13.0
Well stimulation

A BG Group business

13.0 Well stimulation

Condition 49e and 49f

13.1 BACKGROUND

Well stimulation techniques can increase CSG production from low yielding or otherwise uneconomic wells. The objective of hydraulic well stimulation is to enhance openings in the coal and increase the pathways for gas to flow.

13.1.1 A WELL STIMULATION TREATMENT

The well stimulation technique involves the high pressure pumping of a fluid into the well to break or fracture the coal seams below ground. Chemicals are introduced into the water/sand mix in a batch mixer or blending system prior to injection.

Hydraulic fractures are placed in open hole or cased wells and access to reservoir zones are by perforating the casing at those locations. Water blended with chemicals to increase its viscosity and sand is pumped into the well to keep the newly created coal seam pathways open and allow the fluid and gas to flow out into the well.

Each well is carefully planned and subject to a well-specific risk assessment prior to commencement. Every effort is made to isolate the fracture from the main aquifer zones in the vicinity of the well to be stimulated and from fractures in other stimulated wells.

13.1.2 PLANNING AND RISK ASSESSMENT

QGC has formalised its internal risk assurance process and compliance with EA conditions through compulsory use of its Stimulation Risk Assessment form and process. It incorporates risk aspects such as well and cement bond integrity, geology, hydrogeology, location and depths of used and abandoned groundwater extraction bores, geomechanics and localised faulting and chemical use as well as monitoring plans to assure containment. The process establishes accountability, specific roles and responsibilities for every segment of the assessment – and requires multi-departmental discussions so that all relevant information is included in the risk assessment.

The WCM are generally 200 m to 300 m thick with coals occurring in narrow bands and of limited lateral extent, interspersed amongst more competent sedimentary strata. Overall coal thickness in the WCM is on average 30 m. Stimulation activities normally occur at depths greater than 400 m.

QGC uses industry-wide acknowledged hydraulic fracture modelling software to predict fracture spread. Fracture geometries are modelled for all proposed activities to provide a high degree of confidence the fractures will remain within the WCM. Typically fracturing of the WCM has an estimated fracture height range of between 0 m to 40 m and an estimated average lateral extent of approximately 100 m.

In the event of hydraulic fracturing, water quality is assessed in the well and all active landholders' groundwater bores (subject to access being permitted by the landholder) according to EA conditions for:

- All active landholders' groundwater bores (subject to access being permitted by the landholder) that are located within a 2 km horizontal radius from the location of the stimulation initiation point
- All active landholders' groundwater bores within 200 m vertically of the stimulation initiation point
- Any other bore that could potentially be adversely impacted by the stimulation activity in accordance with the findings of the risk assessment.

This monitoring occurs at a frequency of monthly for the first six months and then annually for another five years in accordance with DEHP EA conditions.

QGC's stimulation monitoring and management process includes the use of a range of diagnostic tools to measure hydraulic fracture stimulation performance, such as:

- Production logging tools
- Temperature surveys
- Production testing and sampling
- Tracers to measure extent of the fracture
- Microseismic wells which register ground vibration
- Tiltmeter arrays to measure ground movement.

13.1.3 STIMULATION REGULATION AND REPORTING REQUIREMENTS

QGC reports details of its well stimulation program, covering completed activities and wells listed for possible stimulation in the year ahead. QGC's current and short term stimulation program is focussed on trialing, developing and optimising stimulation techniques prior to full scale stimulation activities commencing. This is not expected to occur until 2018. Consequently, in calendar year 2011, only two well stimulations were undertaken and four well stimulations have been completed in 2012 to date (refer Table 22). Another 18 wells are listed in the 2012 and 2013 program as shown in Table 23. An indicative stimulation program for 2014/2015 could consist of up to 50 wells per year.

The significantly lower level of activity that was previously advised in the Stage 1 WMMP reflects the company's decision to defer well hydraulic stimulation activities (e.g. on the Woleebee Creek Block) due to a revised completion strategy for the Juandah Coal Measures. QGC will continue to optimise its completion strategy for the Taroom Coal Measures.

Locations are shown at Figure 50.

Well Name	Tenure	StimCompleted 2011	E_MGA94	N_MGA94
Celeste 10	ATP 648	22 November 2011	270893.177	6990093.819
Celeste 11	ATP 648	20 November 2011	270686.906	6988593.259
Myrtle 9	ATP 621	20 April 2012	268484.019	6966408.579
Myrtle 10	ATP 621	30 April 2012	268659.053	6967122.603
Cameron 8	ATP 852	24 May 2012	769685.104	7109076.459
Cameron 10	ATP 852	7 June 2012	769482.536	7108052.597

Table 22 – Well stimulations 2011 and 2012

Tenure	Block	Well #	E_MGA94	N_MGA94
ATP 651	Kathleen	2	765622.029	7099344.181
ATP 651	Kathleen	4	765956.606	7098499.797
ATP 651	Kathleen	3	766686.401	7098716.391
ATP 648	Celeste	7	271490.685	6989177.864
ATP 648	Clunie	7	288871.862	6977144.186
ATP 648	Clunie	8	288208.117	6976713.765
ATP 648	Clunie	9	289544.685	6976881.201
ATP 648	Clunie	10	288499.574	6977848.566
ATP 651	Woleebee Creek	109	7093096.268	7093096.268
ATP 651	Woleebee Creek	110	7093062.867	7093062.867
ATP 651	Woleebee Creek	121	7092206.653	7092206.653
ATP 651	Woleebee Creek	129	7092165.978	7092165.978
ATP 651	Kathleen	6	766550.423	7097888.643
ATP 651	Kathleen	5	765315.585	7098418.099
PLA 278	Jammat	5	264871.231	7008941.267
ATP 648	Celeste	135	271498.858	6990402.033
ATP 648	Celeste	166	271298.745	6988372.115
ATP 648	Celeste	174	271021.866	6987686.489

Table 23 – Planned well stimulations 2012 and 2013

A hydraulic well stimulation pond containing flowback water.

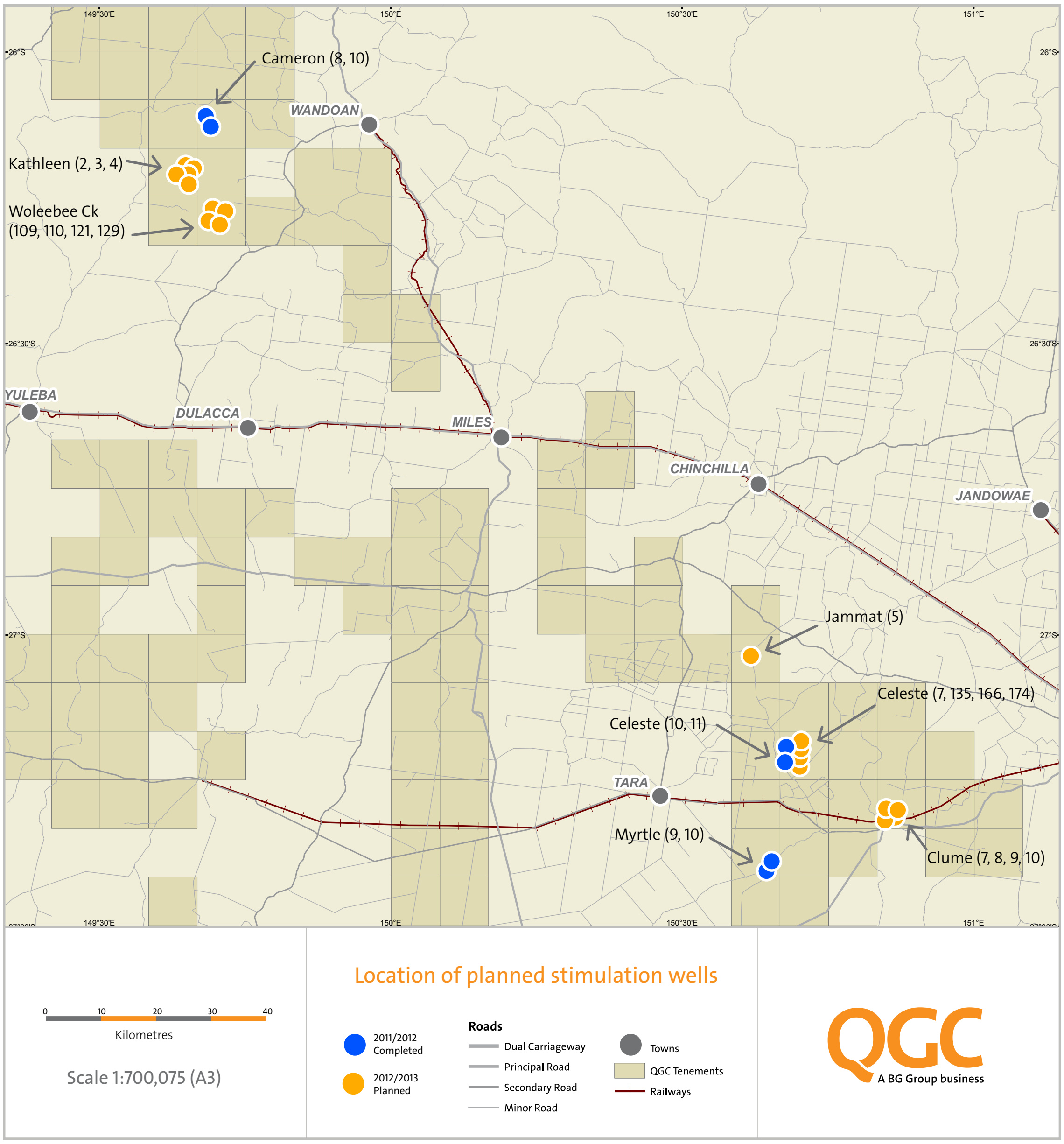

Figure 50 – Location of planned stimulation wells

At this stage no well stimulations beyond those identified in Table 22 are planned. Stimulation requirements for the QCLNG project beyond 2014 will be developed over the next two years. It is expected that in the order of 1,900 wells will be stimulated over the life of the QCLNG project.

QGC has committed to providing the Australian Government with an annual review of QCLNG well stimulation activities and estimated activities for the year ahead.

The annual review will include:

- Details of wells stimulated in previous year and proposed for current year
- Location plans
- Update of indicative estimates of stimulations for future years
- Tabulated summary of completed stimulation risk assessments, and submitted Queensland statutory reports (e.g. Notices of Completion, Hydraulic Completion Report (refer details outlined below)
- Toxicological and ecotoxicological profiles of any new chemicals proposed to be used
- Exception reporting.

The annual review will form part of QGC's annual reporting obligations to SEWPAC, which includes publishing of annual reports on QGC's website at the same time it is provided to SEWPAC in October each year.

Queensland Government Requirements

DEHP and DNRM are informed of all hydraulic stimulation activities according to Queensland Co-ordinator-General, Environmental Authority (EA) conditions and Petroleum Regulations. Reporting requirements include:

Timing relative to stimulation activities	Report required
10 days before stimulation	Notice of Intent
10 days after stimulation	Notice of Completion
Within 2 months of stimulation completion	Hydraulic Stimulation Report

Table 24 – Timing relative to stimulation activities

The Notice of Completion includes:

- Commencement and completion dates
- A description of activities carried out. This may include the running of a post-frac temperature log to assess vertical isolation and containment of the fracture
- Incident reporting that may have resulted in environmental ahrm or caused an adverse impact on any overlying or underlying aquifers whilst undertaking activities
- Volume of fluid injected including volumes of water, proppant and specific wet and dry chemicals.

The Hydraulic Completion Report includes:

- Hydraulic fracturing fluid statement including volumes of various chemicals injected
- Contractor Post-Job Report.

QGC maintain monitoring records of stimulation as per DEHP requirements with all documents to be maintained for a minimum of five years.

13.1.4 STIMULATION FLUID CONSTITUENTS

QGC uses its own produced CSG water to perform hydraulic stimulations. Well stimulation fluid is 99% water and sand, supplemented with chemicals found in many household products. It may contain gels, nitrified foam and carbon dioxide. Various proppant types are used including sand, resin-coated sand and man-made ceramics depending on the permeability or grain strength needed. For each well stimulation, QGC teams make a selection from the chemicals (including biocides, corrosion inhibitors and other chemicals) listed in Table 25. These chemicals are listed on the QGC website at: http://www.qgc.com.au/environment/environmental-operations/chemicals-used-in-hydraulic-fracturing.aspx

Typically, these chemicals are supplied under a variety of different product names from various suppliers. The chemicals are divided into 'cross link' and 'no cross link' categories. Cross link chemicals connect guar gum polymers which makes the frac fluid more viscous and which consequentially allows more sand grain per litre of water to be carried into the frac voids. 'Breaker' chemicals are required to break the connection created in guar gum polymers to assist in returning frac fluid to the surface.

For ideal performance, fracturing fluids possess the following five qualities:

- Be sufficiently viscous (thick) to create a fracture of adequate width
- Maximise fluid travel distance to extend fracture length
- Be able to transport required amounts of proppant (e.g. sand) into the fracture
- Require minimal gelling agent to allow for easier degradation or 'breaking'
- Not lead to contamination of aquifers used or potentially used by others.

Queensland government EA requirements preclude the use of polycyclic aromatic hydrocarbons or products that contain polycyclic aromatic hydrocarbons in stimulation fluids at concentrations above the reporting limit.

13.1.5 STIMULATION FLUID CHEMICAL SELECTION

QGC use the following approach to the selection of chemicals:

- Proprietary chemicals provided by stimulation contractors are initially screened for a range of organic chemicals of concern which are prohibited for use by QGC. These include:
  - Benzene
  - Toluene
  - Xylene
  - Diesel
  - Kerosene
  - Naphthalene
  - Phenanthrene
  - Fluoroscene
  - Ethylene
  - Phenol
  - Ethylene Glycol
  - Aromatic Solvents
  - Formaldehye
- Chemicals that pass this initial screening are further evaluated by assessment of Material Safety Data Sheets and the development of toxicological and ecotoxicological profiles by specialist service providers
- Chemicals that are deemed suitable after this second screening exercise are then added to QGC's list of approved chemicals on QGC's website.

QGC's current list of chemicals shown on its website are presented in Table 25.

Service Company Name or Handling Name and Function	Chemical composition	Common uses	NICNAS Listing
Biocide			
BE-09	Tributyl tetradecyl phosphonium chloride	Biocide used industrial cleaning, oil field waters, papermaking	81741-28-8
BE-6	Bronopol	Eliminates bacteria in water	52-51-7
Magnacide 575	Tetrakis (hydroxymethyl) Phosphonium sulfate	Eliminates bacteria in water for farming uses	55566-30-8
M275, BPA68915	Magnesium Nitrate	Eliminates bacteria in water	10377-60-3
Sodium Hypochlorite, BE-7	Sodium hypochlorite	Household bleach, disinfectants	7681-52-9
K-38	Disodium octaborate tetrahydrat	Fertiliser	12008-41-2
Clay control			
L064, ClayTreat-3C	Tetramethylammonium chloride	Salt used for protein purification	75-57-0
KCl	Potassium chloride	Fertilisers	7447-40-7
Corrosion inhibitor			
Gelatine	Gelatine	Marshmallows, canned hams, desserts and dairy products, pharmaceuticals	9000-70-8
Crosslinker			
XLW-10A	Sodium Tetraborate	Detergents, soaps	1303-964
L010, Boric Acid	Boric acid	Antiseptic for abrasions, flame retardant	10043-35-3, 001333-73-9
K-38	Disodium octaborate tetrahydrate	Flame Retardant, Wood treatment	12008-41-2
CL-28M	Borate Salt	Agricultural Plant Food/Fertilizer, Industrial Glass Manufacturing Additive	14808-60-7
Gel			
J580, GW-3, GW-4, GW-38, WG-36, WG-11	Guar gum, Polysaccharide, Carbohydrate polymer	Food thickening agent	9000-30-0, 68130-15-4
GLFC-5	Guar slurry	Thickening agent	9000-30-0
WG-21, WG-17	Cellulose derivative	thickening agents, creams, ointments	9004-62-0
Gel breaker			
GBW-30	Hemicellulase enzyme carbohydrates	Food additives, coffee processing	9012-54-8
GBW-12CD	Hemicellulase enzyme carbohydrates	Food additives, coffee processing	9025-56-3
Optiflow THE	Silica (with crushed walnut shells)	Cosmetics, exfoliants	14808-60-7
GBW-18	Sodium persulfate	Hair bleaching, detergents	7775-27-1
Vicon NF	Chlorous acid, sodium salt	Food Additive	7758-19-2
J218, J479, GBW-5	Diammonium peroxidisulphate	Hair bleach, household cleaners, etching copper, printed circuit boards	7727-54-0
Gel stabiliser			
Gel-Sta L	Sodium Thisosulfate	Preservative, Stain Remover, Bleach and Chlorine Remover	7772-98-7

Service Company Name or Handling Name and Function	Chemical composition	Common uses	NICNAS Listing
Friction Reducer			
FR-46	Ammonium sulfate	Fertilisers	7783-20-2
Other			
Nitrogen	Nitrogen	Refrigeration, supercooling, inert gas	7727-37-9
Carbon Dioxide	Carbon Dioxide	Dry Ice	124-38-9
Sodium Chloride, Rock Salt	Sodium chloride	Table salt	7647-14-5
Oxygen Scavenger			
Oxygen	Organic acid salt	Removal of dissolved oxygen in fluids, meat processing	6381-77-7
GS-1L	Sodium thiosulfate	Leather tanning, fish farming, photography, medicines	7772-98-7
pH buffer			
M003, Soda Ash	Sodium carbonate	Neutralise acids, water softening	497-19-8
Sodium Hydroxide	Sodium hydroxide	Manufacturing of paper, textiles, drinking water, soaps, detergents, drain cleaner	1310-73-2
BF-3	Sodium Bicarbonate	Baking soda	144-55-8
BF-7L	Potassium carbonate	Additive in soaps, wines, dyes, glass	584-08-7
J494	Carbonic Acid,sodium salt (2:3)	Detergents, soaps	533-96-0
Acetic Acid, BF10L, L401	Acetic acid	Vinegar	64-19-7
HCl	Hydrochloric acid	Swimming pool pH control	7647-01-0
FE-300	Citric acid	Naturally occurring in citrus fruits, flavouring, cosmetics	77-92-9
Scale inhibitor ScaleChek LP-55	Polyarcylate	Paint Hardener, Detergent, Children's Bathwater Additive, Food Defoaming Agent	9003-05-8
Surfactant			
GasPerm 1100	Ethanol, Terpene and Terpenoid, Sweet orange-oil	Bathroom Cleaner, Dishwashing Detergent, Dish Soap, Multi-surface Cleaner, Beer	64-17-5, 68647-72-3
Superflo 2000	Terpene	Used as a food additive in Beer	68647-72-3

Table 25 – Hydraulic fracturing fluid consituents

13.1.6 STIMULATION FLUID TOXICOLOGY AND ECOTOXICOLOGY

QGC prepared a Hydraulic Fracturing Risk Assessment and Management Plan in March 2011 in response to Appendix 2, Part 2, Condition 25 of the Coordinator General (CG) report on the QCLNG Project. An independent third party, Environmental Resources Management Australia (ERM), was contracted by QGC to undertake the development of toxicological and ecotoxicological profiles and associated environmental and health-based risk assessment of the chemicals proposed for use in stimulation activities. The Plan and associated toxicological profiles and risk assessment were provided with the Stage 1 WMMP at Appendices F and G and covered persistence and bioaccumulation potential. Appendix G has been reproduced as Appendix W.1.

In particular, ERM's February Report 2011 provided toxicological and ecotoxicological data and qualitative risk assessment for:

- (Rock Salt) Sodium Chloride
- Silica Sand, Ground Walnut Hulls
- Sodium Chloride
- Potassium Chloride
- Sodium Hypochlorite with/without Sodium Hydroxide
- Guar Gum, Hydroxy-Propyl Guar, Carboxy-Methyl, Hydroxy-Propyl Guar, Hydroxy-Ethyl Cellulose
- Disodium Octaborate Tetrahydrate, Boric Acid, Boric Oxide
- Hemicellulase Enzyme with/without Sodium Chloride
- Sodium Persulfate, Diammonium Peroxidisulphate
- Hydrochloric Acid (also known as Muriatic Acid)
- Sodium Hydroxide, Potassium Carbonate
- Sodium Carbonate (Soda Ash)
- Tetrakis (hydroxymethyl) Phosphonium Sulfate (or THPS).

13.1.7 CHEMICAL TOXICITY ASSESSMENTS PROGRAM

QGC has an ongoing program of screening for toxicity assessment for new chemicals that are planned to be used for stimulation purposes. The screening process includes independent toxicity and ecotoxicity assessment and qualitative risk assessment. Since the submission of the Stage 1 WMMP, an additional eight chemicals have been evaluated. Additional risk assessment reports which include toxicology and ecotoxicology information are provided in Appendices W.2 – W.6.

Chemicals assessed include:

- Sodium Thiosulphate
- Citric Acid
- Gelatine
- Sodium Erythorbate
- GLFC5 (Saraline)
- Biocide BPA68915
- Sodium sesquicarbonate
- Clay Stabiliser.

To ensure compliance with EPBC approval conditions, QGC commits to providing toxicity and ecotoxicity profiles (where available) for those additional chemicals for which profiles have not previously been prepared, and water quality trigger values as required by December 2013.

13.2 WATER MANAGEMENT

Stimulation activities typically involve the injection of 1000 m^3 to 3000 m^3 of CSG water, around 200 tonnes of sand and less than 1% chemical additives. QGC's EA conditions require 150% of the stimulation volume to be extracted. This 'flowback' water is stored in 6 mm HDPE lined ponds.

Stored 'flowback' waters are currently reused for other stimulations, pumped out and trucked to QGC's main storage ponds or evaporated. No flowback waters are released to receiving waters.

13.2.1 STIMULATION POND DESIGN, OPERATION AND DECOMMISSIONING

QGC considers a number of factors prior to confirming the use of ponds for a stimulation. Ponds carry a number of risks in regard to the environment, as well as an obligation to remediate the pond upon conclusion of its use. These risks are weighed up against the expected water volumes to be generated, the proximity of the well to be stimulated to any existing gathering lines or water collection infrastructure, and any proposed production testing. Options such as connection to existing water gathering systems, the use of tankers and the use of portable tanks are also considered at this stage.

QGC applies a number of standards to the design and delivery of its ponds. These include a number of both internal QGC/BG Group standards, and external standards (e.g. Australian and International standards) as well as associated regulatory requirements.

Where utilised stimulation ponds are typically designed to accommodate stimulation water flowback, any additional waters generated during the flowback phase of the stimulation and to accommodate any limited production testing QGC may look to complete following the stimulation.

Stimulation ponds have a design life of no more than three years, and are typically designed with an approximate capacity of 5,500 m^3. This includes an allowance of 0.5 m below the crest to allow for rainfall events. During the wet season water volumes stored in the pond are monitored and where necessary water is removed (via increasing tanker truck removal) to manage rainfall inflows and pond water levels.

Once the ponds are emptied the pond is decommissioned, the liner is removed and the site remediated. QGC is also exploring options around the use of portable tanks that may replace the stimulation ponds. These tanks offer increased flexibility (number, capacity, positioning on the lease) as well as minimising the need for rehabilitation of the area following the completion of stimulation activities.

Condition 49f

13.2.2 STIMULATION WATERS AND CHEMISTRY

QGC is required under Condition 49f to provide 'details of constituent components of any hydraulic fracturing agents and any of the reinjected fluid(s), and their toxicity as individual substances and as total effluent toxicity and ecotoxicity, based on methods outlined in the National Water Quality Management Strategy.'

In addressing this condition QGC has firstly considered the agents used in a hydraulic stimulation and the monitoring suite currently in place.

Typical concentrations of stimulation fluids that are used in the QCLNG project are provided in Table 25.

Stimulation Fluids Chemical Constituent	Range of Concentrations (mg/L)	
	Non-Cross Link	**Cross Link**
Sodium chloride	4,000 – 6,000	0 – 4,000
Potassium chloride	0 – 6,000	0
Sodium hydroxide	0 – 300	0 – 32
Tetrakis Hydroxylmethyl Phosphonium Sulphate	65	65
Hydrochloric acid	260 – 1,000 (32%)	260 – 1,000 (32%)
Hemicellulose enzyme breaker	30 – 40	30 – 40
Sodium hydroxide	0 – 300	0 – 300
Guar gum	0	30 – 40
Disodium octaborate tetrahydrate	0	0 – 40
Boric acid	0	0 – 40
Boric oxide	0	0 – 200
Sodium carbonate	0	0 – 200
Sodium persulphate	0	0 – 500
Diammonium peroxidisulphate	0	0 – 20
Potassium carbonate	0	0 – 65

Table 26 – Composition of stimulation fluids proposed for use in the QCLNG Project

Table 27 shows the typical composition of fluids from two completed stimulations. Data is submitted in this form to DNRM as part of Notice of Completion documentation. The hydraulic stimulation process involves the addition of small quantities of selected constituents to enable the sands to move more effectively through the fractures created. The volumes of the constituents added to the stimulation fluid makes up a very small percentage of the total fluid composition.

QGC has also provided an assessment of comparative studies of various stimulation scenarios with regard to water interaction. The comparative studies include:

- A comparison of WCM waters from CSG wells pre-stimulation to the observed quality of the waters in the post-stimulation flowback water storage ponds
- A comparison of the water quality in post-stimulation flowback water storage ponds to recognised water quality criteria.

	Additive name	Purpose	Stimulation 1 % of total injected fluid volume	Stimulation 2 % of total injected fluid volume
Liquid	Water		91.16	95.41
	Sodium Hypochlorite	Sterilizer to remove bacteria	0.07	0.03
	Hydrochloric Acid	pH control	0.02	0.04
	Magnacide 575	Biocide	<0.01	0.01
	Sodium Hydroxide	pH control	0.14	0.09
	Hemicellulase Enzyme Concentrate (GBW-12CD)	Gel 'breaker' reduces viscosity	0.05	0.04
	Boric Acid	Gelling agent	0.38	0.31
	Sodium Thiosulphate (GS-1L)	Stabilising agent	0.01	<0.01
	Acetic Acid	pH buffer	0.02	0.01
Solid	Sand	Proppant	8.00	3.95
	Gelatin	Corrosion inhibitor	<0.01	<0.01
	Citric Acid	Prevents iron precipitation	<0.01	<0.01
	Guar gum (GW3)	Increases viscosity	0.15	0.10

Table 27 – Stimulation fluid composition

13.2.3 STIMULATION WATER QUALITY MONITORING

In order to effectively monitor the recovery of the stimulation fluids (flowback) and to evaluate any geochemical reactions that may have occurred as a result of the stimulation, QGC collects water samples and submit them for detailed laboratory analysis.

Water samples collected at the various stages of the stimulation are analysed for the chemical parameters outlined in Table 28. The chemical parameters are used as indicators of the presence of the various chemicals used in the stimulation activity as well as providing information on CSG water quality.

Table 28 also indicates which laboratory analysis parameter can be used as a guide to assess the presence of particular chemical constituents. However, due to most chemical species being present in CSG waters it is difficult to exactly quantify contributions to flowback water quality of the various chemicals used. CSG waters in particular are rich in bicarbonates, which influences pH and solubility of many trace elements and compounds.

The range of concentrations for stimulation constituents when used for non-cross link and cross-link purposes are also shown in Table 28. Non-cross link applies to the chemical when it is used to decrease the viscosity of the stimulation fluid. Cross link concentrations apply to the chemical when it is used to increase the viscosity of the stimulation fluid (i.e when it is used as a gelling agent).

Queensland Environmental Authority Stimulation Monitoring Water Analytes	Units	Chemical used in stimulation contributing to measurement	Range of concentrations (mg/L)	
			Non-cross link	Cross link
Physical measurements				
pH		Sodium chloride	4,000 – 6,000	0 – 4,000
		Hydrochloric acid	260 – 1,000 (32%)	260 – 1,000 (32%)
		Sodium carbonate	0	0 – 200
		Sodium hydroxide	0 – 300	0 – 300
Major anions				
Chloride	mg/L	Sodium chloride	4,000 – 6000	0 – 4,000
		Hydrochloric acid	260 – 1,000 (32%)	260 – 1,000 (32%)
		Potassium chloride	0 – 6,000	0
Sulphate as SO4(2-)	mg/L	Tetrakis (hydroxymethyl) phosphonium sulphate	65	65
		Diammonium peroxide sulphate	0	0 – 20
		Sodium persulfate	0	0 – 500
		Sodium thiosulfate		
Major cations				
Sodium	mg/L	Sodium hydroxide	0 – 300	0 – 32
		Sodium chloride	4,000 – 6,000	0 – 4,000
		Sodium persulfate	0	0 – 500
		Sodium thiosulfate		
		Sodium erythorbate		
Potassium	mg/L	Potassium chloride	0 – 6,000	0
		Potassium carbonate	0	0 – 65
Trace elements (dissolved unless otherwise stated)				
Boron	mg/L	Boric acid	0	0 – 40
		Boric oxide	0	0 – 200
		Disodium octaborate tetraydrate	0	0 – 40
Silica (SiO2)	mg/L	Sand		
Nutrients				
Total oxidised nitrogen	mg/L	Diammonium peroxidisulphate	0	0 – 20
Disinfectants				
Sodium hypochlorite	mg/L	Sodium hypochlorite		

Note: Other chemicals required by EA conditions to be analysed as part of Stimulation Monitoring Plans include:
Physical measurements: Temperature, Conductivity, Total dissolved solids, Total suspended solids, Sodium adsorption ratio
Major anions: Carbonate, Bicarbonate, Hydroxide, Total alkalinity, Fluoride, Nitrate, Total cyanide
Major cations: Calcium, Magnesium
Trace elements (dissolved unless otherwise stated): Aluminium, Arsenic, Total arsenic, Barium, Beryllium, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Mercury, Molybdenum, Nickel, Selenium, Strontium, Silver, Vanadium, Zinc
Hydrocarbons: Total petroleum hydrocarbons, Benzene, toluene, ethylbenzene and xylenes
Polycyclic aromatic hydrocarbons (PAH): Phenols, Volatile organic compounds (VOC)
Radionuclides: Alpha activity, Beta activity
Dissolved gases: Carbon dioxide – free, Methane, Hydrogen sulphide
Nutrients: Dissolved organic carbon, Total organic carbon
Disinfectants: Free chlorine

Table 28 – Hydraulic fracturing fluid analysis suite

Under EA conditions, QGC are required to collect water samples for the analysis suite above at a series of points prior to, during, and following a stimulation. For example:

- From the stimulation fluids to be used in stimulation activities at sufficient frequency and which sufficiently represents the quantity and quality of the fluids used
- From flowback waters from stimulation activities at sufficient frequency and which sufficiently represents the quality of that flowback water
- From flowback waters from stimulation activities at sufficient frequency and accuracy to demonstrate that 150% of the volume used in stimulation activities has been extracted from the stimulated well.

For each stimulation campaign, QGC prepares and implements a Stimulation Monitoring Plan (as required by EAs) which presents in detail the sampling regime to be implemented. The number of samples collected can range up to twenty and beyond for one stimulation.

In accordance with Queensland EA compliance requirements, QGC will commit to ensure representative samples of flow back water are collected immediately after stimulation activities and the date and time of testing is recorded.

13.3 WATER QUALITY ASSESSMENTS

Pre-stimulation to post-stimulation water quality

The data in Table 29 compares waters collected from two CSG wells prior to stimulation to the waters collected from storage ponds post-stimulation.

Chemical Parameters		Pre-stim WCM water quality (mg/L unless stated)	Pre-stim WCM water quality (mg/L unless stated)	Post-stim pond water quality (mg/L unless stated)	Post-stim pond water quality (mg/L unless stated)
Physical measurements	Temperature	26.8 °C	27.1 °C	28.5 °C	27.7 °C
	pH	8.3	8.3	8.9	9.1
	Conductivity (µS/cm)	9,400	9,700	6,800	5,500
	Total Dissolved Solids	5,300	5,900	4,400	3,300
	Total Suspended Solids	310	330	25	9
	Sodium Adsorption Ratio	110	140	78	69
Major Anions	Chloride	2,000	2,500	1,600	1,200
	Sulphate as $SO_4(^{2-})$	<1	<1	1	6
	Carbonate (as $CaCO_3$)	80	60	100	80
	Bicarbonate (as $CaCO_3$)	1800	1900	700	600
	Hydroxide (as $CaCO_3$)	<1	<1	< 1	< 1
	Total Alkalinity (as $CaCO_3$)	1,900	2,000	800	680
	Fluoride	1.6	1.7	1.1	1
	Nitrate as N	0.01	<0.01	< 0.01	< 0.01
	Nitrite as N	< 0.01	< 0.01	< 0.01	< 0.01
	Total Cyanide	< 0.01	< 0.01	< 0.004	< 0.004
	Total Anions (mEq/L)	96	110	61	48
Major Cations	Calcium	20	21	14	11
	Magnesium	4.9	4.4	3	2.6
	Sodium	2,200	2,600	1,300	980
	Potassium	8.5	9.4	5.1	4.9
	Total Cations (mEq/L)	98	120	55	44

	Chemical Parameters	Pre-stim WCM water quality (mg/L unless stated)	Pre-stim WCM water quality (mg/L unless stated)	Post-stim pond water quality (mg/L unless stated)	Post-stim pond water quality (mg/L unless stated)
Metals (dissolved)	Aluminium	0.05	0.068	0.015	0.034
	Arsenic	0.0016	0.0018	0.001	0.002
	Total Arsenic	0.0034	0.0019	0.001	0.002
	Barium	1.8	2.2	0.93	0.57
	Beryllium	<0.001	< 0.001	< 0.001	< 0.001
	Boron	0.92	1.2	0.53	0.59
	Cadmium	<0.0005	<0.0005	< 0.0001	< 0.0001
	Chromium	0.002	0.003	< 0.001	< 0.001
	Cobalt	< 0.001	< 0.001	< 0.001	< 0.001
	Copper	0.002	0.002	0.002	0.002
	Iron	0.077	0.083	0.018	0.029
	Lead	< 0.001	< 0.001	< 0.001	< 0.001
	Manganese	0.054	0.02	0.002	0.001
	Mercury	<0.0005	<0.0005	< 0.0001	< 0.0001
	Molybdenum	0.004	0.003	0.004	0.006
	Nickel	0.01	0.003	0.001	0.001
	Selenium	<0.005	<0.005	< 0.005	< 0.005
	Silica (SiO_2)	22	27	11	6.6
	Strontium	3.6	3.8	1.5	1
	Silver	< 0.005	< 0.005	< 0.005	< 0.005
	Vanadium	<0.001	<0.001	0.001	0.002
	Zinc	0.026	0.006	0.001	0.002
Hydrocarbons	Total Petroleum Hydrocarbons (TPH)	0.48	0.46	< 0.05	< 0.05
	Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX)	All <0.001	All <0.001	All <0.001	All <0.001
	Polycyclic Aromatic Hydrocarbons (PAH)	All <0.001	All <0.001	All <0.001	All <0.001
	Phenols	Below Lab Limit of Detection	Phenol 0.003 Balance below detect limit	Below Lab Limit of Detection	Below Lab Limit of Detection
	Volatile Organic Compounds (VOC)	Below Lab Limit of Detection	Below Lab Limit of Detection	Below Lab Limit of Detection	Below Lab Limit of Detection
Radiation	Alpha activity (Bq/L)	<0.4	<0.5	<0.05	<0.05
	Beta activity (Bq/L)	<1	<1	<0.05	0.15
Dissolved gasses	Carbon Dioxide – Free	16	17	1	1
	Methane	11	12	0.2	0.026
	Hydrogen Sulphide	< 10	< 10	< 10	< 10
Nutrients	Dissolved Organic Carbon	N/A	N/A	11	15
	Total Organic Carbon	2	2	13	23
	Total Oxidised Nitrogen	0.01	< 0.01	< 0.01	< 0.01
Disinfectants	Free Chlorine	< 1	< 1	< 1	< 1
	Sodium Hypochlorite	< 5	< 5	< 5	< 5

Table 29 – Pre and post-stimulation water chemistry

The data indicates:

- There is a reduction in concentrations of a number of constituents between the pre and post-stimulation sampling including reductions in conductivity, TDS, TSS, SAR, chlorides, bicarbonate, alkalinity, sodium and some dissolved metals
- The reduced concentrations may be due to the pond water being exposed for long periods to water oxygenation and diluted by rainfall
- Bacterial and other chemical reactions, including precipitation could potentially occur.

Post-stimulation to guideline criteria

The data in Table 30 compares flowback water quality in ponds from the two stimulations with Australian Drinking Water Guidelines, ANZECC Water Quality Guidelines for Freshwater Ecosystems (95% and 80% ecosystem protection) and criteria for livestock drinking water quality. It should be noted that the guidelines utilised have been selected considering a conservative approach.

	Chemical Parameters	Post-stim pond water quality (mg/L unless stated)	Post-stim pond water quality (mg/L unless stated)	Pre-stim WCM water quality (mg/L unless stated)	Australian Drinking Water Guidelines (mg/L unless stated)	ANZECC Water Quality Guidelines		
						Freshwater Ecosystems (95% Protection) (mg/L)	Freshwater Ecosystems (80% Protection) (mg/L)	Stock Watering (mg/L)
Physical measurements	Temperature	28.5 ºC	27.7 ºC	27.1 ºC	N/A	ID	ID	N/A
	pH	8.9	9.1	8.3	6.5 – 8.5[6]	6.5 – 8.0	6.5 – 8.0	N/A
	Conductivity (µS/cm)	6,800	5,500	9,700	N/A	125 – 2200[5]	125 – 2200[5]	N/A
	Total Dissolved Solids	4,400	3,300	5,900	600[6]	N/A	N/A	2,500[8]
	Total Suspended Solids	25	9	330	N/A	N/A	N/A	N/A
	Sodium Adsorption Ratio	78	69	140	N/A	N/A	N/A	N/A
Major Anions	Chloride	1,600	1,200	2,500	250[6]	N/A	N/A	N/A
	Sulphate as SO4(2-)	1	6	<1	500	N/A	N/A	1,000
	Carbonate (as CaCO3)	100	80	60	N/A	N/A	N/A	N/A
	Bicarbonate (as CaCO3)	700	600	1,900	N/A	N/A	N/A	N/A
	Hydroxide (as CaCO3)	< 1	< 1		N/A	N/A	N/A	N/A
	Total Alkalinity (as CaCO)	800	680	<1	200[6]	N/A	N/A	N/A
	Fluoride	1.1	1		N/A	N/A	N/A	2
	Nitrate as N	< 0.01	< 0.01	2,000	50	0.7	17	400
	Nitrite as N	< 0.01	< 0.01		3	N/A	N/A	30
	Total Cyanide	< 0.004	< 0.004	1.7	0.08	0.007	0.018	N/A
	Total Anions (mEq/L)	61	48	<0.01	N/A	N/A	N/A	N/A
Major Cations	Calcium	14	11	< 0.01	N/A	N/A	N/A	1,000
	Magnesium	3	2.6	< 0.01	N/A	N/A	N/A	ID
	Sodium	1,300	980	110	180[6]	N/A	N/A	N/A
	Potassium	5.1	4.9		N/A	N/A	N/A	N/A
	Total Cations (mEq/L)	55	44	21	N/A	N/A	N/A	N/A

	Chemical Parameters	Post-stim pond water quality (mg/L unless stated)	Post-stim pond water quality (mg/L unless stated)	Pre-stim WCM water quality (mg/L unless stated)	Australian Drinking Water Guidelines (mg/L unless stated)	ANZECC Water Quality Guidelines		
						Freshwater Ecosystems (95% Protection) (mg/L)	Freshwater Ecosystems (80% Protection) (mg/L)	Stock Watering (mg/L)
Metals (dissolved)	Aluminium	0.015	0.034	4.4	0.26	0.055 (pH > 6.5)	0.15 (pH > 6.5)	5
	Total Arsenic	0.001	0.002	9.4	0.01	0.037[1]	0.5[1]	0.5
	Barium	0.93	0.57	120	2	N/A	N/A	N/A
	Beryllium	< 0.001	< 0.001	0.068	0.06	ID	ID	ID
	Boron	0.53	0.59	0.0018	4	0.37	1.3	5
	Cadmium	< 0.0001	< 0.0001	0.0019	0.002	0.0002	0.0008	0.01
	Chromium	< 0.001	< 0.001	2.2	0.05[7]	0.001	0.04	1
	Cobalt	< 0.001	< 0.001	< 0.001	N/A	ID	ID	1
	Copper	0.002	0.002	1.2	2	0.0014	0.0025	1[8]
	Iron	0.018	0.029	<0.0005	0.3[6]	ID	ID	NST
	Lead	< 0.001	< 0.001	0.003	0.01	0.0034	0.0094	0.1
	Manganese	0.002	0.001	< 0.001	0.5	1.9	3.6	NST
	Mercury	< 0.0001	< 0.0001	0.002	0.001	0.0006	0.0054	0.002
	Molybdenum	0.004	0.006	0.083	0.05	ID	ID	0.15
	Nickel	0.001	0.001	< 0.001	0.02	0.011	0.017	1
	Selenium	< 0.005	< 0.005	0.02	0.01	0.011	0.034	0.02
	Silica (SiO2)	11	6.6	<0.0005	80[6]	N/A	N/A	N/A
	Strontium	1.5	1	0.003	N/A	N/A	N/A	N/A
	Silver	< 0.005	< 0.005	0.003	0.1	0.00005	0.0002	N/A
	Vanadium	0.001	0.002	<0.005	N/A	ID	ID	ID
	Zinc	0.001	0.002	27	3[6]	0.008	0.031	20
Hydrocarbons	Total Petroleum Hydrocarbons (TPH)	< 0.05	< 0.05	3.8	N/A	N/A	N/A	N/A
	Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX)	All <0.001	All <0.001	Below Lab Limit of Detection	0.001 (Benzene)	0.2[2]	0.342[2]	N/A
	Polycyclic Aromatic Hydrocarbons (PAH)	All <0.001	All <0.001	<0.001	0.00001 (benzo-a-pyrene)	0.016[3]	0.085[3]	N/A
	Phenols	Below Lab Limit of Detection	Below Lab Limit of Detection	0.006	0.02 (Chlorophenol)	0.01 (Pentachloro-phenol)	0.027 (Petachloro-phenol)	N/A
	Volatile Organic Compounds (VOC)	Below Lab Limit of Detection	Below Lab Limit of Detection	0.46	0.0003 (vinyl chloride)	1.4[4]	4[4]	N/A
Radiation	Alpha activity (Bq/L)	<0.05	<0.05	All <0.001	N/A	N/A	N/A	0.5
	Beta activity (Bq/L)	<0.05	0.15	All <0.001	N/A	N/A	N/A	0.5 (excluding K-40)
Dissolved gasses	Carbon Dioxide – Free	1	1	Phenol 0.003 Balance below detect limit	N/A	N/A	N/A	N/A
	Methane	0.2	0.026	Below Lab Limit of Detection	N/A	N/A	N/A	N/A
	Hydrogen Sulphide	< 10	< 10		0.05[6]	0.001	0.0026	N/A
Nutrients	Dissolved Organic Carbon	11	15	< 0.5	N/A	N/A	N/A	N/A
	Total Organic Carbon	13	23	< 1	N/A	N/A	N/A	N/A
	Total Oxidised Nitrogen	< 0.01	< 0.01	17	N/A	N/A	N/A	N/A
Disinfectants	Free Chlorine	< 1	< 1	12	5	0.003	0.013	N/A
	Sodium Hypochlorite	< 5	< 5	< 10	N/A	N/A	N/A	N/A

1 – derived by adding all species together
2 – conservative utilizing the p-xylene guideline
3 – conservative utilizing the napthelene guideline
4 – conservative utilizing the ethanol guideline
5 – as stated in Table 3.3.3 of the WQG, lowland rivers
6 – aesthetic guideline
7 – as Cr(vi)
8 – applies to dairy cattle
N/A – not applicable
NST – not sufficiently toxic
ID – Insufficient data to derive a reliable trigger value

Table 30 – Pre and post-stimulation water chemistry risk assessment

The data indicates:

- Overall salinity reflects salinities that are typical of groundwater from the WCM:
  - Elevated TDS relative to selected guideline criteria
  - Elevated chloride, alkalinity and sodium relative to selected guideline criteria
  - No other criteria for the waters collected from the stimulation ponds exceed the relevant criteria
- Elevated boron relative to 95% freshwater ecosystem protection guidelines
- Elevated copper relative to 95% and 80% freshwater ecosystem protection guideline
- No other criteria for the waters collected from the stimulation ponds exceed the relevant criteria.

The ANZECC Water Quality Guidelines provide screening values of chemical parameters that signify the percentage of species expected to be protected, relevant to the disturbance level of the receiving ecosystem. The Guidelines indicate that in most cases, the 95% protection level trigger values should apply to ecosystems that could be classified as slightly-moderately disturbed. For ecosystems that can be classified as highly disturbed, the 95% protection trigger values can still apply. However, depending on the state of the ecosystem and management goals, the Guidelines indicated that it can be appropriate to apply a less stringent guideline trigger value of 80% for an intermediate target for water quality improvement. QGC have compared post-stimulation water quality to both of these guideline values.

The highest protection level (99%) is used for ecosystems with a high conservation value or when the ecosystem is classified as undisturbed-slightly disturbed. The Guidelines indicate that the 99% protection levels can also be used as default values for slightly-moderately disturbed systems where local data are lacking on bioaccumulation effects or where it is considered that the 95% protection level fails to protect key test species. If the results shown in Table 26 are compared to ANZECC 99% protection of freshwater ecosystems guidelines, the data indicates:

- Elevated aluminium and total arsenic for one pond
- Elevated boron and copper for both ponds
- No other criteria for the waters collected from the stimulation ponds exceed the relevant criteria.

13.3.1 WATER QUALITY ASSESSMENT STAGE 1

Flowback water toxicity has been previously assessed in the Stage 1 WMMP. The findings are repeated here in Section 9.1 and Appendix W.1. In summary, flowback waters were assessed from 15 fraccing ponds weeks to months after fraccing. Data from multiple samples from the Jammat #4 test indicated that a number of organics (refer Section 9.1 and Appendix W.1) and metals were liberated from the coal seam into the formation water during the fraccing process. No BTEX or PAH were detected. The chemicals appeared in the flowback water for a short period, and declined steadily during the test. The formation water had returned to background quality at the end of the test (one week from completion), and none of the observed organic chemicals were detected.

Apart from one sample which contained 5 µg/L of phenol, none of the organic chemicals reported from the Jammat # 4 test were detected in the samples from the 15 fraccing ponds, which indicates that the organic chemicals are not persistent in flowback waters and were not measurable due to potentially dilution, volatilization and biodegradation. The assessment of the data from the 15 ponds was that apart from the effects of evaporation, flowback water quality was not significantly different to WCM groundwater.

13.4 ENVIRONMENTAL RISK ASSESSMENT STAGE 1 WMMP

The environmental risk assessment reported in the Stage 1 WMMP was carried out using an industry recognized process and involved four main stages:

- Issues identification
- Hazard assessment
- Exposure assessment
- Risk characterization.

The ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality was used as a screening level assessment of water quality for a range of environmental values as part of the environmental risk assessment process.

A Conceptual Site Model was developed and provides the qualitative description of the plausible mechanisms by which receptors may be exposed to potential hazards:

- Source-pathway-exposure mechanisms were evaluated for completeness by assessing
- A potential hazardous chemical source
- A mechanism for release of the chemical or hazard from the source
- A pathway for the chemical or hazard to migrate to a potential receptor
- Potential receptors of hazard
- A mechanism for chemical or hazard exposure by receptors.

The risk assessment provides:

- A description of the stimulation process, including the process QGC uses to design stimulation wells, select locations of stimulation wells and assess the potential geological risks at each stimulation well site
- The processes QGC will undertake to contain inter-aquifer connectivity, should a stimulation well demonstrate interconnectivity with non coal seam aquifers
- Chemicals proposed for use at stimulation wells for the QCLNG project
- Issue identification, hazard assessment, exposure assessment and risk characterisation for each chemical
- Management of chemicals during the stimulation process, including undiluted chemicals and chemicals returned to the surface
- The monitoring plan for stimulation, including monitoring of third party groundwater bores in proximity to stimulation wells, stimulation fluids and solids returned from stimulation wells and stimulation fluid contained in any storages (stimulation pond or tank) at the stimulation site.

13.4.1 EXPOSURE PATHWAYS

As outlined in Appendix W.1, a number of potential surface and sub-surface exposure pathways for stimulation fluids to reach the receiving environment have been identified.

Surface pathways	Sub-surface pathways
• Handling of chemicals at surface prior to stimulation (health) • Handling of stimulation flowback water at the surface following stimulation (health) • Accidental release (spills and leaks) of chemicals, stimulation fluids or flow back water to soils or surface waters at the well site (ecological) • Inappropriate discharge of flow back water to the treatment network (ecological or health).	Migration of stimulation injection water or water with compounds derived from coal mining during the stimulation process into aquifers in the vicinity of the stimulation well: • Via new fractures developed during stimulation, leading to connection with the overlying Springbok Sandstone or underlying Hutton Sandstone • Via pre-existing hydraulic continuity with the Springbok or Hutton Sandstone • Via leakage around the casing of the drilled well itself, into overlying aquifers, including near surface alluvial aquifers.

Table 31 – Summary of surface and sub-surface exposure pathways

Sub-surface pathways identified above were assessed and it was concluded that under most circumstances, these pathways will not exist. This is due to the standard procedure of developing the well shortly after stimulation, causing groundwater and any stimulation chemicals that have migrated away to flow back towards the well and be captured at the surface.

13.4.2 RISK ASSESSMENT FINDINGS – GENERAL

The risk assessment demonstrated that with appropriate management of stimulation chemicals and fluid at the surface, both pre- and post-stimulation, there is no significant risk to health or the environment. For there to be a risk to health or the environment, there needs to be an exposure pathway to humans or an ecological group. It was concluded that there will be no significant risk to health or the environment via surface pathways at the well head, provided that appropriate health and safety procedures are used, stimulation ponds are properly lined and contain adequate stormwater storage capacity, and that appropriate management, treatment and disposal methods are used.

Although the risk assessment has indicated low risk to health and environment for stimulation chemicals used, QGC will monitor water from the stimulation well, the stimulation pond / tank and water bores surrounding the stimulation well in accordance with EA requirements. Should monitoring indicate a potential risk to human health or the environment, QGC will implement mitigation measures.

Water quality in the Walloon Coal Measures aquifer was assessed pre- and post-stimulation as part of the risk assessment of stimulation fluid (refer to Appendix W.1). Ambient water quality in the WCM typically has salinity and metal levels in excess of ecological screening criteria. Following stimulation, monitoring of wells targeting the WCM indicates increases in TDS, chloride, sodium, calcium, boron, sulphate, magnesium, manganese, zinc and phenol. It was concluded that the long-term changes in these parameters do not result in a change in classification of the water relative to the selected human health and ecological threshold criteria. On the basis of this, the changes are not considered to represent a significant risk to health or the environment over the long-term.

It was concluded that from a health and safety perspective, flowback water should be treated as an irritant.

13.4.3 RISK ASSESSMENT – FURTHER CONSIDERATIONS

As part of the Stage 2 WMMP, QGC has further considered the risks of stimulation activities to groundwater and surface waters.

Risk to groundwater

Due to the depth of stimulation activities in the WCM (greater than 400 m), limited coal thickness and extent, the estimated fracture height range of between 0 m and 40 m and an estimated average lateral extent of about 100 m, and the stimulation fluid water quality, there is considered to be little risk of contamination of other formations and negligible risk of contamination of surface waters.

Risk to surface waters

QGC has undertaken a comparative assessment of Walloon Coal Measures groundwater quality pre-stimulation and post-stimulation, flowback water quality, and various water quality criteria.

The data indicates that:

- Pre and post-stimulation water quality actually improves, with this being attributed to exposure to rainfall and potentially other geochemical and bacterial activity
- Flowback water quality is very similar to Walloons groundwater, which is commonly used for stimulation purposes.

In other words, the quantities of chemicals added to raw stimulation water has had little influence on formation water quality or flowback water quality and hence the total toxicity of stored flowback waters is likely to be very similar to applied stimulation water.

Flowback water quality in stimulation ponds has then been compared with Australian Drinking Water Guidelines, ANZECC Water Quality Guidelines for Freshwater Ecosystems (95% and 80% ecosystem protection) and criteria for livestock drinking water quality.

The data indicates:

- Overall salinity reflects salinities that are typical of groundwater from the WCM
- Elevated TDS relative to selected guideline criteria
- Elevated chloride, alkalinity and sodium relative to selected guideline criteria for both flowback and natural groundwater
- There is no evidence of elevated trace element or organics concentrations in pond flowback waters
- Water quality of stored post-stimulation flowback is unlikely to be more hazardous than Walloon Coal Measures groundwater quality.

Given these water quality findings and that:

- Stimulation ponds are designed with 0.5 m of freeboard
- No stimulation waters are released to receiving waters
- Ponds have a short design life of up to three years
- All stored stimulation waters are either:
  - Reused
  - Extracted from stimulation ponds when no longer required and transferred to QGC's aggregation ponds
  - Evaporated in situ.

There is little risk of stimulation waters entering receiving waters of the Murray-Darling Basin or Dawson River catchment.

Need for Total Toxicity and Ecotoxicity Assessment

Given the findings of the above risk assessment, QGC consider that total toxicity and ecotoxicological testing of stimulation flowback waters is unnecessary.

It should be noted that ecotoxicological testing is often carried out when process wastewaters are required to be released to receiving environments (e.g. sewage treatment plants, power station cooling water blowdown).
In QGC's assessment, total effluent toxicity from flowback waters from hydraulic well stimulations is very similar to regular CSG water which existing users access for stock and domestic purposes and for which water licenses have been issued. QGC's robust water gathering, handling and treatment approach can adequately transport and treat the flowback waters without providing an uncontrolled pathway to an MNES receptor.

Release of stimulation waters to receiving environments is not part of QGC's stimulation pond water management strategy and is not authorised by QGC's Environmental Authorities.

However, in order to demonstrate the potential effects on MNES of stimulation compounds individually and their presence in fraccing fluids and flowback waters, QGC will commit to:

- Assessing toxicity of individual stimulation chemicals of concern
- Assessing contribution of stimulation chemicals to toxicity of stimulation fluids and flowback waters.

In relation to the second point above, QGC will assess the relative hazard of flowback water to coal seam groundwater by:

- Undertaking ecotoxicological testing to support the claim that the toxicity of flowback waters is similar to coal seam groundwater (CSG water). A possible program may include the testing of (i) CSG water, (ii) CSG water with stimulation chemicals, and(iii) stimulation chemicals in fresh water, and/or stimulation/flowback waters at various stages in the hydraulic stimulation process.
- Ecotoxicity assessments will be carried out in accordance with the 2000 NWQMS Australian and New Zealand Guidelines for Fresh and Marine Water Quality
- Having an independent review of the testing program undertaken prior to proceeding
- Submission of a peer reviewed report in December 2013.

QGC has commenced discussions with other CSG proponents to develop a collaborative program of ecotoxicological testing in a form similar to the one described above. A work program will be prepared by April 2013 and the study completed in December 2013.

13.5 SUMMARY

This section includes information on:

- QGC's 2011, 2012 and 2013 well stimulation program
- Details of stimulation fluid constituents
- An assessment of stimulation pond design, operation and decommissioning
- Stimulation regulation and reporting requirements
- Details of a typical stimulation fluid mix
- A comparative assessment of WCM groundwater quality, stimulation pond water quality and water quality criteria
- A qualitative groundwater and surface water quality risk assessment.

Due to the depth of stimulation activities in the WCM, limited coal thickness and extent, estimated height and extent of fractures and the stimulation fluid water quality, there is considered to be little risk of contamination of other geological formations and negligible risk of contamination of surface waters.

Release of stimulation waters to receiving environments is not part of QGC's stimulation pond water management strategy and is not authorised by QGC's Environmental Authorities.

There is little risk of stimulation waters entering receiving waters of the Murray-Darling Basin or Dawson River catchment. Consequently, QGC consider that total toxicity and ecotoxicological testing of stimulation flowback waters to protect MNES is unnecessary.

13.6 COMMITMENTS

QGC has made the following commitments:

- Assessing toxicity of individual stimulation chemicals of concern
- Provision of toxicity and ecotoxicity data, where available, for chemicals not previously provided in the Stage 1 WMMP
- Ecotoxicity assessments will be carried out in accordance with the 2000 NWQMS Australian and New Zealand Guidelines for Fresh and Marine Water Quality
- Having an independent review of the testing program undertaken prior to proceeding
- Submission of a peer reviewed report in December 2013
- Commitment to ensure representative samples of flow back water are collected immediately after stimulation activities and the date and time of testing is recorded.

QGC's commitment schedule for stimulation-related tasks is summarised below:

Commitments	Target completion date
Annual update of bores to be stimulated	October 2013 and Annually thereafter
Submission of reports to Queensland regulatory agencies	As required
Toxicity and Ecotoxicity Profiles for new chemicals. Completion of total toxicity and ecotoxicity testing. Ecotoxicity testing to be carried out in accordance with the 2000 NWQMS Australian and New Zealand Guidelines for Fresh and Marine Water Quality.	December 2013
Collection of representative samples of flowback water immediately post-stimulation and analysis	Ongoing

The above commitments are aimed at satisfying Conditions 49e and 49f.