Bandanna Formation** |
| **pH** | pH units | 7.7 (6.5-8.9) | 8.0 (6.4-8.5) | 7.9 (7.3-8.4) | 8.7 (8.4-8.8) | 7.8 (5.9-8.2) | 7.6 (6.4-8.1) | 7.2-7.4 | 8.6 (6.4-9.1) |
| **Conductivity** | µS/cm | 557 (305-3,360) | 870 (350-1,250) | 4,535 (1,450-8,633) | 1,220 (944-1,640) | 1,100 (230-3,350) | 730 (240-2,130) | 5,760-6,260 | 4,057 (143-14,200) |
| **Fe** | mg/L | 0.33 (0.04-1.93) | 0.01 (0.01-0.60) | 0.10 (0.03-0.16) | 0.18 (0.12-0.30) | 0.09^ | 0.6 (0.1-10.0) | na | 0.16 (<0.05-27.00) |
| **Mn** | mg/L | 0.083 (0.01-0.148) | 0.01 (0.01-0.04) | 0.030 0.01-0.69) | 0.009 (0.002-0.026) | 0.03-0.08^ | na | 0.046-0.49 | 0.005 (0.001-0.350) |

(1) Data sourced from DNRM (2013a) and Santos GLNG (2013a) databases.

(2) na = no data available.

(3) * Median not calculated as only 2 samples.

(4) ^ Only 1 sample available.

## 14.4.3 Receptors and environmental values

### 14.4.3.1 Sensitive groundwater receptors

The sensitive groundwater receptors in the GFD Project area are:

- Hydrogeological units used for domestic water supplies and stock watering, and to a lesser extent, agriculture, aquaculture and industrial purposes
- Springs, including spring vents and watercourse springs which provide baseflow to streams.

#### *Hydrogeological units used for water supply*

Groundwater bores in Queensland are registered in the Department of Natural Resources and Mines (DNRM) groundwater database, and water licence information is recorded in the DNRM's Water Management System (WMS). Bore data provided by the OGIA (2013) (originally sourced from the DNRM groundwater database and WMS) indicate there are 872 registered landholder bores located within the GFD Project tenures. There are also likely to be unregistered bores located within the GFD Project tenures.

The number of registered bores in each hydrogeological unit in the GFD Project tenures, and the volume of take estimated by the OGIA, are provided in Table14-4 (OGIA, 2013). Most registered bores in GFD Project tenures take groundwater from the Bungil, Mooga and Gubberamunda Sandstones in the Roma area, the Hutton and Precipice Sandstones in Scotia, and the Precipice Sandstone in Fairview. There are no registered bores screened in the Bandanna Formation in GFD Project tenures. The UWIR identified 21, 200 registered water bores within the Surat CMA and their total water extraction is estimated at about 215, 000 ML per year (QWC 2012).

Table14-4 Number of registered bores per hydrogeological unit in GFD Project tenures

| Hydrogeological unit | Number of registered bores | Volume of estimated take (ML/year) | Gas fields | GFD Project tenures |
|---|---|---|---|---|
| Alluvium | 29 | 87 | Arcadia, Scotia, Roma | ATP 803P, ATP 868P, PL 3, PL 13, PL 236 |
| Cainozoic Sediments | 6 | 18 | Arcadia, Roma | ATP 526P, ATP 745P, PL 3 |
| Tertiary Volcanics | 8 | 24 | Arcadia | ATP 745P |
| Wallumbilla Formation | 18 | 88 | Roma | PL 3, ATP 631P, ATP 708P, PL 10, PL 6, PL 7, PL 9 |
| Bungil Formation | 107 | 649 | Roma | ATP 336P R, ATP 631P, ATP 665P, ATP 708P, PL 10, PL 11, PL 13, PL 176, PL 3, PL 310, PL 314, PL 315, PL 6, PL 7, PL 8, PL 9 |
| Mooga Sandstone | 262 | 1,459 | Roma | ATP 336P R, ATP 631P, ATP 665P, ATP 708P, PL 10, PL 11, PL 13, PL 3, PL 309, PL 310, PL 314, PL 315, PL 6, PL 7, PL 8, PL 9 |
| Mooga Sandstone and Springbok Sandstone | 1 | 13 | Roma | PL 6 |

| Hydrogeological unit | Number of registered bores | Volume of estimated take (ML/year) | Gas fields | GFD Project tenures |
|---|---|---|---|---|
| Orallo Formation | 13 | 65 | Roma | ATP 708P, PL 13, PL 3, PL 309, PL 314, PL 6, PL 7 |
| Gubberamunda Sandstone | 153 | 1,869 | Roma | ATP 336P R, ATP 631P, ATP 708P. PL 13, PL 3, PL 309, PL 310, PL 314, PL 315, PL 6, PL 7, PL 8, PL 9, PL 93 |
| Gubberamunda Sandstone and Precipice Sandstone | 1 | 13 | Roma | PL 6 |
| Birkhead Formation | 1 | 5 | Scotia | PL176 |
| Walloon Coal Measures | 61 | 337 | Fairview, Scotia, Roma | ATP 655P, ATP 708P, ATP 803P, ATP 868P, PL 176, PL 3, PL 309, PL 314, PL 6 |
| Eurombah Formation | 4 | 46 | Scotia | ATP 803P, ATP 868P |
| Hutton Sandstone | 94 | 1,198 | Fairview, Scotia, Roma | ATP 655P, ATP 803P, ATP 868P, PL 10, PL 100, PL 13, PL 176, PL 309, PL 314, PL 315, PL 6, PL 9, PL 99 |
| Evergreen Formation | 30 | 150 | Fairview, Scotia, Roma | ATP 655P, ATP 803P, PL 100, PL 176, PL 314, PL 91, PL 92, PL 99 |
| Precipice Sandstone | 28 | 389 | Fairview, Scotia, Roma* | ATP 655P, ATP 708P, ATP 803P, ATP 868P, PL 13, PL 176, PL 3, PL 6, PL 91, PL 92, PL 99 |
| Moolayember Formation | 2 | 14 | Arcadia, Roma | PL 3, PL 236 |
| Clematis Sandstone | 45 | 378 | Arcadia, Scotia, Roma | ATP 526P, ATP 653P, ATP 803P, PL 11, PL 235, PL 236, PL 3 |
| Rewan Group | 9 | 45 | Arcadia | ATP 653P, ATP 745P |
| Total | 872 | 6,856 | | |

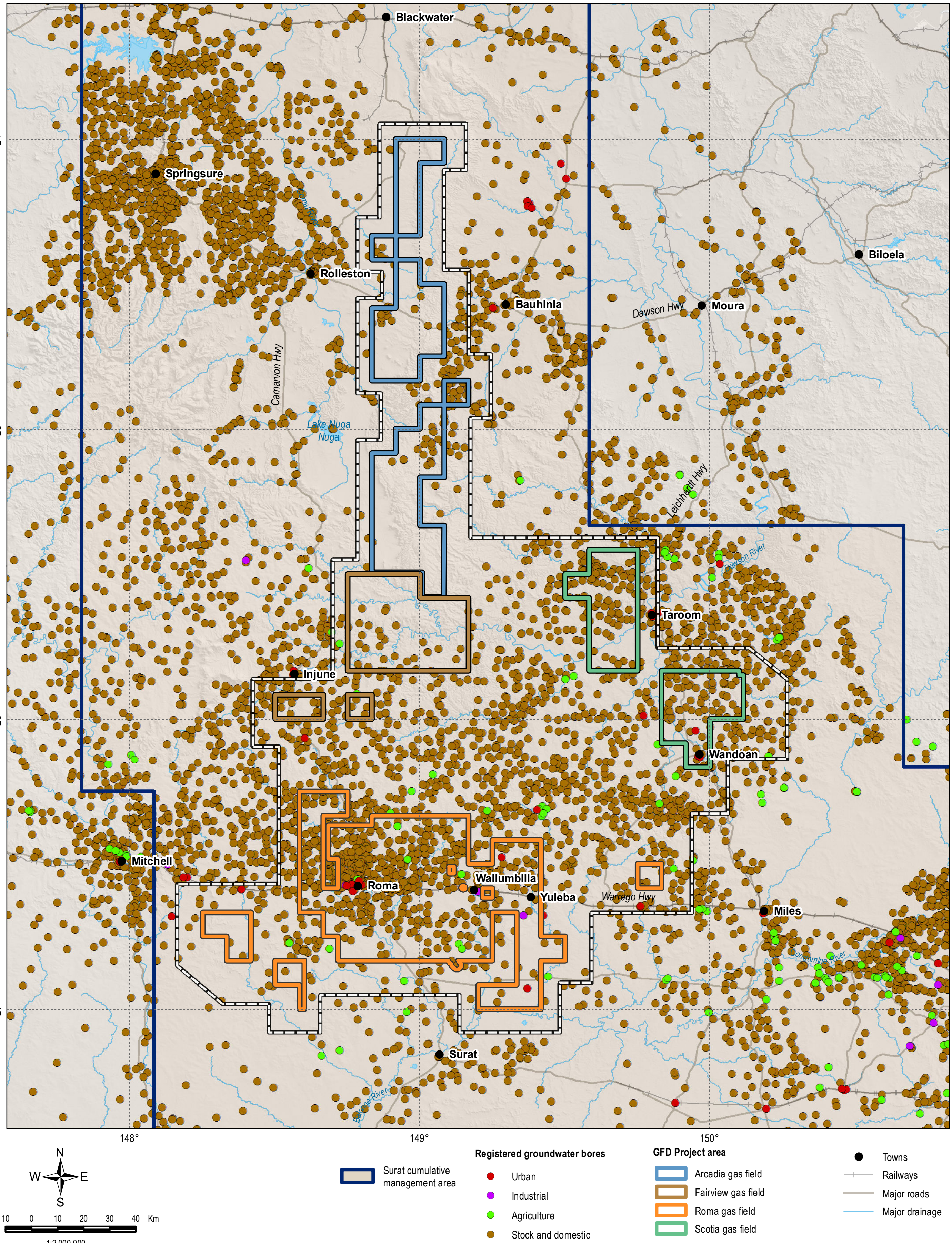
Source: OGIA, 2013
*The Precipice Sandstone does not generally supply water to Roma and there is just one bore in Roma area recorded in OGIA database as accessing this aquifer.

Registered bore data (OGIA, 2013) indicate that groundwater in GFD Project tenures is mainly used for stock and domestic supply and to a lesser extent for urban water supply, agriculture (including irrigation and intensive stock watering) and industrial purposes (Table 14-5) (OGIA, 2013). The spatial distribution of registered landholder bores and their use is shown on Figure 14-5. Groundwater used for petroleum and gas production is exempt from requiring a water licence and is not included in Figure 14-5.

Table 14-5 Volume of groundwater extracted across the GFD Project tenures

| Registered use | Agriculture | Industrial | Stock/Domestic | Urban |
|---|---|---|---|---|
| Number of bores | 6 | 6 | 842 | 18 |
| Annual volume total megalitres per year (ML/year) | 105.7 | 1,481 | 4,827^ | 442.1 |
| Average annual volume per bore (ML/year) | 17.6 | 246.8 | 5.7 | 24.6 |

Note: Groundwater taken for petroleum and gas production not presented
Bore data provided by the OGIA (2013) was originally sourced from the DNRM groundwater database and WMS
^ Stock/domestic volumes estimated by the OGIA where not licensed.




Source:Data supplied by client and by Parsons Brickenhoff



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**REGISTERED BORES WITHIN THE SURAT CMA**

URS

**GROUNDWATER**

Figure: **14-5**

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### Springs

Natural discharge from aquifers of the GAB may feed spring vents and watercourse springs. Groundwater dependent ecosystems (GDEs), i.e. communities of plants, animals and other organisms that depend on groundwater for survival, are present within the GFD Project area.

A spring vent is a single point in the landscape where groundwater is discharged at the surface. A spring vent can be mounded or flat and may be represented by wetland vegetation with no visible water at the location of the spring. A group of spring vents located in close proximity to each other is called a spring complex. Spring vents in a spring complex are located in similar geology, are connected to the same source aquifer, and individual vents are never more than 6 km apart.

There are 72 spring complexes comprising 329 spring vents in the Surat CMA (OGIA, 2013) (Figure 14-6).

Some spring vents in the Surat CMA are of conservation significance as they provide unique ecological habitats.  The need to protect the unique species associated with these springs has been recognised under the EPBC Act and the NC Act.

Spring vents located within GFD Project tenures are listed in Table 14-6. The table also identifies EPBC Act protection status of the springs as well as their respective GAB springs conservation ranking. The GAB spring conservation rankings are described in Table 14-7 (Fensham et al., 2012).

Table 14-6 Spring vents located in GFD Project tenures

| Complex number | Complex name | Vent number | Source aquifer(s) | Gas field | EPBC Act | Conservation Ranking (see Table 14-7) |
|---|---|---|---|---|---|---|
| 78 | 78 | 551, 552 | Clematis Sandstone | Arcadia | No | 3 |
| 229* | Ponies | 284 | Hutton Sandstone | Fairview | No | 2 |
| 230 | Lucky Last | 287, 340, 686, 687.1, 687.2, 687.3, 687.4, 687.5, 687.6, 688, 689 | Evergreen Formation (Boxvale Sandstone), Precipice Sandstone | Fairview | Yes | 1b |
| 308 | 308 | nv383 | Clematis Sandstone | Arcadia | No | - |
| 311 | 311 | 499, 500, 500.1, 535, 536, 536.1, 536.2, 537, 692, 693, 694, 695, 696, 697, 698, 699, 704 | Precipice Sandstone | Fairview | No | 2 |
| 327 | 327 | nv385 | Precipice Sandstone | Fairview | No | - |
| 507 | VI_mile | 188, 679, 680, 680.1 | Gubberamunda Sandstone | Roma | No | 4b |
| 561 | Spring Rock Creek | 285 | Evergreen Formation (Boxvale Sandstone), Precipice Sandstone | Fairview | No | 3 |

| Complex number | Complex name | Vent number | Source aquifer(s) | Gas field | EPBC Act | Conservation Ranking (see Table 14-7) |
|---|---|---|---|---|---|---|
| 583 | Lenore Hills | nv621 | Tertiary Volcanics, Clematis Sandstone | Arcadia | No | 3 |
| 591 | Yebna 2 | 534 | Evergreen Formation, Precipice Sandstone | Fairview | Yes | 3 |
| 592 | Abyss | 286, 286.1, 286.2, 286.3 | Hutton Sandstone | Fairview | 286 | 1b |

*These springs are most likely associated with perched groundwater systems and therefore unlikely to be affected by water level changes in the aquifer.

'-' no conservation ranking.

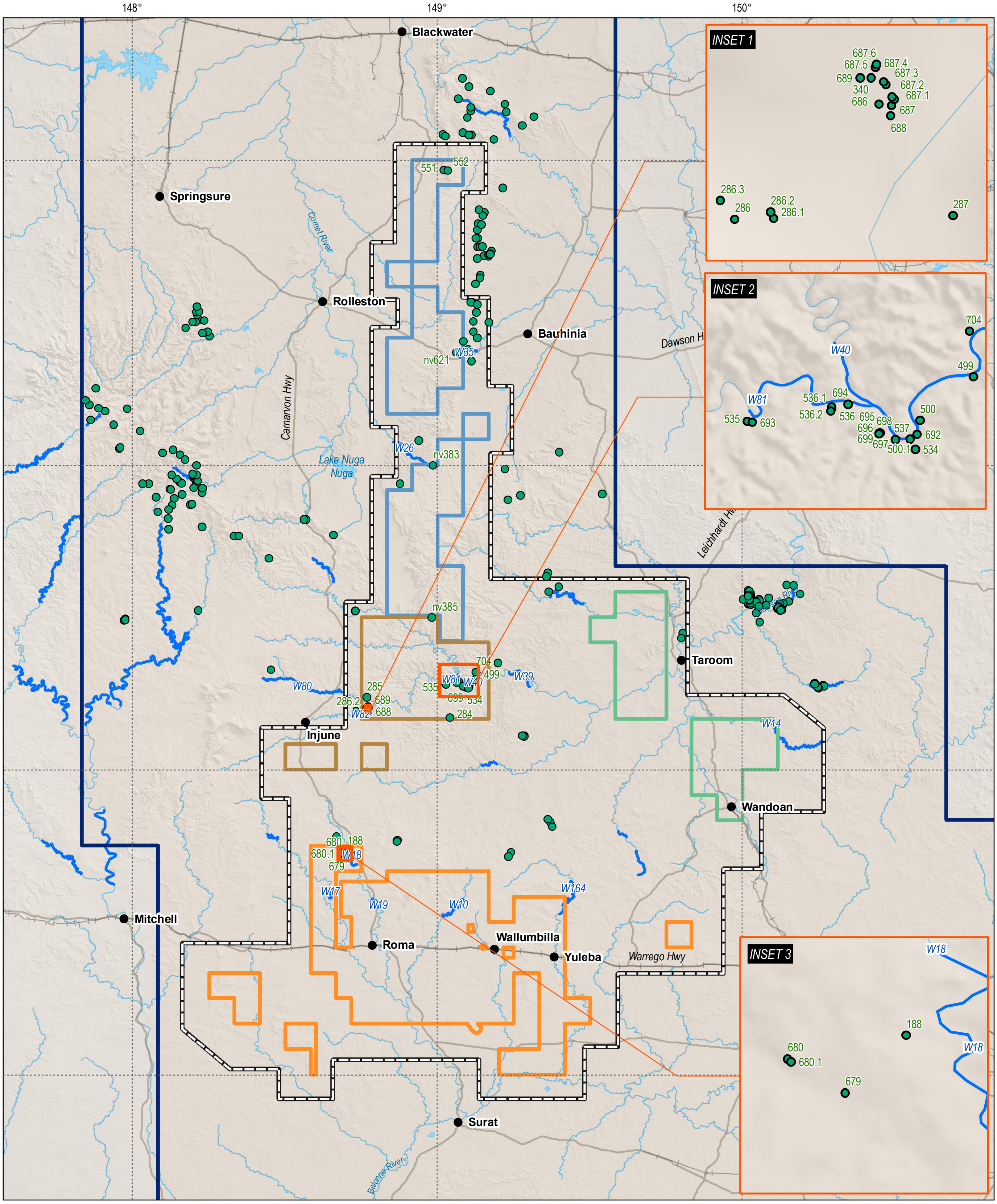
Table 14-7 Conservation ranking of Great Artesian Basin springs

| Conservation ranking category | Description |
|---|---|
| 1a | Contains at least one GAB endemic species not known from another location beyond this spring complex. |
| 1b | Contains endemic species known from more than one spring complex; or has populations of threatened species listed under State or Commonwealth legislation that do not conform to Category 1a. |
| 2 | Provides habitat for populations of plant and/or animal species not known from habitat other than spring wetlands within 250 km. |
| 3 | Spring wetland vegetation without isolated populations (Category 2) with at least one native plant species that is not a widespread coloniser of disturbed areas. |
| 4a | Spring wetland vegetation comprised of exotic and/or only native species that are wide spread colonisers of disturbed areas. |
| 4b | The original spring wetland is destroyed by impoundment or excavation. The probability of important biological values being identified in the future is very low. |
| 5 | All springs inactive. |

A watercourse spring is a section of a watercourse where groundwater enters the stream from a GAB aquifer through the streambed. This type of spring is also referred to as a baseflow-fed watercourse (QWC, 2012a).

Watercourse springs provide baseflow to streams and support in-stream aquatic ecosystems, and may be of particular ecological importance during periods of low rainfall. There are 43 watercourse springs in the Surat CMA (OGIA, 2013) (Figure 14-6). It is important to note that many of the watercourse springs in the Surat CMA have not been ground-truthed and may not actually be present.

Eleven watercourse springs are located within GFD Project tenures. These are listed in Table 14-8. Figure 14-6 also shows inset figures showing the OGIA designated numbers of some watercourse springs and spring vents.

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Projection: GDA94

- Spring vents (OGIA, 2013)
- Watercourse springs (OGIA, 2013)
- Surat cumulative management area

**GFD Project area**

- Arcadia gas field
- Fairview gas field
- Roma gas field
- Scotia gas field
- Possible area for supporting infrastructure

- Towns
- Railways
- Major roads
- Major drainage

Source:Data supplied by client and by Parsons Brickenhoff



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# SPRING VENTS AND WATERCOURSE SPRINGS WITHIN THE SURAT CMA

URS

GROUNDWATER

Figure: 14-6

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Table 14-8 Watercourse springs located in GFD Project tenures

| Site number | Source aquifer (OGIA, 2013) | Watercourse receiving baseflow | Gas field |
|---|---|---|---|
| W10 | Mooga Sandstone, Gubberamunda Sandstone | Blyth Creek | Roma |
| W14 | Hutton Sandstone | Bungaban Creek | Scotia |
| W17 | Mooga Sandstone | Bungeworgorai Creek | Roma |
| W18 | Gubberamunda Sandstone | Bungil Creek | Roma |
| W19 | Mooga Sandstone | Bungil Creek | Roma |
| W26 | Clematis Sandstone | Clematis Creek | Arcadia |
| W35 | Clematis Sandstone | Conciliation Creek | Arcadia |
| W40 | Precipice Sandstone | Dawson River | Fairview |
| W81 | Hutton Sandstone | Hutton Creek | Fairview |
| W82 | Hutton Sandstone | Injune Creek | Fairview |
| W164 | Mooga Sandstone | Yuleba Creek | Roma |

### 14.4.3.2 EPP Water environmental values

The EPP Water provides a framework for identifying EVs for Queensland waters and the water quality guidelines (WQGs) and water quality objectives (WQOs) to enhance or protect those EVs.

The EPP Water defines environmental values of water as:

*"particular values or uses of the water that are conducive to a healthy ecosystem or for public amenity, safety or health and that require protection from the effects of habitat alteration, waste releases, contaminated runoff and changed flows".*

The Arcadia, Fairview and Scotia gas fields are located within the Comet and Dawson river sub-basins of the Fitzroy River Basin. Final EVs and WQOs have been adopted by the Queensland Government for these sub-basins and are included in the following documents listed under Schedule 1 of the EPP Water:

- Comet River Sub-basin Environmental Values and Water Quality Objectives (DERM, 2011a).
- Dawson River Sub-basin Environmental Values and Water Quality Objectives (DERM, 2011b).

The Roma gas field is located in the Condamine-Balonne River Basin. Draft EVs have been developed by the Condamine Alliance (2012a and 2012b) for this river basin.

The EVs identified for the Comet, Dawson and Condamine-Balonne river basins are summarised in Table 14-9.

Table 14-9 Environmental values of groundwater in the Comet, Dawson and Condamine-Balonne river basins

| EVs | *Comet River Sub-basin* | *Dawson River Sub-basin* | *Condamine-Balonne River Basin* |
|---|---|---|---|
| Protection of aquatic ecosystem | ✓ | ✓ | ✓ |
| Primary contact recreation (e.g. swimming)* | ✓ | ✓ | ✓ |
| Secondary recreation (e.g. boating)* | ✓ | ✓ | ✓ |
| Visual (no contact) recreation* | ✓ | ✓ | ✓ |
| Drinking water supplies | ✓ | ✓ | ✓ |
| Crop irrigation | ✓ | ✓ | ✓ |
| Stock watering | ✓ | ✓ | ✓ |
| Farm supply/use | ✓ | ✓ | ✓ |
| Aquaculture (e.g. red claw, barramundi) | × | ✓ | ✓ |
| Human consumers of aquatic food | ✓ | ✓ | × |
| Industrial use (including manufacturing plants, power generation) | ✓ | ✓ | × |
| Protection of cultural and spiritual activities | ✓ | ✓ | ✓ |

*Primary, secondary and visual recreation contact have been included as EVs for groundwater due to groundwater contributions to surface water baseflow in some tenures.

## 14.5 Potential impacts

A number of GFD Project activities have the potential to cause adverse impacts on the identified groundwater EVs without adequate management controls in place. Such activities and their associated potential impacts are identified and described in the following sub-sections.

An estimate of the GFD Project's water balance and the total amount of water expected to be extracted over the life of the GFD Project is provided in Appendix U2: Report on Matters of national environmental significance (water resources).

### 14.5.1 Numerical groundwater model impact assessment results

The extraction of groundwater is an integral part of the production of gas from coal seams and has the potential to change regional aquifer pressure. The impacts of depressurisation of the coal seams on bores and springs (including due to induced flow between aquifers) have been assessed quantitatively using numerical groundwater modelling.

Depressurisation is a reduction in groundwater pore pressure (pressure head) in a confined groundwater system due to extraction of groundwater. Drawdown is the change in groundwater level in a bore, or the change in water table elevation in an unconfined groundwater system, due to the extraction of groundwater. Refer to Table 5-2 in Appendix O:Groundwater for the groundwater levels in the GFD Project area.

#### 14.5.1.1 Impacts to landholder bores

The modelling approach and impact assessment results are provided in detail in section 7 of Appendix O: Groundwater and are summarised in this section. The modelling shows the change in area of impact due to the EIS Scenario, compared to the UWIR Scenario (shown on Figure 14-7).

The area of impact has been assessed in a similar way to the LAA described in the UWIR. The LAA is the area that may experience groundwater pressure reductions greater than 5 m for consolidated aquifers, or 2 m for unconsolidated aquifers, at some time in the future due to cumulative water extraction by petroleum tenure holders.

The results indicate the area of impact will increase due to the expansion of areas being developed. The largest increases in depressurisation impacted areas occur within the two target coal formations (the Walloon Coal Measures and the Bandanna Formation). There are also increases in the extent of the depressurisation impacted areas within the overlying Springbok Formation, the Hutton Sandstone and the Gubberamunda Sandstone.

Landholder bores where aquifer pressure is predicted to decline within three years (by more than 5 m for consolidated aquifers and 2 m for unconsolidated aquifers) were identified in the UWIR in 2012. The predicted changes in depressurisation due to the proposed GFD Project will not result in additional impacts to landholder bores before 2015, as the additional production wells are not proposed to start production until after that date.

The UWIR in 2012 predicted that 528 landholder bores would be cumulatively impacted due to petroleum and gas development in Surat CMA. Under the EIS Scenario, an additional 73 private water bores in the Surat CMA, 48 of which are in the GFD Project tenures, are predicted to be impacted by a decline in groundwater pressure of more than 5 m for consolidated aquifers at some time in the future (Section 7.3.2 of Appendix O: Groundwater). A. The numerical groundwater model identified that no bores associated with unconsolidated aquifers were potentially impacted.

The UWIR and OGIA model uses Queensland Government databases to identify the number and location of private bores. In accordance with its obligations under the Water Act, gas proponents undertake a bore assessment on each bore as when it is deemed to lie within an IAA (as described in the UWIR). Bore assessments provide the means of determining fair and equitable make good measures on the basis of the predicted impacts, as well as objective information such as bore design, groundwater hydrology, available pump capacity and water storage capacity. Experience of gas proponents to date has been that one quarter to one third of bores in OGIA database that have been identified as been potentially impacted have been abandoned or can no longer be found. Baseline assessments, which include site visits, are performed to obtain basic information about private bores. GLNG Baseline Assessment Program seeks to benchmarks data for the private water bores located on its tenures, prior to any impact of production activities. Santos GLNG completed baseline assessments between 2009 and 2013, involving assessment of 793 bores associated with the Santos GLNG tenures (Appendix O: Groundwater). Similar to industry experience the Baseline Assessment Program indicates that of the 48 potentially impacted bores which are located on GFD Project tenures:

- 66% (32) were observed to be in use by the landholder
- 23% (11) could not be located by the landholder, or else were not in use or were abandoned
- 10% (5) of private water bores have not yet been surveyed, and will be assessed in accordance with the UWIR.

#### 14.5.1.2 Impacts to springs

There are 45 spring complexes and 33 watercourse springs located within the Surat CMA that have been recognised as springs of interest. Groundwater model results for the EIS Scenario were used to conduct an initial screening to identify springs of interest; defined as springs underlain by a formation (including the coal seams) where the long-term maximum predicted impact on water pressures at the location of the spring (but not necessarily in the source aquifer of the spring) exceeds 0.2 m, or is within 10 km of 0.2 m of depressurisation. As a precautionary approach, EPBC springs located within 5 km beyond the 10 km buffer were also included as springs of interest. The buffers are precautionary as they allow for the limitations associated with modelling very small changes in water pressure.

A risk-based methodology was employed to assess the likelihood of the springs of interest experiencing impacts due to the cumulative development of gas in the Surat CMA under the EIS scenario (section 7.3.3 of Appendix O: Groundwater). A total of 13 spring complexes and 19 watercourse springs have been identified as being at risk of impacts due to the cumulative development of gas in the Surat CMA under the EIS scenario. Among the identified springs at risk of impact, 8 spring complexes and 12 watercourse springs are located within or near GFD Project tenures (Figure 14-8).

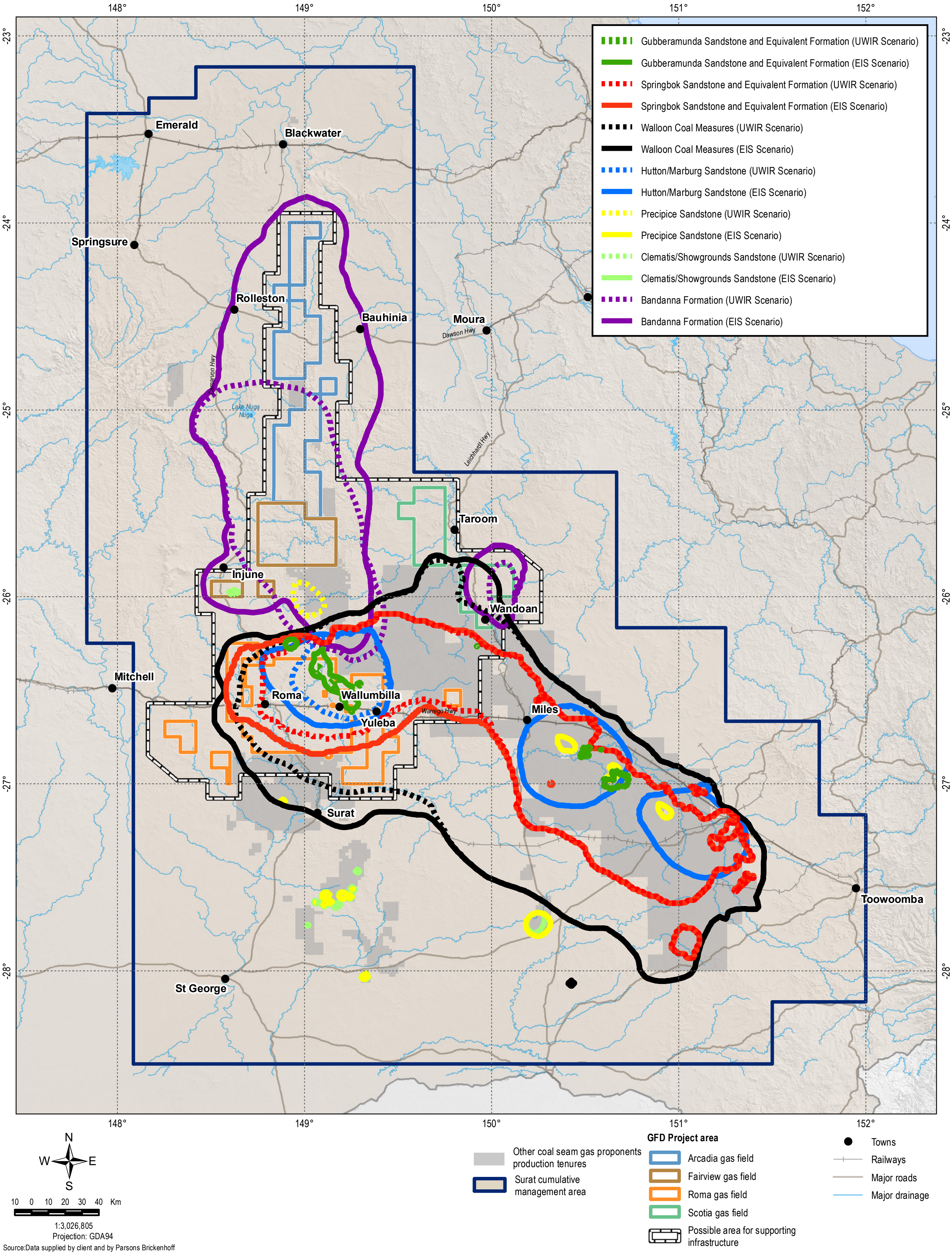
The UWIR identified 6 spring complexes and 12 watercourse springs located within or near Santos GLNG tenures to be at risk of impacts. Two additional spring complexes (302 and 339) and one additional watercourse spring (W141) located within or near GFD Project tenures have been assessed to be at risk of impacts under the EIS scenario.

### 14.5.2 Potential subsidence impacts related to coal seam depressurisation

Although pressure reductions in the coal seams are expected to occur as a result of GFD Project operations (section 14.5.1), the risk of significant subsidence of the land surface is very low because:

- The pressure reductions are predicted to occur in formations comprising consolidated rock
- The greatest pressure reductions are predicted to occur at depths of several hundred metres or more below the surface.

Subsidence modelling predicted maximum differential settlements at the surface of 0.06 m over a distance of 1.5 km for the Roma gas field, and 0.045 m over a distance of 3 km for the Arcadia and Fairview gas fields. Settlements of this scale are too small to cause changes to surface water or groundwater flow paths and as a result, no impact to groundwater EVs is expected (Santos GLNG, 2013c). For further information refer to section 8.1. of Appendix O:Groundwater 1 and Appendix AE-E:Ground deformation monitoring and management plan.




Source:Data supplied by client and by Parsons Brickenhoff



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# AREAS OF IMPACT UNDER THE UWIR AND EIS SCENARIOS

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GROUNDWATER

Figure: **14-7**

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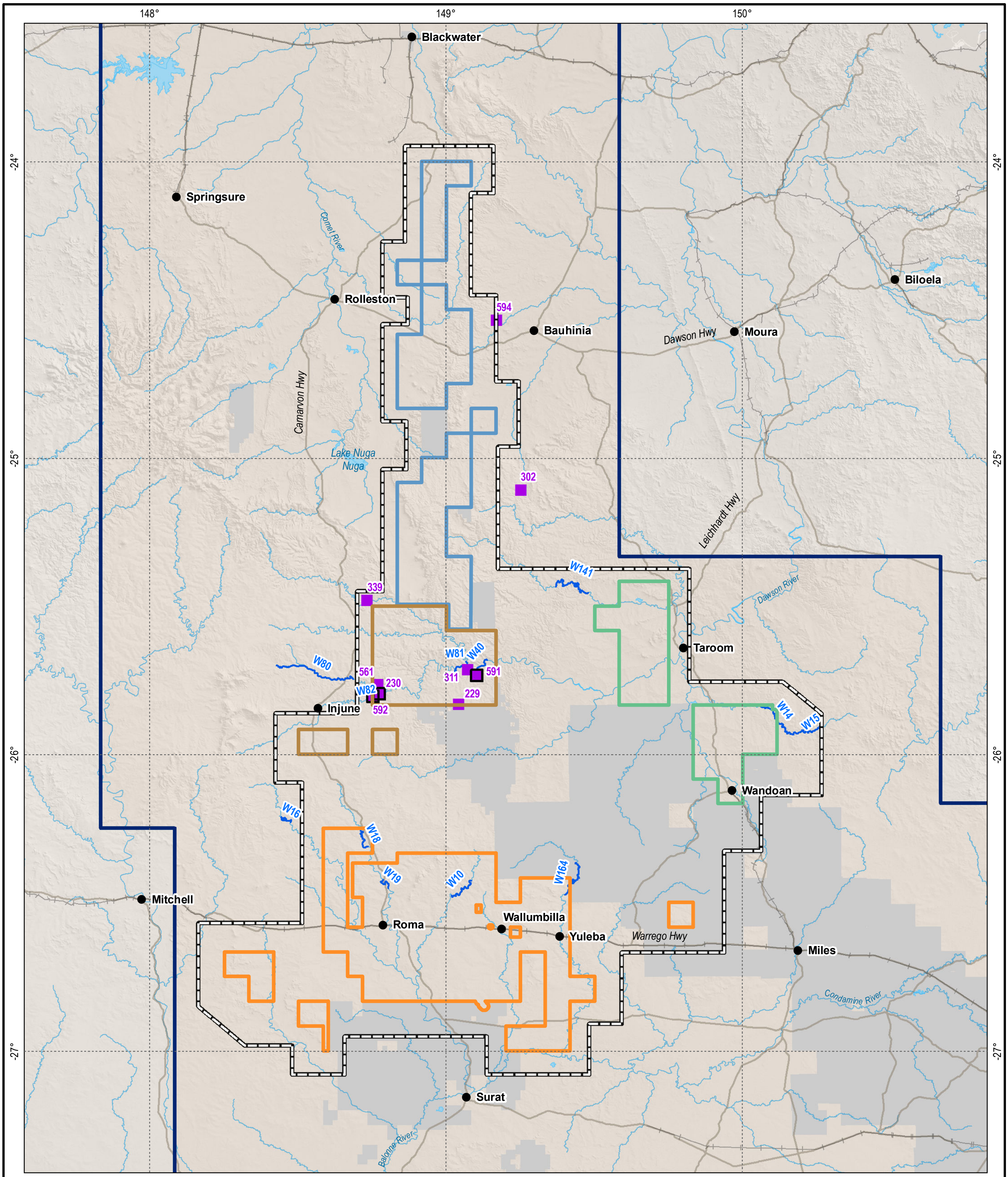


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Projection: GDA94

| | |
|---|---|
| Other coal seam gas proponents production tenures | |
| Surat cumulative management area | |
| Spring complex at risk of impacts (EIS scenario) | |
| EPBC spring complex | |
| Watercourse springs at risk of impacts (EIS scenario) | |

**GFD Project area**

- Arcadia gas field
- Fairview gas field
- Roma gas field
- Scotia gas field
- Possible area for supporting infrastructure

- Towns
- Railways
- Major roads
- Major drainage

Source:Data supplied by client and by Parsons Brickenhoff



Santos GLNG Project

GFD PROJECT EIS

# SPRINGS AT RISK OF IMPACTS WITHIN OR NEAR GFD PROJECT TENURES

URS

**GROUNDWATER**

Figure: **14-8**

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### 14.5.3 Potential impacts on groundwater levels related to other project activities

Without adequate controls in place construction, operation, decommissioning and rehabilitation of other project components of the GFD Project may involve work with the potential for short to long-term impact on groundwater levels(refer to Appendix O:Groundwater). These activities include:

- Drilling and construction of production wells, re-injection wells, water supply bores and monitoring bores
- Hydraulic fracturing
- Shallow subsurface activities.

#### 14.5.3.1 Drilling and construction of wells

The drilling, construction, operation, maintenance and decommissioning of production wells, as well as the construction of re-injection wells, water supply bores and monitoring bores, is required for production of natural gas from coal seams. The wells to be constructed for the GFD Project will intersect multiple hydrogeological units and although the likelihood is considered remote, there is the potential for localised depressurisation of aquifers to occur through the following:

- Without adequate controls in place constructed wells could create a connection between previously isolated aquifers, inducing vertical leakage of groundwater within the borehole. This could affect water levels in nearby bores and spring flow. Construction controls mean the likelihood of this happening is low
- Without adequate controls in place management of artesian flow (where encountered) can lead to uncontrolled flow of groundwater at the surface. Uncontrolled artesian flow can depressurise aquifers and adversely affect water levels in nearby bores. Construction controls mean the likelihood of this happening is low.

#### 14.5.3.2 Hydraulic fracturing

Hydraulic fracturing, or coal seam stimulation, is a process used to improve the efficiency of natural gas extraction from coal seams. Hydraulic fracturing is not used for all wells and most wells drilled to date in Queensland have not been fracture stimulated. Hydraulic fracturing is generally, used in areas where the coal seams have lower permeability. By improving the production efficiency, it potentially reduces the number of required wells.

The hydraulic fracturing process is designed to ensure that fracturing remains within the target seam, thus preventing the formation of new pathways to other aquifers. Fractures created during the hydraulic stimulation process generally are of the order of several millimetres wide and may propagate up to 50 m horizontally away from the well. The potential for the hydraulic fracturing process to impact groundwater levels or pressures by creating a pathway between the coal seam and an aquifer is considered low due as the hydraulic fracturing process is designed to ensure that fracturing remains within the target seam, thus preventing the formation of new pathways to other aquifers.

#### 14.5.3.3 Shallow subsurface activities

Other GFD Project components with potential to impact on groundwater levels and pressures are the ancillary infrastructure activities such as construction of borrow pits, buried pipelines and storage dams. The disturbance created by these activities is generally the product of excavation and is restricted to within several metres of the surface. At these depths, aquifers are almost always unconfined and any depressurisation due to excavation activities is likely to be negligible.

### 14.5.4 Potential changes to groundwater quality

A number of GFD Project activities have the potential to impact groundwater quality, including:

- Drilling and construction of wells
- Groundwater extraction for gas production
- Hydraulic fracturing
- Storage of coal seam water
- Brine management and injection
- Managed aquifer recharge
- Beneficial use for irrigation or stock watering
- Surface activities

Degradation of groundwater quality can lead to following potential impacts:

- Loss or degradation of springs or other GDEs dependent on affected aquifers
- Degradation of the beneficial use of groundwater supplies
- Degradation of the beneficial use of surface water supplies (where watercourse springs are affected).

#### 14.5.4.1 Drilling and construction of wells

The drilling, construction, operation, maintenance and decommissioning of production wells, as well as the construction of re-injection wells, water supply bores and monitoring bores, are required for production of gas. The wells to be constructed for the GFD Project will intersect multiple hydrogeological units and there is the potential for localised changes to the quality of groundwater to occur through the following:

- Without adequate controls in place constructed wells can create an artificial connection between previously isolated aquifers, inducing vertical leakage of groundwater within the borehole. This can change water quality. Construction controls mean the likelihood of this happening is low
- Without adequate controls in place the management of artesian flow (where encountered) can lead to uncontrolled flow of groundwater at the surface. Uncontrolled artesian flows can adversely affect the quality of underlying shallow aquifers. Construction controls mean the likelihood of this happening is low.

#### 14.5.4.2 Groundwater extraction for gas production

Depressurisation of the coal seams for production of gas has the potential to induce flow between aquifers above and below the Walloon Coal Measures or Bandanna Formation. This can lead to changes in groundwater quality if aquifers of differing water quality become hydraulically connected.

The results of numerical groundwater modelling indicate that depressurisation impacts are significantly reduced away from the coal seams, suggesting the potential for leakage between aquifers induced by coal seam depressurisation is limited.

#### 14.5.4.3 Hydraulic fracturing

Hydraulic fracturing is a process used to improve the efficiency of gas extraction from coal seams as described in section 14.5.3.2 above and section 8.1.2 of Appendix O: Groundwater. Hydraulic fracturing fluid typically includes around 99% water and sand, with about 1% of a range of additives in diluted quantities which assist in carrying and dispersing the sand through the coal seam. The materials used by Santos GLNG uses in the hydraulic fracturing process have been subjected to a risk assessment (Santos GLNG, 2014) and are publicly disclosed on the Queensland Department of Environment and Heritage Protection (EHP) website. In accordance with Qld regulations the materials used do not include BTEX or PAHs compounds as additives.

Transport of gas and remnant hydraulic fracturing fluids have the potential to impact water quality within the target coal seams and in the hydrogeological units connected to them. This may subsequently affect the water quality of landholder water supplies and springs. The transport of gas and fluids from the coal seams may occur along faults or fractures/unconformities within the rock, or as a result of failures in the casing or seals of production wells.

The results of groundwater modelling indicate that the coal seams have limited connectivity with the adjacent aquifers. The majority of gas and fracturing fluid transport is therefore likely to occur within the target coal seams themselves. The hydraulic fracturing process is designed to ensure that fracturing remains within the target seam, thus preventing the formation of new pathways to other aquifers.

#### 14.5.4.4 Storage of coal seam water

The water extracted from coal seams in the GFD Project area is likely to be of variable quality and there is potential for the salinity of this water to be higher than that in shallow aquifers and surface water bodies in the area.

Coal seam water has the potential to impact on water quality in shallow aquifers through seepage from storage ponds. The potential for this to occur is limited as storage dams will be constructed and operated in accordance with the EHP guidelines for the management of regulated dams (EHP, 2012b) which limit the potential for seepage.

#### 14.5.4.5 Brine management and injection

The quality of water extracted from coal seams will determine the management options for its beneficial use or disposal in accordance with the Coal Seam Gas Water Management Policy (EHP, 2012a). If the management of the water extracted from coal seams requires treatment such as desalination (e.g. using reverse osmosis technology), this will result in the generation of brine as effluent from the process. The management and injection of brine and disposal of solid salt has the potential to impact groundwater quality through:

- Seepage of brine from storage dams to shallow aquifers
- Leakage from licenced waste disposal facilities where salts are disposed
- Cross-flow of aquifers due to incorrectly constructed injection wells.

Construction controls of dams, waste disposal facilities and wells mean the likelihood is limited.

The management of brine and/or solid salt will be in accordance with the Coal Seam Gas Water Management Policy (EHP, 2012a) and EPBC approval conditions. Considered management options include:

- Commercial salt production where practicable including collaboration with other proponents
- Brine injection into selected deep saline aquifers. Santos GLNG currently has approval to inject brine into the Timbury Hills Formation in the Fairview gas field and is currently undertaking feasibility studies for injection into the Timbury Hills Formation in the Roma gas field
- Crystallisation to form solid salt for disposal into a licensed waste disposal facility.

#### 14.5.4.6 Managed aquifer recharge

Managed aquifer recharge (MAR) will be employed into the Gubberamunda Sandstone aquifer near Roma and is being considered for other development areas. MAR involves the injection of treated coal seam water into aquifers.

As the injection water proposed for the MAR scheme near Roma has an electrical conductivity of approximately 500 µS/cm which is substantially lower (i.e. better quality) than the average electrical conductivity in the receiving Gubberamunda Sandstone aquifer, which is approximately 1,284 µS/cm (see section 5.7.3 of Appendix O: Groundwater), its impact on water quality is likely to be very low or beneficial.

#### 14.5.4.7 Beneficial use for irrigation and stock watering

Options for the beneficial use of coal seam water include irrigation and stock watering. Over-irrigation using coal seam water has the potential to cause localised impact of shallow groundwater resources and impacts to nearby groundwater users and springs or other GDEs if not managed in accordance with regulatory water quality limits. This is considered unlikely due to management controls.

#### 14.5.4.8 Surface activities

The construction and decommissioning of ancillary infrastructure where there is some component of excavation (such as borrow pits, buried pipelines and storage dams) without adequate controls in place has the potential to impact shallow aquifers through leaks and spills. Potential impacts will be restricted to areas where groundwater is shallow or the water table is intersected, and will be short-term and localised.

Fuel spills, during construction and decommissioning activities, can leak into the underlying hydrogeological unit and impact the water quality of shallow aquifers. Without adequate controls in place and the presence of a flow pathway this has the potential to cause localised impacts to nearby shallow aquifers.

## 14.6 Mitigation measures

The Water Act regulates groundwater impacts caused by petroleum tenure holders by setting out monitoring and reporting requirements, groundwater drawdown trigger threshold levels, and make good obligations if the extraction of coal seam water adversely affects groundwater supply to a third-party water bore or a natural spring.

The management measures for the GFD Project will be in accordance with the commitments made in 2012 under the UWIR for the Surat CMA, and additional commitments imposed by future updates to UWIR. These commitments include the completion of bore assessments and make good agreements with specified landholders, completion of baseline assessments of landholder bores, development of spring impact mitigation strategies, and undertaking groundwater and spring monitoring.

Santos GLNG will also implement the commitments of the Joint Industry Plan for the Monitoring and Protection of the EPBC Springs, which provides an early warning system and response plan for springs protected by the EPBC Act to ensure that adequate time is available for assessment and implementation of management measures prior to potential adverse impacts.

Santos GLNG's groundwater monitoring program meets the requirements of environmental authorities granted under the EP Act is outlined in the Appendix Y: Draft environmental management plan. Santos GLNG's groundwater monitoring program to meet the requirements of the Water Act through the UWIR and Commonwealth Government under the EPBC Act is outlined in Appendix AE: Water resource management plan.

If approved the GFD Project development will be included in the impact assessment for the subsequent UWIR and the resulting monitoring and reporting requirements will be incorporated into relevant Santos GLNG monitoring programs.

Santos GLNG is committed to implementing the mitigation measures in Table 14-10 to manage potential groundwater related impacts. These measures will be incorporated into Santos GLNG's management framework for the GFD Project, as described in Appendix Y: Draft environmental management plan.

Table 14-10 Mitigation measures

| Management plan | Commitments |
|---|---|
| GFD Project Environmental protocol for constraints planning and field development (the Constraints protocol) | The Constraints protocol applies to all gas field related activities. The scope of the Constraints protocol is to:<br>• Enable Santos GLNG to comply with all relevant State and Federal statutory approvals and legislation<br>• Support Santos GLNG's environmental policies and the General Environmental Duty (GED) as outlined in the EP Act<br>• Promote the avoidance, minimisation, mitigation and management of direct and indirect adverse environmental impacts associated with land disturbances<br>• Minimise cumulative impacts on environmental values.<br>The Constraints protocol provides a framework to guide placement of infrastructure and adopts the following management principles:<br>• Avoidance — avoiding direct and indirect impacts<br>• Minimisation — minimise potential impacts<br>• Mitigation — implement mitigation and management measures<br>• Remediation and rehabilitation — actively remediate and rehabilitate impacted areas<br>• Offset — offset residual adverse impacts in accordance with regulatory requirements.<br>The Constraints protocol enables the systematic identification and assessment of environmental values, including spring vents and spring complexes, and the application of development constraints to effectively avoid and / or manage environmental impacts. |
| Water resource management plan (WRMP) | The WRMP has been developed to proactively detail how Santos GLNG manages and monitors potential adverse impacts to water resources, recently defined as a matter of national environmental significance.<br>The WRMP includes the following management plans or studies:<br>• Hydraulic connectivity characterisation<br>• Joint Industry Plan for EPBC Act listed springs<br>• Evaluation of Prevention or Mitigation Options for Fairview Springs<br>• Stimulation Impact Monitoring Program<br>• Hydraulic Fracturing Risk Assessment: Compendium of Assessed Fluid Systems<br>• Dawson River Discharge Scheme Receiving Environment Monitoring Program Summary. Monitoring will take place throughout construction, during operation and during decommissioning, as per legislative requirements. |
| Ground deformation monitoring and management plan (GDMMP) | The GDMMP details how Santos GLNG monitors and manages the risk from subsidence across its tenures. The plan includes monitoring methodology, exceedance management and response, and reporting requirements. |
| Stimulation impact monitoring program | This program was developed to provide a general description of the stimulation activities to be conducted by Santos GLNG, the regulatory requirements pertinent to stimulation monitoring, as well as the practices and procedures that comprise the monitoring program. |

| Management plan | Commitments |
|---|---|
| Underground water impact report for the Surat Cumulative Management Area | Santos GLNG will comply with the requirements of the Surat CMA UWIR which include:<br>• Groundwater monitoring in accordance with the water monitoring strategy<br>• Development of a spring impact mitigation strategy for specified springs<br>• Spring monitoring in accordance with the spring monitoring program<br>• Conducting bore assessments and entering into make good agreements with specified landholders<br>• Developing and implementing a baseline assessment plan.<br>The UWIR is a statutory instrument used to define appropriate spring and landholder bore impact management and mitigation actions in accordance with the Water Act. The UWIR is revised every three years, with the next UWIR due for release in 2015. It identifies immediately (i.e. in the next three years) affected landholder bores for which Santos GLNG is obliged to undertake a bore assessment of and ultimately reach a make good agreement, and spring impact monitoring and management activities. The 2015 UWIR will incorporate the GFD Project development, and therefore GLNG will implement appropriate impact management and mitigation action as defined necessary by that report and in accordance with Santos GLNG's obligations under the Water Act. |
| Coal seam water management strategy(CWMS) | The CWMS outlines the overarching approach to managing coal seam water. The strategy prioritises the beneficial use of coal seam water where practicable, while avoiding, minimising and mitigating environmental impacts in accordance with the relevant regulatory framework. |
| Draft Environmental management plan (Draft EM Plan) | The Draft EM Plan identifies the environmental values potentially affected by the GFD Project and proposes measures to manage the risk of potential adverse impact to these environmental values. The Draft EM Plan includes:<br>• Environmental values potentially affected by the GFD Project<br>• Environmental management objectives and associated management measures<br>• Environmental monitoring and reporting<br>• Coal seam water management plan<br>• Proposed conditions. |
| Hydraulic fracturing risk assessment: compendium of assessed fluid systems (Hydraulic fracturing risk assessment) | The Hydraulic fracturing risk assessment synthesises the hydraulic fracturing risk assessments completed on various hydraulic fracturing fluids and provides a framework for including new fluid systems within the risk assessment document.<br>The report provides generalised information, including the geology and hydrogeology of the area, risk assessment methodologies (qualitative and quantitative) and a high level understanding of current results. The appendices include risk assessments of individual hydraulic fracturing fluid systems. |
| Contingency plan for emergency environmental incidents (Contingency plan) | The Contingency plan details the management practices in place within Santos GLNG to minimise environmental harm during an emergency environmental incident. The plan identifies potential incidents, and provides response actions, including escalation, communication, reporting and monitoring. |
| Land release management plan (LRMP) | The LRMP addresses the management of releases of water to land in Santos GLNG's gas fields, including:<br>• Coal seam water use for irrigation, construction and operations purposes<br>• Treated sewage effluent releases to land<br>• Use of treated sewage effluent for construction and operational purposes<br>• Low point drain water releases to land<br>• Hydrostatic test water releases to land.<br>The document includes the principles, methods and controls to effectively manage and minimise the risk environmental harm being caused by release of water to land. |

| Management plan | Commitments |
|---|---|
| Chemical and fuel management plan (CFMP) | The CFMP details the appropriate storage and handling practices of chemicals and fuels. The objectives of the plan are to:<br>• Facilitate compliance with relevant legislation, regulations and approvals<br>• Provide a framework for Santos GLNG to store and handle bulk chemicals and fuels in a way that minimises risk to the environment and human health<br>• Assess the potential risk of a chemical or fuel prior to its use<br>Identify and implement appropriate mitigation measures. |
| Joint industry plan for an early warning system for the monitoring and protection of EPBC springs (Joint Industry Plan) | The joint industry plan has been collaboratively developed by Santos GLNG, Origin Energy and Queensland Gas Company (the Proponents).<br>The objectives of the joint industry plan are to:<br>• Summarise the monitoring requirements that have been requested of the Proponents in the Surat Underground Water Impact Report for the Surat Cumulative Management Area (Queensland Water Commission, 2012)and in the Proponents' approval conditions by the Department of the Environment<br>• Propose an early warning system monitoring network and escalating levels of triggers to manage EPBC Act-listed springs from adverse impacts associated with coal seam water extraction<br>• Demonstrate that the Proponents will endeavour to identify potential adverse impact early and adequately respond to prevent adverse impact to EPBC Act listed springs<br>• Identify which Proponent is responsible for management actions for each spring<br>• Demonstrate the Proponents' commitments to meet the requirements of the EPBC Act approval. |

### 14.6.1 Bore impact management measures

The Water Act requires petroleum and gas companies to make good impairment to the adequacy of water supply from bores resulting from their water extraction. Petroleum tenure holders must carry out a bore assessment and enter into a make good agreement with the owner of bores in the immediately affected area (IAA), the area within which water levels are predicted by a UWIR to decline by more than 5 m within three years.

The Water Act also requires petroleum tenure holders to carry out baseline assessments of water bores on their tenures before production commences. A baseline assessment is an assessment of a private bore to obtain information about the bore condition and performance and baseline water levels and quality. The objective of the baseline assessments is to support the settling of make good agreements should they be required in the future.

The UWIR assigns Santos GLNG as responsible for impacts to one bore located in the IAA. Santos GLNG has completed a bore assessment and entered into a make good agreement with the owner of this bore. The agreement specifies the measures to be implemented to minimise the impacts to the affected bore owner. Measures which may be considered for make good agreements include:

- Deepening of bores and/or pumps to increase available drawdown
- Subsidising increased pumping costs
- Replacing pumps
- Replacing/relocating bores
- Constructing additional bores
- Increasing water storage capacity
- Treating water to mitigate changes in water quality
- Providing alternative water sources.

The predicted changes in depressurisation due to the proposed GFD Project will not result in additional impacts to landholder bores before 2015, as the proposed additional production wells are not scheduled to start production until after that date. This means the current IAA will not change under the GFD Project and there are no additional requirements for Santos GLNG to undertake bore assessments or enter into make good agreements with bore owners. Santos GLNG will comply with requirements for bore assessments and make good agreements identified in the subsequent UWIR.

Through Santos GLNG's already established groundwater monitoring program, potential impacts on private bores will be identified before the impacts become material. Where monitoring indicates that water extraction by Santos GLNG is affecting, or has the potential to affect supply from an existing bore, then Santos GLNG will undertake a bore assessment and enter into a make good agreement with the bore owner.

### 14.6.2 Springs impact mitigation strategy

The springs identified in the UWIR as requiring development of a Spring Impact Mitigation Strategy are those where an impact of more than 0.2 m is predicted in the source aquifer of the spring.

Santos GLNG as the tenure holder is responsible for preparing Spring Impact Mitigation Strategies for three spring vent complexes in the Surat CMA:. The UWIR identifies a range of potential mitigation measures where EVs at springs are found to be at risk. The applicability of these measures to the spring vent complexes have been investigated by Santos GLNG and an Evaluation of Prevention or Mitigation Options Report (EPMOR) (Golder, 2014) has been prepared and submitted to the OGIA for consideration. For further details refer to sections 8.2.1 and 9.1.3 of Appendix O: Groundwater.

The results of the numerical groundwater modelling undertaken for the GFD Project indicate there are no new spring complexes where an impact of more than 0.2 m is predicted in the source aquifer under the EIS Scenario compared to the UWIR Scenario. However, Santos GLNG may be required to prepare a Spring Impact Mitigation Strategy where drawdown impacts have increased under the EIS Scenario, such as for Spring Ridge (complex 506). If an additional Spring Impact Mitigation Strategy is required by the subsequent UWIR, Santos GLNG will comply with regulatory requirements.

### 14.6.3 EPBC Act Spring management measures

For the GFD Project Santos GLNG will also implement the commitments of the JIP for the Monitoring and Protection of the EPBC Springs, which provides an early warning system and response plan for springs protected by the EPBC Act to ensure that adequate time is available for assessment and implementation of management measures prior to potential adverse impacts. Santos GLNG, together with three other proponents in the Surat CMA, have developed a JIP for a groundwater monitoring and management system to have no adverse impact to EPBC springs protected by the EPBC Act from the production of gas (Santos GLNG, 2013b).

The JIP establishes an Early Warning System (EWS) to provide adequate time for assessment and implementation of management measures prior to potential adverse impacts on the EVs of springs associated with an EPBC Act listing. A groundwater monitoring bore network that focuses on the primary source aquifers of springs associated with an EPBC Act listing (primarily the Hutton Sandstone and Precipice Sandstone) is currently being installed and includes:

- Early Warning Monitoring Installations (EWMI) close to the area of coal seam water extraction or between the extraction areas and the spring
- Trigger Monitoring Points (TMP) located within close proximity of the spring.

The JIP establishes drawdown triggers that instigate actions commensurate with increasing risk to springs associated with an EPBC Act listing:

- Investigation triggers
- Management/mitigation triggers.

For further details refer to sections 8.2.1 and 9.1.3 of Appendix O: Groundwater.

### 14.6.4 Construction of wells and shallow subsurface activities

Measures to minimise impacts to groundwater levels/pressure and quality from the drilling, construction and decommissioning of production wells, injection wells, water supply bores and monitoring bores, include the following:

- In addition to Santos GLNG's own design standards and robust safety procedures, the construction, operation and decommissioning of production wells will be in accordance with the *Code of practice for constructing and abandoning gas wells and associated bores in Queensland* (DNRM, 2013b) and the *Code of practice for gas well head emissions detection and reporting* (DEEDI, 2011). These standards require that production wells be lined with steel casing, which is cemented in place to isolate aquifers overlying the coal seam, and are pressure cemented to surface once they are no longer producing commercial quantities of gas
- Well Integrity Plans will be developed for gas wells. These are risk management plans which evaluate and address potential risks to the environment for each well
- DNRM is responsible for regulating gas production well construction, reviewing construction logs and periodically auditing drilling and construction procedures
- Fuel or oil storage facilities will be contained within bunded (secondary containment) areas and accurate records kept of fuel, oil or chemical volumes stored on tenure to allow regular quantity monitoring
- The construction of water supply bores and monitoring bores will be in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (National Water Commission, 2012).

Measures to minimise impacts to groundwater from shallow sub-surface activities, including the rehabilitation of borrow pits, laydown areas, buried pipelines and storage dams, are detailed in the Rehabilitation management plan (Santos GLNG, 2014e).

### 14.6.5 Mitigation measures for hydraulic fracturing

The risk of impacts to groundwater from hydraulic fracturing are expected to be minimal, however, the following controls will be implemented to ensure the risks remain minimal:

- Spill containment procedures will be implemented to prevent migration of chemicals into shallow groundwater systems
- Pressure tests of well casing and cement will be conducted prior to hydraulic fracturing to confirm the integrity of the well
- Chemicals will be subject to assessment through a Quantitative Risk Assessment prior to use
- Process design will aim to retain fluids within the target seam
- Flow back fluids will be appropriately contained, managed, recycled or disposed of in accordance with regulatory requirements.

Further detail is provided in the Appendix Y: Draft environmental management plan and Appendix AE-F: Hydraulic fracturing risk assessment.

## 14.7 Significance assessment

As discussed in section 14.3.2 impacts were assessed using the significance assessment methodology. Table 14-11 summarises the assessment undertaken for the potential impacts of the GFD Project on the environmental values detailed in section 14.4. For each identified potential impact the significance assessment considered:

- The potential pre-mitigated significance, which assumes that only the Constraints protocol has been applied and the potential impacts are at their greatest
- The mitigation measures that will be used to manage the potential impacts on groundwater values. These measures will reduce the magnitude of the potential impacts
- The residual significance of the potential impact after the implementation of mitigation measures.

The residual significance takes into account the potential for impact that remains after the mitigation measures are applied.

The assessment in Table 14-11 does not consider cumulative depressurisation impacts associated with the operation of production wells for the GFD Project as these are quantitatively assessed in section 14.5.1 using the numerical groundwater modelling.

Table 14-11 Groundwater significance assessment

| Potential impacts | | Phase | Pre-mitigated significance | | | Mitigation | Residual significance | |
|---|---|---|---|---|---|---|---|---|
| | | | Sensitivity | Magnitude | Significance | | Magnitude | Significance |
| Aquifer depressurisation | Decline in groundwater levels/pressure in bores and reduced supply to groundwater users | Construction | Moderate | Low^ | Low | Water resource management plan (WRMP)<br>Coal seam water management strategy(CWMS)<br>Draft Environmental management plan (Draft EM Plan)<br>Hydraulic fracturing risk assessment: compendium of assessed fluid systems<br>Contingency plan for emergency environmental incidents<br>Land release management plan<br>Underground water impact report for the Surat Cumulative Management Area<br>Joint industry plan for an early warning system for EPBC | Low^ | Low |
| | | Operations | | Low^ | Low | | Low^ | Low |
| | | Decommissioning | | Low^ | Low | | Low^ | Low |
| | Reduced stream baseflow (watercourse spring flow) and loss or reduction of supply to downstream surface water users | Construction | Moderate | Low^ | Low | | Low^ | Low |
| | | Operations | | Low^ | Low | | Low^ | Low |
| | | Decommissioning | | Low^ | Low | | Low^ | Low |
| | Reduced spring flow and loss or degradation of MNES dependent ecosystems | Construction | High | Moderate^ | High | | Low^ | Moderate |
| | | Operations | | Moderate^ | High | | Low^ | Moderate |
| | | Decommissioning | | Moderate^ | High | | Low^ | Moderate |
| | Reduced stream | Construction | Moderate | Low^ | Low | | Low^ | Low |
| | | Operations | | Low^ | Low | | Low^ | Low |

| Potential impacts | | Phase | Pre-mitigated significance | | | Mitigation | Residual significance | |
|---|---|---|---|---|---|---|---|---|
| | | | Sensitivity | Magnitude | Significance | | Magnitude | Significance |
| | baseflow (watercourse spring flow) and loss or degradation of dependent aquatic ecosystems | Decommissioning | | Low^ | Low | springs quality plan (EWS Plan) Ground deformation monitoring and management plan (GDMMP) Stimulation impact monitoring program | Low^ | Low |
| | Subsidence, altering groundwater flow paths and aquifer storage | Construction | Moderate | Low | Low | | Low | Low |
| | | Operations | | Moderate | Moderate | | Moderate | Moderate |
| | | Decommissioning | | Low | Low | | Low | Low |
| | Subsidence, causing ground surface displacement and altering surface water flow paths | Construction | Moderate | Low | Low | | Low | Low |
| | | Operations | | Low | Low | | Low | Low |
| | | Decommissioning | | Low | Low | | Low | Low |

| Potential impacts | | Phase | Pre-mitigated significance | | | Mitigation | Residual significance | |
|---|---|---|---|---|---|---|---|---|
| | | | Sensitivity | Magnitude | Significance | | Magnitude | Significance |
| Changes to water quality | Degradation of the beneficial use of groundwater supplies | Construction | Moderate | Moderate | Moderate | | Low | Low |
| | | Operations | | Moderate | Moderate | | Low | Low |
| | | Decommissioning | | Low | Low | | Low | Low |
| | Loss or degradation of MNES ecosystems dependent on springs sourced from affected aquifers | Construction | High | Moderate | High | | Low | Moderate |
| | | Operations | | Moderate | High | | Low | Moderate |
| | | Decommissioning | | Low | Moderate | | Low | Moderate |

^ Does not consider depressurisation impacts associated with the operation of production wells for the GFD Project as these are quantitatively assessed in Section 14.5.1 and section 7of Appendix O: Groundwater using numerical groundwater modelling.

### 14.7.1 Monitoring and review

Strategies for implementing monitoring throughout the duration of the GFD Project have been identified. Monitoring programs have been integrated into the management plans and provide a basis to measure the effectiveness of the management strategies and enable review and update of processes. All monitoring will be carried out at a frequency to demonstrate and ensure compliance with regulatory approvals.

Santos GLNG's groundwater monitoring program to meet the requirements of environmental authorities granted under the EP Act is outlined in Appendix Y Draft environmental management plan (Draft EM Plan). Santos GLNG's groundwater monitoring program to meet the requirements of the Water Act through the UWIR and Commonwealth Government under the EPBC Act is outlined in Appendix AE Water resource management plan.

If approved, the proposed GFD Project development will be included in the impact assessment for the subsequent UWIR and the resulting monitoring and reporting requirements will be incorporated into relevant Santos GLNG monitoring programs.

#### 14.7.1.1 Groundwater pressure and quality

Existing and currently planned groundwater monitoring in the vicinity of GFD Project tenures 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. If indicated to be required following subsequent updates to the UWIR, Santos GLNG's regional groundwater monitoring network will be adapted to ensure appropriate monitoring for the GFD Project area.

Since 2008, Santos GLNG has implemented and operated a regional groundwater monitoring program. The current network extends across Santos GLNG's approved gas fields, as well as a number of the proposed GFD Project tenures and includes a total of 211 locations; refer to section 9.1.1 of Appendix O: Groundwater for further information.

The UWIR for the Surat CMA (QWC, 2012a) includes a Water Monitoring Strategy which requires petroleum tenure holders to:

- Install groundwater monitoring locations to form a regional groundwater monitoring network for the Surat 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 Water Monitoring Strategy, which includes 120 water pressure monitoring points and 24 water quality monitoring points in various formations of the Surat CMA, refer to section 9.1.1 of Appendix O: Groundwater for further information. Santos GLNG regularly submits updates of the implementation plan to the OGIA. Santos GLNG will comply with updates to the Water Monitoring Strategy that may be required by subsequent updates to the UWIR.

#### 14.7.1.2 Baseline assessment of landholder bores

Santos GLNG completed baseline assessments between 2009 and 2013, involving assessment of 793 bores associated with the Santos GLNG tenures refer to section 9.1.1 of Appendix O: Groundwater for further information. Santos GLNG will undertake additional baseline assessments if required in accordance with the Water Act and subsequent updates to the UWIR.

#### 14.7.1.3 Springs monitoring

The UWIR for the Surat CMA (QWC, 2012a) requires petroleum tenure holders in the Surat CMA to monitor springs in accordance with the spring monitoring program. The locations and details of springs that are currently being monitored by Santos GLNG in accordance with the spring monitoring program are provided in section 9.1.3 of Appendix O: Groundwater. Santos GLNG will comply with updates to the springs monitoring program that may be required by subsequent updates to the UWIR.

As a condition of the GLNG Project EPBC approval Santos GLNG is also implementing the commitments of the JIP for the Monitoring and Protection of EPBC Springs for the GLNG Project. The springs that are currently being monitored by Santos GLNG in accordance with the JIP are provided in section 9.1.3 of Appendix O: Groundwater. The JIP includes the monitoring of the springs on a quarterly basis to match the frequency in the UWIR.

## 14.8 Conclusions

The groundwater impacts that remain after the application of mitigation and management measures are detailed in Table 14-12. The assessment found that the significance of the residual impacts of the GFD Project on groundwater are expected to be low to moderate.

Table 14-12 Residual significance - groundwater

| Potential Impacts | | Residual significance | | |
|---|---|---|---|---|
| | | Construction | Operations | Decommissioning |
| Aquifer depressurisation | Decline in groundwater levels/pressure in bores and reduced supply to groundwater users | Low | Low | Low |
| | Reduced stream baseflow (watercourse spring flow) and loss or reduction of supply to downstream surface water users | Low | Low | Low |
| | Reduced spring flow and loss or degradation of MNES groundwater dependent ecosystems | Moderate | Moderate | Moderate |
| | Reduced stream baseflow (watercourse spring flow) and loss or degradation of dependent aquatic ecosystems | Low | Low | Low |
| | Subsidence, altering groundwater flow paths and aquifer storage | Low | Moderate | Low |
| | Subsidence, causing ground surface displacement and altering surface water flow paths | Low | Low | Low |
| Changes to water quality | Degradation of the beneficial use of groundwater supplies | Low | Low | Low |
| | Loss or degradation of MNES ecosystems dependent on springs sourced from affected aquifers | Moderate | Moderate | Moderate |

The assessment in Table 14-12 involved a qualitative assessment of depressurisation impacts from the GFD Project's production wells.

A separate quantitative assessment of cumulative depressurisation impacts associated with the operation of production wells of the GFD Project together with those of the petroleum and gas producers in the Surat CMA (cumulative impacts) has been carried out through numerical groundwater modelling detailed in section 7 of Appendix O: Groundwater using the numerical groundwater modelling.

The significance of these cumulative impacts has been assessed as high for MNES springs (due to the high probability and duration of the impact and their high environmental sensitivity) and moderate for bores.