8.0 Springs monitoring and management – the Joint Industry Plan

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#	Department Condition		Description	Completion date	Status
	Pre-Dec 2012	Post-Dec 2012			
18	**52d III**	**53B eci**	Implementation of agreed collaborative industry approach to springs monitoring and management. Derivation of trigger thresholds and finalisation of response actions.	October 2013	● (Commitments completed)
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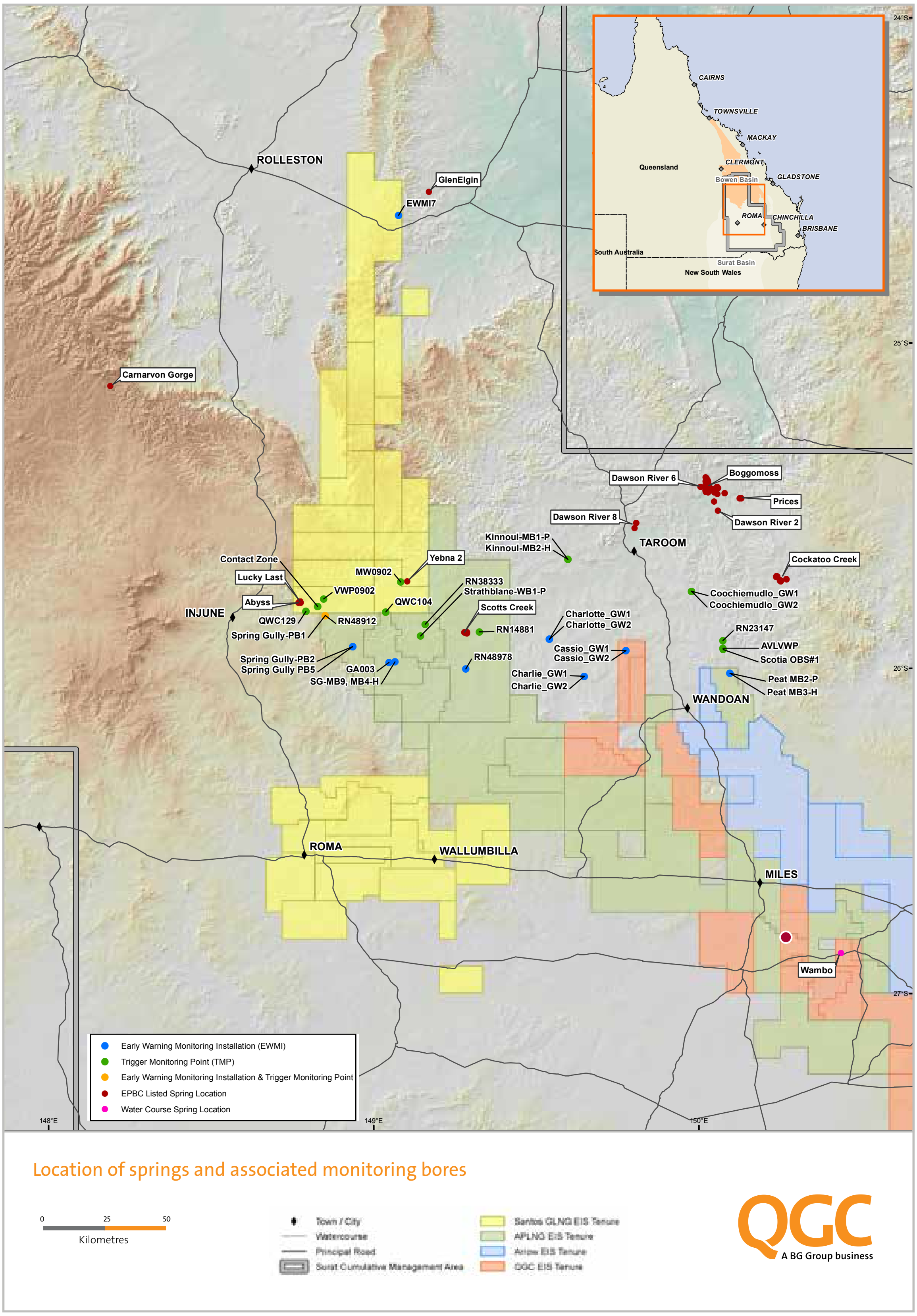
8.1 APPROACH TO SPRINGS MANAGEMENT

Groundwater-fed springs are an important water environment feature in the Surat Basin and the CSG industry has committed to protecting these springs against potential impacts from CSG-related groundwater abstraction. The CSG operators in the southern Bowen and Surat Basins, Santos, Origin Energy and Origin Energy on behalf of APLNG (hereafter referred to as Origin) and QGC (from here on jointly referred to as the Proponents) have developed a Joint Industry Plan (JIP) for a groundwater monitoring and management system to ensure springs protected by the EPBC Act are not impacted by CSG production. This is a requirement of the Proponent's project approvals under the EPBC Act which require the CSG activities to have 'no adverse impacts' to Matters of National Environmental Significance (MNES), which for groundwater relates to discharge from the Great Artesian Basin via springs (EPBC springs). Appendix J presents the JIP in full. The JIP has been submitted for regulatory approval and is being actively implemented with construction of monitoring bores and the adopting of agreed springs monitoring strategies.

The fundamental concept for springs monitoring and management is to measure groundwater drawdown at locations and times such that meaningful responses can be undertaken before there is any impact on MNES springs. The joint industry strategy for springs further includes the clear allocation of monitoring bores between proponents and the allocation of springs to proponents to ensure consistency across the industry. The chosen approach minimises disturbance by elimination of duplicate monitoring points and optimises spatial coverage. The plan has been developed in accordance with comments received from Geoscience Australia (GA, 2011, 2012), the Department and the Expert Panel for Major Coal Seam Gas Projects (Expert Panel).

The plan is also intended to align with spring monitoring and mitigation requirements obligated by the Surat Cumulative Management Area (Surat CMA) Underground Water Impact Report (UWIR) (QWC 2012).



Location of springs and associated monitoring bores

Figure 8-1 – Spring and associated monitoring bore locations

The fundamental concepts and primary principles of the JIP are:

- To ensure consistency in the approach to springs monitoring and management between the proponents;
- To measure groundwater drawdown at locations and times such that meaningful responses can be undertaken before there is any impact on MNES springs;
- An early warning approach based on modelling and monitoring to manage increasing levels of risk;
- The use of the Surat CMA cumulative impact model (CIM) to assess risks to the springs;
- A clearly defined network of monitoring bores allocated to each of the proponents;
- Single proponent responsibility for each EPBC spring aligning with Surat CMA UWIR Springs Strategy;
- Differences in individual company approaches to limit/trigger setting at monitoring bores; and
- Alignment on exceedance response process and timing.

Figure 8-1 illustrates the locations of the springs of interest in relation to the Proponents' tenements.

8.2 RESPONSIBILITY FOR SPRINGS

The UWIR identifies 33 spring vents amongst ten spring complexes and five watercourse springs that are at a higher risk of being affected by CSG activities. The principal risk criterion cited in the UWIR is the prediction of potential to experience more than 0.2 m drawdown in the source aquifer(s) at the spring location at any time. Not all of these higher risk springs are classified as EPBC springs and only five EPBC spring complexes were considered to be in the higher risk category. Drawdown greater than 0.2 m is not predicted to occur at any spring until 2017 or later and none of the higher risk watercourse springs contain MNES.

The UWIR assigns responsibility to petroleum tenure holders for specific monitoring and mitigation actions at higher risk springs. Under the JIP, responsibility for the management and mitigation of potential impacts to springs will be in accordance with the responsible tenure holder assignations of the UWIR.

On-tenement springs are the responsibility of the tenure holder and off-tenure springs are generally the responsibility of the closest tenure holder. Springs at which the Surat CMA UWIR Cumulative Impact Model (CIM) does not predict drawdown (e.g. Cockatoo Creek, Boggomoss, Prices, Dawson River 2 and Dawson River 6) do not have a responsible tenure holder identified. Should future iterations of the CIM show an increased level of risk at those springs, responsibility will be assigned in accordance with the UWIR, using the same principle of closest producing tenure holder. In accordance with these principles, responsibility for each of the springs is identified in Table 8-1.

Spring complex	Primary source aquifer	Location of spring	UWIR – selected spring for monitoring	UWIR – selected spring for mitigation	MNES present	EPBC listed spring	Responsible proponent
Scotts Creek	Hutton Sandstone	On APLNG tenement	✓	✓	✓	✓	Origin
Yebna 2	Precipice Sandstone	On Santos tenement	✓	✓	✓	✓	Santos
Lucky Last	Precipice Sandstone	On Santos tenement	✓	✓	✓	✓	Santos
Elgin 2	Clematis Sandstone	Off-tenure			✓	✓	Santos
Abyss	Hutton Sandstone	On Santos tenement	✓		✓	✓	Santos
Barton	Gubberamunda Sandstone	On APLNG tenement	✓	✓			Origin
Spring Rock Creek	Precipice Sandstone	On Santos tenement	✓	✓			Santos
Abyss	Hutton Sandstone	On/off Santos tenements	✓				Santos
Yebna 2	Precipice Sandstone	On Santos tenement	✓	✓			Santos
Ponies	Hutton Sandstone	On Santos tenement	✓				Santos
Wambo	Quaternary Sediments	On QGC tenement	✓				QGC
Carnarvon Gorge	Precipice Sandstone	Off-tenure			✓	✓	ND
Cockatoo Creek	Precipice Sandstone	Off-tenure			✓	✓	ND
Dawson River 2	Precipice Sandstone	Off-tenure			✓	✓	ND
Boggomoss	Precipice Sandstone	Off-tenure			✓	✓	ND
Dawson River 6	Precipice Sandstone	Off-tenure			✓	✓	ND
Prices	Precipice Sandstone	Off-tenure			✓	✓	ND
Dawson River 8	Hutton Sandstone	Off-tenure	✓		✓	✓	QGC
W39	Watercourse Spring	On Origin tenement	✓				Origin
W40	Watercourse Spring	On Santos tenement	✓				Santos
W80	Watercourse Spring	On Santos tenement	✓				Santos
W81	Watercourse Spring	On Santos tenement	✓				Santos
W82	Watercourse Spring	On Santos tenement	✓				Santos

NA = Not applicable, ND = responsibility will be allocated to the responsible tenure holder if future iterations of the Surat CMA CIM indicate potential drawdown at spring complex in source aquifer

Table 8-1 – Responsibility for EPBC listed springs

8.3 POTENTIAL PRESSURE PROPAGATION TO SPRINGS

Monitoring and management of impact to an EPBC springs must take cognisance of the mechanism(s) by which drawdown is likely to be propagated from the source (CSG production area) to the receptor (EPBC spring), as per the source-pathway-receptor model of assessing hydrogeological risk. The protection of all receptors requires a robust conceptual model to be developed. The vertical and areal distribution of the springs allows the development of fewer models, with the level of risk assessed to be proportional to the distance from the source of the potential drawdown. Therefore, focusing monitoring efforts on the gas fields in closest proximity to the springs, the formations through which the drawdown must propagate, and the springs closest to the relevant development areas, will be the most effective approach to managing potential risks.

Based on groundwater pressures, Industry stratigraphy knowledge, outputs of the CIM, impact propagation conceptual models have been developed for the Surat Basin CSG production fields.

The primary mechanisms for the transmittal of drawdown to EPBC springs has been identified as the vertical propagation of pressure reduction from CSG production in the Walloon Coal Measures through the siltstones underlying the coal seams (including the Eurombah Formation) and into the Hutton Sandstone and from there potentially to the Precipice Sandstone (Appendix 5). This is illustrated on Figure 8-2.

- The low vertical permeability of the siltstones will both attenuate and delay the magnitude of drawdown propagating to the Hutton Sandstone. Due to the relatively higher horizontal permeability of the Hutton Sandstone, the drawdown will then spread laterally from the areas of development outwards over time towards the springs;
- Drawdown will first be realised at the springs closest in to the Walloon Coal Measure developments and closest to where development commences e.g. Scott's Creek and Dawson River 8 spring complexes, Scotts Creek spring complex lies approximately 40 km northwest of Origin's Combabula field and the QGC Woleebee Creek fields (QCLNG project) are approximately 55 km to the south-east;
- All other Hutton Sandstone sourced EPBC springs are at a greater distance from Walloon Coal Measures production. While the same mechanism for drawdown would apply, the magnitude of drawdown will be less and the time lag greater; and
- Drawdown to the Precipice Sandstone from this mechanism would need to transmit through the Evergreen Formation, which would significantly reduce the magnitude of drawdown in the spring source area.

Analysis of time-series drawdown data from the UWIR model, confirms these mechanisms as the modelled sources of potential impacts to EPBC springs. The model does not appear to indicate any propagation of drawdown through intervening Evergreen Formation with the exception of an area between Miles and Dalby. This is of limited lateral extent and magnitude and, not in the vicinity of EPBC springs, therefore drawdown at an EPBC spring is more likely to be realised via the primary pathway.

Monitoring will therefore focus on the currently determined spring source aquifer. To provide an early warning of potential impacts to the EPBC springs, it is essential that the monitoring focuses on the source and the pathway to the spring, rather than in the immediate vicinity of the spring itself. Further, monitoring of the CSG reservoir formation will provide an indication of whether the timing of transmitted drawdown is likely to be greater or earlier than that modelled, and hence provide an indicator of the level of risk to the EPBC springs of concern.

Spring complex	Interpreted source aquifer	Source of interpretation of source aquifer	Impact propagation pathway
Cockatoo Creek	Precipice Sandstone, with possible influence of the Evergreen Formation	KCB, 2012	Vertically from the extraction in the WCMs, through the Hutton Sandstone then Evergreen Formation, and then laterally through the Precipice Sandstone. Potentially from underdrainage through contact between Permian Coals (Bandanna equivalent) and Precipice Sandstone at Scotia/ Peat
Dawson River 2	Precipice Sandstone, with possible influence of the Evergreen Formation	KCB, 2012	Vertically from the extraction in the WCMs, through the Hutton Sandstone and Evergreen Formation, and then laterally through the Precipice Sandstone. Potentially from underdrainage through contact between Permian Coals (Bandanna equivalent) and Precipice Sandstone at Scotia/ Peat
Boggomoss	Precipice Sandstone	KCB, 2012	
Dawson River 6	Precipice Sandstone, with possible influence of the Evergreen Formation	KCB, 2012	
Prices	Precipice Sandstone	KCB, 2012	
Dawson River 8	Hutton Sandstone, possibly lower Birkhead Formation	KCB, 2012	Vertically from the extraction in the WCMs and then laterally through the Hutton Sandstone to the spring
Scotts Creek	Hutton Sandstone	KCB, 2012	Vertically from the extraction in the WCMs and then laterally through the Hutton Sandstone to the spring
Yebna 2	Precipice Sandstone, Evergreen Formation	KCB, 2012; Santos, 2013	Underdrainage through contact between Bandanna Formation and Precipice Sandstone at Fairview/Spring Gully. Potentially underdrainage from the WCMs propagating to the Precipice Sandstone and then laterally to the spring.
Lucky Last	Precipice Sandstone	Santos	Underdrainage through contact between Bandanna Formation and Precipice Sandstone at Fairview/Spring Gully
Elgin 2	Clematis Sandstone	KCB, 2012	Vertically through the Rewan Formation from drawdown in the Bandanna Formation
Abyss	Hutton Sandstone	Santos, 2013	Vertically from the extraction in the WCMs and then laterally through the Hutton Sandstone to the spring. Potentially underdrainage from the WCMs propagating to the Hutton Sandstone and then laterally to the spring.

Notes:
1. Santos interpretation of the source aquifer is based on physico-chemical sampling started early in 2013 at the springs and work performed for the preparation of mitigation options selection reports (also referred as EPMOR) for the Queensland Government.

2. Both Evergreen Formation or Boxvale Sandstone (which is part of the Evergreen Formation) formation names are used in the literature to define spring aquifer sourced from the Boxvale Sandstone

Table 8-2 – Impact propagation pathways for EPBC springs

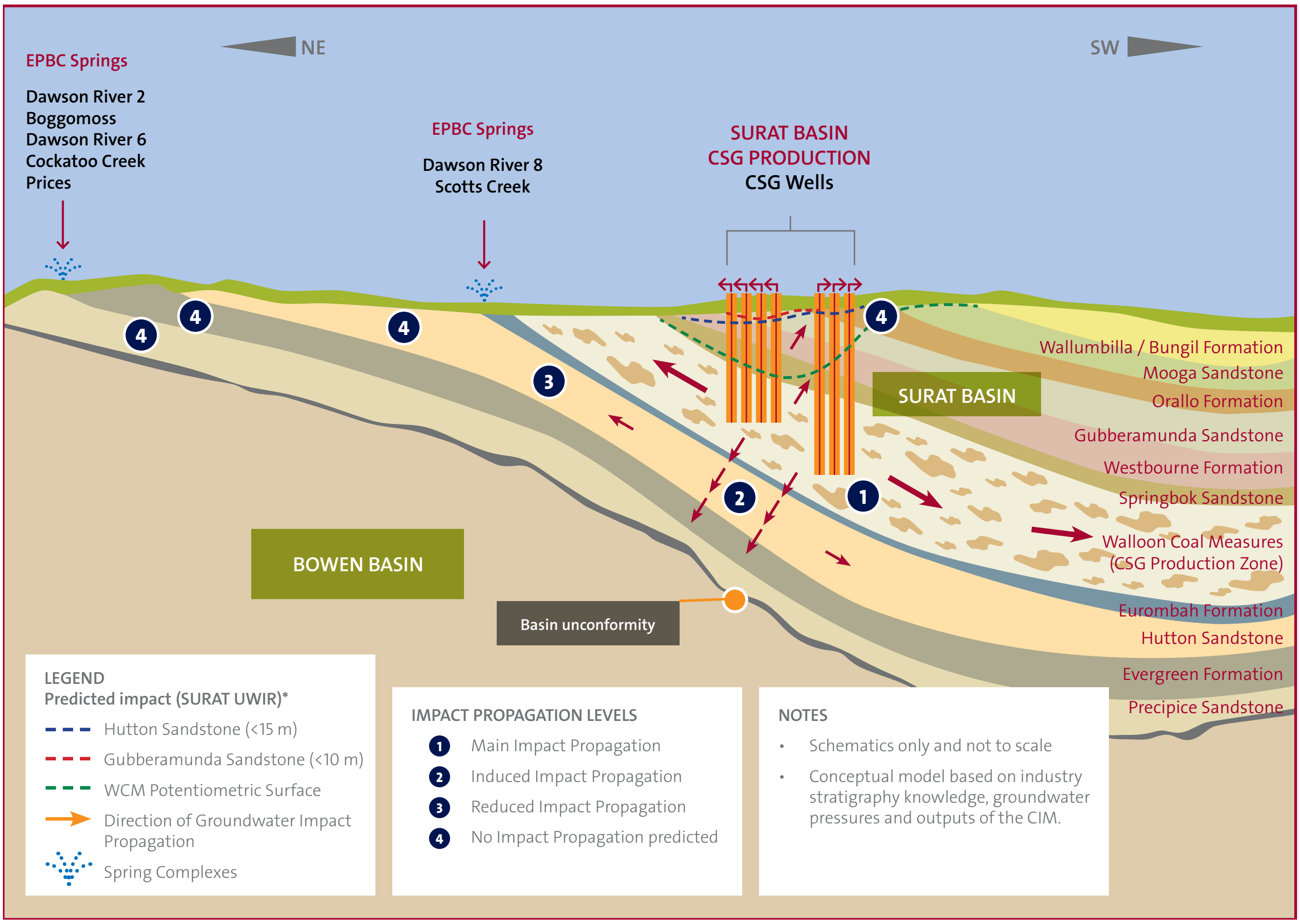


Figure 8-2 – Conceptual Model of Impact Propagation – Surat Basin

8.4 THE EARLY WARNING AND THRESHOLD MONITORING SYSTEM

An early warning system (EWS) has been developed to provide adequate time for assessment and implementation of management measures prior to potential negative effects on MNES.

The EWS is based on the underlying assumption that MNES are dependent on spring flow. The sensitivity of the spring flow to drawdown in the source aquifer is dependent on the hydrogeological environment in which the spring exists, particularly the pressure at the spring and the flow path for the water reaching the surface. The time delay between an exceedance of the monitoring trigger and an exceedance of the management/mitigation trigger is estimated to be a minimum of three years for off tenements springs. Initial site-specific conceptual hydrogeological models have been developed for the springs which the UWIR indicates are at a greater risk of potential drawdown. Conceptual hydrogeological models for springs that are more distant from CSG production have not yet been developed and will be developed for all springs at the completion of the baseline monitoring.

This EWS is based on a groundwater monitoring bore network that will be used to provide early warning of potential impact to a spring or spring complex (Figure 8-1). It comprises 14 Hutton Sandstone monitoring locations, 16 Precipice Sandstone monitoring locations and one Clematis Sandstone monitoring location.

These monitoring bores are a subset of the Proponent's combined groundwater monitoring bore network. The combined monitoring network will exceed the requirements of the Surat CMA UWIR and Geoscience Australia's recommendations to the Department. Approximately 30% of the EWS monitoring bores are already in place. QGC has constructed the majority of its monitoring bores – six bores out of eight in four locations targeting the Hutton and Precipice Formations. Prioritisation of the EWS monitoring bore installation is scheduled to enable the early commencement of data collection at locations close to early CSG development areas. The bores have been constructed to allow the collection of both water pressure and water quality data.

The network comprises two types of installations:

- An Early Warning Monitoring Installation (EWMI) is typically be on-tenure and close to the area of CSG 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. At these locations groundwater drawdowns are expected to be more pronounced due to their proximity to the source of drawdown. The primary purpose of EW bores is to monitor trends. Should the data suggest significant departure from model predictions then investigation and model recalibration would be instigated;
- Trigger Monitoring Point (TMP) located closer to the spring (i.e. further away from the CSG production area).

Figure 8-3 illustrates the schematic relationships between the monitoring bores, CSG producing horizons, springs source aquifers and the springs themselves. It shows the format of the various drawdown triggers.

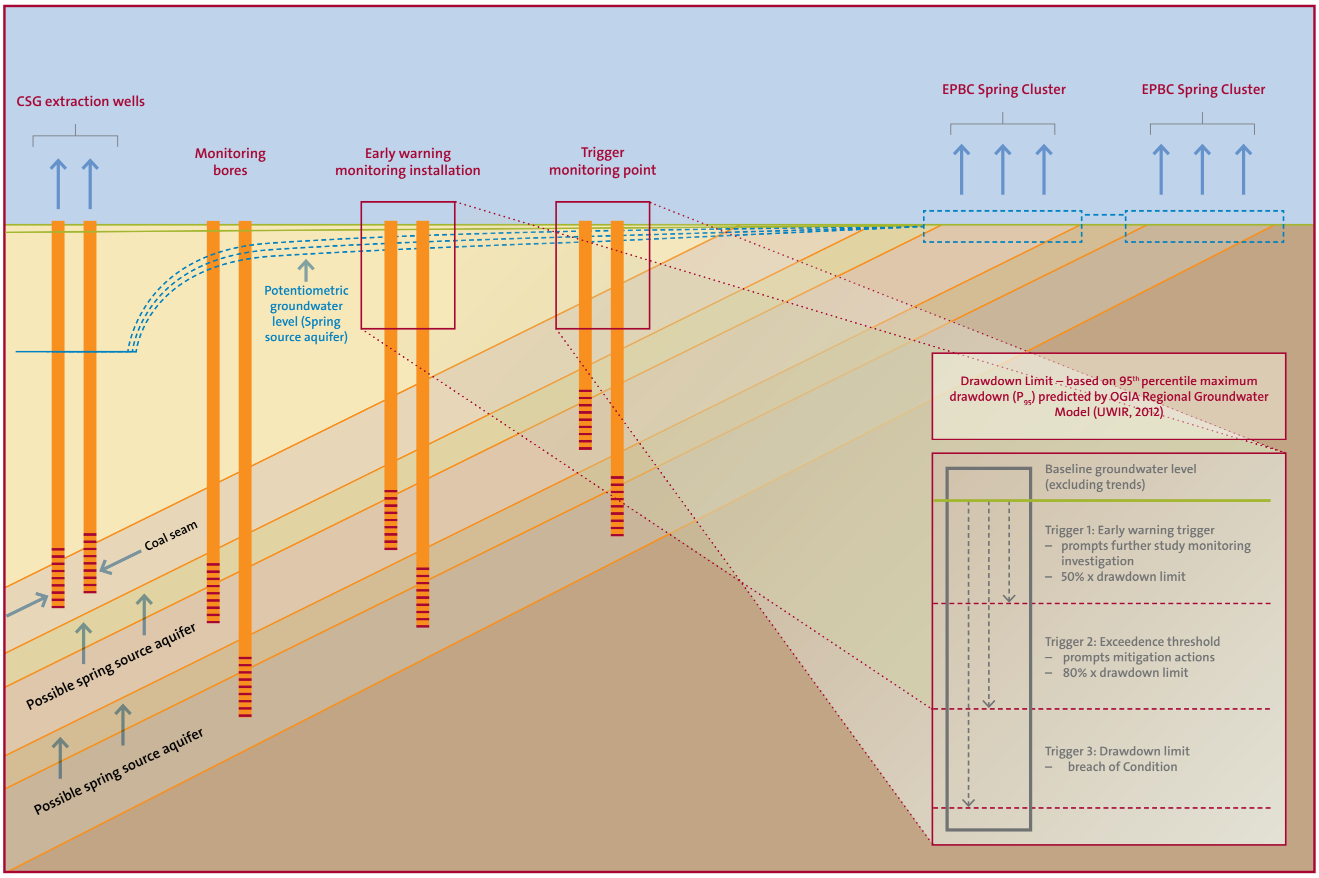


Figure 8-3 – Schematic of springs monitoring system

In addition to the above network, the Proponents will also be monitoring the CSG reservoirs (Walloon Coal Measures and the Bandanna Formation) to understand the timing and magnitude of drawdown at its source.

The EWS is built on the following key elements:

- The use of groundwater level variations as an early warning proxy for impact to the ecosystem supported by the spring. This is conservative as a decrease in pressure does not necessarily result in an impact to MNES;
- A groundwater monitoring network that focuses on the primary source aquifers of EPBC springs (primarily Hutton and Precipice Sandstones). Intervening aquitards will be monitored through selective VWPs, as the drawdown must first propagate through either of the primary aquifers;
- The use of the regional cumulative impact model (CIM) developed for the Surat CMA UWIR to set action triggers, primarily using the 95th percentile prediction (95th percentile) of drawdown. This corresponds to a drawdown that represents a statistical value from the 200 model runs for which 95% of the model runs have a smaller predicted drawdown. In other words, there is only 5% likelihood that this value be exceeded. Use of the 95th percentile is conservative and therefore aligns with the Precautionary Principle;
- The development of drawdown trigger response processes that respond to increasing levels of risk to MNES;
- The ability to use the entire network of monitoring bores to support the assessment of regional scale responses to better understand the source of actual CSG-induced drawdown, and the associated potential risks to MNES;
- The development of the Early Warning System monitoring network takes cognisance of the mechanisms by which drawdown is propagated from the source (CSG production area) to the receptor (spring). Two primary mechanisms are postulated for the transmittal of drawdown from CSG production to springs;
- Hutton Sandstone primary sourced springs – Vertical propagation of pressure reduction from CSG production in the Walloon Coal Measures through the siltstones underlying the coal seams (including the Eurombah Formation aquitard) and into the Hutton Sandstone. The only spring sourced from the Hutton Sandstone that the Surat CMA CIM considered to be at high risk is Scotts Creek. A similar vertical propagation of pressure reduction would be required to cause drawdown in the on-tenure springs overlying Walloon Coal Measure production (Wambo and Barton);
- Precipice Sandstone primary sourced springs – Lateral propagation of depressurisation from potential CSG production from the Bandanna Formation at Spring Gully and Fairview, resulting in underdrainage of the Precipice Sandstone where the Bandanna Formation subcrops to the west of Fairview/Spring Gully (Santos refers to this area as the Contact Zone). The underdrainage would propagate a cone of depression laterally through the Precipice Sandstone to the springs, such as the Lucky Last spring complex. A similar mode of potential drawdown exists at the Scotia/Peat fields, where the Permian coals targeted for gas production subcrop beneath the Precipice Sandstone. The CIM does not predict drawdown from these fields propagating to the Precipice Sandstone sourced springs in the east (e.g. Boggomoss, Prices, and Cockatoo Creek); and
- It is noted that other mechanisms are possible (e.g. a component of local flow).

The UWIR model does not indicate material propagation of drawdown through the Evergreen Formation aquitard which separates the Hutton and Precipice Sandstones. If the EWS monitoring bores detect water pressure changes ahead of the model predictions, an investigation will be executed.

8.5 RESPONSE PLANS

Threshold values for bore drawdown are defined in Chapter 4, if these are breached the data will be subjected to the trend analysis procedure also documented in Chapter 4. If the corrected drawdown exceeds a trigger, a response process will be implemented as described in Chapter 13. The response plan is based on the following principles:

- Understand the cause and/or deviation from the model;
- The investigation phase will comprise the targeted data collection for and evaluation of potential mitigation measures to lead to the selection of a preferred mitigation measure; and
- Exceedance of the management/mitigation threshold will trigger the implementation of that preferred mitigation measure as long as conditions have not significantly changed to negate the preferred option.

QGC's approach to groundwater level risk management for protection of MNES springs incorporates Geoscience Australia's strategy of enabling action commensurate with escalating risk (GA, 2012). This approach makes use of an exceedance envelope and is depicted in Figure 8-4. The figure shows a range of groundwater management regimes that could apply over time that are dependent on observed drawdowns and how these relate to trigger thresholds (as derived from the the OGIA regional model developed under Conditions 61 and 62).

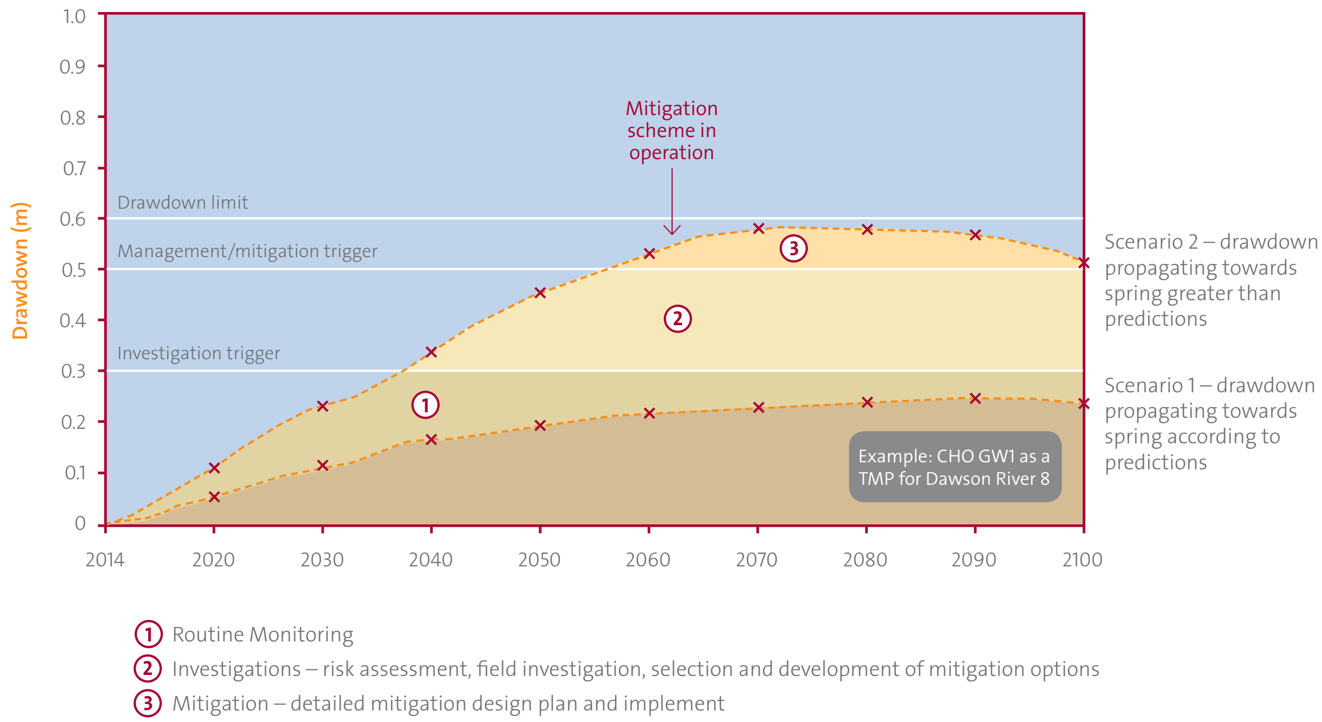


Figure 8-4 – Example of envelope to groundwater risk management

8.6 SPRINGS MONITORING

Springs monitoring is being undertaken quarterly. The first baseline monitoring exercise was completed in October 2013. The monitoring activities are in line with the UWIR requirement, and comprise the following:

- Surveying of spring vent locations and elevations, and the establishment of a permanent survey mark at each vent;
- Collection of water quality data, for a wide range of chemical parameters;
- Measurement of spring flow or spring wetted area; and
- Monitoring of the physical condition of the spring.

The first year of quarterly monitoring will constitute the baseline period. In addition to those items above, the baseline monitoring is including assessment of fauna, flora and macro-invertebrates, and collection of groundwater samples for isotope analysis; however these will not be part of ongoing monitoring. There are a range of weather stations across the area and others will be installed in close proximity to spring complexes, where required.

The Proponents are using a common field team to undertake the spring baseline monitoring to ensure consistency between the companies.

A Quality Plan for EWS monitoring has been developed by the Proponents which standardises:

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

Collection of monitoring data is the responsibility of the proponent responsible for installation of each of the EWMIs and TMPs. The Proponents can share the monitored data with each other through a range of existing data sharing agreements, and via provision of the data to the Office of Groundwater Impact Assessment.

Reports will be prepared by the Proponents in accordance with their individual CSG WMMPs but will include a minimum of:

- Simple reporting of data every year (data and plots of data against trigger as appropriate, trend analysis after collection of baseline); and
- A more substantial consolidated report every three years.

8.7 CONCEPTUAL MODELS OF GROUNDWATER FLOW TO SPRINGS

The first twelve months of springs monitoring will be completed in October 2014. A joint industry spring baseline report will be submitted in April 2015, which will include a hydrogeological conceptual model for each of the EPBC spring complexes.

The development of the conceptual models will take into consideration other anthropogenic influences upon the source aquifers in the vicinity of each spring and more specifically:

- Location and rate of source aquifer extraction and entitlement from abstraction bores;
- Local land use and land management practices relevant to groundwater; and
- Any proposal for artificial groundwater recharge possibly affecting the spring.

Hydrogeological conceptual models have already been developed for those EPBC springs closest to CSG activities at which a risk of impact is predicted by the Surat CIM. This applies to the following spring complexes:

- Lucky Last;
- Yebna 2;
- Abyss; and
- Scotts Creek.

In addition to those, KCB had developed early hydrogeological cross sections for a number of spring complexes (KCB, 2012). Newly developed and/or updated conceptual models for each of the EPBC spring cluster will be included with the baseline results in the April 2015 submission (Commitment 59).

8.8 CHANGE TO SPRING ATTRIBUTES

Changes to measurable attributes at the springs (e.g. discharge volumes, wetted area and vegetation response) occur on a regular basis and therefore future changes may not necessarily arise from regional changes to pressure head in the source aquifer due to CSG activities. Recent publications from the National Water Commission (National Water Commission, 2013) provide the results of an extensive study of springs in the western GAB. The reports identify the seasonal variability of spring ecology and the variability of flow to the spring. For example, it is noted that some spring vents discharge water on an intermittent basis, independent of fluctuations in potentiometric surface in the source aquifer, while other spring vents sometimes die out entirely with the creation of a new vent occurring nearby.

Measurable changes to the springs' attributes may therefore not necessarily be related to CSG water extraction. Changes to spring hydrology may instead be due in part or wholly to changes in:

1. Local landholder groundwater extraction processes (e.g. increased or decreased extraction rates);
2. Local meteorological conditions (e.g. short-term variations in air pressure, variable or sustained wet or dry periods);
3. Influences of earth tides;
4. Other natural indirect influences such as those relating to loading over aquifers after major wet seasons;
5. Natural physio-chemical, cyclic or non-cyclic succession of spring hydrology caused by the precipitation of material or ground slumping leading to clogging of spring flows and localised build-up of groundwater pressure:
    - This in turn results in local redirection of groundwater flow and the dissolution or erosion of originally precipitated or slumped material;
    - The succession would be cyclic if the redirection of groundwater flow returned to the original vent location; and
    - Climate change.

Spring hydrodynamics vary from spring to spring as a matter of groundwater pressure, pathway of water to surface, source aquifer hydro geochemistry and natural factors affecting a spring system. A detailed assessment for each spring would be carried out as a response to an exceedance of the investigation trigger. This work is already underway (as a requirement from the Queensland Government) for the following EPBC springs:

- Lucky Last;
- 311/Yebna 2 complexes (Spring complex 311 is not EPBC classified but is located in the same area as the Spring Complex Yebna 2 with both having a potential impact exceeding 0.2 m, and thus are studied jointly); and
- Scotts Creek.

As mentioned in Section 8.7, conceptual hydrogeological models will be developed or refined, if already existing, for all EPBC springs at the end of the spring baseline program and a report will be submitted to The Department of the Environment by April 2015.

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