

Hydraulic Fracturing Risk Assessments for the Tight Gas Sands Project

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Hydraulic Fracturing Risk Assessments for the Tight Gas Sands Project

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Definitions and Abbreviations

AICIS	Australian Industrial Chemicals Introduction Scheme
ALARP	As Low as Reasonably Practicable
ANZECC	Australian and New Zealand Environment and Conservation Council
API	American Petroleum Institute
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASC NEPM	National Environment Protection (Assessment of Site Contamination) Measure 1999
ATP	Authority to Prospect
ATSDR	Agency for Toxic Substances and Disease Registry
BHAs	Bottom Hole Assemblies
BHP	Brake horsepower
CBL-VDL	Cement Bond and Variable Density Logging Tool
CCL	Casing Collar Locator
CITHP	Closed-in Tubing Head Pressure
Code of Practice	Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland, Version 2 2019
COPC	Contaminants of potential concern
CSG	Coal Seam Gas
CST	Capillary Suction Time
DAFF	Department of Agriculture, Fisheries and Forestry
DAWE	Department of Agriculture, Water and the Environment
dBA	Decibels
DCAF	Discipline Controls and Assurance Framework
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DoEE	Department of the Environment and Energy
DEP	Design and Engineering Practice
DES	Department of Environment and Science
Design of Service	A basis of design

DFIT	Diagnostic Fracture Injection Testing
DRDMW	Department of Regional Development, Manufacturing and Water
EA	Environmental Authority
EPA	<i>Environmental Protection Act</i>
EPBC	<i>Environmental Protection and Biodiversity Conservation Act</i>
EPP	Environmental Protection (Water and Wetland Biodiversity) Policy 2019
ERP	Emergency Response Plan
Examine	Phase 1 of Appraisal wells
Frac	A hydraulic stimulation stage
GAB	Great Artesian Basin
GDEs	Groundwater Dependent Ecosystems
Gohfer	A hydraulic fracture stimulation design modelling software package
GR	Gamma ray
GRAS	Generally Regarded as Safe
GWDB	Groundwater database – Queensland (https://www.data.qld.gov.au/dataset/groundwater-database-queensland)
HHP	Hydraulic horsepower
HSIS	Hazardous Substance Information System
HVFR	High Viscosity Friction Reducers
ISIP	instantaneous shut-in pressure
KCL	Potassium chloride
L/s	litres per second
mAHD	metres Australian Height Datum
mbgl	metres below ground level
mD	milliDarcies
MDRT	Measured Depth Rotary Table
Measure	Phase 2 of Appraisal wells
MPD	Managed Pressure Drilling

Na	Sodium
NEPM	National Environment Protection (Assessment of Site Contamination) Measure 1999
NHMRC	National Health and Medical Research Council
NICNAS	National Industrial Chemicals notifications and Assessment Scheme
NWQMS	National Water Quality Management Strategy
ODI	One-Day-Install Skid
P&A	Plug and abandonment Involves plugging back a well and securing it temporarily (a few months to years) or permanently
P&G Act	<i>Petroleum and Gas (Production and Safety) Act 2004</i>
Perf	Perforation Using an explosive shaped charge to penetrate the casing wall and provide a pathway to the reservoir
PBT assessment	A screening method to assess the potential persistence, bioaccumulation, and toxicity of the hydraulic fracture stimulation chemicals
PNEC	Predicted no-effects concentration
Proppant	A proppant is a solid material, typically sand, treated sand or man-made ceramic materials, designed to keep an induced hydraulic fracture open.
PRV	Pressure Reduction Valves
PSBR	Process Safety Basic Requirements
psi	Pound-force per square inch One psi is approximately 6,895 pascals (N/m ²).
PSL	Product Specification Level
QGC	QGC Pty Limited
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RfD	Reference doses
RME	Reasonable maximum exposure
RPM	Revolutions per minute
RSH	Riser Speed Head
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
SIMOPS	Simultaneous Operations Multiple independent operations that occur on a location at the same time
SIT	Subsurface Integrity Test
SOW	Slip On-weld

SVHCs	substances of very high concern
TGS	Tight Gas Sands
TRS	Tubular running services
TRVs	Toxicity reference values
TVD	True Vertical Depth
WATER ACT	<i>Queensland Water Act (2000)</i>
WIT	Wellhead Integrity Test
XRD	X-ray diffraction

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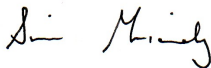
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Table of Contents

Executive Summary	i
1.0 Introduction	7
1.1 Study scope	7
1.2 Approach	7
1.3 Structure of the risk assessment	8
1.4 Risk assessment process	8
1.5 Regulatory considerations	9
2.0 Hydraulic fracture stimulation for the TGS Project	14
2.1 Location	14
2.2 The TGS Project	14
2.3 Well Integrity	16
2.3.1 Well design	17
2.3.2 Drilling and casing	20
2.3.3 Surface completion	21
2.3.4 Casing selection and installation procedures	23
2.3.5 Logging of the borehole	24
2.3.6 Cementing	25
2.3.7 Well integrity testing	28
2.4 Hydraulic fracture stimulation	30
2.4.1 Background	30
2.4.2 Hydraulic stimulation overview	33
2.4.3 Containment of hydraulic fracture stimulation	33
2.4.4 Pre-Hydraulic Stimulation Activities	38
2.4.5 Design and safe operating limits	38
2.4.6 Control	38
2.4.7 Preparation	39
2.4.8 Operation	39
2.4.9 Fluid systems	47
3.0 Risk Assessment Process	55
3.1 Problem formulation	55
3.1.1 General	55
3.1.2 Issue identification	56
3.1.3 Objective	56
3.2 Qualitative risk assessment	56
3.2.1 Receptors and exposure pathways	56
3.2.2 Risks and mitigation measures	57
3.2.3 Identification of Contaminants of Potential Concern	64
3.2.4 Identification of human health COPC in flowback fluid	66
3.3 Qualitative human health risk assessment	68
3.3.1 Exposure assessment	68
3.3.2 Potential exposure pathways and receptors	69
3.3.3 Quantification of exposure	69
3.4 Human health risk assessment	69
3.4.1 Toxicity assessment – human health	70
3.4.2 Selection of toxicity values	70
3.4.3 Risk characterisation	73
3.5 Environmental risk assessment	74
3.5.1 Exposure assessment	74
3.5.2 Potential exposure pathways and receptors	75
3.5.3 Toxicity assessment	75
3.6 Quantification of exposure	77
3.6.1 Source point concentrations	77
3.7 Screening level environmental risk characterisation	77
3.7.1 Estimation of risk	77
3.8 Noise and vibration	78

3.9	Regional ecosystems	79
3.10	Uncertainty assessment	82
3.10.2	Toxicity uncertainties	82
4.0	References	83
Appendix A		
	TGS Campaign	A
A.1	Introduction	A-1
A.1.1	Locations and schedule	A-1
A.1.2	Receiving environment	A-2
A.1.2.1	Surface setting	A-2
A.1.2.1.2	Climate	A-2
A.1.2.1.3	Topography	A-4
A.1.2.1.4	Hydrology	A-4
A.1.2.1.4.1	Surface features at each Appraisal well	A-7
A.1.2.2	Geological setting	A-13
A.1.2.2.1	Regional geology	A-13
A.1.2.2.2	Site specific geology	A-15
A.1.2.2.3	Structural geology	A-16
A.1.2.3	Gas Targets	A-26
A.1.2.3.1	Geological targets at ATP645	A-26
A.1.3	Hydrogeological setting	A-33
A.1.3.1.1	Hydrogeological context of TGS project	A-34
A.1.3.1.2	Major aquifers and proximity to tight sands	A-34
A.1.3.1.3	Hydraulic properties of geological formations in the TGS project area	A-34
A.1.3.2	Groundwater resources	A-36
A.1.3.2.1	Groundwater flow	A-37
A.1.3.2.2	Groundwater yields	A-39
A.1.3.2.3	Groundwater recharge and discharge	A-39
A.1.3.2.4	Groundwater quality	A-40
A.1.3.2.5	Suitability of analytical limits of reporting for stimulation monitoring	A-47
A.1.3.3	Groundwater use	A-48
A.1.3.3.1	Water supply bores (P&G Act)	A-48
A.1.3.3.2	Water entitlements	A-51
A.1.3.4	Groundwater environmental values	A-54
A.1.3.4.1	Aquatic ecosystem environmental value	A-55
A.1.3.4.2	Farm supply use	A-55
A.1.3.4.3	Stock water	A-55
A.1.3.4.4	Raw water for drinking water consumption	A-55
A.1.3.4.5	Cultural and spiritual values and uses of water	A-55
A.1.3.4.6	Surface water – groundwater interaction	A-56
A.1.4	Hydraulic fracture stimulation process	A-56
A.1.4.1	Well cleanout and well completion	A-57
A.1.4.2	Fluid system mass balance	A-57
A.1.5	Qualitative risk assessment	A-59
A.1.5.1	Overall approach	A-59
A.1.5.2	Problem formulation	A-59
A.1.5.3	Risks and mitigation measures	A-59
A.1.6	Identification of contaminants of potential concern	A-62
A.1.6.1	Introduction	A-62
A.1.6.2	Screening of chemicals for low human health concern	A-62
A.1.6.3	Identification of human health COPC	A-63
A.1.6.4	Persistence, bioaccumulation, and environmental toxicity – identification of environmental COPCs	A-65
A.1.7	Residual chemical fate and transport modelling	A-71
A.1.7.1	Environmental fate of inorganic COPC	A-71
A.1.7.2	Fate and transport modelling of COPC	A-71
A.1.7.2.1	Horizontal transport distance	A-72
A.1.7.2.2	Screening existing wells for potential sub-surface connection	A-73

A.1.7.2.3	Qualitative fate and transport assessment summary	A-73
A.1.8	Quantitative human health risk assessment	A-74
A.1.8.1	Exposure assessment	A-74
A.1.8.2	Potential exposure pathways and receptors	A-74
A.1.8.3	Exposure parameters	A-76
A.1.8.4	Exposure Point Concentrations	A-76
A.1.8.5	Human Health Toxicity Assessment	A-76
A.1.8.7	Conclusions	A-79
A.1.9	Environmental risk assessment	A-79
A.1.9.1	General	A-79
A.1.9.2	Identification of Chemicals of Potential Environmental Concern (COPEC)	A-79
A.1.9.3	Tier 1 Environmental Screening Assessment	A-82
A.1.9.4	Exposure Assessment	A-84
A.1.9.5	Potential exposure pathways and receptors	A-85
A.1.9.6	Interpretation of environmental significance	A-88
A.1.9.7	Conclusions	A-89
A.1.10	Uncertainty assessment	A-89
A.1.10.1	Exposure uncertainties	A-89
A.1.10.2	Toxicity uncertainties	A-89
A.1.11	Conclusions	A-90
Appendix B		
	Hydraulic Fracture Stimulation Fluid Mass Balance	B
Appendix C		
	Hydraulic Fracture Stimulation Fluid Toxicological Profiles	C
Appendix D		
	Exposure and Risk Calculations	D
Appendix E		
	PAH and BTEX analytical results	E

List of Plates

Plate 1	Final reservoir water	46
Plate 2	Closest registered bores and TGS Appraisal wells (Google Earth)	52
Plate 3	Surat rainfall data (1881 to 2023)	A-2
Plate 4	Bathurst 5 location (Google Earth)	A-9
Plate 5	Dunk 5 location (Google Earth)	A-10
Plate 6	Overton 6 location (Google Earth)	A-11
Plate 7	Overton 6 location (QGlobe)	A-12
Plate 8	Mapped fault across ATP645 (QGlobe)	A-17
Plate 9	Risk levels	A-21
Plate 10	Typical TGS Production Well and hydrostratigraphic units	A-72

List of Tables

Table 1	Summary of regulatory approval conditions related to hydraulic fracture stimulation	10
Table 2	Examine preliminary wells details	16
Table 3	TGS project 4 string casing summary	19
Table 4	Water utilisation volumes for the TGS Project	44
Table 5	TGS Well Testing	49
Table 6	Qualitative human health and environmental risk assessment and consideration of the need for Quantitative risk assessment	58
Table 7	PBT criteria adopted by NICNAS	67
Table 8	EU REACH screening criteria for persistent (P), very persistent (vP), bio-accumulative (B), very bio-accumulative (vB) and toxicity (T)	67
Table 9	Summary of assessment factors for estimating a PNEC (AEA 2009)	76
Table 10	Protecting acoustic values – Noise nuisance limits	78

Table 11 Watercourses as defined by the Water Act	A-4
Table 12 Summary of the geological units underlying ATP645	A-15
Table 13 Stratigraphic data at the TGS project	A-30
Table 14 Aquifer hydraulic parameters in the TGS project	A-35
Table 15 Flow rate information	A-39
Table 16 Griman Creek Formation hydrochemistry summary	A-40
Table 17 Mooga Sandstone hydrochemistry summary	A-40
Table 18 Magnetic GW1 hydrochemistry summary	A-41
Table 19 Gubberamunda Sandstone hydrochemistry summary	A-44
Table 20 Springbok Sandstone hydrochemistry summary	A-45
Table 21 Hutton Sandstone hydrochemistry summary	A-45
Table 22 'Lower' Precipice Sandstone hydrochemistry summary	A-46
Table 23 'Upper' Precipice Sandstone hydrochemistry summary	A-46
Table 24 ATP645 Water Supply bore summary	A-48
Table 25 Water license search summary	A-52
Table 26 Aquifer systems included in the EPP	A-54
Table 27 Chemicals used in the HVFR_A hydraulic fracture stimulation fluid	A-57
Table 28 Chemicals used in the HVFR_B hydraulic fracture stimulation fluid	A-57
Table 29 Chemicals used in the HVFR_Hybrid hydraulic fracture stimulation fluid	A-58
Table 30 Qualitative human health and environmental risk assessment and consideration of the need for Quantitative risk assessment for the campaigns	A-60
Table 31 Chemicals of low human health concern	A-62
Table 32 Theoretical concentrations of COPC in flowback fluid – HVFR_A Fluid System	A-63
Table 33 Theoretical concentrations of COPC in flowback fluid – HVFR_B Fluid System	A-63
Table 34 Theoretical concentrations of COPC in flowback fluid – HVFR Hybrid Fluid System	A-64
Table 35 PBT assessment of the hydraulic fracture stimulation fluid system chemicals to be used by QGC for the Campaign	A-66
Table 36 Identification of Potential Human Receptors and Pathways	A-75
Table 37 Exposure Parameters – Trespassers	A-76
Table 38 Toxicity Data for Chronic Oral/Dermal Exposures and Drinking Water Screening Criteria for COPC in all Fluid Systems	A-76
Table 39 Risk associated with potential exposure to trespassers – HVFR_A (theoretical data)	A-77
Table 40 Risk associated with potential exposure to trespassers – HVFR_B hydraulic fracture stimulation fluid system (theoretical data)	A-78
Table 41 Risk associated with potential exposure to trespassers – HVFR_Hybrid (theoretical data)	A-78
Table 42 Summary of derived TRVs for protection of aquatic species (PNECs) for the HVFR_A Fluid System	A-80
Table 43 Summary of derived TRVs for protection of aquatic species (PNECs) for the HVFR_B Fluid System	A-80
Table 44 Summary of derived TRVs for protection of aquatic species (PNECs) for the HVFR_Hybrid Fluid System	A-81
Table 45 Summary of COPEC for the HVFR_A Fluid System	A-83
Table 46 Summary of COPEC for the HVFR_B Fluid System	A-83
Table 47 Summary of COPEC for the HVFR_Hybrid Fluid System	A-83
Table 48 Identification of Potential Environmental Receptors and Pathways	A-86
Table 49 Results from quantitative human health and environmental risk assessment for the campaign	A-92

List of Figures

Figure 1 ATP645 TGS well pad locations	14
Figure 2 TGS project ATP645	15
Figure 3 TGS Conceptual 4 String Well Design Base Case	19
Figure 4 Typical wellhead with Frac tree, Flow-back tree, and Production tree (source: Vault pressure control)	22
Figure 5 Pressure cement job equipment and setup (API, 2009)	26
Figure 6 Example of a cement bond log, an integrity assessment technique	29
Figure 7 Natural gas resources (http://www.eia.doe.gov)	30

Figure 8 Wells targeting shale/tight gas plays shown on the depth grid for the base of the Rewan Group/top Bandanna Formation (source: Hall et al, 2018)	31
Figure 9 Taroom Trough Focus Area	32
Figure 10 TGS Project hydraulic stimulation ‘frac’ model	34
Figure 11 Dunk #1 target sand	35
Figure 12 Example of pressure and conductivity models before and after frac closure	36
Figure 13 Example of Hydraulic Stimulation Lease Layout	41
Figure 14 Magnetic GW1	43
Figure 15 Magnetic GW1 locality plan	43
Figure 16 API Guidance/Best Practices supporting Hydraulic Fracture Stimulation (API, 2013)	54
Figure 17 Risk Assessment Approach	55
Figure 18 Screening process to identify chemicals of potential concern for human health	64
Figure 19 Regional ecosystems	80
Figure 20 Drilling targets	81
Figure 21 Regional context	A-3
Figure 22 Surface water drainage lines	A-6
Figure 23 Existing local water storages identified via aerial photo (purple: 60 km buffer, blue: 100 km buffer)	A-7
Figure 24 Surficial geology and registered groundwater bores	A-14
Figure 25 Mapped structures	A-18
Figure 26 Stratigraphic cross-section across ATP645	A-19
Figure 27 3D mapped Tinowon target Sand	A-20
Figure 28 Tinowon target Sand level faulting	A-20
Figure 29 Wallabella Coal Member depth and structures	A-22
Figure 30 Queensland stress map	A-23
Figure 31 Local scale horizontal stress data	A-24
Figure 32 Historic seismicity	A-25
Figure 33 Earthquake summary (1850 to 2021)	A-25
Figure 34 Mapped wells at ATP645	A-27
Figure 35 Gas targets	A-28
Figure 36 Generalised stratigraphic chart of the ATP645 area	A-29
Figure 37 Target rock properties	A-35
Figure 38 Geological formations in the MDB area	A-37
Figure 39 Deep Bowen Basin sediments hydrostratigraphy (DNRME, 2018)	A-37
Figure 40 RN22622 locality plan	A-44
Figure 41 Registered bores	A-50
Figure 42 Water entitlements	A-53

Executive Summary

Shell QGC Pty Limited commissioned AECOM Australia Pty Ltd to complete a Hydraulic Stimulation Risk Assessment for the planned and potential future hydraulic stimulation campaigns throughout the appraisal phase of the Bowen Basin Tight Gas Sands (TGS) Project.

The Hydraulic Stimulation Risk Assessment addressed aspects of Shell QGC's regulatory approvals and was conducted in general accordance with relevant protocols and guidelines. The environmental risk assessment process adopted includes:

- the regulatory background for the risk assessment
- details of the risk assessment process
- details the hydraulic stimulation process for the TGS project
- details the assessment framework and process for considering the human health and environmental risks for the hydraulic stimulation campaign.

The risk assessment assessed potential sources, pathways, receptors, and potential outcomes, specifically the following:

- source of chemicals and emissions
- pathway/media to receptors
- exposure routes
- identification of the people and communities potentially affected (receptors) and their proximity to the hydraulic stimulation operations
- likely concentration of contaminants at receptors
- potential health endpoints from their exposure to the contaminants.

The TGS project is referred to as Examine and Measure, where the Examine campaign consists of three Appraisal wells on individual pads. On completion of the Examine campaign, and based on sub-surface outcomes, there is the option for an additional four wells to be executed in the Measure campaign. The Appraisal wells will be drilled vertically to the Lorelle Sandstone and then horizontally landing in the Tinowon Formation. All wells are intended to be stimulated within the Tinowon Formation reservoir.

Shell QGC include quality control procedures and testing during the well design, construction, and eventual abandonment that ensures that well integrity is maintained. To ensure that their operations meet international best practice in this regard, Shell QGC have developed internal policies and procedures that meet or exceed all aspects of the regulatory framework and industry standards as specified by the American Petroleum Institute. Aspects of the well design and construction phases, which ensure the integrity of the well include:

- design of the well construction to adhere to the local sub-surface conditions
- conducting a downhole geophysical survey of the drilled borehole, prior to the installation of well casing
- constructing the well using casing materials suitable for the pressures to which the well will be subjected during its lifetime
- utilising appropriate cementation materials and techniques
- pressure testing of the casing after installation and cementation
- conducting downhole surveying of the well casing following cementation to confirm integrity.

The risk of the loss of an appraisal well and the generation of preferential flow paths for hydraulic stimulation fluids is, therefore managed through quality control procedures and testing. The risk is further negated through the well design, construction methods, well integrity testing, and material selection, which reduces potential instability risks leading to well abandonment. Any lost wells are managed through a detailed well abandonment strategy.

For the tight gas sands, hydraulic fracturing is required to enable gas production. Hydraulic stimulation is a process where fluid and sand is injected at high pressure to re-open natural fractures and create pathways for gas to flow. Containment of hydraulic stimulation fractures within the target strata, considers lithologic stress barriers, target TGS and cap formations, and controlled fracture stimulation. Predictions of hydraulic fracture stimulation, using modelling software, was conducted. The hydraulic fracture stimulation modelling allowed for the design of the hydraulic stimulation to limit pressures and

injected fluid volume to contain height growth into the target TGS formation, thereby avoiding the potential for inadvertent injection into overlying or underlying units. To assure fracture containment within the deep gas reservoir, Shell QGC undertakes fracturing risk assessment and the development of a management plan. This includes a multi-disciplinary assessment of the perceived risks to people, assets, environment, reputation, and social risks in several areas, including:

- wellbore, casing, and cement bond integrity
- geology and hydrogeology
- geo-mechanics and localised faulting
- planned chemical usage
- fluids recovery and disposal
- monitoring plans.

Shell QGC has identified High Viscosity Friction Reducer as the preferred fracturing fluid because of its ability to reduce pipe friction, high proppant volume placement, potential to create more fracture networks, use fewer additives (decreasing the relative environment footprint), and improved production results. This fracturing fluid is also considered more suitable from an environmental perspective compared to the traditional cross linked borate systems.

Reservoir access via the Appraisal wells will be through the use of a single point entry system comprising of a hydraulic toe port at the base of the well and cemented sleeves placed along the remaining lateral length of the well. The toe-port is activated hydraulically, with the well pressured up to a pre-determined pressure to activate the port. The remaining 15 stages use the dropping of a ball to seat on a baffle, which is integral to the cement sleeve. Once the balls seats on the baffle a pressure differential is created across the baffle shifting the sleeve open and allowing a new conduit to the reservoir. The access to the TGS reservoir using hydraulic stimulation is, based on modelling, controlled fracture stimulation and the lithology, will not impact on overlying aquifers.

Water requirements for drilling and stimulation of appraisal wells shall be trucked from an existing Mooga Sandstone water bore. This aquifer, some 500 to 600 m below surface, is not used for private water use within the ATP645 and so the risk of water take on existing groundwater supplies is low. The risk to existing deep aquifers (not currently in use at ATP645) with extracting groundwater from the Mooga Sandstone is also low given the aquitards that separate the aquifers.

During hydraulic stimulation, the fluid pumped to hydraulically fracture an interval of the TGS will become pressurised. After hydraulic stimulation is complete water within the well will flowback back to surface, referred to as flowback fluid. The flowback fluid may contain fluid from the pad and slurry volumes as wells as groundwater native to the tight sands. The fluid flowed back from the well is stored in on-site flowback tanks.

During the hydraulic fracture stimulation operation, the injection pressure and fluid volume is continuously monitored to immediately identify a condition that would indicate the loss of integrity of the well casing or target sands overburden layer. Following the completion of the hydraulic fracture stimulation operation the formation pressure, flow rates, and the quality (chemistry) of water flowed back from Appraisal wells is continually monitored. A change in pressure or flow rate is used as a primary indicator of potential loss of containment warranting further investigation. A change in water chemistry may take some time to become apparent in the groundwater flowing back from the well (due to large volumes and dilution effects), hence, changes in water chemistry is used as a secondary indicator warranting further investigation. This data also can be used to confirm the hydraulic fracture stimulation has not created a hydraulic connection between the tight sands with adjacent hydrostratigraphic units.

A review of groundwater bores, which could potentially be impacted by the proposed hydraulic stimulation, indicated that there was only one existing registered bore located within 2 km of the proposed TGS appraisal wells. This bore is only 32 m deep within the Tertiary sediments and, as the hydraulic stimulation is aimed to occur within the TGS some 2,800 m below surface, is not within 200 m vertical distance from the frac zone. All other closest registered bores are > 5 km from the TGS appraisal wells.

The potential risks to human health and the environment associated with hydraulic fracture stimulation for the campaign were undertaken in accordance with enHealth, NEPM and ANZECC guidance, with reference to peer-reviewed international guidance where relevant.

Detailed operational procedures have been developed that are designed to contain the hydraulic fracture stimulation fluids within the TGS, such that groundwater utilised for the purpose of extraction (for any beneficial use), or springs is not impacted by hydraulic fracture stimulation chemicals.

The risk of chemical exposure to workers involved in the operation of hydraulic fracture stimulation activities (including the transportation of chemicals) was not quantitatively evaluated as this risk is addressed through the implementation of appropriate occupational health and safety procedures and management plans.

Potential exposures to hydraulic fracture stimulation chemicals were therefore assessed to be limited to the above ground storage and handling of flowback fluid. Management of TGS water involves temporary storage of flowback fluid in above ground fluid flowback tanks, after which the fluid will be transported to an off-site disposal facility. Exposure point concentrations were developed for each of the hydraulic fracture stimulation fluid systems using theoretical calculations.

The toxicity of the chemicals used in the hydraulic fracture stimulation process has been assessed for persistence, bioaccumulation, and aquatic toxicity (PBT), and human health toxicity. The chemicals used in the hydraulic fracture stimulation process do not contain benzene, toluene, ethylbenzene, xylene (BTEX) or polycyclic aromatic hydrocarbons as additives. It is noted that none of the chemicals of potential concern (COPC) identified for consideration in this risk assessment are persistent and bioaccumulative and toxic, hence there are no secondary pathways of concern (such as accumulation in crops and produce, and subsequent human consumption) that require quantification.

Based on the operational controls and management practices implemented by Shell QGC, the design of the flowback tanks and groundwater fate and transport assessment, the potentially complete exposure pathways identified and assessed in the risk assessment comprised the following:

- incidental ingestion and dermal contact by trespassers at the flowback fluid flowback tank; and
- potential releases of water to aquatic environments.

Based on the quantitative risk analysis, with consideration of the uncertainties identified, the following can be concluded in relation to potential exposures to flowback fluid from well hydraulic fracture stimulation activities:

- no unacceptable risks to trespassers were identified. Conservative risk scenarios assessed included regular access to the flowback tank, where swimming type activities were undertaken, with exposures to high theoretical concentrations of COPC in the flowback fluid. It is noted that this scenario is highly unlikely as the flowback tank is covered with a floating cover, further limiting trespassers access into the tank.
- potential impacts to aquatic receptors could occur if releases of flowback fluid reach surface waterbodies. The worst-case scenario was assumed where the assessed water body was located adjacent to the flowback tank.
- the likelihood that any of these chemicals may be discharged to an environment where any level of exposure may occur is managed via the implementation of existing operational management measures consistent with API guidance and 'Best Practice' specifications for the design and implementation of all hydraulic fracture stimulation operations that are conducted for the Project. The flowback tanks are held on-site for a maximum period of 3 years, after which the fluid will be trucked off-site to a disposal facility. Considering Shell QGC's operational management measures, the likelihood of a substantial release of flowback fluid from the tank during this period is low.

The effective operational controls and management implemented by Shell QGC which minimises the potential for exposures include the following:

1. Layout design development criteria are followed for placement of petroleum activity infrastructure, to minimise activities that require earthworks, vegetation clearing and/or placing fill (other than that is associated with the construction of linear infrastructure) in or within watercourses, wetlands, lakes, and springs.
2. Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals, and if a spill was to occur, rectification measures would be taken

immediately and notification to DES of any unauthorised releases would be made. Secondary containment berms or bunds are added to the drill pads as a spill containment measure.

3. Routine integrity inspections are undertaken of equipment and storage tanks prior, during and post stimulation. Continuous monitoring and evaluation of well production data versus fluid storage and transfer during the production test phase.
4. Routine inspection of the flowback tank(s) and associated equipment (e.g., blender, hoses, pumps) to check for leakage of flowback fluid.
5. Flowback tank and equipment is manned during the hydraulic fracture stimulation operation and as required, fluid is transferred to vacuum truck for disposal to ensure freeboard in the tank is maintained.
6. Pre-job inspection of the flowback tank and fluid connections to confirm integrity.
7. A vacuum truck with 20,000 L capacity and a front-end loader excavator located permanently on the site, available to assist in emergency spill situations, if required.

On every wellsite included in the campaign, a Shell QGC representative inspects the site to verify controls 3 to 7 from the above list are occurring. The operational controls are routinely evaluated by Shell QGC and modifications and revisions made, where necessary.

The summary of the results from the human health and environmental risk assessment and associated risk mitigation measures is presented in the Table below.

In summary, Shell QGC's operational and management controls can be further supported by the following recommendations:

- maintain compliance with QGC's Stimulation Impact Monitoring Plan, which will be developed to monitor the impact of hydraulic fracture stimulation in the project area.

	Identified Potential Hazard	Hazard Causes and Consequences	Risk Mitigation Measures	Reason for carrying forward the potential hazard into the subsequent Quantitative Risk Assessment	Results of Quantitative Risk Assessment	Recommended Mitigation to Address Residual Risk
Surface Environment	The loss of containment of chemicals used for hydraulic fracture stimulation	Exposure of workers, residents or the environment to potentially hazardous hydraulic fracture stimulation chemicals, resulting from loss of containment occurring: - Whilst in transit to site; - During the mixing of hydraulic fracture stimulation fluid on site; or (In diluted form) during the storage and transport of well flowback fluid.	QGC implement a range of engineering and operational control measures to ensure the risk of hydraulic fracture stimulation fluid spills are minimised during hydraulic fracture stimulation operations, including during transport to and from the wellsite and during the flowback of hydraulic fracture stimulation chemicals from the well. These control measures include: - Adherence to the material storage and transport requirements as stipulated on the chemical Safety Data Sheets (SDS). - Adherence to the Transport of Dangerous Goods by Road Regulations (for chemicals classified as a 'Dangerous Goods'). - Ensuring chemicals remain in their original containers and are not decanted into smaller containers which may not be fit for purpose. - During hydraulic fracture stimulation operations, the use of secondary containment beneath all equipment holding or pumping chemicals. - Using fit for purpose flowback fluid storage tanks. Conducting regular integrity checks of fluid storage tanks, during commissioning and use. Ensure adequate freeboard is maintained at all times.	The evaluation of the risk to workers involved in the operation of well hydraulic fracture stimulation activities (including transportation of the COPC to the site) is not considered warranted in this risk assessment, as it is addressed via the implementation of appropriate occupational health and safety procedures and management plans. Further consideration is warranted regarding the risk of above ground exposure relating to the handling and storage of hydraulic fracture stimulation chemicals and flowback fluid. This is addressed in Section 3.4.3. Further assessment is warranted regarding the risk associated with the potential concentrations of COPC in flowback fluid; and the presence of other COPC that may have been liberated during the hydraulic fracture stimulation operations. This is addressed in Section 3.4.3. Further assessment is warranted regarding the chemical and physical properties of the constituents used in hydraulic fracture stimulation fluids that result in the potential for these chemicals to be present in flowback fluid and to be of concern in relation to potential acute or chronic risks. This is addressed in Section 3.4.3.	Exposures by workers involved in the operation of well hydraulic fracture stimulation activities have not been evaluated as their exposures are addressed through the implementation of appropriate occupational health and safety procedures and management plans. The PBT assessment of the chemicals indicated that none of the COPCs identified for consideration in this risk assessment are persistent and bioaccumulative and toxic, hence secondary pathways (such as accumulation in crops and produce, and subsequent human consumption) were not quantified. Polyacrylamide has limited biodegradation potential however, it is not bioaccumulative and is essentially non-toxic to aquatic species. Petroleum distillates meet the screening criteria for bioaccumulation and toxicity; however, the chemical is expected to be biodegradable and adverse chronic outcomes are not evident based on its lack of persistence in the environment. Didecylmethyl ammonium chloride meet the screening criteria for toxicity, however adverse chronic outcomes are not evident based on their lack of persistence and bioaccumulation potential in the environment. The assessment has focused on the theoretical dataset, assuming between 20% and 60% of the mass of chemicals injected into the well will be present in the flowback fluid. Based on the conceptual site model, the potentially complete exposure pathways identified and assessed in the risk assessment comprised the following: - Incidental ingestion and dermal contact by trespassers at the flowback tanks; and - Potential releases of water to aquatic environments. The results of the risk assessment indicated the following: - No unacceptable risks to trespassers were identified. Conservative risk scenarios considered included exposures that involved regular access to the flowback tanks, where swimming type activities were undertaken, with exposures to high theoretical concentrations of COPC in the flowback fluid. It is noted that this scenario is highly unlikely as the flowback tanks are covered with a floating cover.	Operational controls which could further minimise the potential for exposure include monitoring weather forecasts and implementing flowback tank over-flow prevention measures, as required. If the flowback tanks are to be left unattended for an extended period whilst containing residual flowed-back material, perform routine flowback tank inspections to confirm adequate freeboard and to check for leakage of flowback fluid.

	Identified Potential Hazard	Hazard Causes and Consequences	Risk Mitigation Measures	Reason for carrying forward the potential hazard into the subsequent Quantitative Risk Assessment	Results of Quantitative Risk Assessment	Recommended Mitigation to Address Residual Risk
Subsurface Environment	Contamination of groundwater in the target TGS, which is then accessed by landholder bores	Based on the hydrogeological setting within the project area (refer to Section 2.2.3), in order for the pathway to be valid in the context of exposure to hydraulic fracture stimulation fluids, a potential landholder groundwater supply bore would need to source groundwater from directly within the hydraulically fractured zone of the TGS.	QGC have protocols in place which preclude hydraulic fracture stimulation operations impacting landholder bores. Prior to commencing a hydraulic fracture stimulation campaign, QGC perform Baseline Assessments of all groundwater bores within 2 km of horizontal separation from a target well. Part of this assessment is to understand the precise location of bores and their likely source aquifer. If a landholder bore is potentially screened within the radius of influence of a hydraulic fracture stimulation operation (both horizontally and vertically), that gas well is not hydraulically fractured. Hence this scenario becomes invalid.	The protocols that QGC has in place to prevent hydraulic fracture stimulation occurring near landholder bores screened in target TGS, negate the requirement for further consideration of the risks of this scenario.	To evaluate the likelihood that gas wells might be located in a position where a groundwater extraction well could theoretically be affected, QGC has carried out a baseline survey and GIS proximity analysis in which the existing identified groundwater wells have been screened for depth relative to the top of the Back Creek Group. This has identified no groundwater wells deeper than 150 m, within the petroleum tenures and for a 2 km radius around the boundary of the tenures. The majority of identified bores are separated by a vertical distance of more than 1600 m from the Back Creek Group. Three bores were identified within a vertical distance of 1050 m of the Back Creek Group in petroleum tenure ATP 645. The use of these bores is unknown. The qualitative assessment of the fate and transport of residual COPCs in the TGS after hydraulic fracture stimulation (see Section A.1.7) determined minimal potential for COPC migration beyond the hydraulically fractured zone. There are no landholder bores installed within both 750 m horizontal separation and 100 vertical metres of the top of the TGS.	Risk mitigation achieved via QGC's existing operational controls described in Section 2.3 and Stimulation Impact Monitoring Plan.

1.0 Introduction

1.1 Study scope

QGC Pty Limited (QGC) commissioned AECOM Australia Pty Ltd (AECOM) to perform a Risk Assessment for planned and potential future hydraulic stimulation campaigns throughout the appraisal phase of the Bowen Basin Tight Gas Sands (TGS) Project.

The campaign will consist of three initial appraisal wells (Overston-6, Bathurst-5, and Dunk-5) to prove the viability of the project. The wells are intended to replicate the unconventional well models currently used to exploit tight reservoirs across other global Shell operations.

AECOM were initially commissioned to provide a review of the existing Shell QGC risk assessments, specifically focusing on the subsurface risks, chemical and water management of the hydraulic fracturing operation for the potential TGS resources on petroleum tenure (ATP645) in the Bowen Basin.

AECOM were asked to review the Shell QGC hydraulic fracturing risk assessments and to benchmark those risk assessments with other examples from AECOM's experience of similar operations in the Surat Basin and shale exploration in the Beetaloo Basin. Specifically, the review was to assess if the hydraulic fracturing risk assessments address potential short, cumulative, and long-term health risks arising from the use of chemicals.

During the study review process, AECOM were requested to complete a Hydraulic Stimulation Risk Assessment for the TGS resources on ATP645, which included human health and ecological risk assessments for the hydraulic stimulation chemicals. The risk assessment also included:

- A qualitative assessment of human health and environmental risks to the receiving environment associated with the injection of hydraulic fracturing fluids
- A qualitative assessment of the potential risks to aquatic, terrestrial and human health toxicity associated with the process of hydraulic fracturing and the management and storage of flow back fluids above ground
- A quantitative assessment of the potential risks to aquatic, territorial, and human receptors associated with the management and storage of flow back fluids.

1.2 Approach

AECOM completed the Hydraulic Stimulation Risk Assessment in general accordance with the following protocols or guidelines:

- Australian Industrial Chemicals Introduction Scheme (AICIS) (formerly National Industrial Chemicals Notifications and Assessment Scheme (NICNAS)), National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia, 2017
- Department of the Environment and Energy, Exposure Draft - Chemical Risk Assessment Guidance Manual: for chemicals associated with coal seam gas extraction, 2017
- enHealth. Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards, 2012 2 of 12
- National Environment Protection (Assessment of Site Contamination) Measure 1999 (ASC NEPM); Schedule B4, Site-specific health risk assessment methodology, 2013.

The risk assessment is detailed in Section 1.4 and the regulatory conditions specific to this risk assessment are detailed in Section 1.5.

The risk assessment addresses aspects of Shell QGC's regulatory approvals for conducting hydraulic fracture stimulation operations in the project area, specifically:

- Commonwealth Government Department of Sustainability, Environment, Water, Population and Communities (SEWPaC), now Department of Agriculture, Water and the Environment (DAWE): Environmental Protection and Biodiversity Conservation (EPBC) Act Approval 2017/7902.

- Queensland Government Department of Environment and Science (DES): Environmental Approval (EA) EPPG00839513 dated 27 October 2022.

1.3 Structure of the risk assessment

To adhere to the environmental risk assessment process, whilst addressing all the regulatory conditions, the report has been structured as follows:

- **Section 1.0:** Describes the regulatory background for the risk assessment and the details the risk assessment process.
- **Section 2.0:** Details the hydraulic fracture stimulation process for the TGS campaign, including integrity of TGS wells, hydraulic fracture stimulation process, operation, monitoring and assessment.
- **Section 3.0:** Details the assessment framework and process for considering the human health and environmental risks for QGC's hydraulic fracture stimulation campaign.
- **Appendix A:** Assesses the campaign-specific human health and environmental hydraulic fracture stimulation risks, including hydraulic fracture stimulation locations and schedule, the receiving environment, fluid systems.

1.4 Risk assessment process

The framework for an environmental risk assessment is similar to the one adopted for the human health risk assessment and is consistent with guidance provided in the ASC NEPM Guideline on Environmental Risk Assessment", Schedule B5, 2013 and in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC) 2000. The risk assessment also considered the guidance presented in National Health and Medical Research Council, Australian Drinking Water Guidelines (NHMRC 2011) for the derivation of drinking water guidelines where applicable.

The risk assessment comprises the following tasks:

1. **Issue identification** – Identification of the key issues amenable to the risk assessment, includes a description of the current environmental setting, detailed geological and hydrogeological information, well integrity and a description of the hydraulic fracture stimulation process including an identification of the constituents of the hydraulic fracture stimulation fluid. The task concludes with a register of the potential risks of Shell QGC conducting hydraulic fracture stimulation operations in the project area, both the risks that are negated by Shell QGC Shell's control measures and those that warrant further assessment in the subsequent sections of the report.
2. **Chemical Hazard/Toxicity assessment** – An evaluation of the environmental hazard of the chemical additives in the hydraulic fracture stimulation fluid, based on their environmental persistence, bioaccumulation, and aquatic toxicity properties. Chemicals of potential concern are identified for further assessment. An evaluation of human health toxicity is also provided.
3. **Exposure assessment** – The exposure assessment comprises of an evaluation of surface and sub-surface exposure pathways assessment and mass balance calculation to identify the amount of each chemical additive of the hydraulic fracture stimulation fluid.
4. **Risk characterisation** – A quantitative evaluation of the risks using toxicity values and quantitative estimates of chemical intake to provide an estimate of potential human health and environmental risk associated with the hydraulic fracture stimulation activities, based on the identification of complete exposure pathways and hazard identification.

The risk assessment approach presented in this report provides a methodology for assessment of the risks posed by mixtures that meet the requirement in the EA consent conditions. This approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total fluid toxicity and ecotoxicity (i.e., the total sum of the components of the formulations), which is consistent with the National Water Quality Management Strategy (NWQMS) and the principles outlined in the Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) guidelines.

1.5 Regulatory considerations

The main references in the existing body of legislation applicable to the downhole environment of chemical risk assessments as per the TGS project are:

1. The Department of Environment's Risk Assessment Guidance Manual: for chemicals associated with coal seam gas extraction (2017). This describes the assessment in terms of potential routes of environmental exposure and as well as receptors of the proposed chemical through the conceptual site modelling. The relative hazard profile of the chemical in relation to the environment is assessed with an ecotoxicity review, and environmental fate analysis. The reference groups drilling, completion and stimulation and fracking activities as relevant.
2. The *Environmental Protection Act (1994)*. This prescribes certain requirements that must be complied with by operators in Queensland for activities including restricted stimulation fluids.
3. The Petroleum and Gas (General Provisions) Regulation (2017). This defines stimulation as a technique used to increase the permeability of a natural underground reservoir, including, for example, hydraulic fracturing, cavitations, fracture acidizing, and the use of proppant treatments. Permeability is however not defined in Queensland legislation.
4. *Environment Protection and Biodiversity Conservation Act 1999*.

In addition, the TGS project is also subject to requirements of EA Permit EPPG00839513 and Shell QGC Stimulation Risk Assessment Guideline QGCLNG-BA-ENV-APR-000001 (QGC, 2018).

The risk assessment will assess potential sources, pathways, receptors, and potential outcomes, specifically the following:

- Source of chemicals and emissions
- Pathway/media to receptors
- Exposure routes
- Identify the people and communities potentially affected (receptors) and their proximity to the hydraulic fracture operations
- Likely concentration of contaminants at receptors
- Potential health endpoints from their exposure to the contaminants.

This report will provide a methodology for assessment of the risks, evaluation of the toxicity of the chemicals used in the hydraulic stimulation, and characterisation of the cumulative risks of the total effluent toxicity and ecotoxicity. Furthermore, the risk assessment will be reviewed against the specific Environmental Authority conditions presented in Table 1.

Table 1 Summary of regulatory approval conditions related to hydraulic fracture stimulation

Condition Number	Description	Section in Risk Assessment Report	Comments regarding EA Condition
Condition 48	The petroleum activities must not involve well stimulation activities at a well located within 2 kilometres laterally of a landholder's active groundwater bore and sourced from a formation within 200 metres vertically of the stimulation impact zone.	A.1.1	Locations and Schedule
		A.1.2	Receiving Environment - Groundwater Use
		A.1.3	
Condition 49	Stimulation activities must not result in:		
	(a) negative impacts to groundwater quality beyond the stimulation impact zone; or	Outcome of risk assessment.	
	(b) negative impacts to water quality in landholder's active groundwater bore(s) which tap into the target formation; or	A.1.3.2.4 A.1.3.4	Groundwater Quality Groundwater Environmental Values
	(c) interconnectivity between the target formation and another aquifer.	A.1.3	Hydrogeological Setting
Condition 52	Additives that contain polycyclic aromatic hydrocarbon or products that contain polycyclic aromatic hydrocarbons, must not be used in stimulation fluids in concentrations above the reporting limit.	Appendix E No PAHs are used by Shell/QGC during hydraulic fracture stimulation.	PAH and BTEX analytical results
Condition 56	Prior to undertaking well stimulation activities, the holder of this environmental authority must develop a risk assessment to ensure that stimulation activities are managed to prevent environmental harm.	This report	
Condition 57	The stimulation risk assessment must include, but not necessarily be limited to:		
	(a) a process description of the stimulation activity to be applied, including equipment and a comparison to best international practice;	Section 2.3	Hydraulic Fracture Stimulation
	(b) provide details of where, when, and how often stimulation is to be undertaken on ATP645 under this environmental authority;	Section 2.3 A.1.1	Hydraulic Fracture Stimulation Locations and Schedule
	(c) a geological model of the field to be stimulated including geological names, descriptions and depths of the target gas producing formation(s);	A.1.2.2	Receiving Environment - Geological Setting
	(d) naturally occurring geological faults;	A.1.2.2.3	Receiving Environment - Structural Geology
	(e) seismic history of the region (e.g. earth tremors, earthquakes);	A.1.2.2.3.1 A.1.2.2.3.2	Receiving Environment - Stress-field Setting and Seismic History of the Project Area
	(f) proximity of overlying and underlying aquifers;	A.1.3.1.2	Receiving Environment - Major aquifers and proximity to coal measures
	(g) description of the depths that aquifers with environmental values occur, both above and below the target gas producing formation;	A.1.3 A.1.3.4	Hydrogeological Setting Receiving Environment - Groundwater Environmental Values

Condition Number	Description	Section in Risk Assessment Report	Comments regarding EA Condition
	(h) the environmental values of groundwater in the area;	A.1.3.4	Receiving Environment - Groundwater Environmental Values
	(i) description of overlying and underlying formations in respect of porosity, permeability, hydraulic conductivity, faulting, and fracture propensity;	A.1.3.1.3	Receiving Environment - Hydraulic properties of geological formations in the project area
	(j) consideration of barriers or known direct connections between the target gas producing formation and the overlying and underlying aquifers;	Section 2.3.3 A.1.2.2 A.1.3	Containment of Hydraulic Fracture Simulation Receiving Environment – Geological Setting Receiving Environment – Hydrogeological Setting
	(k) a description of the well mechanical integrity testing program;	Section 2.2.7	Well Integrity - Well integrity testing
	(l) process control and assessment techniques to be applied for determining extent of stimulation activities (e.g., microseismic measurements, modelling etc);	Section 2.3.6	Hydraulic Fracture Stimulation - Control
	(m) practices and procedures to ensure that the stimulation activities are designed to be contained within the target gas producing formation;	Section 2.3.5 Section 2.3.6	Hydraulic Fracture Stimulation - Design and safe operating limits Hydraulic Fracture Stimulation - Control
	(n) locations of landholders' active groundwater bores;	A.1.3.3	Receiving Environment - Groundwater Use
	(o) groundwater transmissivity, flow rate, hydraulic conductivity, and direction(s) of flow;	A.1.3.2	Receiving Environment - Groundwater resources
	(p) a description of the chemicals used in stimulation activities (including estimated total mass, estimated composition, chemical abstract service numbers and properties), their mixtures and the resultant compounds that are formed after stimulation;	Section 5.3, Appendix B (Mass Balance), Appendix C (Toxicological Profiles)	Hydraulic fracture stimulation process
	(q) a mass balance estimating the concentrations and absolute masses of chemicals that will be reacted, returned to the surface or left in the target gas producing formation subsequent to stimulation;	Appendix B	Mass Balance
	(r) an environmental hazard assessment of the chemicals used to include their mixtures and the resultant chemicals that are formed after stimulation including:	Section 3.0 Section A1.5 Section A1.6 Section A1.8 Section A1.9	Risk Assessment Process Qualitative Risk Assessment Identification of Contaminants of Potential Concern Quantitative Human Health Risk Assessment Environmental Risk Assessment
	i. toxicological and ecotoxicological information of chemicals used;		
	ii. information on the persistence and bioaccumulation potential of the chemicals used;		
	iii. identification of the stimulation fluid chemicals of potential concern derived from the risk assessment;		

Condition Number	Description	Section in Risk Assessment Report	Comments regarding EA Condition
	(s) an environmental hazard assessment of use, formation of, and detection of polycyclic aromatic hydrocarbons in stimulation activities;	No PAHs are used by Shell/QGC during hydraulic fracture stimulation	
	(t) identification of whether radioactive tracer beads are proposed to be used in the stimulation activity and if so, provide an environmental hazard assessment of using radioactive tracer beads in stimulation activities;	Radioactive tracer beads will not be used in this campaign.	
	(u) an environmental hazard assessment of leaving stimulation chemicals in the target gas producing formation for extended periods subsequent to stimulation;	Sections A.1.7.3	Cumulative underground impacts
	(v) human health exposure pathways to operators and the regional population;	Sections A.1.8.1	Quantitative Human Health Risk Assessment-Exposure Assessment
	(w) risk characterisation of environmental impacts based on the environmental hazard assessment;	Section A.1.9	Environmental Risk Assessment
	(x) potential impacts to landholder bores as a result of stimulation activities; and	Section A1.3.3	Receiving Environment - Groundwater Use
	(y) potential environmental or health impacts which may result from stimulation activities including but not limited to water quality, air quality (including suppression of dust and other airborne contaminants), noise and vibration.	Outcome of risk assessment.	
Condition 58	The stimulation risk assessment must be carried out for every well to be stimulated prior to stimulation activities being carried out at that well.	This report	
Condition 59	(a) all landholders' active groundwater bores (subject to access being permitted by the landholder) that are spatially located within a two (2) kilometre horizontal radius from the location of the stimulation initiation point within the target gas producing formation;	Section 2.3.9.4	
	(b) all landholders' active groundwater bores (subject to access being permitted by the landholder) in any aquifer that is within 200 metres above or below the target gas producing formation and is spatially located with a two (2) kilometre radius from the location of the stimulation initiation point	Section 2.3.9.4 A.1.7.2.1	
	(c) any other bore that could potentially be adversely impacted by the stimulation activity(ies) in accordance with the findings of the risk assessment required by Condition 56 and Condition 57.	A.1.3.3	Receiving Environment - Groundwater Use
Condition 64	The Stimulation Impact Monitoring Program must be able to detect adverse impacts to water quality from stimulation activities and must consider the findings of the risk assessment	The Shell/QGC Stimulation Impact Monitoring is included in Section 2.3.9.2.	

Condition Number	Description	Section in Risk Assessment Report	Comments regarding EA Condition
	required by Conditions 56 and 57 that relate to stimulation activities and must include, as a minimum, monitoring of:		
	(a) the stimulation fluids to be used in stimulation activities at sufficient frequency and which sufficiently represents the quantity and quality of the fluids used; and		
	(b) flow back waters from stimulation activities at sufficient frequency and which sufficiently represents the quality of that flow back water; and		
	(c) flow back 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; and		
	(d) all bores in accordance with Condition 59.		

2.0 Hydraulic fracture stimulation for the TGS Project

2.1 Location

The Bowen TGS field is located on ATP645, which is situated near the towns of Roma and Condamine in the state of Queensland, Australia and is 100% Shell QGC owned. This portion of the southern Bowen Basin (Taroom Trough) has seen several discoveries and developments from the Tinowon Formation, including Myall Creek Field, Churchie field (both west of Overston area), and Waggamba field (southwest of Overston area).

The project area for the risk assessment is exclusively located within ATP645 petroleum tenement. The project area is included in Figure 2.

2.2 The TGS Project

An appraisal drilling program is planned to commence in 2023, as part of the TGS project. The current program consists of seven wells, although this may increase or decrease depending on the initial results. The appraisal program is currently split into two stages, including:

- Phase-1 appraisal wells, which includes Overston-6, Dunk 5, and Bathurst 5 (Figure 1). The current scope has the three areas, with one appraisal well to each area. The wells include a vertical pilot, two of which will be drilled to the Lorelle Sandstone, and a horizontal well kicked off and landed in the Tinowon Formation. All horizontal wells will be hydraulically stimulated.
- In Phase-2, it is planned to drill an additional four wells on 2 of the 3 existing pad sites. These wells are intended to have the same functional design as Phase-1 with the exception that no pilot hole is required.

The phase-1 wells will be unsuspended and well tested with the phase-2 wells, after which all appraisal wells will be suspended pending future field development decisions.

Approximate total vertical depth (TVD) of the horizontal production hole section is 3,000 m +/- with measured depths (MD) at the toe of approximately 4,000 m +/-.

Figure 1 ATP645 TGS well pad locations

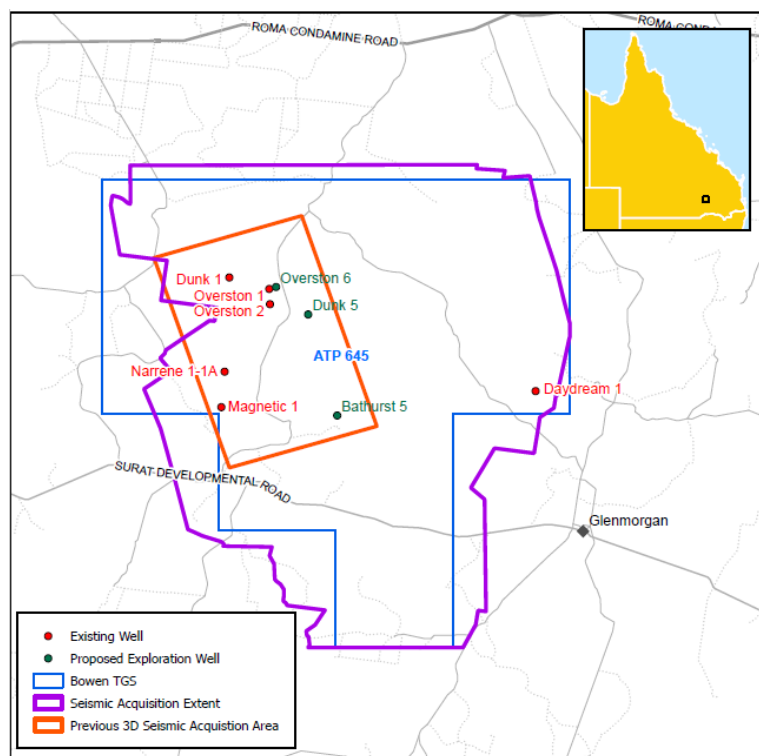
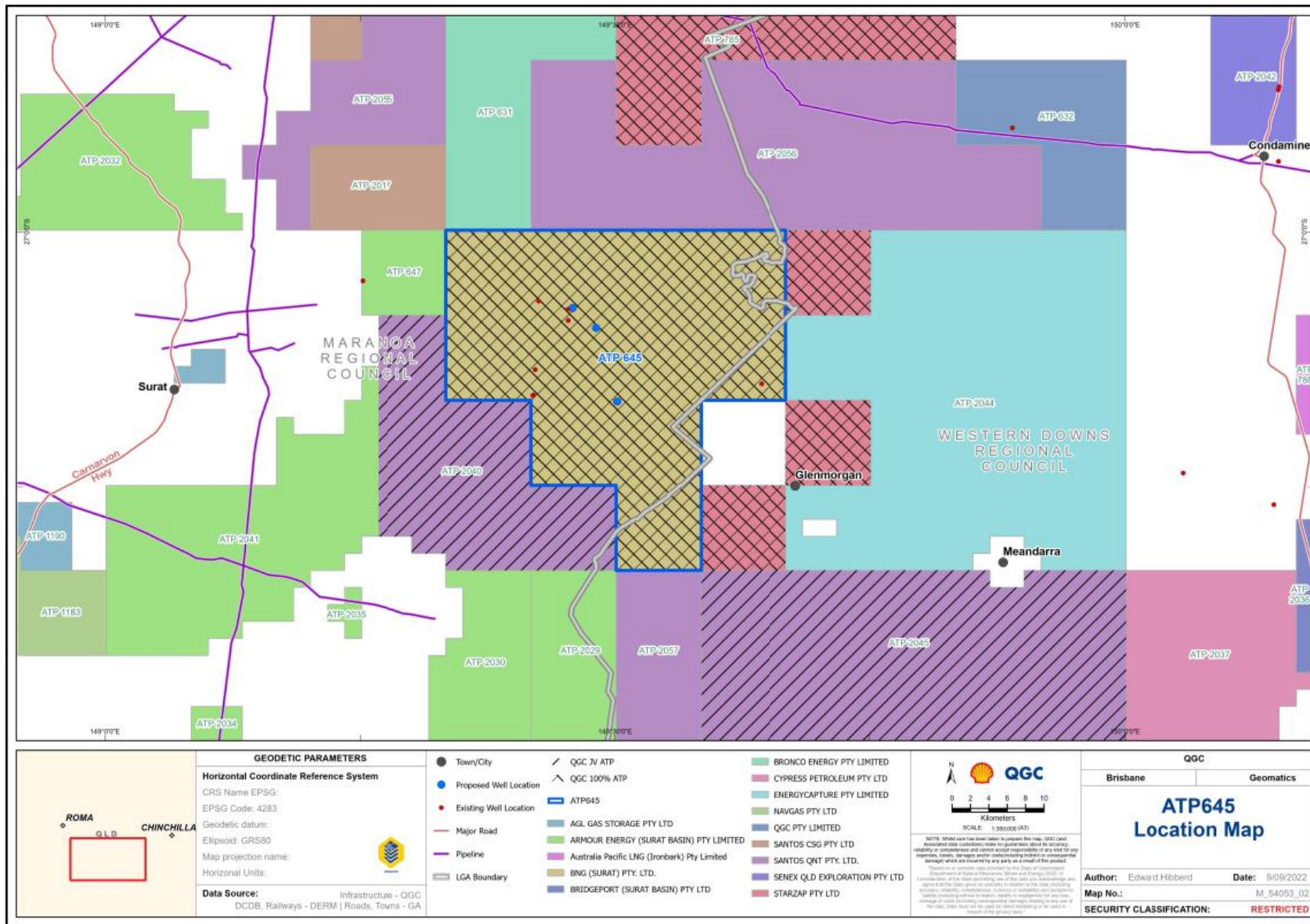


Figure 2 TGS project ATP645



This TGS project will comprise:

- New wells and well pads
- New well surface equipment
- Temporary gas and water testing systems
- Temporary water storage and treatment infrastructure.

For clarity these new campaigns on ATP645 are also referred to as Examine and Measure. The Examine campaign consists of three wells on individual pads. On completion of the Examine campaign, and based on sub-surface outcomes, there is the option for an additional four wells to be executed in the Measure campaign.

The location of the first stage Appraisal wells will include new well pads on Overston, Dunk, and Bathurst (Figure 1). The current scope includes a vertical pilot, with two wells which will be drilled to the Lorelle Sandstone, and a horizontal well landed in the Tinowon Formation. The geological units and depths across ATP645 are included in **Appendix A.1.2.2**.

The horizontal well component is above and beyond the tenure commitments. All wells are intended to be stimulated along horizontal sections within the Tinowon Formation reservoir.

Appraisal well details

The three Examine well details are summarised in Table 2.

Table 2 Examine preliminary wells details

Well name	Latitude	Longitude	Depth
Dunk 5	27° 05' 39.274" S	149° 28' 53.022" E	4,228.88 MDRT ¹
Overston 6	27° 04' 33.075" S	149° 27' 40.744" E	4,219 MDRT
Bathurst 5	27° 09' 58.742" S	149° 30' 07.464" E	4,179.07 MDRT

Note: Well locations are subject to change based on land owner negotiations

The drilling scope includes the engineering design, procurement, and drilling of wells including installation of the wellhead. Detailed well engineering design for the well construction, containment, relief well planning, equipment delivery, and contingency planning was completed according to internal and external requirements.

Once the well pads are constructed the drilling rig will be mobilized and assembled on the well pad to allow well drilling operations to commence. The current planned sequence for drilling is Overston, Bathurst, and Dunk; this sequence is largely driven by land access.

2.3 Well Integrity

Well failure can occur due to poor well construction, incorrectly sealed wells, or through deterioration due to pressure, stresses, and corrosion. If the cement or casing around the well fails, then there is a risk of polluting the overlying aquifers. Therefore, correct well construction and integrity is crucial in containing potential contaminants and protecting groundwater.

To inform the risk assessment of the hydraulic fracture stimulation within the TGS project area, the mechanical integrity of the TGS wells must be evaluated.

The mechanical integrity of a well describes its ability to isolate fluids (both hydraulic fracture stimulation and production fluids) within the well from the surface and sub-surface zones exterior to the well during its working life and beyond, including after it has been abandoned by the mandated well abandonment processes.

Essential for managing the risks of hydraulic fracture stimulation is the capability of a well to isolate any groundwater resources exterior to the target formation from the fluid used to conduct the hydraulic

¹ Measured depth referenced to rotary table

fracture stimulation (the increase in hydraulic pressure applied inside the well during hydraulic fracture stimulation), and the differential pressures across the casing walls during subsequent production.

It is the robustness of the well design, construction, and eventual abandonment that ensures that well integrity is maintained. To ensure that their operations meet international best practice in this regard, Shell QGC have developed internal policies and procedures that meet or exceed all aspects of the regulatory framework and industry standards as specified by the American Petroleum Institute (API).

The Shell QGC procedure Well Integrity Management Plan Legacy Tight Gas Sands (TGS) Appraisal Wells QCOPS-BA00-PRD-STD-000002 Revision 0 (QGC, 2022) mandates the testing and maintenance procedures which are to be employed to ensure that the integrity of well and wellhead equipment is maintained throughout all stages of the TGS Appraisal data compilation project.

Throughout the well design and installation process, Shell QGC will employ quality control procedures and testing, to ensure the integrity of each well before it is hydraulically fractured. Aspects of the well design and construction phases, which ensure the integrity of the well include:

- Design of the well construction to adhere to the local sub-surface conditions
- Conducting wireline logging of the drilled borehole, prior to the installation of well casing
- Constructing the well using casing materials suitable for the pressures to which the well will be subjected during its lifetime
- Utilising appropriate cementation materials and techniques
- Pressure testing of the casing after installation and cementation
- Conducting downhole surveying (wireline logging) of the well casing following cementation to confirm integrity.

These procedures are discussed proceeding sections of this report.

2.3.1 Well design

One of the primary objectives of the Examine and Measure TGS project well design is to always maintain the mechanical integrity of the wells. The well design phase is critical to meeting this objective.

Shell QGC has developed internal guidance documents to ensure that well designs and installation procedures meet regulatory frameworks and international best practices. The relevant documents are:

- Well Fracture Stimulation and Basis of Design documents:
 - Completion and stimulation activities will be executed by the selected contractors as outlined in the Design of Services
 - Bowen TGS Well Testing: Basis for Design QCLNG-BA00-ENG-BOD-000017
 - Detailed Well Design Endorsement (DCAF 1394) - provides detailed basis information to enable engineering and procurement of the selected Well Design concept
 - Wells Material Selection Project – TGS Examine (Version 1)
 - Water Bore Pad Surface Facilities Basis for Design, which provides the detailed basis information underpinning the equipment requirements for appraisal water supply (stimulation and drilling).
- Drilling and Completions Standards (Barriers, Casing & Tubing, Cementing, Well Integrity):
 - Design output will comply with the applicable legal and regulatory requirements, codes, and standards, and Shell QGC requirements as detailed in the individual contracts for the associated scope of work.
 - Design & Engineering Practice (DEP) 25.80.10.21-GEN Well Stimulation
 - The design will meet the requirements of the Shell Discipline Controls and Assurance Framework (DCAF), will be fully compliant with the relevant Wells Manuals, and all process safety basic requirements (PSBRs) as defined in the Design and Engineering Management (DEM2) standards.

- Cementing Manual WS 38.80.31.38-Gen.
- Casing and tubing design manual WS 38.80.31.31-Gen

The Shell QGC wells designs used in the TGS project adhere with the regulatory specification which dictates the construction requirements for installing wells in Queensland, The *Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland, Version 2* (Petroleum and Gas Inspectorate, 2019), (henceforth 'the Code of Practice'). The Code of Practice mandates that the design and construction of the well must ensure isolation between the well and the geological formations that are not the target of the well, and that the production fluids must travel inside the well conduit directly to the surface infrastructure.

It is noted that Shell QGC include control points during the entire design, drilling, and hydraulic stimulation process. This approach adopted by Shell QGC demonstrates that Shell QGC has a process with milestones and auditable. Where there are drilling risks that are applicable to hydraulic stimulation (e.g., cementing, faults, borehole instability, etc) these have been included in the risk assessment.

Previous wells

Prior to this phase of the TGS project, five key wells (Narrene 1/1A, Overston 1, Overston 2/2A, Dunk 1, and Magnetic 1) have been drilled on the Overston 3D with significant data acquired including several free flow-test and one frac & flow test. This information has significantly de-risked the execution design and reduced the need for data acquisition in the northern region of the Overston 3D.

The location of the five QGC exploration wells across ATP645 is included in Figure 34.

Conceptual well design

The conceptual well design has been based on the premise that a drilling liner will be required to isolate the Intra-Rewan (a sub member of the Rewan Group) prior to drilling the lateral production hole section. A 4-string design with 7" drilling liner is the base case for all the planned seven wells.

NOTE: If borehole stability risks across the build section can be adequately mitigated, a 3-string design may be utilised for the four well Measure campaign by removing the 7" liner from the design.

Borehole stability will be discussed in Section 2.3.2.1, where drilling risks were assessed as a driver for the use of drilling fluids and additives.

Three Examine wells are planned at approximately 3,000 m true vertical depth (mTVD) targeting the Tinowon Formation. The lateral section length shall be approximately 1,000 m to 1500 m MD at approximately 4,000 m +/-.

The Appraisal wells will include an 8-1/2" pilot hole to 3,000 mTVD, which will be plugged back prior to drilling the build and lateral sections.

The four Measure wells are planned at approximately 3,000 mTVD. The lateral section length will also be 1,000 m with at MD approximately 4,000 m +/-.

Figure 3 shows the conceptual four string well design and schematic diagrams of the well designs. Table 3 presents the casing string summary.

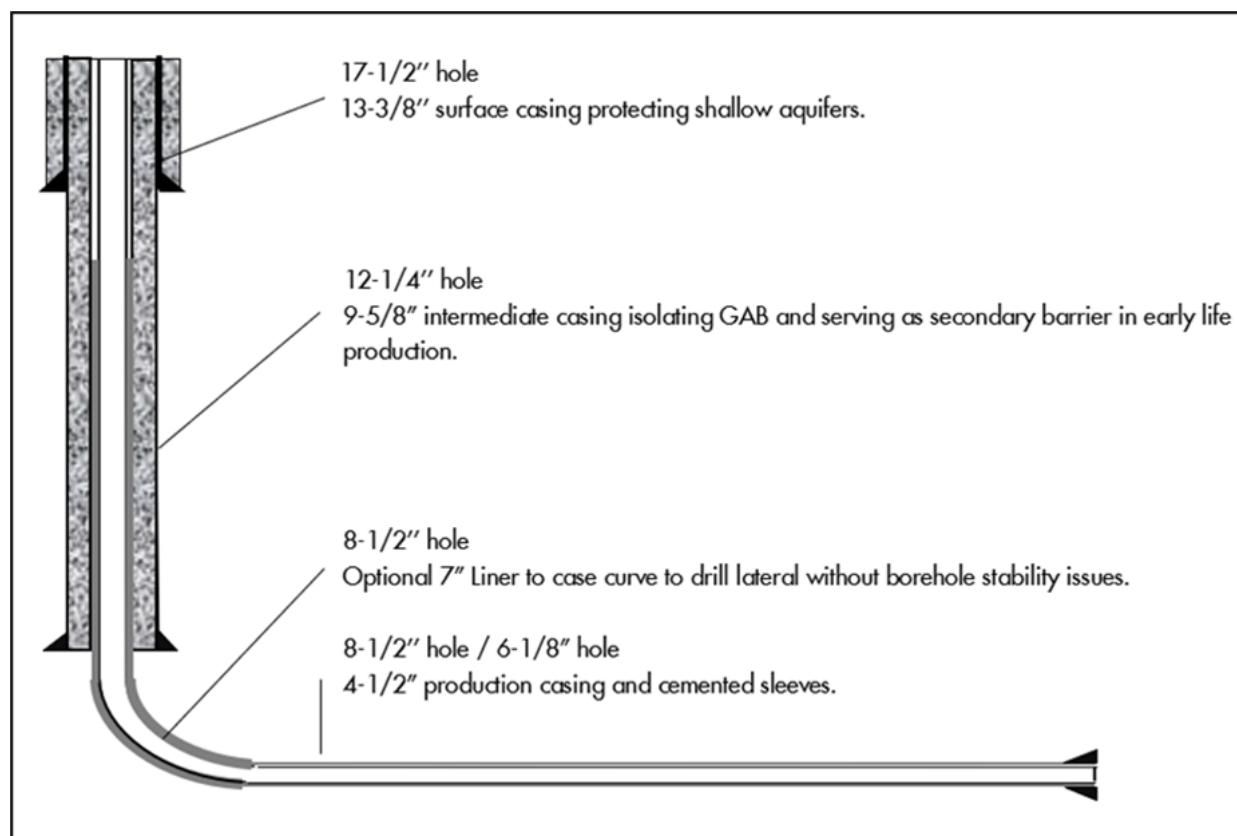


Figure 3 TGS Conceptual 4 String Well Design Base Case

Table 3 TGS project 4 string casing summary

Casing type	Size	Weight (ppf) ²	Wall thickness	Grade	Comments
Surface	13-3/8"	61	0.430"	J/K55	Exposure to shallow external environments
Intermediate	9-5/8"	53.5	0.545"	P110	Exposure to external environments and secondary barrier to production casing
	9-5/8"	47	0.472"	P1101CY	
Liner	7"	23	0.317"	P110	
	7"	23	0.317"	Q125	
Production	4½"	13.5	0.290"	P1101CY	Primary barrier during early life flow and secondary barrier after completion
Velocity String	2-3/8"	4.7	0.190"	J55	Sliding sleeve at bottom
Production Tubular	2-3/8"	4.7	0.190"	L80	Isolated A annulus with packer

² Pounds per feet

2.3.2 Drilling and casing

As part of the well design process, casing material types and depths are considered to ensure that complete well integrity is obtained. Shell QGC wells are designed with multiple sections of casing that become sequentially smaller in diameter as the well is drilled deeper. The advantages for installing multiple sections of casing include borehole stability, isolation of non-targeted formations, and well control (containment of gas and artesian flow of groundwater). In addition to the internal well design guidance documents (Section 2.3.1) Shell QGC meet the mandatory and recommended practices for casing type and depths outlined in the Code of Practice.

The well cased sections include surface, intermediate, and production sections. Depending on the geology of the well installation location, an additional liner section may also be used after the intermediate section, to seal-off a particular depth interval (the unstable Intra-Rewan), before the production section is drilled. The surface, intermediate, liner, and production casing sections are cemented, and pressure tested to ensure zonal isolation is achieved. Surface, intermediate, and liner sections are used to isolate non-targeted formations and to provide the well with well control integrity.

The production section forms the conduit for the hydraulic fracture stimulation fluid to be pumped into the target sands and for gas and produced water to be extracted. A final completion string is installed within the production casing which may include extraction pumps or pressure monitoring equipment to aid production from the well.

Project wells are installed and cased in accordance with:

- Casing and tubing design manual WS 38.80.31.31-Gen
- Wells Material Selection Project – TGS Examine (Version 1).

2.3.2.1 Consideration of drilling risks

Drilling risks have been identified for TGS project, which has allowed for optimum well design. These risks relate to the completion of the well installation. The highest risk sections, with reference to Table 3, are those below the 9-5/8" casing shoe (i.e., the 8½" pilot hole, build section and the 6-1/8" lateral).

The Borehole Stability Report, produced by Shell Pty geo-mechanics team in 2021, indicates that most drilling problems in ATP645 have been encountered in the build section (which includes the coal rich Kiangra). The numerous coals intersected during drilling, at higher inclinations, can provide risks to the well construction.

Fractures present in coal formations, which could compromise the mechanical strength of these formations, can contribute to borehole stability issues.

The loss of an appraisal well due to collapse, depending on location and depth, may lead to the creation of preferential flow paths for hydraulic stimulation fluids. This low risk is managed as follows:

- Drilling risks are managed through the proactive use of bridging materials to seal potential fractures in the coal bearing formations. Slot testing has been performed in the laboratory to select optimal bridging materials using fracture size data from offset TGS project wells.
- Any lost or collapsed wells, due to bore instability, will be managed according to:
 - Shell Well Abandonment Manual (WS 38.80.31.35-Gen. Revision 1.3)
 - Queensland Petroleum and Gas Inspectorate Code of Practice: For the construction and abandonment of petroleum wells and associated bores in Queensland.
 - Subsurface Isolation Strategy (Bowen TGS) (QCLNG-BA00-GEO-RPT-000002)
 - Approved and draft Well Abandonment Functional Specifications for TGS abandonment campaign in 2023
 - Shell Well Abandonment Manual. It should be noted that the referenced version of the Well Abandonment Manual (WS 38.80.31.35-Gen. Revision 1.1) is set to expire October 1, 2021.

It is, therefore, considered that the loss of an appraisal well and the generation of preferential flow paths for hydraulic stimulation fluids is well managed which negates this risk through:

- The well design, construction methods, and material selection reduce the potential instability risks leading to well abandonment.
- A detailed well abandonment strategy included in the Shell QGC Detailed Well Design Endorsement (DCAF 1394) document.

2.3.3 Surface completion

Wellheads and stimulation trees are the point at the surface of the well that allows safe access into and out of the well. The equipment that is installed onto the casing to provide a seal at the surface. The wellhead is critical in maintaining well integrity at surface.

Shell QGC uses wellheads in line with the Shell Wells Publication Wellhead and Tree Equipment Manual WS.38.80.31.37-Gen Revision 1.3 (Shell, 2021) and API specifications. The wellhead is generally divided into three sections: A Section (casing head), B section (tubing head) and the tree (Figure 4).

Each section serves as a point to isolate the well interior from the surface. Shell QGC and their suppliers follow stringent pressure testing procedures (API Spec 6A) to ensure that the wellheads are adequate barriers from downhole conditions.

For wellhead equipment is rated to the maximum anticipated pressure at surface. For the purposes of the stimulation a 15,000-psi pressure rated wellhead will be used for the first phase of the project. As per API 6A this equipment is tested to 1.5 of this rated working pressure value (i.e., 22,500 psi).

Included in the pressure rating of the wellhead is allowance for the sudden pressure / water hammer load. Wellhead failures in the industry that are attributed to the water hammer load occurred in slip on-weld (SOW) type of wellhead (welded). TGS project Appraisal wells will be equipment with threaded type of wellhead attached to the 13-3/8" surface casing reducing the risk of wellhead connection failures.

Regulatory Requirements - compliance

Section 3.8.2 of the Queensland Code of Practice outlines 'means of compliance' with the Code with respect to Wellheads. Key items for wellhead design from the section:

- b) Wellhead equipment and running tools must be specified in accordance with API Specification 6A/ISO 10423 and NACE MR0175/ISO 15156.
- c) Wellhead and production tree pressure ratings must exceed all reasonably expected loads for the entire life of the well. Wellhead product specification level (PSL) and trim must be matched to the fluid properties, pressure, and temperature of flowing conditions.

The three Examine wells shall utilise a compact RSH-2³ wellhead system sourced via Vault Pressure Control (formerly GE). The wellhead component specification is manufactured in accordance with API Spec 6A.

³ The Riser Speed Head (RSH) wellhead is designed to deliver maximum safety and well control for almost any well design

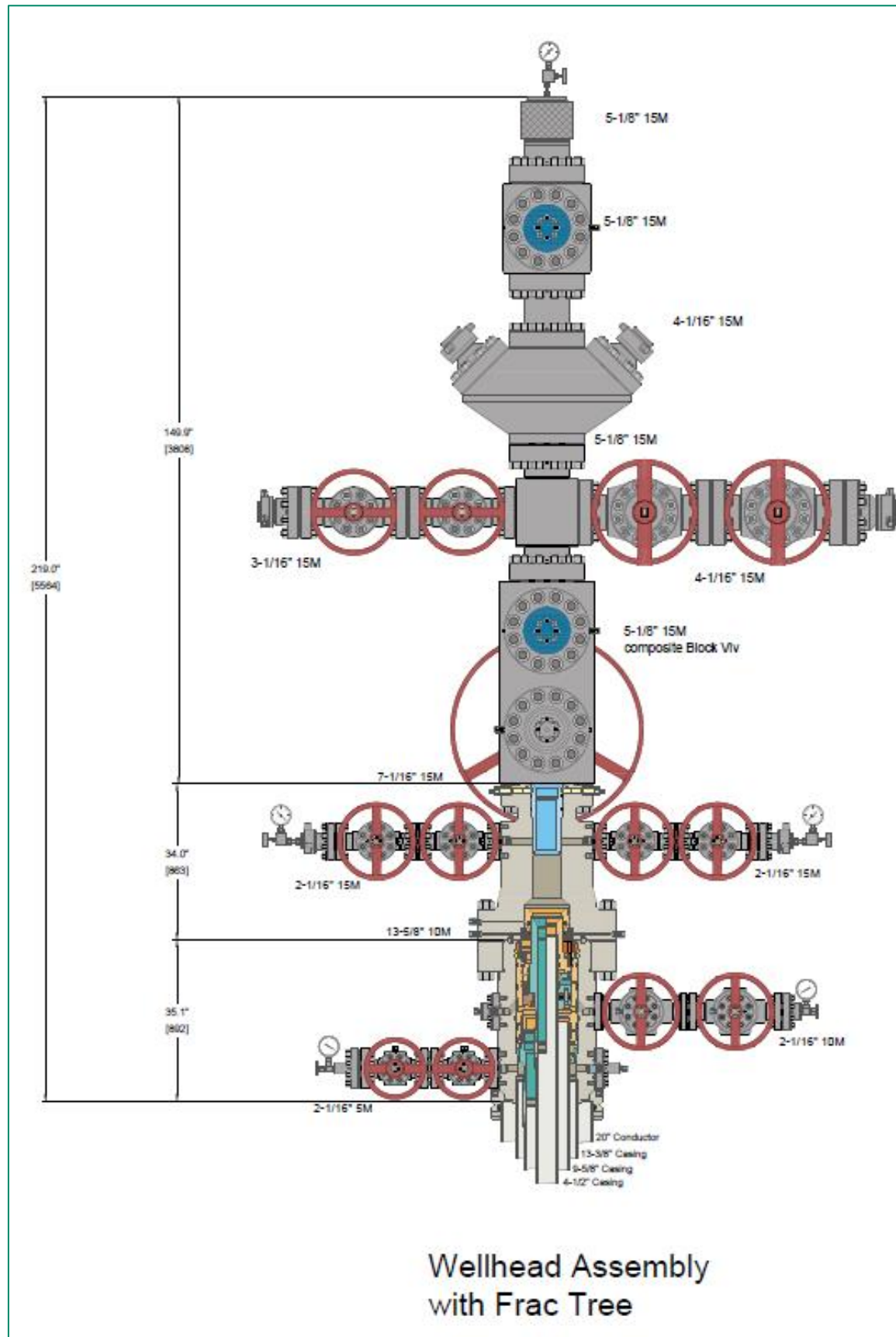


Figure 4 Typical wellhead with Frac tree, Flow-back tree, and Production tree (source: Vault pressure control)

2.3.4 Casing selection and installation procedures

The well casing (steel pipe), which QGC use for the construction of their TGS project wells, can withstand the compressive, tensile, and bending forces associated with the construction, operation, and abandonment of the well, as well as any potential corrosive groundwater conditions which may be encountered within the TGS project area.

The steel casing used is manufactured to comply with API standards 5B and 5CT, for which casing must meet strict tension, compression, collapse and burst resistance requirements. The casing conforms to API 5CT. API 5B provides specifications for API threaded connections (STC, LTC and Buttress), which is applicable to the surface casing. For the other casing strings premium connections are used, which are superior to those covered in API 5B. The acceptable premium connections are covered in the Casing and Design manual (below).

The TGS project wells are to be installed and cased in accordance with QGC manuals, including:

- Casing and tubing design manual WS 38.80.31.31-Gen
- Wells Material Selection Project – TGS Examine (Version 1).

These manuals ensure compliance with the following Shell QGC requirements:

- The well designer SHALL ensure that design check equations for all relevant design load scenarios are fulfilled
- Casing and tubing connections used for barrier elements SHALL be Shell approved
- Well construction materials SHALL be selected to withstand the construction and production fluids environment during their design lifetime.

Following the installation and cementing of the casing, Shell QGC performs casing pressure tests. The purpose of these tests is to ensure that the casing can withstand pressure which may be encountered during the life of the well. The pressure tests are completed following the installation of each string of casing.

As mandated by the Queensland Code of Practice, all wells which are hydraulically fractured are constructed using cement, casing, casing connections, wellheads, and valves capable of withstanding the hydraulic pressures used during the hydraulic fracture stimulation process.

During the installation of a string of casing in the borehole, each individual length of casing (referred to as a casing joint) is connected to the previous length of casing using casing grease (referred to as pipe dope⁴) that meets or exceeds the requirements outlined in recommended practice API 5A3. The casing joint is then tightened to within the recommended range of torque or in accordance with the torque-marker indicator on the casing.

API guidance documents highlight that too little torque may results in leaky connections; whilst over-torquing the connections may results in failures in the casing threads. The casing used by Shell QGC is threaded at each end and is designed to be screwed together using the drilling rigs mechanical jaws. Casing requiring welded connections is not used by Shell QGC. For the running of premium casing connections, a contractor that specialises in tubular running services (TRS) will be engaged for the installation of these joints of casing.

Shell QGC drilling teams and well site supervisors undertake onsite audits and supervision of the casing install process. The Shell QGC operating company representative and drilling manager conduct quality control over the casing installation process, this includes:

- Confirming the quality of the casing construction by checking the inner diameter, outer diameter, and grade of the casing
- Measuring the length of each individual length of casing ('strapping' the casing)
- Inspecting the casing and casing threads

⁴ The grease used, as supplied by the manufacturers, has been included in this risk assessment

- Reviewing the casing tally to ensure the correct installation depth
- Overseeing the casing installation process.

2.3.5 Logging of the borehole

Prior to the installation of the production casing Shell QGC conduct downhole borehole logging activities to assess the geological conditions of the strata within the immediate vicinity of the well. The logging tools determine the rock type, porosity, fluid quality, and fluid content of the measured formations. To obtain this petrophysical data several logging tools that use a variety of sensors and probes are run in the open borehole (prior to the installation of well casing) by a wireline operator.

The data is extracted from the tools and provided to Shell QGC as well logs. The well logs are analysed by Shell QGC petroleum engineers to assess the TGS target sands and formations. The depth intervals of the geological formations are interpreted from the well logs to ensure that aquifers will be isolated by the casing design.

Shell QGC also use the log outputs for planning the hydraulic fracture stimulation design and to design the well completion; including which tight sands the well will target and the zones for hydraulic fracture stimulation.

Borehole and well logging is performed in accordance with the QGC following:

- Design and Engineering Practice Specification Logging Program Design DEP 25.80.10.15-Gen. February 2023

The petrophysical logging tools used by QGC may include a combination of the following:

- **Caliper:** The caliper tool provides a measurement of the inside diameter of the borehole. The measurements are used to calculate borehole volume, a data input for the design of casing pressure cementing operations and to identify any zones where the borehole is undersized (referred to as a 'tight zone') or oversized (referred to as a 'washout') in the formation(s). If problem zones in the borehole are identified, remedies are used during the installation and cementing of casing.
- **Gamma Ray:** Gamma ray probes identify naturally occurring gamma radiation in the adjacent strata and are used to identify formation boundaries between low permeability clay-rich formations and higher permeability, coarser grained formations. Clean sandstone appears as low gamma readings whilst siltstone and mudstone appear as high readings.
- **Density and Neutron:** The density logging tool uses a radioactive source which emits medium energy gamma rays into the surrounding formation. Formations with a high density of electrons have a very low bulk density reading as most of the gamma emitted into the formation is lost into the formation. A formation with a low level of electrons has a high bulk density as there are fewer electrons to react with and the signal reflects. The combined density and neutron readings are used to estimate the porosity of all formations.
- **Resistivity Array:** The resistivity tool measures the electrical resistance of formations, using either inductions coils or laterolog (direct current) tools. The data output from this tool is used to derive in situ water saturation in the formations. It is noted that the in-situ water is not necessarily part of the groundwater ecosystem. This water may be trapped in ancient sedimentary sediments, which are not connected to surface recharge.
- **Sonic Log:** The sonic tools measure the travel time of an acoustic wave to be received by one or more transmitters. The transmitters then reconvert the acoustic wave into an electrical signal which is recorded on the petrophysical log. The sonic based logs are used to identify porosity and geomechanical rock properties with correlation and calibration to laboratory data.

Subsurface operation decisions

For the TGS project, upon completion of wireline logging there will be a subsurface decision point (essentially a 'go / no-go' on whether to drill the lateral) which is dependent of the presence, thickness, and quality assessment of the Tinowon Formation.

Upon completion of the well logs, sidewall core will be acquired across the Lorelle Formation and the Tinowon Formation (Figure 36), but the sidewall coring will not inform the 'go / no-go' decision. The decision will be made concurrently with plug-back operations and sidewall coring and in the 'go' case will also inform the exact landing point for the lateral (on the second and third wells there will be a period spent rigging up MPD⁵ and fingerprinting which will also help to mitigate the decision making from impacting critical path).

2.3.6 Cementing

The pressure cementing of the TGS project Appraisal and Measure wells is a highly controlled and engineered process. For each string of casing pressure cemented, on every well installed, a tailored cementing program is designed by specialised well cementing service companies. The cement program varies the density and volume of the cement used to match the purpose and design of the well and local geology. QGC conducts an independent review of each cement program and approves the design, prior to commencement of each cementing event (referred to as a cement 'job').

Well cementing is performed in accordance with the Cementing Manual WS 38.80.31.38-Gen (Shell, 2023b), API standards 10A, and API RP 10B-2, which are consulted by QGC and their cementing contractor when designing and testing the cement mixes.

The cement slurry design used is laboratory-tested by the cementing contractor prior to their arrival on site, to confirm suitability and ascertain curing times. Individual batches of additives are kept in the laboratory for a period of up to 6 months for quality controls.

The cement job consists of mixing water with cement on site 'on-the-fly' (i.e., cement is blended with water in the cementing unit just prior to being pumped down the well). This allows the cementer to control the density of the cement, as well as the pumping rate and the pumping pressure as the cement job proceeds.

During a cement job, cement slurry is pumped from surface, down the inside of the well casing; upon reaching the casing shoe, the cement slurry exits the casing and begins to return to surface from the bottom of the well, up the annulus between the casing and the natural geological formation around the casing. Once the volume of cement required to fill the annulus between the well casing and the natural formation has been pumped (including excess for safety) the cement is displaced from the interior of the casing with a brine fluid.

Cementing 'wiper plugs' are pumped down the well at various stages of the cementing operation, to both separate the cement slurry from the displacement brine, and to clear remnant cement from the interior wall of the casing.

Once the wiper plug reaches the casing float (a one-way valve located close to the bottom of the casing string), it forms a seal at the bottom of the casing string and the flow of fluid out of base of the casing string is blocked.

A pressure test is then conducted after cementing, noting that this pressure test is conducted at much lower pressures than the high-pressure test that is conducted at the start of completion operations prior to frac. This distinction is important, as Shell QGC do not want to balloon the casing with a high-pressure test immediately after cementing then bleed off that pressure, as it can result in a micro-annulus.

For the test pressure is raised inside the casing until the desired pressure is achieved for conducting a casing pressure test, at which point the casing is sealed at surface, 'shutting-in' the pressure in the casing. The pressure test consists of holding the pressure in the casing for a specified duration to confirm that the casing can hold pressure, thus confirming the integrity; the ability of the casing to isolate pressure within the casing from the surrounding geological formations. A typical pressure cement job setup is illustrated in Figure 5.

During the cement job a Shell QGC representative supervises the cementing contractor, to witness the actions of the cementer and confirm that the cement job proceeds without incident. Data from the

⁵ MPD, or Managed Pressure Drilling, is the use of specialized equipment (which can include such items as a Rotating Control Device, additional choke manifold, drill string check valves and fluid/solids control equipment among others) to control the pressure in a well being drilled. It is noted that Shell QGC will use MPD on all three Examine wells.

cementing unit including injection pressures, pumping rates and cement density is recorded throughout the cementing process. Samples of cement are taken at various times during the cement job as a quality control procedure to confirm the cement density and the required curing time.

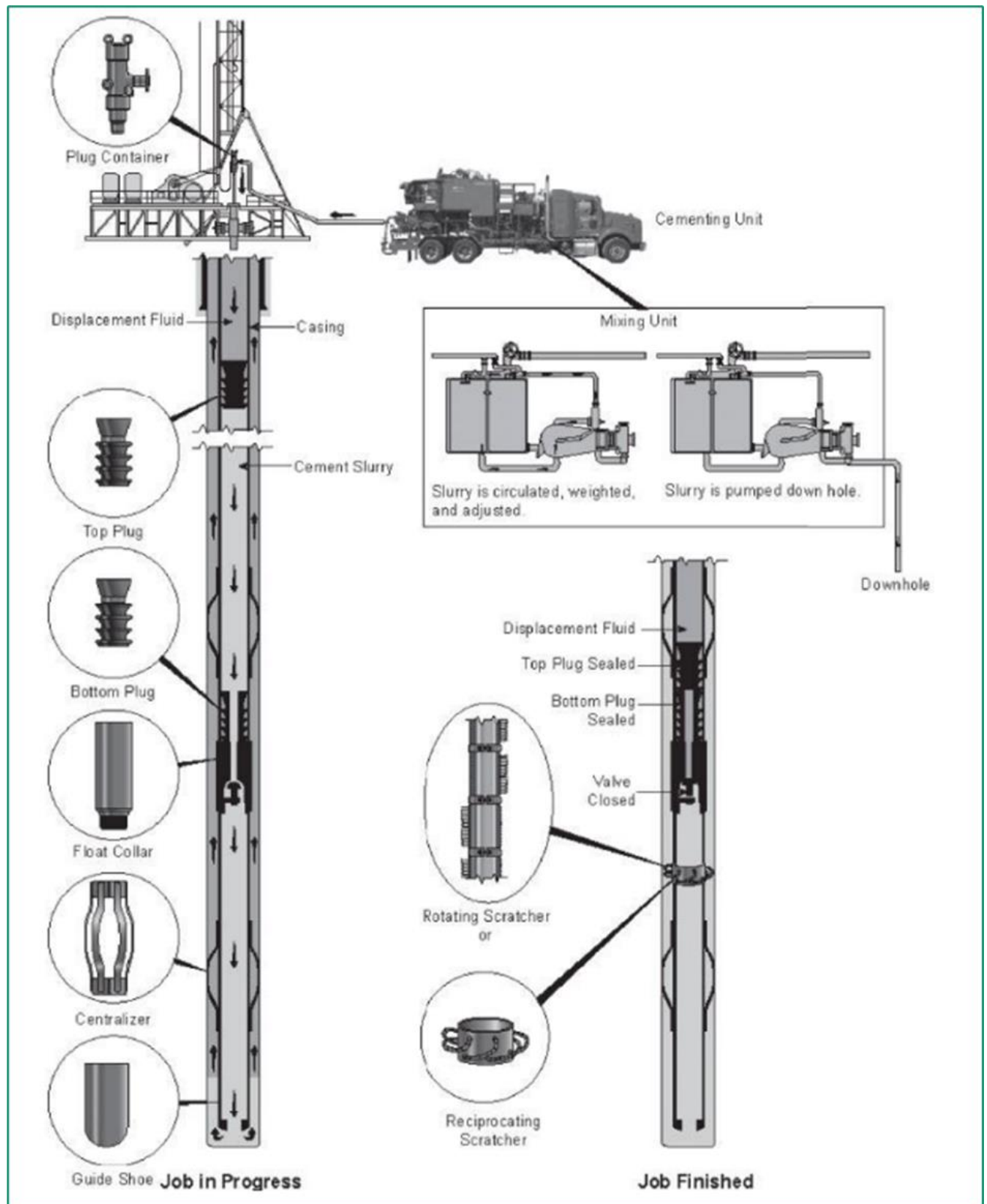


Figure 5 Pressure cement job equipment and setup (API, 2009)

The properly conducted application of cement will:

1. Evenly distribute cement in the annulus between the casing and formation(s)
2. Prevent migration paths and isolate the targeted zone from other formations
3. Protect groundwater resources from contamination
4. Maintain aquifer pressures and quality
5. Obtain and maintain well integrity
6. Protect the casing from corrosion.

The Queensland Code of Practice provides cement installation requirements to which Shell QGC adheres, these include:

1. Cement curing times
2. Minimum cement overlap depths between casing sections
3. Pressure testing parameters
4. Non-conforming cement job written notification procedures
5. Cement laboratory testing (in adherence with API RP10B-2)
6. Minimum compressive strengths and specific strength parameters for hydraulic fracture stimulation wells.
7. Restrictions regarding calcium chloride or other chloride-based accelerants
8. Minimum cement sheaths thickness
9. Casing centraliser use and placement frequency
10. Use of cementing wiper plugs.

API standards also supply industry best practices to the cement operators. The key cement application API standards that are used by QGC and their contractors are:

- API Spec 10A – Well Cements
- API RP 10F – Cement Float Equipment
- API 10B-2 - Well Cement Testing
- API 10B-3 – Cement Testing in Deepwater Well Construction
- API 10B-4 – Preparation and Testing of Foamed Cement
- API 10B-6 – Determining the Static Gel Strength of Cement
- API RP 65 – Part 2 Isolation of Potential Flow Zones
- API RP 10D – Specification for Bow-string Casing Centraliser
- API TR 10TR4 – Selection of centraliser.

2.3.7 Well integrity testing

Following the drilling, casing, and cementing of the well, isolation between each aquifer intersected by the well must be achieved to prevent both the leakage of groundwater between geological formations via the annulus of the well casing and the connection of the target sands from any overlying aquifers. This zonal isolation is achieved by ensuring sufficient cement is present throughout the annulus of the well casing, particularly in the depth intervals where natural aquitards are present. Evaluation is performed in accordance with the QGC Well Integrity Management Manual (Shell, 2023c).

To verify the effectiveness of the casing cement job, a downhole survey of the well is performed on all QGC wells to be stimulated using a cement bond and variable density logging tool (CBL-VDL). Typically, a gamma ray (GR) and Casing Collar Locator (CCL) tool is run concurrently with the CBL-VDL survey, so that the results can be correlated with any petrophysical surveys performed (Section 2.3.5). For the production hole, CBLs will be performed on all wells until repetitive success of slurry designs has been established. This is aligned with Section f) of section 3.6.3 in the code of practice.

If following the CBL-VDL log the cement job is deemed to be inadequate the hydraulic fracture stimulation will not be conducted. A secondary (remedial) cement job may then be performed on the well, prior to any further works (including hydraulic fracture stimulation) being conducted on the well.

The CBL tool is an acoustic device, the output of which can be used to infer quality of the bond between the casing and the surrounding cement; the cement bond quality can vary from a 'good' to 'non-existent' (free pipe). The tool transmits a continuous sound or vibration signal inside the casing and records the amplitude of the reflected signal. Casing that has a poor bond with the surrounding cement sheath produces a high amplitude returned acoustic signal, as most of the acoustic energy is reflected off the wall of the casing and surrounding fluid. Casing that has a good bond with the surrounding cement sheath will have a much smaller amplitude signal reflect to the tool, as a higher proportion of the acoustic energy is absorbed by the surrounding geological formation after it is transmitted via the better cement bond. The well will be filled with treated water post cementing of the production hole. The log will be run into the well to the point of resistance and then logged to surface. Through examining the trajectory of the well the CBL will cover the critical geological boundaries.

The VDL tool also provides a graphical representation of a reflected sonic waveform; however, the transmitter and receiver are located at an increased spacing on the logging tool compared to the CBL transmitter/receiver. This allows the VDL to interpret the quality of the bond between the cement sheath and the surrounding geological formation.

The CBL and VDL tools are complementary and always performed concurrently. An example of a CBL-VDL output (not related to this project) is presented as Figure 6. In this figure, the green line is a natural gamma plot (relevant to indicate permeability of the geology with respect to depth), the blue line is the CBL and the plot on the right is the VDL log, intervals of poor cement bond are represented by high peaks amplitude the blue plot and the thick black lines.

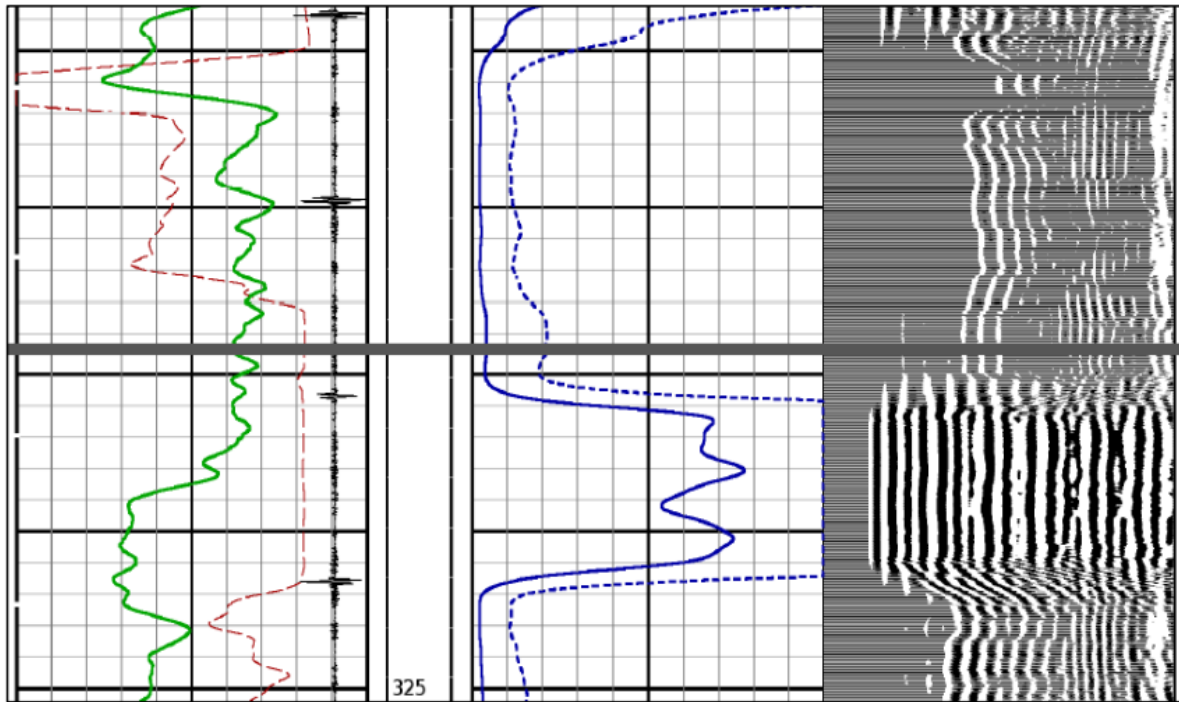


Figure 6 Example of a cement bond log, an integrity assessment technique

TGS project testing

The Design of Service draft document, dated March 2023, assumes the completion system for the first three Examine wells are cemented in place and that a landing dart and wiper ball will be pumped from the surface to clean the system of cement, and Toe-XT hydraulic sleeve activated to initiate the first treatment with successful casing pressure test (Section 2.3.6) and Diagnostic Fracture Injection Testing (DFIT) performed.

DFIT, also called mini-frac, mini fall-off or data frac, is a pressure transient test conducted to understand rock strength and potentially permeability and pressure information of a formation. This information enables better hydraulic stimulation parameter selection.

2.4 Hydraulic fracture stimulation

2.4.1 Background

2.4.1.1 Unconventional gas

Natural gas is combustible gas that is formed and held in underground deposits. This gas is composed mainly of methane with varying amounts of other trace gas elements depending on how and where it is formed. Some sources of natural gas are called 'unconventional' because they are more difficult to extract and require additional technology or effort beyond that required for conventional gas.

Unconventional gas types, vary depending on their geological origin and are divided into three main types:

- Coal seam gas (CSG) found in shallow coal seams
- Tight gas sands (TGS) are found in sandstone layers that do not have sufficient permeability (too 'tight') for the gas to flow through and hence trap the gas, and
- Shale gas is found in shale layers (see Figure 7 Natural gas resources (<http://www.eia.doe.gov>)).

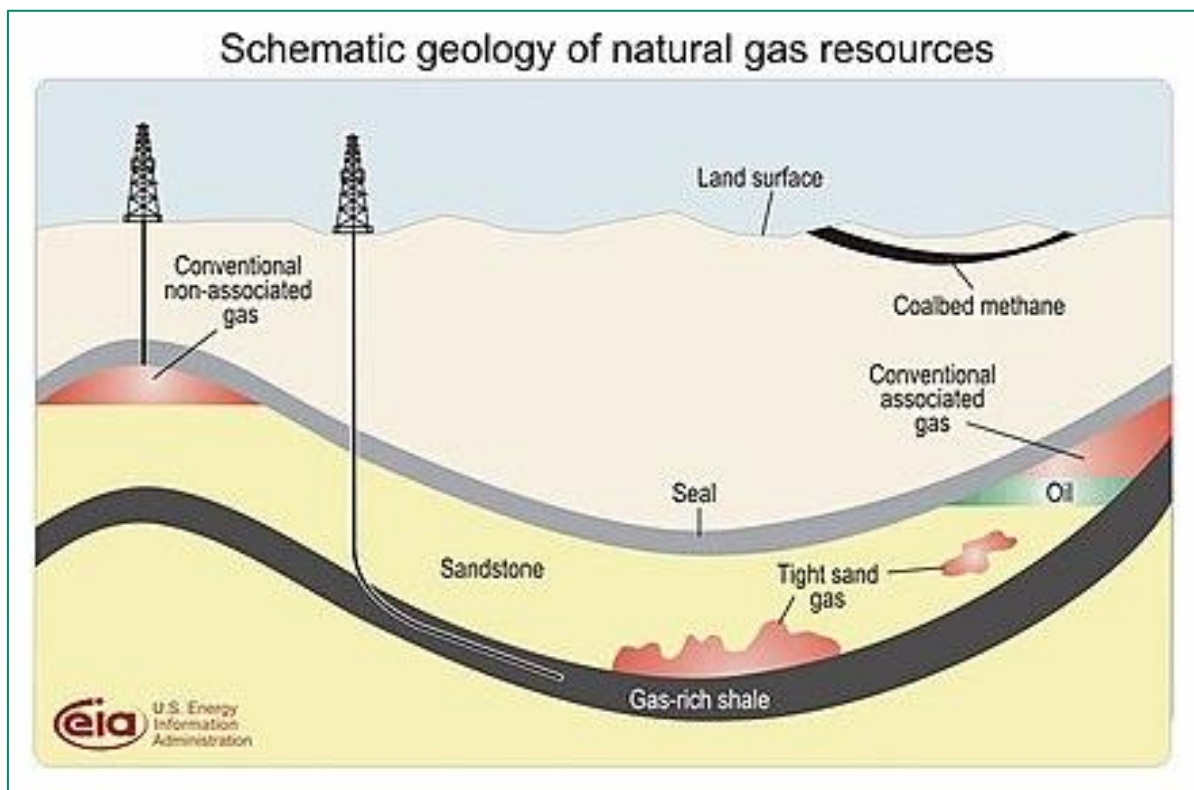


Figure 7 Natural gas resources (<http://www.eia.doe.gov>)

For the exploitation of deep gas deposits, also known as tight gas deposits, it is necessary to stimulate wells using a method known as hydraulic fracturing or hydraulic stimulation. This process requires the use of various chemicals which undergo a rigorous risk assessment prior to selection. Fracture stimulation is essential to commercially produce deep tight gas reservoirs, because the gas is often not initially mobile unless a significant pressure differential can be applied over the large inflow area of the fracture. For this reason, the wells are termed 'unconventional gas' wells.

Tight gas differs from coal seam gas in that the gas reservoirs can be comprised of sandstones, siltstones, and mudstones as well as coal seams, in this case the gas is within sandstone reservoirs. Typically, the reservoir rocks in the study area will be between 2,500 m and 4,500 m below surface (currently targeting the Tinowon Formation, some 3,000 m). These are significantly deeper than the existing CSG reservoirs produced in the Surat Basin.

2.4.1.2 Potential

Tight gas resources have long been known in Queensland. Historically, exploration for conventional petroleum throughout Queensland has identified formations with promising gas shows, while the reservoirs were evaluated as too tight. These basins include the Georgina, Adavale, Galilee, Cooper, Maryborough, and Laura basins. The utilisation of new drilling and completion technology resulted in renewed interest for exploring tight gas resources in sandstones of the Permian Tinowon Formation in the southwest Bowen Basin within the early 2000s.

The Bowen Basin succession contains multiple proven and potential source rocks. Geochemical studies have linked oil and gas accumulations in the southern Taroom Trough to coal and associated organic-rich sediments of the uppermost Permian coal measures (including the Kianga Formation), and the Triassic age Snake Creek Mudstone (**Appendix A.1.2.2**). Potential source rocks of relevance to shale and tight gas exploration are likely to be present within both coal-rich and marine Late Permian units, particularly the Black Alley Shale.

Between 2010 and 2015, Shell QGC undertook a tight gas exploration program in the southern Taroom Trough, drilling 7 wells. The results of the drilling campaign demonstrated that the basin has the necessary ingredients for large basin-centered gas/ liquids resources, which includes thick, low permeability reservoirs, abundant mature source rocks, and anomalous pressures.

Tight gas exploration in the southern Taroom Trough has focused on sandstone units in the Rewan Group, Kianga Formation, and Tinowon Formation. The Taroom Trough thickens and deepens to the north (Figure 8) (Hall, et al, 2018).

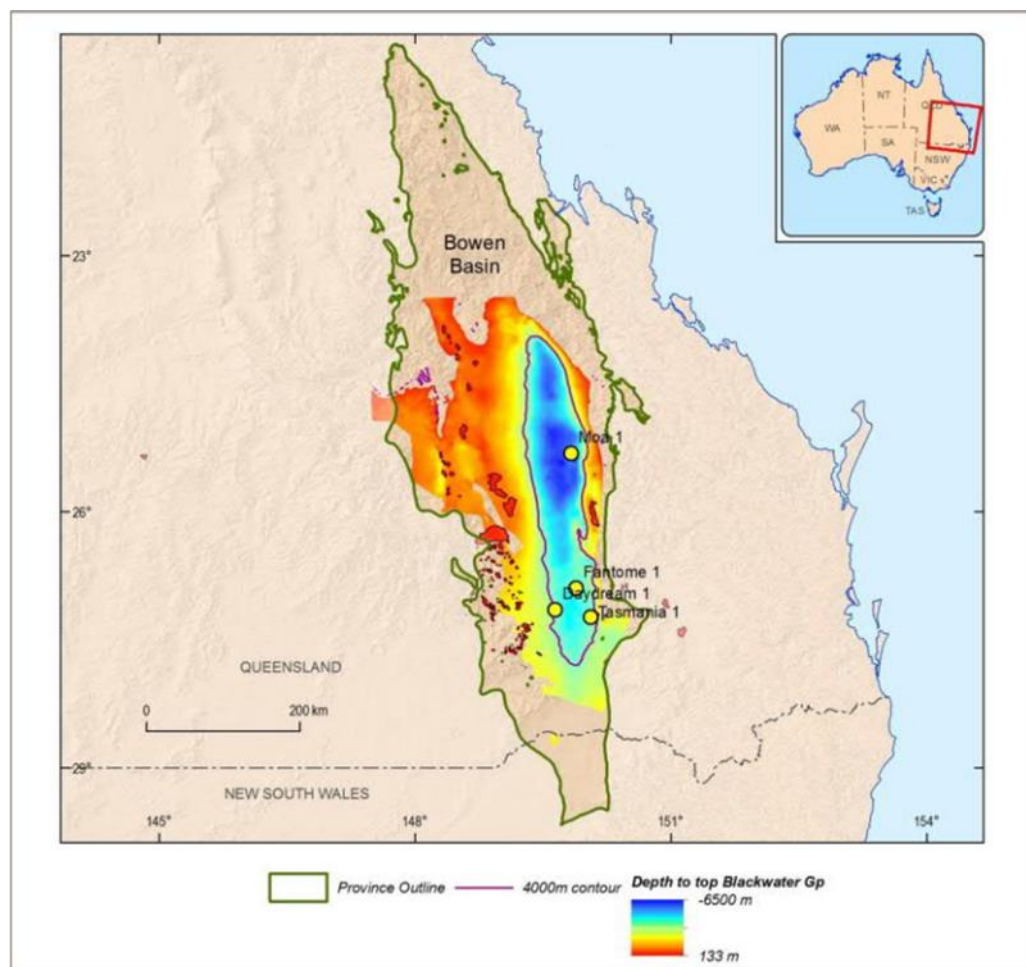


Figure 8 Wells targeting shale/tight gas plays shown on the depth grid for the base of the Rewan Group/top Bandanna Formation (source: Hall et al, 2018)

Note: Daydream 1 is located within ATP645

The Bowen Basin has some of the oldest petroleum wells in the country which have been producing from conventional fields for decades. Unconventional exploration unofficially commenced with Mosaic Energy chasing the Tinowon Formation as far back as 2004. Figure 9 shows the TGS project area of interest and underlying geology and previously drilled wells.

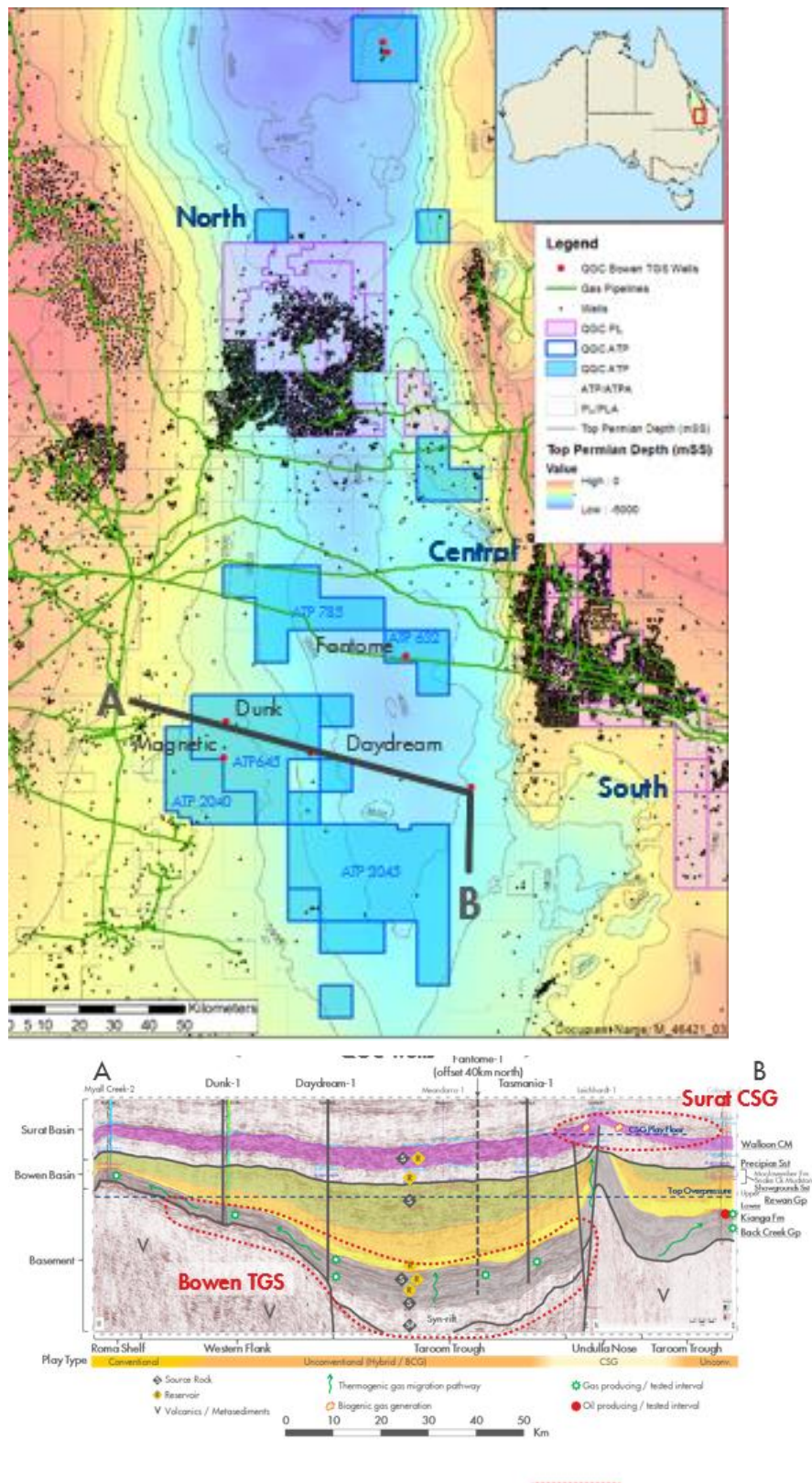


Figure 9 Taroomb Trough Focus Area

2.4.1.3 Appraisal

The TGS project (Examine and Measure) wells are drilled to quantify the size and nature of the gas resource.

For shale and tight gas, hydraulic fracturing is usually required to enable gas production. Hydraulic fracturing is a process where fluid and sand is injected at high pressure to re-open natural fractures and create pathways for gas to flow. Hydraulic fracturing requires significant volumes of water, typically in quite dry areas, which can present its own challenges and risks (Section 2.4.8.3 details the hydraulic stimulation source water).

Planned fracture stimulation

During Phase-1, wells entry points will be via sliding sleeves and a hydraulic opening toe sleeve. The toe sleeve will be used to simplify operations and enable the use of pump down balls and enable pumping DFIT.

2.4.2 Hydraulic stimulation overview

The hydraulic fracture stimulation process is a series of operations performed on gas production well, to increase the permeability of the target sands in the immediate surrounds of the well. The process consists of pumping fluid at a high pressure down the well then out into the target unit; the pressure of the fluid opens existing natural fractures and / or hydraulic stimulation induced fractures within the tight sands.

As the pressure is sustained the fractures propagate radially from the well, through the target sands. Once optimal fracture propagation has been achieved, uniformly grained sand or other propping material, referred to as “proppant” is pumped down the well and into the open fractures. The hydraulic fracture stimulation fluid carries the proppant in suspension. Once the pumping of fluid ceases, the proppant is deposited in the fractures. As pressure on the sands is removed, the fractures are held open by the proppant, thus the permeability within the tight sands is increased. This allows both liquid and gas to flow more readily, improving the efficiency of gas recovery from the well.

The target horizons are tight gas sands with a permeability of less than 0.05 milliDarcies (mD). Multiple fractures (15 - 30 per well for 1,000 – 2,000 m lateral length per well) are typically placed over a substantial interval (1,000 – 2,000 m) to achieve an adequate permeable thickness for potentially commercial gas production rates at this depth.

2.4.2.1 In-situ differential stresses

In-situ stress and the relative stress difference between geologic strata are important influences on fracture development. A formation underground has the weight of overlying strata and the constriction of lateral movement to create stress in the formation. These stresses occur in three dimensions, defining a maximum stress direction, intermediate stress direction, and minimum stress direction. These stresses are normally compressive and vary in magnitude throughout the stratigraphy, particularly in the vertical direction (from layer to layer).

The magnitude and direction of the stresses are important because they control the pressure required to create and propagate a fracture, the shape and vertical extent of the fracture, and the direction of the fracture. To initiate and propagate a fracture, the minimum stress must be overcome by the pressure of the fracturing fluid. In a uniform medium, the plane of a fracture is perpendicular to the direction of the minimum stress, (i.e., fractures propagate parallel to maximum and intermediate stress, opening against minimum stress).

At the ~ 3,000 m depths, targeted for the TGS project, the direction of minimum stress is in a horizontal direction and so a vertical fracture is likely to be created. This is supported by the hydraulic fracture stimulation model (Section 2.4.3).

2.4.3 Containment of hydraulic fracture stimulation

Containment of hydraulic fracture stimulation within the target strata is provided by lithologic stress barriers. Low stress rock provides a preferential fluid ‘sink’ during fluid injection, whereas high stress rock (siltstone and shale) are barriers to fluid flow, (i.e., the fluid/pressure wave is arrested at high stress barriers).

High and low stress rocks can be readily identified from dipole-sonic wireline logs, which are run prior to hydraulic fracture stimulation. The dipole-sonic logs are calibrated using rock strength and/or closure pressure data from DFITS, leak-off tests or ISIP (instantaneous shut-in pressure). The calibrated dipole sonic logs are used to build a mechanical earth model, which is generated to identify stress barriers. The process of generating a Gohfer Static Model (Figure 10).

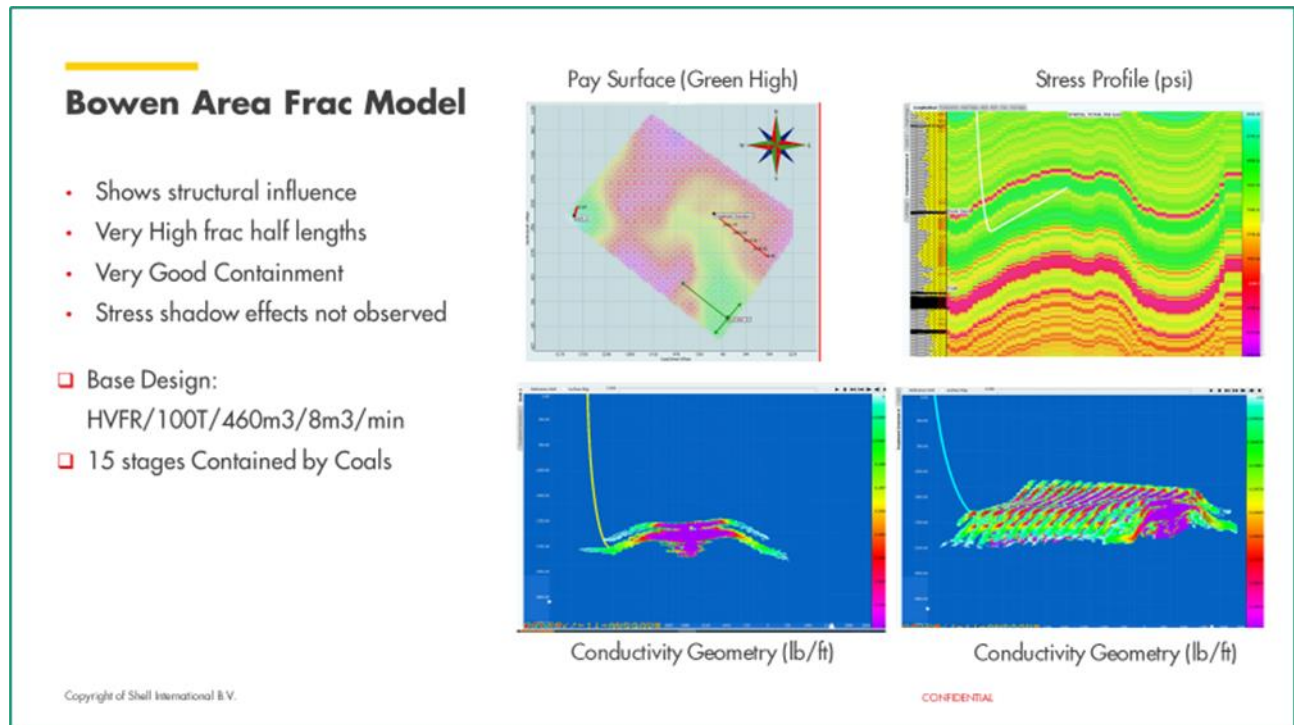


Figure 10 TGS Project hydraulic stimulation ‘frac’ model

The identification of stress barriers in combination with the controlled hydraulic fracture stimulation are used in hydraulic fracture stimulation design modelling software package (Gohfer). Using stress barriers and initiation points as inputs, hydraulic fracture stimulation is designed to limit pressures and injected fluid volume to contain height growth into the target formations, thereby avoiding the potential for inadvertent injection into overlying or underlying units.

The hydraulic stimulation modelling aids in ensuring the fractures do not extend outside the pre-identified regional cap rocks. For the TGS project the hydraulic stimulation approach will ensure the fractures remain within the Back Creek Group (Figure 36).

Fracture treatment designs are formulated using an in-house developed routine (macro) that uses open-hole logs, formation thickness, depth (as proxy for stress state) and permeability data. The macro honours prescribed stand-off distances from identified geohazards or between treatment zones. These designs are then reviewed manually by subsurface teams for cross validation and for any possible manual modifications based on either field observations during previous operations or results from detailed modelling done on a few selected wells or zones using the hydraulic fracture stimulation design modelling software package (Figure 10).

A secondary safeguard is in place during the actual pumping, at the stage when pressure diagnostics indicate excessive height growth (e.g., related to small faults), that stage of hydraulic fracture stimulation is stopped.

Historic hydraulic fracture stimulation

Hydraulic stimulation at exploration well Dunk #1 (Figure 34) was conducted, which aimed at a 40 m thick sandstone in the Late Permian Tinowon Formation. The target sand identified within Dunk #1 is included in Figure 11.

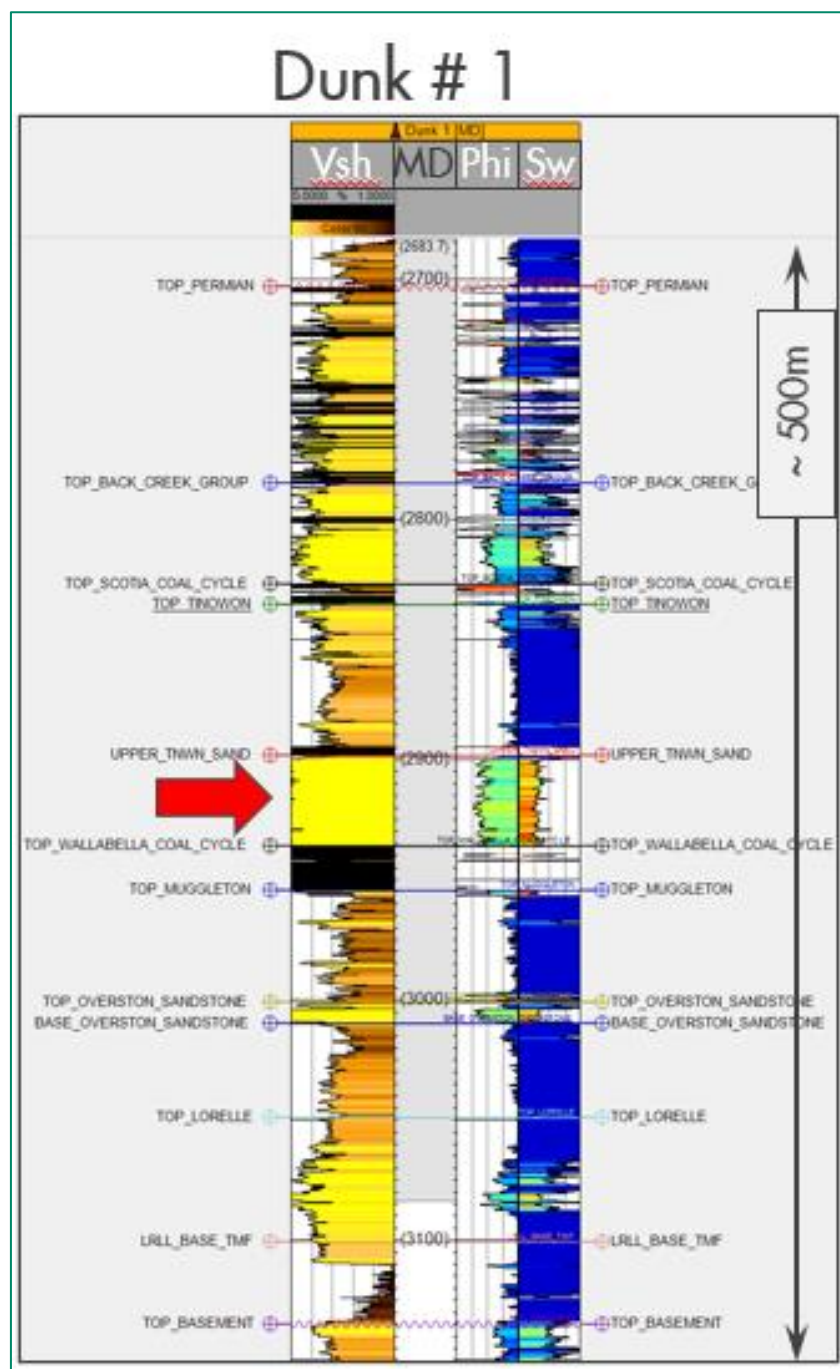


Figure 11 Dunk #1 target sand

Observations made during the hydraulic stimulation modelling process indicated that:

- All modelled hydraulic stimulation (frac) stages were contained within the sand layers
- The modelled fracs did not extend beyond the interbedded coals, even in frac stages close to coals
- The most likely frac height was 52 m (range 46 to 55 m)
- Modelling indicated that the risk of frac out of containment zone in the Dunk well area is low (i.e., the confidence in frac containment is high)
- Downward frac propagation will be contained by the Wallabella coal (i.e., a frac barrier)
- Offset well review is required if wells are within 1,600 m of existing wells.

Hydraulic fracture stimulation model

Based on current frac modelling, the expected conductive frac length in the current well designs are approximately 70 to 400 m with a high confidence that hydraulic fracture half lengths will not exceed 1,400 m offset in direction of Sigma Max (Figure 12).

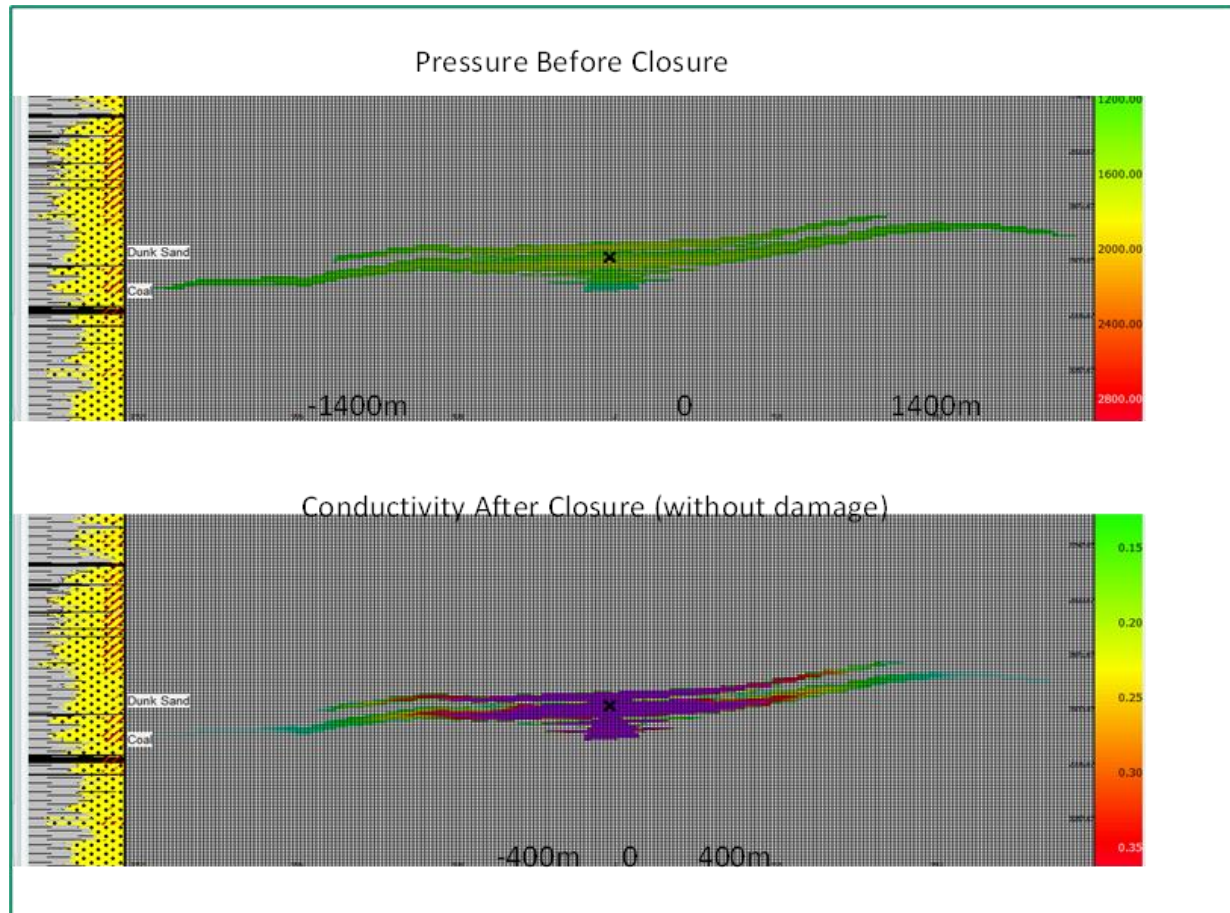


Figure 12 Example of pressure and conductivity models before and after frac closure

A summary of the hydraulic fracture stimulation model indicated:

- Modelling indicates no change to hydraulic stimulation design required or recommended
- Low risk of interwell connectivity (IWC) based on limited risk for fracs extending out of zone
- No execution issues were evident
- Basis of Design (100T HVFR⁶)
- Hydraulic fracture XL (half length) of 1,400 m
- Conductive length 70 m to 400 m
- Effective length 35 m to 200 m (assumed 50% of conductive).

⁶ HVFR - high-viscosity friction reducers, a high-salinity (150,000 mg/L TDS brine) which improves proppant transport

Verification of fracturing

To assure that fracture containment within the deep gas reservoir, Shell QGC undertakes fracturing risk assessment and the development of a management plan. This includes a multi-disciplinary assessment by several departments within Shell QGC of the perceived risks to people, assets, environment, reputation, and social risks in several areas, including:

- Wellbore, casing, and cement bond integrity
- Geology and hydrogeology
- Geo-mechanics and localised faulting
- Planned chemical usage
- Fluids recovery and disposal
- Monitoring plans.

The in-house risk assessment identifies the nearest aquifer, the potential existence of unknown aquifers, the known barriers to fracture height growth, the well construction details, the potential for 'non optimal hydraulic fracture design', non-compliance to EA conditions, and bores within the vicinity. The likelihood and severity of potential hazards are identified, and the resultant risk calculated.

The review process also defines the areas of accountability, responsibility, and consultation for each component of the risk assessment, requiring multi-departmental discussions and understanding to ensure all teams are aligned to develop practicable and achievable outcomes.

According to EA requirements, chemical analyses of pumped fluids and post-treatment fluid production (flow back) will be performed on each treated well, as well as on neighbouring water bores within 2 km laterally of the stimulation well and in an aquifer that is within 200 m vertically of the target formation (in-line with the Environmental Authorities). Well integrity assessment shall be conducted with all wells within 2,000 m radius and a simultaneous operations risk assessment (SIMOPS) plan prepared, with reference to Bowen Area Fracture Modelling in Gohfer (Shell, 2021).

Requirements for timing/frequency of the groundwater monitoring of neighbouring bores (if present) are specified in the Environmental Authority, and include monthly monitoring during the first six months following hydraulic fracturing, and annual monitoring for the first five years following hydraulic fracturing (or until analytes are not detected above baseline monitoring data for two consecutive monitoring events)

To better differentiate the downhole gas reservoirs and to understand fluid and gas recovery on a zone-by-zone basis, Shell QGC may incorporate chemical tracers in selected treatments in each geological area. These chemical tracers could be commercially available tracers that can be added in known concentrations and easily identified during post-fracture flow-back analyses. Different tracers can be applied for gas and fluids. By studying this in several wells, some general trends in flow-back behaviours and post-fracture clean-up should be discernible. The final selection of tracers has not been concluded at the time this report was written and as such the use of chemical tracers is not included in this initial risk assessment. Should chemical tracers be selected and approved internally at Shell QGC, a separate risk assessment on the chemical tracers will be provided at that time.

2.4.4 Pre-Hydraulic Stimulation Activities

Prior to commencing mobilisation for hydraulic stimulation, the contractor working closely with Shell QGC will undertake a health and safety risk assessment and produce the health and safety management plan for the operations in accordance with the *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act).

The well site is evaluated for environmental and social constraints, and the site layout designed accordingly (e.g., hydraulic stimulation above ground tank location, security, waste management requirements).

Set-up / layout

The frac spread will be laid out to ensure operations can be carried out in an efficient and safe manner. All storage areas will be positioned a safe distance from the hazardous areas. Fracturing pumps and equipment have been positioned close to the wellhead whilst still allowing for access behind the spread, space to refuel, load sand and transfer chemicals once rigged up.

2.4.5 Design and safe operating limits

The design principles used by Shell QGC aim to maximise the zone of influence of each hydraulic fracture stimulation operation (i.e., each frac).

As part of the hydraulic fracture stimulation design process for a production well, Shell QGC engineers have conducted fracture stimulation modelling and testing. From this modelling and testing, the target sands within a well to be hydraulically fractured are selected.

For Appraisal, each well is completed with multi-stage of 15 stages with 1 x Toe-XT II Hydraulic Sleeve for the first stage and 15 x H3 Diffusor Sleeve™, each comprising 6 Slots (equal space) of 0.88" (dia.) x 3.00" length.

For each hydraulic fracture stimulation event, Shell QGC engineers determine a safe operating envelope for injection pressure. The safe operating envelope is selected based on the following considerations:

- CBL results
- Mechanical earth model (see Section 2.4.3)
- Hydraulic fracture stimulation models (see Section 2.4.3)
- Historical tracer results
- Relevant legislation
- Internal and external standards.

If at any stage during the process there is potential for deviation from the established pressure envelope, operations are ceased.

2.4.6 Control

The hydraulic fracture stimulation approach used to stimulate the TGS project wells may differ across the project area due to local characteristics of geology and depth, effectiveness, production characteristics, or other factors. The fracturing approach affects the development (height, length, and width) of hydraulically induced fractures.

The choice of fracturing fluid (e.g., water or gel based) also affects fracture dimensions. Shell globally has performed several laboratories studies and field operations using different fluid systems. Water and gel based fracturing fluids have been also modelled investigating the impact on fracture propagation and geometry.

The High Viscosity Friction Reducer (HVFR) is the preferred fracturing fluid system for the TGS Project because of its ability to reduce pipe friction, high proppant volume placement, potential to create more fracture networks, use fewer additives (decreasing the relative environment footprint), and improved production results. The HVFR is, according to Shell QGC, also considered more suitable from an environmental perspective compared to the traditional cross linked borate systems.

The effects of these fluid-controlled actions interact with and are influenced by the physical properties, depths, and in-situ stress of the geologic formations being fractured. For example, if a hydraulically induced fracture has a relatively constant height due to a geologic layer acting as a barrier to fracture propagation, and the fracture is forced to grow and increase in volume (through an increased volume of fracturing fluid), the fracture will mainly grow in length.

Horizontal fracture geometry varies based on the range of factors discussed above. Based on current frac modelling, the expected conductive frac length in the current well designs are approximately 70 to 400 m with a high confidence that hydraulic fracture half lengths will not exceed 1,400 m offset in direction of Sigma Max.

Well integrity assessment shall be conducted with all wells within 2 km radius and a SIMOPS plan prepared (reference Bowen Area Fracture modelling in Gohfer Final Oct4-2021).

Pumping Operations Testing & Pressure Limitations

The Appraisal stimulation design includes ~100T per stage of silica sand proppant, which will be comprised of a mix of 70/140 mesh and 40/70 mesh proppants. The frac is designed with up to 625 m³ per stage (including contingency and working fluid) HVFR fluid (consisting mostly of water-soluble Polyacrylamide) with biocide and scale inhibitor. Future stimulation designs may be change from the above based on the outcome of the initial stimulations considering the risks and controls outlined in this document.

2.4.7 Preparation

The following will be conducted in preparation for the hydraulic fracture stimulation:

1. The lease will be inspected prior to mobilisation to ensure suitability for operations.
2. Prior to mobilisation a permit will need to be issued to mobilise equipment onsite.
3. Confirm all necessary pre-mobilisation forms/documents are in place.
 - a. All employees have completed Shell QGC required contractor's inductions.
 - b. All necessary units have a weed and seed declaration (self-declaration) and carry a copy of this.
 - c. All employees to ensure they follow any Queensland mandated health protocols.
4. A toolbox meeting will be conducted prior to mobilisation to go through the operational plan, safety plan, and review the risk assessment.
5. A chemical/proppant mobilisation plan is to be agreed upon with QGC to ensure all required materials are delivered to site.
6. Chemicals are to be left in appropriate bunding and correctly segregated in accordance with the Shell QGC Quality, Health, and Safety Management system. Chemicals are transported according to the Australian Dangerous Goods Code.
7. A mobilisation plan will be submitted to QGC and any 3rd party transport provider to ensure the number of vehicles entering the site and to ensure all vehicles comply with the site's regulations.
8. A signed copy of the QGC well program and wellsite emergency response plan (ERP) to be verified and confirmed on site. Shell QGC permit to work system to be implemented.

2.4.8 Operation

Each treatment is pumped through a 15,000-psi wellhead and 4½" production casing⁷. The wellhead and treating lines will be pressure tested prior to pumping downhole. Fracture stimulation operations will occur during the day. Day operations also include moving equipment, material loading and operational preparation.

All the Appraisal well frac stages will be pumped through the 15,000-psi rated wellheads. Up to 4 fracture stimulation treatments will be performed during the dayshift.

⁷ It is noted that the production casing diameter and wellhead may change for future campaigns depending on the pressures identified during the Examine phase. Thus, the casing size may increase to 5.5" and reduce installed wellhead equipment with a pressure rating of 10,000 psi.

The basic outline of the operations involved include:

1. Mobilise Frac Spread to site.
2. Rig up Frac spread on site.
3. Pressure test all surface equipment
4. Function Test pressure reduction valves (PRVs), gas and spring operated PRVs
5. Perform Frac Operations
 - a. Drop ball and displace ball to desired depth (not required on 1st stage).
 - b. Record sleeve shift parameters (peak, trough, breakdown / not required on 1st stage).
 - c. Inject inhibited hydrochloric acid (if required) and perform frac as per program.
 - d. Perform stimulation treatment as per QGC approved pumping schedule.
 - e. Record pressures, plots, and post-job data required.
 - f. Repeat stimulation treatment until all stages have been completed.
6. Rig down and demobilise.

Shell QGC hydraulic fracture stimulation specialists continuously monitor the progress of each hydraulic fracture stimulation operation, to ensure that work is being conducted in line with Shell QGC policies and procedures. Monitoring is in real-time plus site visits are conducted throughout the campaign.

2.4.8.1 Site setup

The hydraulic fracture stimulation operation requires various pieces of equipment, these may include:

- Data unit – The control room from where the hydraulic fracture stimulation contractor and QGC supervisor manage and monitor all aspects of the hydraulic fracture stimulation operation including surface and downhole pressures, injection flow rates and volumes, injected fluid parameters and proppant concentrations. Data Acquisition System comprises a heavy rigid body load truck, with client workstations, QA/QC laboratory for fluids including returns, and communications.
- Temporary above-ground tank - A large above ground tank with sufficient storage capacity (10 ML) used to store water and supply it to the hydraulic fracture stimulation operation as required. The above ground tanks are also be used to temporarily store hydraulic fracture stimulation flowback fluid from the Appraisal well hydraulic fracture stimulation.
- Proppant trailer: a large sand storage and delivery trailer that holds the proppant prior to mixing in the Blender Unit.
- Sand storage unit (two) 3,000 cu ft 4 bins, 1 proppant loading belt for bulk bag loading
- Hydration units: pumps and tanks used to mix the HVFR and water, which forms the basis of fluid viscosity in the hydraulic fracture stimulation fluid.
- Blender unit: pumps which mix the water, proppant, and hydraulic fracture stimulation chemicals on surface to achieve the required fluid consistency, prior to its injection into the well. Fluid is mixed “on-the-fly” as required throughout pumping procedures.
- Ten (10) 2,250 HHP Frac pumps, which are trailer mounted units. 2,500 BHP at 1,900 RPM. 4.0” fluid ends.
- Hydraulic fracture stimulation wellhead and surface lines: a network of pipes and pressure control valves that connect to the high-pressure pumps to the well.
- Coiled tubing unit (if required): a large length of coiled steel pipe that can be temporarily installed in the well to convey hydraulic fracture stimulation fluid from surface to the target depth interval to be fractured. The coil can use several bottom hole assemblies (BHAs) to deploy the hydraulic fracture stimulation.
- Flowback tanks: HydrEra aboveground storage panel tanks, typically 18 panel and 67.6 m in diameter, with approximately 3.6 ML per 1 m wall height storage capacity, are to be used to

temporarily hold all fluid and proppant that flows back from the well following the hydraulic fracture stimulation procedure. These tanks may be open-topped or sealed, depending on the requirements of the hydraulic fracture stimulation operation.

- 500 barrel (bbl), 21,000 gallon / 80,000 litre volume Frac tank.
- Layout and hydraulic stimulation equipment, set-up up to ensure operations can be carried out in an efficient and safe manner, is included in Figure 13. All storage areas will be positioned a safe distance from the hazardous areas. Fracturing pumps and equipment have been positioned close to the wellhead whilst still allowing for access behind the spread, space to refuel, load sand and transfer chemicals once rigged up.

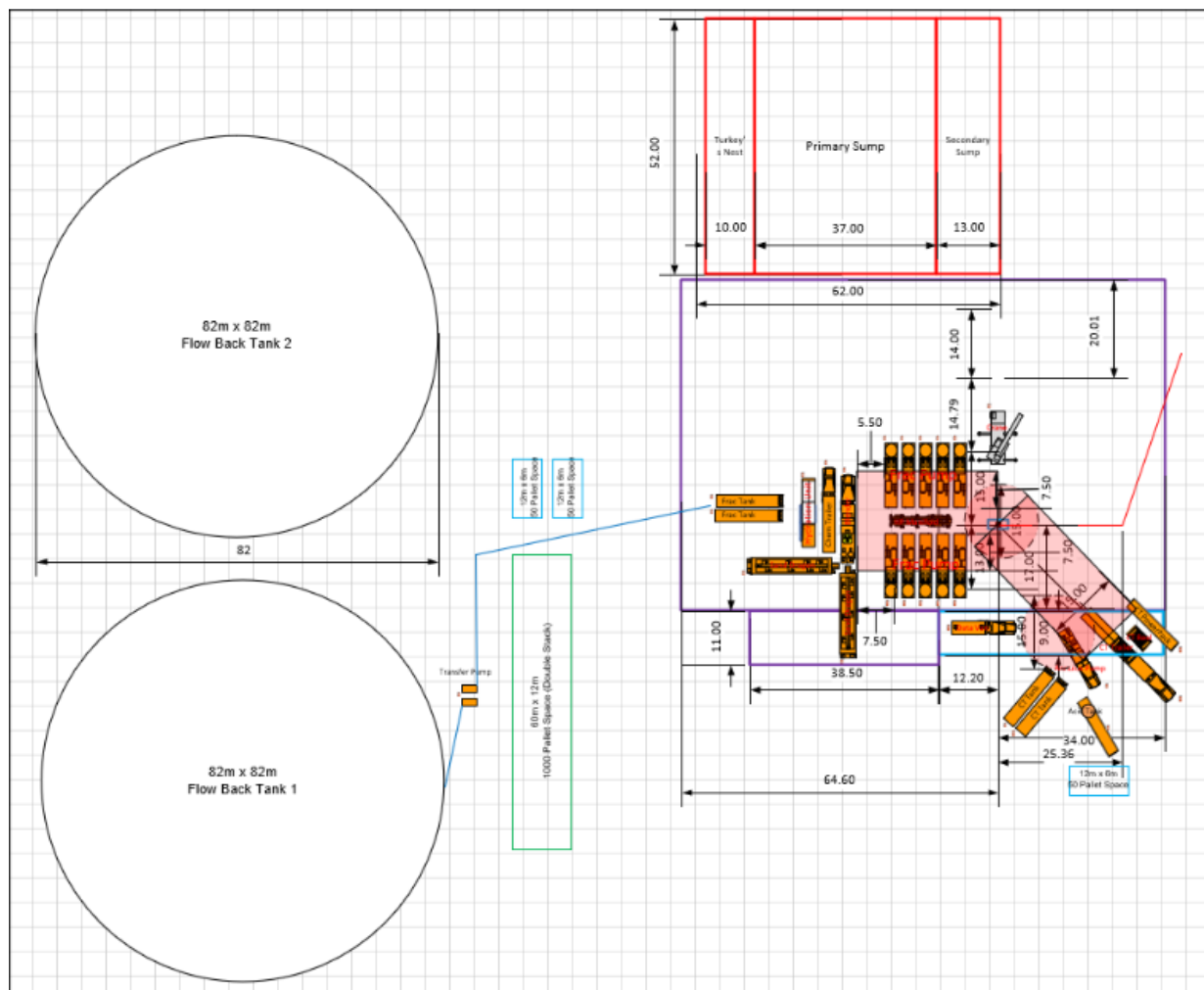


Figure 13 Example of Hydraulic Stimulation Lease Layout

2.4.8.2 Reservoir Access

There are several ways in which the production casing can be connected with the target tight sands reservoir. The two most common methods are plug and perf and single point entry (SPE).

For the Appraisal phase of the TGS project a SPE design has been adopted. This single point entry system comprises of a hydraulic toe port at the base of the well and cemented sleeves placed along the remaining lateral length of the well.

The toe-port is activated hydraulically, with the well pressured up to a pre-determined pressure to activate the port. The remaining 15 stages use the dropping of a ball to seat on a baffle, which is integral to the cement sleeve. Once the balls seats on the baffle a pressure differential is created across the baffle shifting the sleeve open and allowing a new conduit to the reservoir.

An alternative method which may be used in future appraisal wells is plug and perf. Similar to SPE method, a toe port is placed at the toe of the well. In place of cemented sleeves, however, an isolating plug and perforation guns are conveyed into the well. The perforating guns use an explosive shaped charge to penetrate the casing wall and provide a pathway to the reservoir. Once the stage is stimulated via the perforations, a plug is placed above that stage and the process repeated up the lateral length of the wellbore.

2.4.8.3 Hydraulic fracture stimulation source water

Water requirements for drilling and stimulation of appraisal wells shall be trucked from either the existing Magnetic GW1 water bore, or the new water bore (located at Overston Pad) to dedicated storage tanks located on each lease.

Temporary facilities, including truck turn-out, shall be installed adjacent to the Magnetic GW1 water bore to avoid impinging rig access for Plug and Abandonment (P&A) of the Magnetic 1 exploration well (both wells are on the same well pad).

The target water source aquifer for the TGS project, the Cretaceous age Mooga Sandstone, which was selected as water source. This GAB aquifer, some 500 to 600 m below surface within ATP645, was selected due to:

- The Mooga Sandstone is not used as a water source in the ATP645 area for domestic and farming use, as these activities use water from the shallower Cretaceous age Griman Creek Formation.
- As the Mooga Sandstone is not being used in the area as a water source the proposed Shell QGC water use does not compete with other local users,
- The risk to existing water supply availability within the Cretaceous Griman Creek aquifer is low.
- The Cretaceous Orallo Formation, a regional aquitard, underlies the Mooga Sandstone and provides up to 200 m of separation from the other closest aquifer the underlying Gubberamunda Sandstone (some 1,000 m below surface at ATP645). The deepest Jurassic age aquifer is the Precipice Sandstone at 1,300 m below ground level (mbgl).

From various monitoring programs of water bores in QGC tenements, as well as regulator reviews, vertical propagation of pressure drawdown to these GAB aquifers (the Gubberamunda Sandstone and Precipice Sandstone) is considered negligible. Therefore, the risk to existing deep aquifers (not currently in use at ATP645) with extracting groundwater from the Mooga Sandstone water supply bores is low given the distances considered.

Source water (used to mix the hydraulic fracture stimulation fluid on site) is planned to be obtained from the existing Mooga Sandstone groundwater supply bore (Magnetic GW1). Magnetic GW1, a water supply bore constructed for drilling water supply, has been assessed and estimated to have a maximum sustainable pump rate of 1.93 L/s (5 years sustained). Figure 14 presents an illustration of this well.

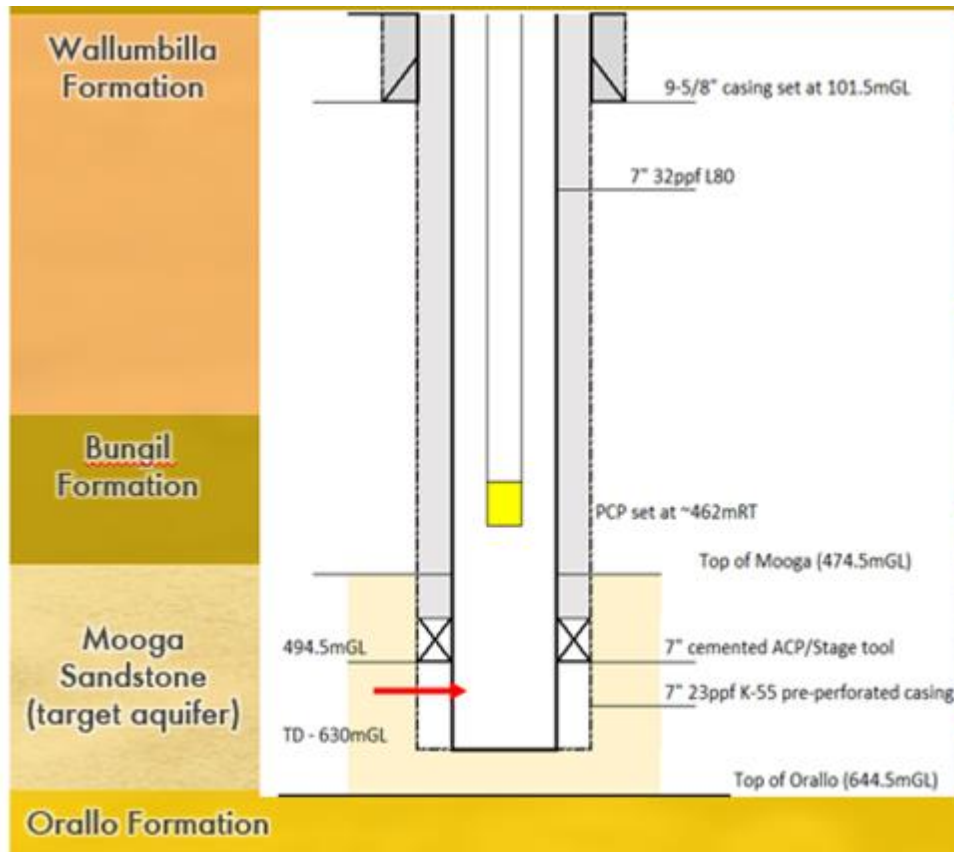


Figure 14 Magnetic GW1

The location of the Magnetic GW1, within ATP645, is included on Figure 15. The distance from Magnetic GW1 to the Overston and Bathurst well pads is approximately 8 to 10 km, respectively.

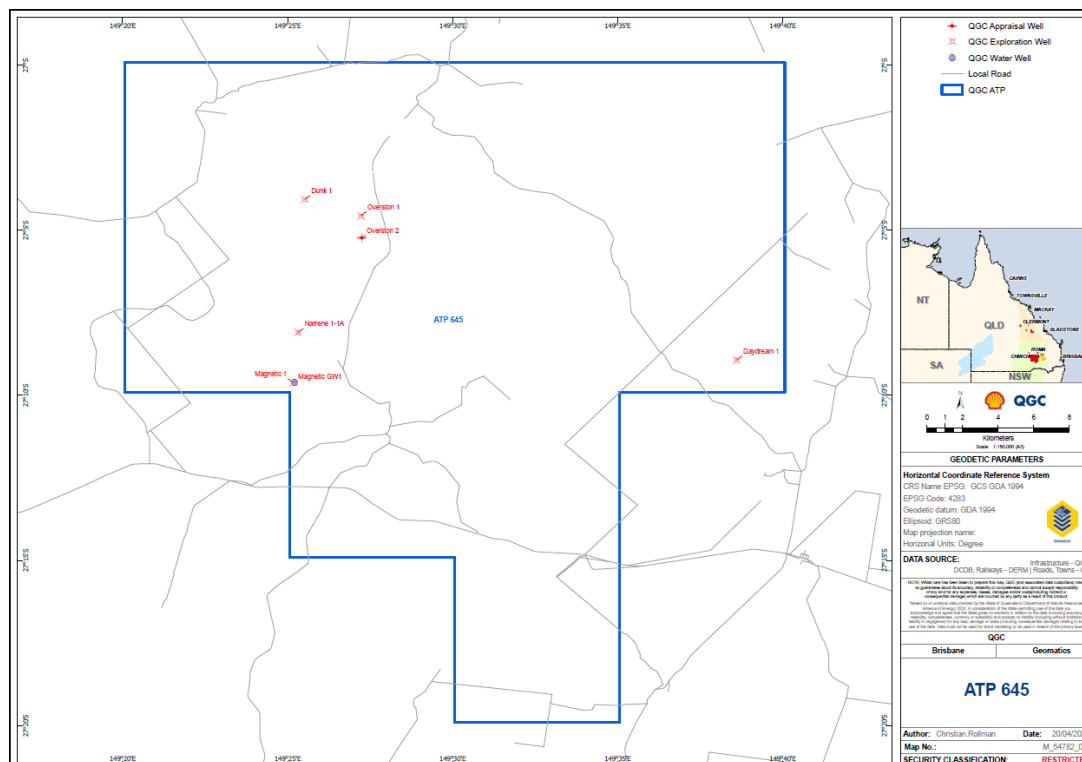


Figure 15 Magnetic GW1 locality plan

Water Take

Table 4 presents the water supply requirements for the TGS project based on the well pad location and phases. Stimulation and drilling volumes are specified. The differences in stimulation volumes between Examine and Measure are due to two wells been drilled on the pad during Measure instead of one.

Table 4 Water utilisation volumes for the TGS Project

Well pad	Wells	Stimulation volume (ML)	Drilling Volume (ML)
Bathurst	1 x Examine	10	3
Overston	1 x Examine	10	3
	2 x Measure	20	6
Dunk	1 x Examine	10	3
	2 x Measure	20	6
TOTAL		70	21

Note: The Measure wells are assumed to be located at the Overston and Dunk well pads, these locations are subject to change based on the Examine well results.

Water Take Approvals

Shell QGC has obtained approval for non-associated water license requests (submitted November 2021), which were granted in February 2023 for the TGS project and all upstream tenures (including ATP645).

Current water entitlements for ATP632, ATP645, and ATP785 indicate Shell QGC have licenses to take water as follows:

- 50 ML/year from the Mooga Sandstone
- 50 ML/year from the Griman Creek Formation
- 50 ML/year from the Gubberamunda Sandstone.

(Source: <https://www.business.qld.gov.au/industries/mining-energy-water/water/maps-data/water-entitlement-viewer>).

Source water storage

The source water is stored on site in an above ground tank capable of holding 10 ML. In preparation for use as a base for the hydraulic fracture stimulation fluid, the water typically has the following added during storage in the above ground tank:

- Acidity regulators (for pH control)
- Biocide (for bacteria growth control).

Post completion, the above ground tank is demobilised.

2.4.8.4 Stimulation stages

A series of fluid injection stages are envisaged, as per the Design of Service.

2.4.8.4.1 Injection and isolation techniques

Following the opening of the multistage fracturing sleeve (Section 2.4.8.2), injection of fluid commences. The injection pressure, injection rates, slurry volumes, fluid viscosity, and proppant concentration are monitored in real-time during each injection, to confirm the success of the procedure and, if necessary, adjust one of the monitored parameters.

Based on the surface pressure recordings, downhole pressure information is calculated and reviewed during the hydraulic fracture stimulation operation. The downhole pressures are calculated based on the wellhead pressure, fluid density, casing diameter and the depth to the target formation.

Once the predetermined volume of fluid has been injected into the well, the operation advances to the next stage of injection.

The fracturing sleeve zones are isolated by a baffle and ball-drop system. In the case of ball system, once the entire hydraulic fracture stimulation operation is complete for a well a completion rig drills-out the balls that were installed for the hydraulic fracture stimulation operation, to clear them from the well.

2.4.8.4.2 Acid injection

Following the drop ball and displace ball operations and prior to hydraulic fracture stimulation, an inhibited acid solution can be spotted across or pumped through the open intervals. Acid spotting improves the injection rates during the hydraulic stimulation operation. Acid spearhead serves to reduce the tortuous path of the fluid from the wellbore into the reservoir reducing the pressure required to perform the stimulation.

The acid spotting process comprises the pumping of a pH-stabilised 15% hydrochloric acid solution down the well, through the open intervals and out into the target sands.

The acid pumping stage is concluded when the injection pressure is noted to decrease whilst the injection pumping rate remains constant, (i.e., as the flow path for the fluid through the openings is widened by the clearing of the remnant cement in and around the openings the injection pressure required to maintain the selected pumping rate decreases).

Following spotting, the acid solution is diluted and pushed further into the sands by the water injected during the next stage of the hydraulic fracture stimulation process.

Based on the relatively short duration of acid spotting, low volumes used and the dilution of the acid by the fluids injected subsequently, the potential for the integrity of the annular cement seal to be impacted by the acid spotting is considered low and localised to the immediate vicinity of the openings.

2.4.8.4.3 Reservoir water composition

For the TGS Project an assessment of possible reservoir water composition was conducted to allow for material selection and engineering predictions. The water composition was based on water that had been extracted from core and the presence of KCl mud. The final composition of fluid for frac includes scale inhibitor and biocide.

Used Shell QGC formation waters data from existing operations and a water sample from previous well test (Dunk #1 well) show that the concentration of sodium in the water sample (surface conditions) was 6,474 mg/L Na and the calculated concentration of potassium in water sample (surface conditions) was 26 mg/L K. Based on mathematical analysis, assessment of surface water quality, and assumptions, the final reservoir water quality is included in Plate 1.

Parameter	Value	Unit
pH	5.8	N/A
Specific Electrical Conductivity	85819	S/m
Hardness	796	mg/L of Mg+2 and Ca+2
Cl-1	11018	mg/l
Na+1	6302	mg/l
K+1	25	mg/l
Ca+2	757	mg/l
Mg+2	39	mg/l
Sr+2	80	mg/l
Fe+2	10	mg/l
Ba+2	0.8	mg/l
HCO3-1	297	mg/l
CO2	415	mg/l
CO3-2	0.1	mg/l
OH-1	0.013	mg/l
SO4-2	113	mg/l

Plate 1 Final reservoir water

2.4.8.5 Coiled Tubing Mill-out

Post stimulation, for both cemented sleeve and plug and perf operations, a coiled tubing unit is used to mill out any objects that are in the well that were used as a part of the stimulation process. The helps to ensure all stimulated zones are contributing to flow.

2.4.8.6 Well flowback

At the cessation of pumping the required volumes of fluid to hydraulically fracture an interval of a well, the target sands, which have become pressurised during the hydraulic fracture stimulation operation, may be allowed to depressurise. This is achieved by closing the injection valve and opening the discharge valve on the wellhead, allowing the well to 'flowback' (i.e., flowback fluid to surface).

The flowback fluid may contain fluid from the pad and slurry volumes as wells as groundwater native to the tight sands. The fluid flowed back from the well is stored in on-site flowback tanks. It is currently planned that two weeks of well flowback or well unload will be required post stimulation of all 15 frac stages before the reservoir is adequately cleaned up for well testing to occur.

The water management strategy for handling of the flowback fluid is to store the fluid in the tanks until it is needed for the next phase of operation.

2.4.8.7 Velocity String Installation

To assist with the wells production a velocity string will be installed in the well. The velocity string will be installed in two parts. The first been the lower completion, conveyed via wireline, consisting of a production packer and tailpipe. The second will be the upper completion connecting the lower completion to the production tree at surface.

2.4.8.8 Well Suspension

Both in the success or failure cases of the appraisal campaign the well will be suspended for a period. Suspension will be critical as well integrity and security are important for risk management and re-entry.

A permanent packer (installed as a part of the lower completion) will be placed below the identified cap rock, the Intra-Rewan. Combining the permanent packer and internal plug in the nipple profiles as a platform for a cement plug will provide the necessary isolation.

Temporary suspension of the successful well will consist of a temporary suspension plug in tailpipe and a plan for Measure. Suspension of the unsuccessful well will be guided by the abandonment plan.

2.4.9 Fluid systems

Hydraulic fracture stimulation fluid for the TGS project will be around 99% (v/v) water and proppant and approximately 1% (v/v) chemical additives introduced to improve the process of hydraulic fracture stimulation.

The composition of fracturing fluids varies to meet the specific needs of each hydraulic fracture stimulation operation based on local geology. Chemical additives may consist of acids, surfactants, biocides, bactericides, pH stabilisers, gel breakers, clay, corrosion, and scale inhibitors, however, not all additive types are used in every fracturing job. For the TGS project the fracturing fluids selected as a base is relatively simple, as it comprises additives for only three functionalities, which include:

- HVFR
- Biocide
- Scale inhibitor.

This is recognised as an advantage, from a risk perspective, over the traditional cross linked borate systems.

The fluid system for the hydraulic fracture stimulation campaign is presented in **Appendix B**.

2.4.9.1 Mass balance

Mass balances for each of the fluid systems, which may be used for the campaign, are included in **Appendix B**.

The mass balance describes the concentration of the chemical components of each fluid system, in terms of weight and volume. The concentration of each chemical injected into the tight sands is calculated, in terms of:

- Weight for weight (w/w), i.e., kg/kg
- Volume for volume (v/v), i.e., L/L
- Weight per volume (w/v), i.e., mg/L.

For the (w/w) and (v/v) calculation the weight/volume of the proppant material is included in the total weight/volume of the fluid system. In the (w/v) calculation, the volume of the proppant is not included in the total volume, to not under-represent the concentration of each chemical relative to the overall fluid system; instead, the total volume used to calculate chemical concentration (w/v) includes only liquids.

The mass balance also estimates the concentration of each chemical that will be returned to surface during the flowback of the hydraulically fractured well, based on an upper and lower estimate of 20% and 60% mass recovery.

2.4.9.2 Monitoring and assessment

Part of the hydraulic fracture stimulation design includes the delineation of an acceptable safe operating pressure envelope. The key information provided in this envelope is the minimum pressures and maximum rates acceptable. If operations exceed these parameters, it is possible that a loss of fracture integrity has occurred.

During the hydraulic fracture stimulation operation, the injection pressure and fluid volume is continuously monitored to immediately identify a condition that would indicate the loss of integrity of the

well casing or target sands overburden layer (Section 2.3.5). In the event a potential loss of integrity is observed the operation will be ceased immediately.

In addition to this monitoring, Shell QGC monitor the pressure, flowrate and the chemistry of water flowed back from gas wells throughout their appraisal phase; this data also can be used to confirm the hydraulic fracture stimulation has not created a hydraulic connection between the tight sands with adjacent aquifers (see **Appendix A**).

Shell QGC sometimes conduct field-based studies which measure the vertical and lateral extent of the fractures that created during a Shell QGC hydraulic fracture stimulation operation, these are discussed below.

2.4.9.3 Well pressure and water quality monitoring

During the hydraulic fracture stimulation operations, the injection pressure is continuously monitored to immediately identify a condition that would indicate the loss of integrity of the well casing or overburden formations. The injection pressure is the principal indicator of a loss of the integrity of either the well casing or target sands overburden layer.

An unexpected drop in injection pressure could be indicative of a hydraulic connection forming between the target sands and an adjacent formation (i.e., the failure of the cap formation(s)), a failure of the well casing, or a new fracture being propagated inside the reservoir.

The determination of whether a pressure drop is indicative of a loss of containment is based on the safe operating pressure envelope, determined by Shell QGC for each well. If the fracturing pressure drops below the safe operating pressure envelope, hydraulic fracture stimulation is immediately ceased.

Following the completion of the hydraulic fracture stimulation operation the formation pressure, flow rates, and the quality (chemistry) of water flowed back from Appraisal wells is continually monitored. A change in pressure or flow rate is used as a primary indicator of potential loss of containment warranting further investigation. A change in water chemistry may take some time to become apparent in the groundwater flowing back from the well (due to large volumes and dilution effects), hence changes in water chemistry is used as a secondary indicator warranting further investigation.

Typical water quality monitoring and data capture during the Shell QGC hydraulic stimulation operations, including locations and frequency, are included in Table 5. These are indicative only and may change. All laboratory analysis will be conducted at NATA accredited laboratories.

Table 5 TGS Well Testing

Shell QGC Pty Ltd							Stream Name	Surge Tank and Condensate Storage Tank	Condensate Export	Water Surge Tank	Water Storage Tank
Tight Gas Sands (TGS) Well Testing											
Unit XXX Well test Separator											
FSampling and Analysis							PFS No				
							Stream No				
							Oper. Pres. Bar g				
							Oper. T°C				
							Phase	L	L	L	L
							Sample Point #				
							Sample Point Type				
							Process analyser				
Justification	Method	Parameter	Unit	Analysis	Sample container	Offsite shipment	Laboratory technique	Freq.	Freq.	Freq.	Freq.
Well Test Surveillance/Water management	ASTM D1125	Conductivity	mS/cm	Onsite			Digital conductivity meter			2 x D	W
	ASTM D1293	pH	/	Onsite			Digital pH meter			2 x D	W
Well Test Surveillance/Water management	ASTM D7678	Total hydrocarbons	mg/L	Onsite			QCL-IR analyser			2 x D	W
	ASTM D5907	Total suspended solids (TSS)	g/L	Offsite	4 x 500 ml plastic	3	Membrane filtration + weighing				Biw
Well Test Surveillance/Water management	ISO 4406	Particle size distribution	µm	Offsite			Particle size counter				Biw
	N/A	Phase behavior	N/A	Offsite			Emulsion bottle test kits				Biw
Well Test Surveillance/Water management	APHA 2580	Redox Potential	mV	Offsite			ORP Analyzer				Biw
	APHA 2130 B	Turbidity	NTU	Offsite			Turbidity Meter				Biw
Water management	APHA 2450 C	Total Dissolved Solids (TDS)	g/L	Offsite			Gravimetric				Biw
Water management	APHA 2320 B	Bicarbonate Alkalinity as CaCO3	mg/l	Offsite			Titration				Biw
		Carbonate Alkalinity as CaCO3	mg/l	Offsite			Titration				Biw
		Hydroxide Alkalinity as CaCO3	mg/l	Offsite			Titration				Biw
		Total Alkalinity as CaCO3	mg/l	Offsite			Titration				Biw
Water management	APHA 4110B	Bromide ion	mg/l	Offsite	4 x 20 ml Glass	4	Ion chromatography				Biw
Water management	USEPA 300	Bromate ion	mg/l	Offsite			Ion chromatography				Biw
Water management	APHA 4500	Chloride ion	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500	Fluoride ion	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4110B	Iodide ion	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500	Sulphate ion	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500	Phosphate ion	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500	Total Cyanide	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 3120/3125; USEPA SW 846 - 6010/6020	Calcium- ion	mg/l	Offsite			ICP				Biw
		Barium ion	mg/l	Offsite			ICP				Biw

		Strontium ion	mg/l	Offsite			ICP				Biw
		Magnesium ion	mg/l	Offsite			ICP				Biw
		Sodium ion	mg/l	Offsite			ICP				Biw
		Potassium ion	mg/l	Offsite			ICP				Biw
		Sodium adsorption ration	mg/l	Offsite			ICP				Biw
		Total Hardness	mg/l	Offsite			Calculation by GC composition				Biw
Water management	APHA 4500	Ammonia	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500	Ammonium ion	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500	Nitrate ion	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500	Nitrite ion	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500-NH3 G	Ammonia as N	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500-NO2 B	Nitrite as N	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500-NO2 B, APHA 4500-NO3 F	Nitrate as N	mg/l	Offsite			Iodometric method				Biw
		Nitrite + Nitrate as N	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500-Norg D, APHA 4500-Norg/NO3	Total Kjeldahl Nitrogen as N	mg/l	Offsite			Iodometric method				Biw
		Total Nitrogen as N	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500-P B&F	Total Phosphorus as P	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 4500-P F	Reactive Phosphorus as P	mg/l	Offsite			Iodometric method				Biw
Water management	APHA 5310 B	Dissolved Organic Carbon	mg/l	Offsite	2 x 40 ml Glass filtered	5	High temperature combustion				Biw
Water management	APHA 5310 B	Total Organic Carbon	mg/l	Offsite	4 x 20 ml Glass	6	High temperature combustion				Biw
Water management	APHA 3125; USEPA 6020	Aluminium	mg/l	Offsite			ICP				Biw
		Arsenic	mg/l	Offsite			ICP				Biw
		Barium	mg/l	Offsite			ICP				Biw
		Beryllium	mg/l	Offsite			ICP				Biw
		Boron	mg/l	Offsite			ICP				Biw
		Cadmium	mg/l	Offsite			ICP				Biw
		Chromium (including all species)	mg/l	Offsite			ICP				Biw
		Cobalt	mg/l	Offsite			ICP				Biw
		Copper (total and ionic)	mg/l	Offsite			ICP				Biw
		Iron (total and ionic	mg/l	Offsite			ICP				Biw
		Lead (total and ionic)	mg/l	Offsite			ICP				Biw
		Lithium	mg/l	Offsite			ICP				Biw
		Manganese	mg/l	Offsite			ICP				Biw
		Molybdenum	mg/l	Offsite			ICP				Biw
		Nickel	mg/l	Offsite			ICP				Biw
		Selenium	mg/l	Offsite			ICP				Biw
		Silica	mg/l	Offsite			ICP				Biw
		Vanadium	mg/l	Offsite			ICP				Biw
		Zinc (total and ionic)	mg/l	Offsite			ICP				Biw
Water management	APHA 3112	Mercury (total and ionic)	mg/l	Offsite			Atomic Absorption Spectrometry				Biw

Water management	USEPA 5030	Total petroleum hydrocarbons/ total recoverable hydrocarbons	mg/l	Offsite	1 x 250 ml glass bottle	7	Purge/trap method				Biw
Water management	APHA 4500	Hydrogen sulphide	mg/l	Offsite	4 x 40 ml glass bottle	8	Iodometric method				Biw
Water management	APHA 4500	Carbon dioxide	mg/l	Offsite			Iodometric method				Biw
Water management	USEPA 8260	Benzene	mg/l	Offsite			GC-MS				Biw
		Toluene	mg/l	Offsite			GC-MS				Biw
		Ethylbenzene	mg/l	Offsite			GC-MS				Biw
		meta- & para-Xylene	mg/l	Offsite			GC-MS				Biw
		ortho-Xylene	mg/l	Offsite			GC-MS				Biw
		Total Xylenes	mg/l	Offsite			GC-MS				Biw
		Sum of BTEX	mg/l	Offsite			GC-MS				Biw
Water management	USEPA 8260	Naphthalene	mg/l	Offsite			GC-MS				Biw
		C6 - C9 Fraction	mg/l	Offsite	1 x 100 ml glass bottle	9	GC-MS				Biw
	USEPA 8015	C10 - C14 Fraction	mg/l	Offsite			GC-FID				Biw
		C15 - C28 Fraction	mg/l	Offsite			GC-FID				Biw
		C29 - C36 Fraction	mg/l	Offsite			GC-FID				Biw
		C10 - C36 Fraction (sum)	mg/l	Offsite			GC-FID				Biw
	USEPA 8260	C6 - C10 Fraction	mg/l	Offsite			GC-MS				Biw
		C6 - C10 Fraction minus BTEX (F1)	mg/l	Offsite			GC-MS				Biw
Water management	USEPA 8015	>C10 - C16 Fraction	mg/l	Offsite			GC-FID				Biw
		>C16 - C34 Fraction	mg/l	Offsite			GC-FID				Biw
		>C34 - C40 Fraction	mg/l	Offsite			GC-FID				Biw
		>C10 - C40 Fraction (sum)	mg/l	Offsite			GC-FID				Biw
		>C10 - C16 Fraction minus Naphthalene (F2)	mg/l	Offsite			GC-FID				Biw
Water management	N/A	Volatile Organic acids	mg/l	Offsite			Ion chromatography				Biw
Water management	N/A	Microbiology	Cell counts	Offsite			ATP/AMP (Note 4)				Biw
	Various	Potable Water	Various				Various	As needed	As needed	As needed	As needed

Notes :

Note 1. 5 samples per well at start of well test to confirm < health limits only.
Note 2. Conditioning system will be a flow through and requires sulfinert coating on sample points and accessories.
Note 3. 5 samples per well at start of well test. Suspend until receipt of offsite data which is more accurate.
Note 4. Frequency as required on each cargo shipped.
Note 5. Assume for cargo FP < 60 C. 1 measurement per 3 months to support transport.
Note 6. 2 assay samples to be taken for each well test when flow conditions are stable given by surveillance criteria
Note 7. For first cargos assumed > 6 ppb total to support transport

5 samples per well as start of well test to confirm < health and design limits.

2.4.9.4 Landholder bore assessments

In accordance with the *Queensland Water Act (2000)* (Water Act), QGC conducts baseline assessments of all landholder water bores (when landholder permission is granted) in areas where petroleum and gas production testing or production has commenced or will soon commence.

Shell QGC assessed baseline bores, using the criteria:

- The bore must be within 2 km of a proposed well to be hydraulically stimulated
- The total depth of the well must be within 200 m of the frac zone.

Only one existing registered bore, RN58538, was located within 2 km of the proposed TGS appraisal wells (Plate 2). This bore is only 32 m deep within the Tertiary sediments and as such does not qualify for a baseline assessment.

The other closest registered bores are > 5 km from the TGS wells.

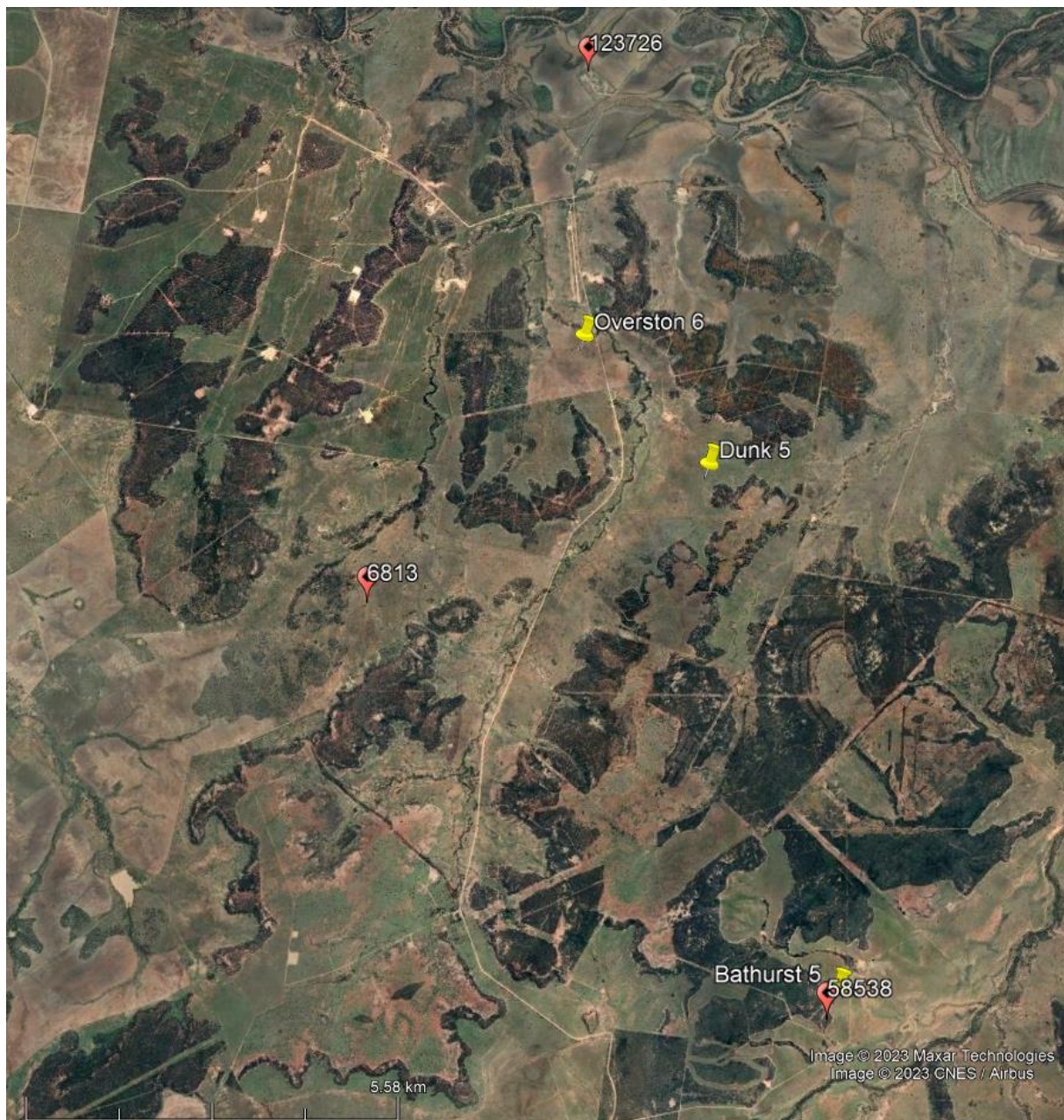


Plate 2 Closest registered bores and TGS Appraisal wells (Google Earth)

2.4.9.5 Comparison to international best practice

Over the last 60 years the hydraulic fracture stimulation process has been continually refined within the oil and gas industry. Modern hydraulic fracture stimulation techniques improve the effectiveness of the hydraulic fracture stimulation, whilst limiting environmental harm. The American Petroleum Institute (API) documents developed over this period provide the industry best practice guidance for the hydraulic fracture stimulation operations and the management of hydraulic fracture stimulation fluids.

The API is the primary distributor of industry standards and guidance, primarily through their recommended practices, technical reports, and standards publications.

The API specifications relevant to hydraulic fracture stimulation are presented in Figure 16.

The API has also published three guidance documents that outline best practices to minimise environmental impacts associated with hydraulic fracture stimulation. These are:

1. *Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines*

This document focuses on groundwater protection related to drilling and hydraulic fracture stimulation operations.

2. *Water Management Associated with Hydraulic Fracturing*

This document focuses on the management of water used for hydraulic fracture stimulation.

3. *Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing*

This document outlines potential impacts to surface waters, soils, and other ecosystems and describes best practices to mitigate these environmental impacts. Shell QGC and Shell QGC contractors adhere to the API guidance and 'Best Practice' specifications for the design and implementation of all hydraulic fracture stimulation operations that are conducted for the TGS Project. In addition, QGC complies with all regulatory directives regarding hydraulic fracture stimulation process.

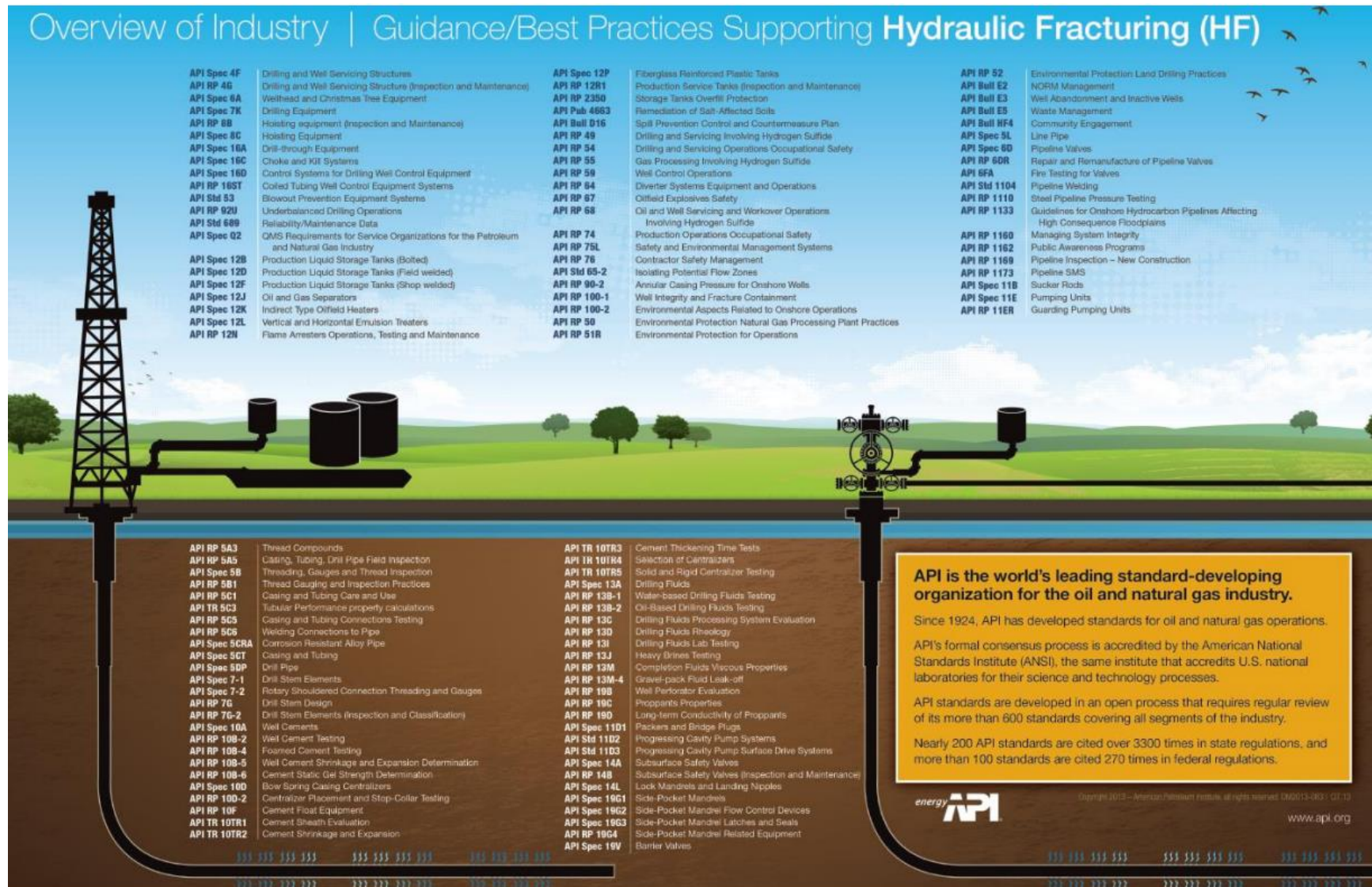


Figure 16 API Guidance/Best Practices supporting Hydraulic Fracture Stimulation (API, 2013)

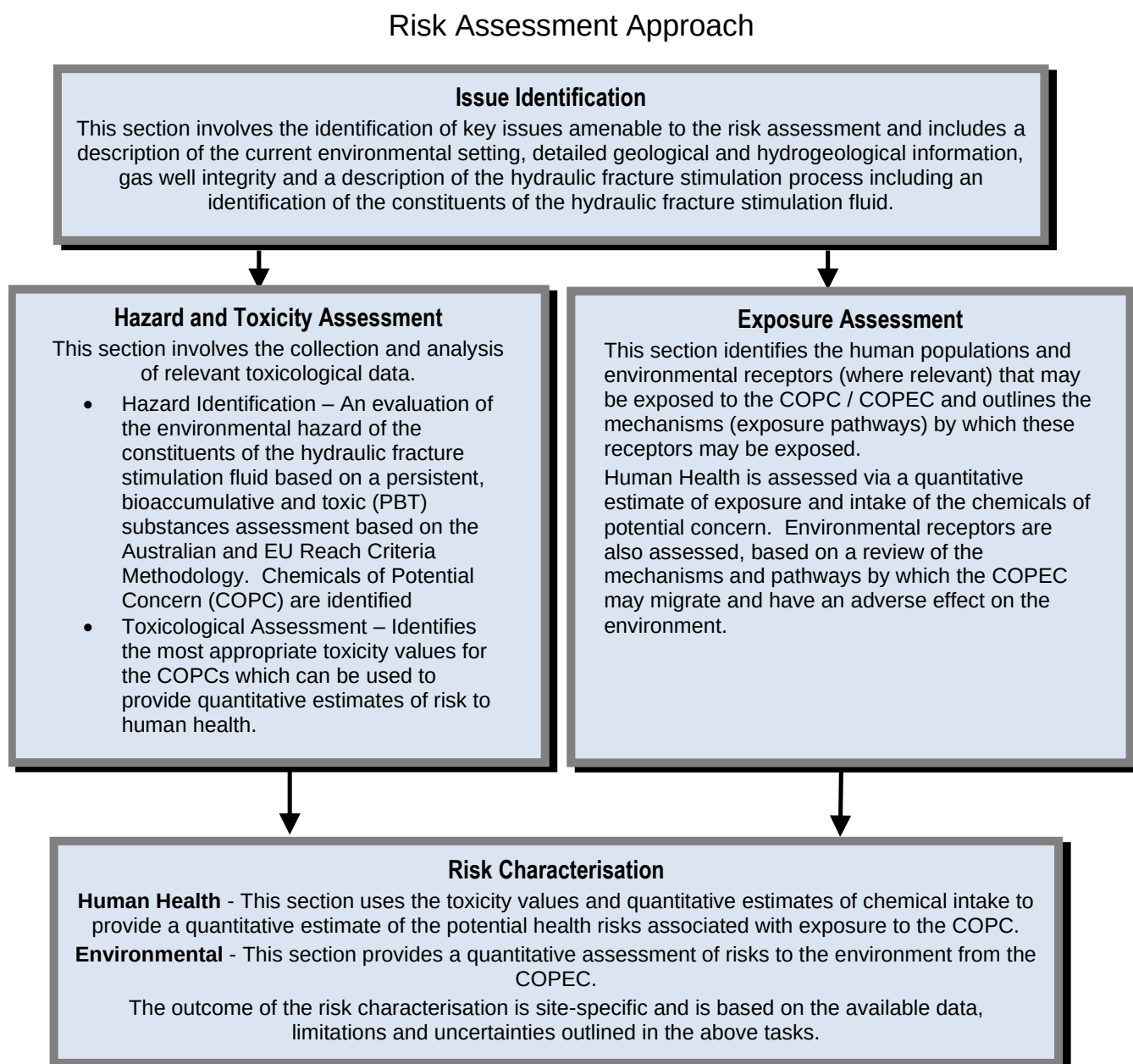
3.0 Risk Assessment Process

3.1 Problem formulation

3.1.1 General

As described in NEPC (2013), the problem formulation establishes the goals and focus of the assessment. Additional products of the problem formulation stage are a conceptual model that identifies the stressors, sources, receptors, exposure pathways and potential adverse human health effects that the risk assessment will evaluate, and a work plan that outlines the approaches that will be used in the risk assessment.

Figure 17 Risk Assessment Approach



3.1.2 Issue identification

In the framework of this assessment, receiving environments are those which have the potential to be affected by hydraulic fracture stimulation within the project area. Based on the information provided in the receiving environment section (**Section A-2**), Shell QGC well integrity section (**Section 2.3**) and the hydraulic fracture stimulation section (**Section 2.4**), the potential hazards to the project area receiving environments associated hydraulic fracture stimulation (as identified in the EA conditions) that require further assessment are the following:

- The exposure of workers, trespassers, or the environment to potentially hazardous concentrations of hydraulic fracture stimulation chemicals as a result of the loss of containment, operational spills and leaks.
- The potential for release of hazardous gases from the TGS well following hydraulic fracture stimulation.
- The potential release of dust from hydraulic fracture stimulation activities.
- Contamination of groundwater in aquifers overlying or underlying the target TGS.
- Contamination of groundwater in the target TGS that is accessed by landholder bores.
- Migration of remnant hydraulic fracture stimulation fluid or chemicals to springs, adversely affecting water quality.
- Hydraulic fracture stimulation triggering earthquakes and/or reactivation of geological faults.

3.1.3 Objective

Based on the information presented in the sections above, the objective of this assessment consists of the following:

- A qualitative assessment of the environmental risks to the receiving environment associated with the injection of hydraulic fracture stimulation fluids into the target TGS of the Tinowon Formation in the Bowen Basin. A qualitative assessment of the potential risks to terrestrial and human health toxicity associated with the process of hydraulic fracture stimulation and the management and storage of flowback fluids above grade.
- A quantitative assessment of the potential risks to human health and aquatic receptors associated with the management and storage of flowback fluids.

The potential complete exposure pathways will be identified through the qualitative evaluation process, and quantitative assessments will then be completed only on those potentially complete exposure scenarios. Through the process of both qualitative and quantitative risk assessment, appropriate management controls will be identified for the management of potential risks.

3.2 Qualitative risk assessment

3.2.1 Receptors and exposure pathways

This section identifies the receptors who may be exposed to the COPC identified for the hydraulic fracture stimulation activities and outlines the mechanisms (exposure pathways) by which these populations may be exposed.

For an exposure pathway to be complete there must be all the following conditions:

- Source of COPC - how the chemical got into the environment.
- A transport media - how the chemical moves or migrates through the environment (soil, water, or air).
- An exposure point - how human and environmental receptors can encounter the chemicals.
- An exposure route - how the chemical could enter the body of the receptor (e.g., inhalation, ingestion, or dermal contact).

If any one of these steps (source, transport media, exposure point or route) is not present, then the exposure pathway is incomplete and, hence, further assessment of risks is not required unless circumstances change.

In the cases where the exposure pathways are complete, or have the potential to be complete, then the pathways can be considered significant or less significant. The significance of the exposure pathway depends on the nature of the impact present and the evaluation of the likely exposure concentrations that may be associated with the pathway.

3.2.2 Risks and mitigation measures

Table 6, below discusses the potential risks identified and the mechanisms by which adverse impacts are proposed to be controlled/managed.

Table 6 Qualitative human health and environmental risk assessment and consideration of the need for Quantitative risk assessment

	Identified Potential Hazard	Hazard Causes and Consequences	Risk Mitigation Measures	Warrants further consideration in this Risk Assessment	Reason for carrying forward the potential hazard into the subsequent Quantitative Risk Assessment
Surface Environment	The loss of containment of chemicals used for hydraulic fracture stimulation	Exposure of workers, residents, or the environment to potentially hazardous hydraulic fracture stimulation chemicals, resulting from loss of containment occurring: • While in transit to site (neat form); • During the mixing of hydraulic fracture stimulation fluid on site; or • (In diluted form) during the storage and transport of well flowback fluid.	QGC implement a range of engineering and operational control measures to ensure the risk of hydraulic fracture stimulation fluid spills are minimised during hydraulic fracture stimulation operations, including during transport to and from the wellsite and during the flowback of hydraulic fracture stimulation chemicals from the well. These control measures include: • Adherence to the material storage and transport requirements as stipulated on the chemical Safety Data Sheets (SDS). • Adherence to the Transport of Dangerous Goods by Road Regulations (for chemicals classified as a 'Dangerous Goods'). • Ensuring chemicals remain in their original containers and are not decanted into smaller containers which may not be fit for purpose. • During hydraulic fracture stimulation operations, the use of secondary containment beneath all equipment holding or pumping chemicals. • Using fit for purpose flowback fluid storage tanks. Conducting regular integrity checks of fluid storage tanks, during commissioning and use. Ensure adequate freeboard is maintained at all times.	Yes	The evaluation of the risk to workers involved in the operation of well hydraulic fracture stimulation activities (including transportation of the COPC to the site) is not considered warranted in the subsequent sections of this risk assessment, as it is addressed via the implementation of appropriate occupational health and safety procedures and management plans. Further consideration is warranted regarding the risk of above ground exposure relating to the handling and storage of hydraulic fracture stimulation chemicals and flowback fluid. This is addressed in Section 3.4.3 Further assessment is warranted regarding the risk associated with the potential and actual concentrations of COPC in flowback fluid; and the presence of other COPC that may have been liberated during the hydraulic fracture stimulation operations. This is addressed in Section 3.4.3. Further assessment is warranted regarding the chemical and physical properties of the constituents used in hydraulic fracture stimulation fluids that result in the potential for these chemicals to be present in flowback fluid and to be of concern in relation to potential acute or chronic risks. This is addressed in Section 3.4.3.

	Identified Potential Hazard	Hazard Causes and Consequences	Risk Mitigation Measures	Warrants further consideration in this Risk Assessment	Reason for carrying forward the potential hazard into the subsequent Quantitative Risk Assessment
	Harm to the environment due to the release of fugitive emissions from hydraulically fractured wells.	Release of hazardous gases from the TGS well at surface following the hydraulic fracture stimulation of a well, e.g., if the hydraulic fracture stimulation injection pressure were to open a micro annulus in the production casing annular cement seal, from the TGS to surface.	QGS's well design protocols mandate the use of both surface and production casing sections. In the unlikely event that a micro annulus was opened in the production casing annular cement seal from a TGS to ground surface, any gas that migrated through that pathway would be contained by the wellhead which is fastened to the top of the surface casing, encapsulating the top of the production casing and production casing annular seal (see Section 2.2) Prior to hydraulic fracture stimulation, QGC evaluates the quality of the cement seal around the production casing of every well by reviewing CBLs performed on the wells. If QGC considers the cement seal of a well to be inadequate for hydraulic fracture stimulation, that well is not hydraulically fractured. If there is uncertainty within QGC as to the suitability of the cement seal of a well, the CBL is reviewed by an independent third party, if they consider the cement seal of a well to be inadequate for hydraulic fracture stimulation, that well is not hydraulically fractured.	No	QGC has in place procedures which: • Reduce the likelihood that wells leak gas through cement seals (the CBL review process) • Eliminate the pathway for gas to leak from a TGS to surface via the production casing cement seal (QGC well design protocols). These measures mitigate the risk associated with gas leaking from TGS to surface because of hydraulic fracture stimulation.

	Identified Potential Hazard	Hazard Causes and Consequences	Risk Mitigation Measures	Warrants further consideration in this Risk Assessment	Reason for carrying forward the potential hazard into the subsequent Quantitative Risk Assessment
	Harm to residents or fauna/flora due release of dust from hydraulic fracture stimulation activities	During the hydraulic fracture stimulation process, certain fluid additives may be present which pose a human health risk due to inhalation due to dust generation. Crystalline silica (sand) is an example of a potential risk additive.	Chemical blending operations are carried out using dust covers, minimising exposure to workers onsite and the potential for creating windblown dust, which could impact residents or flora/fauna. In addition Shell QGC have implemented administrative controls such as placing a temporary hold on work during excessive dust and windblowing in the direction of the sensitive receivers. With this control in place, the risk for dust created by hydraulic fracture stimulation to harm residents or fauna/flora is considered as low.	No	Shell QGC's hydraulic fracture stimulation contractor's work procedures and controls removes the exposure pathway to workers, residents, flora, and fauna, hence no further hazard assessment is warranted.
	Harm to residents or fauna due to noise or vibrations from hydraulic fracture stimulation operations	Significant noise and vibrations can be created during hydraulic fracture stimulation operations by the pumps, blenders, generators used to conduct the operation. This noise has the potential to harm residents or fauna in the short or long term.	During the hydraulic fracture stimulation planning phase, Shell QGC models the noise that will be produced during hydraulic fracture stimulation operations. Shell QGC will also conduct ongoing assurance monitoring at the well locations to validate the noise emissions. Alternative arrangements will also be recommended based on predicted noise impacts from stimulation activities.	Yes	The potential pathway for noise to harm residents is removed by the protocols QGC has in place. Further assessment is warranted regarding the risk of noise or vibrations harming fauna. This is addressed in Section 3.8 .

	Identified Potential Hazard	Hazard Causes and Consequences	Risk Mitigation Measures	Warrants further consideration in this Risk Assessment	Reason for carrying forward the potential hazard into the subsequent Quantitative Risk Assessment
Subsurface Environment	Hydraulic fracture stimulation resulting in seismic activity due to the reactivation of geological faults or alteration of tectonic stresses	Opening of fractures within geological material in the surrounds of dormant geological faults, potentially resulting in fault reactivation.	QGC has a detailed understanding of the geological faults and stress fields (see Section A.1.2.2.3) within the project area, established using the following the techniques: • Development of a mechanical earth model (see Section 2.3.3), incorporating QGC's understanding of the local geological stress regime at each location to be hydraulically fractured. This understanding allows QGC to design hydraulic fracture stimulation considerate of the local geological stress regime. • Seismic surveys (to inform understanding of subsurface geometric relationships). • Widespread geological drilling programs (to inform subsurface stratigraphic understanding).	No	No further assessment of risk is considered warranted, based on the risk mitigation measures in place. • The project area is understood to be one of the least seismically active areas on the Australian continent (see Section A.1.2.2.3.2). • Geological faults within the area are dormant (see Section A.1.2.2.3.2) • Each hydraulic fracture stimulation operation is designed, considerate of the local geological stress regime.

	Identified Potential Hazard	Hazard Causes and Consequences	Risk Mitigation Measures	Warrants further consideration in this Risk Assessment	Reason for carrying forward the potential hazard into the subsequent Quantitative Risk Assessment
	Alteration of groundwater quality in aquifers overlying or underlying the target TGS	Contamination of groundwater in aquifers overlying or underlying the target TGS with either TGS groundwater or hydraulic fracture stimulation chemicals due to: - Hydraulic fracture stimulation creating a hydraulic connection between the target TGS and overlying or underlying aquifers. - Failure of the integrity of the TGS well, resulting in a connection forming between fluid inside the well and the aquifers overlying the target TGS. - Loss of hydraulic fracture stimulation fluids into the overlying or underlying aquifers.	The TGS targeted by QGC hydraulic fracture stimulation operations are separated by low permeability aquitards, made of high strength, ductile rock (see Section A.1.3). Hydraulic fracture stimulation operations are designed so as not to propagate outside of the Back Creek Group; through part of this design is the establishment of a safe injection pressure operating envelope (see Section 2.3.5). This operating envelope is developed based on consideration of: - CBL results - Mechanical earth model (see Section 2.2.3) - Hydraulic fracture stimulation models (see Section 2.3.3) - Historical tracer results - Relevant legislation - Internal and external standards	No	On the basis of the hydrogeological setting within the project area (Section A.1.3), and that QGC adhere to the protocols which they have put in place regarding well integrity (Section 2.2) and hydraulic fracture stimulation process control (Section 2.3.6), there is no complete exposure pathway between groundwater in the aquifers adjacent to the TGS and hydraulic fracture stimulation fluid or TGS groundwater. Hence, no further assessment of this risk is warranted.

	Identified Potential Hazard	Hazard Causes and Consequences	Risk Mitigation Measures	Warrants further consideration in this Risk Assessment	Reason for carrying forward the potential hazard into the subsequent Quantitative Risk Assessment
	Contamination of groundwater in the target TGS with hydraulic fracture stimulation fluid, which is then accessed by landholder bores	Previous hydraulic fracture stimulation pilot campaigns have demonstrated that not all hydraulic fracture stimulation chemicals are recovered from the well) during the flow-back period. To evaluate the likelihood that gas wells might be located in a position where a groundwater extraction well could theoretically be affected, Shell QGC has carried out a baseline survey and GIS proximity analysis in which the existing registered groundwater wells have been screened for depth relative to the top of the Back Creek Group. This has identified no groundwater wells deeper than 150 m. The majority of registered bores are separated by a vertical distance of more than 2,600 m from the Back Creek Group. Based on the hydrogeological setting within the TGS project area (Section A.1.3), in order for the pathway to be valid in the context of exposure to hydraulic fracture stimulation fluids, a groundwater supply bore would need to source groundwater from directly within the hydraulically fractured zone of the TGS.	Shell QGC have protocols in place which preclude hydraulic fracture stimulation operations impacting landholder bores. Prior to commencing a hydraulic fracture stimulation campaign, Shell QGC performs field assessments to identify any groundwater supply bores with contributing aquifers 200 m above or below the target gas producing formation and are spatially located with a two (2) kilometre radius from the TGS well. Part of this risk assessment is to understand the precise location of the water supply bores and their likely source aquifer. If a landholder bore is potentially screened within the radius of influence of a hydraulic fracture stimulation operation (both horizontally and vertically), that gas well is not hydraulically fractured. Hence this scenario becomes invalid.	Yes	The protocols that Shell QGC has in place to prevent hydraulic fracture stimulation occurring near landholder bores screened in target TGS negate the requirement for further consideration of the risks of this scenario. An understanding of the potential for chemicals remaining in the TGS to migrate in groundwater is achieved with a fate and transport assessment (see Section A.1.7).

On the basis of the assessment presented above, the following presents a summary of the key issues that will be considered further:

1. Loss of containment of chemicals used for hydraulic fracture stimulation, causing harm to workers, residents or the environment (to be assessed in **Section 3.0** and **Appendix A**);
2. Harm to residents or fauna due to noise or vibrations from hydraulic fracture stimulation operations (to be assessed in **Section 3.8**); and
3. Contamination of groundwater in the target TGS that may potentially be accessed by landholder bores (to be assessed in **Section A.1.7**).

3.2.3 Identification of Contaminants of Potential Concern

3.2.3.1 Introduction

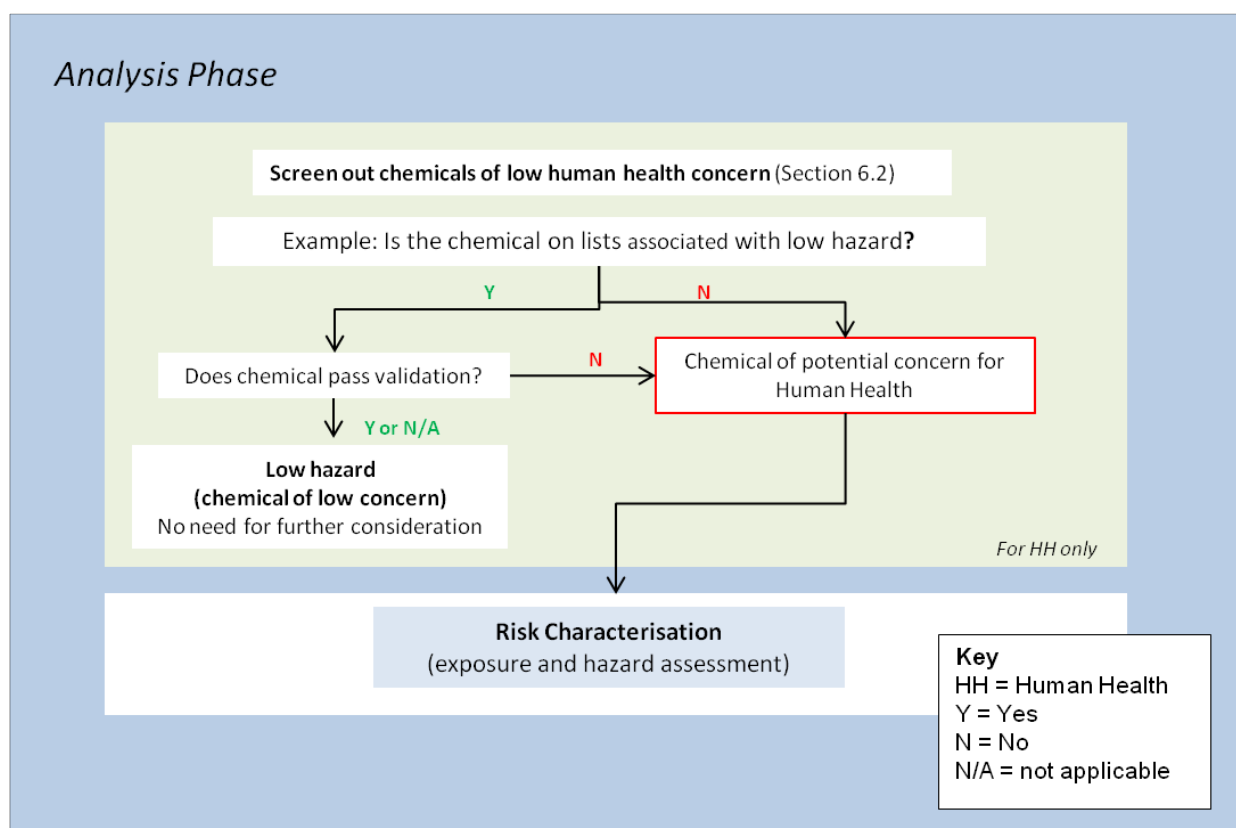
This section identifies the nature of chemicals used and recovered via operations at the site and considers their potential to represent contaminants of potential concern via:

- Screening of chemicals for low human health concern.
- Comparison of chemical concentrations with screening criteria for human health.
- Their Persistence, Bioaccumulation and Toxicity (PBT assessment).
- Comparison of chemical concentrations with screening criteria for environmental impacts.

3.2.3.2 Screening of Chemicals for Low Human Health Concern

The screening process for hydraulic fracture stimulation chemicals in the human health assessment framework is presented in **Figure 18** below and is consistent with the approach outlined in the Department of the Environment and Energy 2017, Exposure Draft - Chemical Risk Assessment Guidance Manual: for chemicals associated with coal seam gas extraction (DoEE 2017).

Figure 18 Screening process to identify chemicals of potential concern for human health



Source: DoEE 2017

Step 1: Identify chemicals of potential low concern for human health based on existing national or international lists of substances applicable to chemicals associated with TGS gas extraction.

If a chemical is listed on either of the following 2 lists as being of low concern, no additional validation is required (DoEE 2017):

1. US EPA High Production Volume (Indicator 1)⁸
2. REACH Annex IV⁹

If a chemical is listed on any of the following three lists as being of low hazard / low concern, additional validation (Step 3) is required to ensure the conclusion is relevant for TGS gas operations:

1. Inert Ingredients eligible for the US Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
2. US Food and Drug Administration (FDA) Generally Regarded as Safe (GRAS) (Type 1)
3. REACH Annex V

Step 2: Apply validation rules developed by the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) in the IMAP framework to confirm low concern

If a chemical is found on any of the lists requiring additional validation, and any of the criteria below are met, further assessment of the chemical should be undertaken:

- chemicals identified as a concern or for which regulatory action has been taken overseas
- chemicals identified in human umbilical cord blood
- chemicals meeting the hazard criteria underpinning the IMAP framework:
 - listed as hazardous chemical in Safe Work Australia's Hazardous Substance Information System (HSIS)
 - classified as hazardous in the EU Regulation on Classification, Labelling and Packaging (CLP)
 - classified as a Group 1, 2A or 2B carcinogen by International Agency for Research on Cancer (IARC)
 - listed in latest National Toxicology Program (NTP) Report on Carcinogens (RoC)
 - listed in US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans
 - classified by the American Conference of Governmental Industrial Hygienists (ACGIH) in carcinogen categories TLV-A1, -A2, or -A3
 - listed in Category 1 or Category 2 on EU list chemicals with endocrine disruption classifications
 - listed by the Agency for Toxic Substances and Disease Registry (ATSDR) to be neurotoxic
- chemicals included in the Poisons Standard (the Schedule for Uniform Scheduling of Medicines and Poisons (SUSMP) (for example TGA 2015)), except where the listing is in **Appendix C**
- chemicals removed from Annex IV of REACH (EC 2008) as part of the review process

⁸ The US EPA High Production Volume (HPV) chemicals are those which are manufactured in or imported into the US in amounts $\geq$ 1million pounds/year. Indicator 1 denotes those chemicals not considered a candidate for testing, based on a preliminary US EPA review indicating testing would not further our understanding of the chemical's properties.

⁹ Annex IV of the European REACH regulation (i.e. Registration; Evaluation; Authorisation; and restriction of Chemicals) contains a list of substances exempt from registration on the basis that they are considered to cause minimum risk due to their intrinsic properties (EC 2008).

- chemicals listed as substances of very high concern (SVHCs) according to Annex XV of REACH5
- strong or moderate acids and bases, quaternary ammonium salts, and anhydrous deliquescent materials

Step 3: Identify additional chemicals of low concern – such as certain binary inorganics, organic acid salts, hydrates, naturally occurring substances, polymers.

- The following additional chemicals can however be identified for inclusion as low concern chemicals: binary inorganic and organic acid salts consisting of Na^+ , K^+ , Mg^+ , Ca^{+2} , Cl^- , CO_3^{-2} , PO_4^{-3} , NO_3^{-1} , OH^{-1} , O^{-2} and SO_4^{-2} , and simple salts of acetate, citrates, lactates, tartrates, malates, and di- and tri- phosphates
- As hydrates of a substance or hydrated ions are formed by association of a substance with water, the hydrates of chemicals considered as being of low concern for human health are themselves also considered as low concern for human health, as are hydrates where the anhydrous form is ruled out due to desiccation effects
- certain naturally occurring chemicals and some materials, for which there are no known toxicological effects (e.g., nut hulls) may also be of low concern to human health. However, it should not be assumed that dusts from these substances do not present a hazard to human health (NICNAS 2017)
- polymers which meet NICNAS's New Chemicals Program Polymer of Low Concern (PLC) criteria may similarly be considered by NICNAS to be of low concern to human health. Details for the criteria and application to chemicals associated with coal seam gas extraction are provided in NICNAS (2017).

3.2.4 Identification of human health COPC in flowback fluid

After the initial screening process as described in **Section 3.2.3.2**, the remaining COPC will be identified as those which are known or suspected to be present at concentrations high enough to warrant inclusion in an assessment of human health risks. The identification of COPC is based on the assessment of the nature and extent of these chemicals in the environment on-site. A theoretical dataset was evaluated in this HHRA.

3.2.4.1 Theoretical dataset

The theoretical dataset calculated exposure point concentrations (EPCs) based on theoretical calculations of exposure using the mass balance data for each hydraulic fracture stimulation fluid system. For the purpose of this assessment, it was assumed that between 20% and 60% of the mass of chemicals injected into the well will be present in the flowback fluid (percentage flowback estimates based on a review of flowback water quality data from other hydraulic fracture stimulation campaigns within the industry). The determination of COPC from the theoretical dataset was based on a comparison of the estimated concentrations with human health-based screening level guidelines. Where available, the Australian Drinking Water Guidelines (ADWG 2018) (i.e., concentrations in water that are safe for all members of the population to consume every day for a lifetime) have been identified and considered in this assessment. Where these guidelines are not available, and the available published reviews have identified a suitable Tolerable Daily Intake (TDI) or No Observed Adverse Effects Level (NOAEL) this value has been presented and used to derive a preliminary drinking water guideline following guidance provided by the National Health and Medical Research Council (refer to **Section A.1.8.5** for further discussion).

3.2.4.2 Persistence, bioaccumulation, and environmental toxicity – identification of environmental COPCs

A requirement of the EA conditions is to undertake an environmental hazard assessment of the current and proposed fracturing chemicals. This semi qualitative assessment is an evaluation of the environmental hazard of the constituents of the hydraulic fracture stimulation fluid based on their persistence (P), bioaccumulation (B) and toxicity (T) or PBT for short. The PBT assessment has been conducted according to guidance developed by NICNAS and DoEE (2017). The criteria considered are presented in **Table 7**.

Table 7 PBT criteria adopted by NICNAS

Criterion	PBT criteria		
P	For PBT purposes a chemical is considered persistent in a particular media if its half-life in the media exceeds the following: Half-life ($T_{1/2}$) >2 months in water Half-life ($T_{1/2}$) >6 months in soil Half-life ($T_{1/2}$) >6 months in sediment Half-life ($T_{1/2}$) >2 days in air		
B	For PBT purposes a chemical is considered to be bioaccumulative if it has a BCF/BAF of >2000, or in its absence of any BCF/BAF measurement a $\log K_{ow}$ >4.2.		
T	For PBT purposes, in respect of aquatic toxicity, a chemical may be considered toxic under the following circumstances (corresponding to criteria for GHS chronic category 1:		
	Non-rapidly degradable substances for which there are adequate chronic toxicity data available	Chronic NOEC or EC_x (for fish)	<0.1 mg/L and/or
		Chronic NOEC or EC_x (for crustacea)	<0.1 mg/L and/or
		Chronic NOEC or EC_x (for algae or other aquatic plants)	<0.1 mg/L
	Rapidly degradable substances for which adequate chronic toxicity data are available	Chronic NOEC or EC_x (for fish)	<0.01 mg/L and/or
		Chronic NOEC or EC_x (for crustacea)	<0.01 mg/L and/or
		Chronic NOEC or EC_x (for algae or other aquatic plants)	<0.01 mg/L
	Substances for which adequate chronic toxicity data are not available (providing criteria for P and B are met)	96 h LC_{50} (for fish)	<1 mg/L and/or
		48 h EC_{50} (for crustacea)	<1 mg/L and/or
		72 or 96 ErC_{50} (for algae or other aquatic plants)	<1 mg/L
		And the substance is not rapidly degradable and/or the experimentally determined BCF is >500 (or, if absent, the $\log K_{ow}$ is >4.2	
	Toxicity to other (terrestrial) organisms	Should be considered on a case by cases basis, compared with the highly toxic classifications DotE has developed for ag/vet chemicals	
	Long term toxicity or evidence such as endocrine disruption effects	Should be considered on a case-by-case basis.	

If the chemical is classified as persistent, bioaccumulative and toxic – that is, meets the criteria for all three – then it is a PBT chemical (DoEE 2017).

The screening criteria developed by the EU for REACH (ECHA, 2008) was also be used as surrogate information to decide whether a substance may potentially fulfil the PBT criteria. A summary of these screening criteria is provided in **Table 8**. It is noted that Shell QGC does not perform any testing on vertebrates for the purpose of chemical selection.

Table 8 EU REACH screening criteria for persistent (P), very persistent (vP), bio-accumulative (B), very bio-accumulative (vB) and toxicity (T)

Type of Data	Criterion	Screening Assignment
Persistence		
Ready biodegradability test	Readily biodegradable	Not P and not vP
Enhanced ready biodegradability test	Readily biodegradable	Not P and not vP
Specified tests on inherent biodegradability		

Type of Data	Criterion	Screening Assignment
Zahn-Wellens (OECD 302B)	>70% mineralization (DOC removal) within 7 days; log phase no longer than 3 days; removal before degradation occurs below 15%; no pre-adapted inoculum	Not P
MITI II test (OECD 302C)	>70% mineralization (O ₂ uptake) within 14 days; log phase no longer than 3 days; no pre-adapted inoculum	Not P
Biowin 2 (non-linear model prediction) and Biowin 3 (ultimate biodegradation time) or	Does not biodegrade fast (probability) and ultimate biodegradation timeframe prediction: >months (value <2.2) Or	P
Biowin 6 (MITI non-linear model prediction) and Biowin 3 (Ultimate biodegradation time)	Does not biodegrade fast (probability <0.5) and ultimate biodegradation timeframe prediction: >months (value <2.2)	P
Bioaccumulation		
Convincing evidence that a substance can biomagnify in the food chain (e.g., field data).	e.g., BMF >1	B or vB, definitive assignment possible
Octanol-water partition coefficient (experimentally derived or estimated by valid QSAR)	Log K _{ow} < 4.5	Not B and not vB
Toxicity		
Short-term toxicity aquatic toxicity (algae, daphnia, fish)	EC ₅₀ or LC ₅₀ <0.01 mg/L	T, criterion considered to be definitely fulfilled
Short-term toxicity aquatic toxicity (algae, daphnia, fish)	EC ₅₀ or LC ₅₀ <0.1 mg/L	T
Avian toxicity (subchronic or chronic toxicity or toxic for reproduction)	NOEC <30 mg/kilogram(kg) food	T

Based on this approach, the chemicals proposed to be used in hydraulic fracture stimulation fluids have been evaluated, with the outcomes of the assessment conducted summarised in and in individual toxicity profiles in **Appendix C**.

3.3 Qualitative human health risk assessment

3.3.1 Exposure assessment

This section identifies the human populations (receptors) who may be exposed to the COPC identified for the site and outlines the mechanisms (exposure pathways) by which these populations may be exposed. The exposure assessment also provides a quantitative estimate of exposure and intake of the COPC.

The assessment of exposure involves the evaluation of the data collected from the site, details associated with the site use and surrounding land uses, the nature of the impact identified and the potential for the impact to migrate off-site. An exposure pathway is a mechanism by which an individual or group of individuals (receptors) may be exposed to the COPC through mechanisms such as direct contact (which includes ingestion and dermal contact) and inhalation.

For an exposure pathway to be complete there must be all the following conditions:

- Source of COPC - how the chemical got into the environment
- A transport media - how the chemical moves or migrates through the environment (soil, water, or air)

- An exposure point - how people can encounter the chemicals (e.g., swimming, gardening, inhalation, direct contact or via the food web)
- An exposure route - how the chemical could enter the body (e.g., inhalation, ingestion, or dermal contact).

If any one of these steps (source, transport media, exposure point or route) is not present, then the exposure pathway is incomplete and, hence, further assessment of risks is not required.

In the cases where the exposure pathways are complete, or have the potential to be complete, then the pathways can be considered significant or less significant. The significance of the exposure pathway depends on the nature of the impact present, and the evaluation of the likely exposure concentrations that may be associated with the pathway.

3.3.2 Potential exposure pathways and receptors

Considering the surrounding areas of the site, the scope of the risk assessment, the current nature and extent of impacts identified in groundwater, the potential receptors, and pathways (significant and less significant) will be identified.

3.3.3 Quantification of exposure

When calculating chemical intake or exposure, the risk assessment process focuses on exposure occurring over a prolonged period; that is, chronic exposure that occurs over years and possibly a lifetime. The following steps have been followed to estimate chemical intake:

- Calculation of **intake factors** for each of the identified exposure pathways and receptors. An intake factor is a site-specific and receptor-specific value which, when multiplied by the concentration of each COPC, provides an estimate of the daily chemical intake of the COPC for each receptor and pathway. Some examples include inhalation rate, exposure frequency (i.e., hours per day or days per year) and exposure duration (e.g., number of years as a resident) and body weight; and
- Estimation of the **chemical concentration** in each medium relevant to the receptor groups and exposure pathways. This involves the use of relevant data collected from the site and surrounds.

The assessment presented has addressed potential worst-case exposure to COPC, and exposure has been calculated for a **Reasonable Maximum Exposure (RME)** scenario estimated by using the intake factors and chemical concentrations that define the highest exposure that is reasonably likely to occur in the area assessed. The RME is likely to provide a conservative estimate of total exposure and therefore health risk.

3.3.3.1 Exposure parameters

Exposure parameters which are considered representative of RME have been selected for the receptor groups evaluated. Where available, exposure parameters have been obtained from Australian sources (CRC care 2011; enHealth 2012; NEPC 2013). As required, this has been supplemented with data from the US EPA (2008 and 2009).

3.3.3.2 Exposure point concentrations

Exposure Point Concentrations (EPC) of COPC requiring further assessment for the theoretical dataset are based on calculations of exposure using the mass balance data for the hydraulic fracture stimulation fluid system (refer **Section 3.2.4.1**).

3.3.3.3 Exposure equations

Exposure equations were used for calculating the intake of COPC are presented in **Appendix D**.

3.4 Human health risk assessment

For those COPC for which potentially complete exposure pathways have been identified, there is a need to quantitatively assess the magnitude of potential exposure with regard to tolerable intakes.

The human health risk assessment (HHRA) was undertaken in general accordance with the following protocols and guidance:

- Amended National Environment Protection (Assessment of Site Contamination) Measure 1999 (Amended ASC NEPM); Schedule B4, Site-specific health risk assessment methodology (NEPC 2013)
- Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012a). These guidelines draw on and are supplemented by those provided by a number of other Australian and international agencies, with some of the key supporting documents listed below:
 - Methodology for setting air quality standards in Australia (NEPC 2011); and
 - Science and decisions: Advancing risk assessment (NRC 2008).

Human health risk assessment can be divided into the following four tasks:

- Issue Identification
- Hazard/Toxicity Assessment
- Exposure assessment.
- Risk characterisation

Guidance provided by enHealth (and detailed by NEPC) is utilised as the primary source. However, where only general guidance for the completion of risk assessment tasks (above) is provided, more detailed protocols and guidelines developed by the National Research Council (NRC 2008) and United States Environment Protection Agency (US EPA) (1989, 1991, 2002, 2005 and 2009) have been used as supplementary guidance.

It is noted that the HHRA approach presented in this report provides a methodology for assessment of the risks posed by mixtures that meet the requirement in the EA consent conditions. This approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total effluent toxicity and ecotoxicity, which is consistent with the National Water Quality Management Strategy (NWQMS) and the principles outlined in the ANZECC & ARMCANZ (2000) guidelines.

3.4.1 Toxicity assessment – human health

The objective of the toxicity assessment is to identify toxicity values for the COPC that can be used to quantify risks to human health associated with the calculated intake. The quantification of risk requires identification of toxicity values for the COPC identified as well as quantification of potential exposure.

Toxicity can be defined as *“the quality or degree of being poisonous or harmful to plant, animal or human life”* (NEPC 2013).

The steps involved in this process include the following:

- Obtain relevant qualitative and quantitative toxicity information on the COPC relevant to the significant exposure pathways being assessed.
- Identify the appropriate toxicity values for assessing both threshold¹⁰ effects and non-threshold carcinogenic¹¹ effects.

3.4.2 Selection of toxicity values

The identification of toxicity values undertaken in this risk assessment has followed ANZECC (1992) guidance, which is in accordance with the NEPC (1999) policy. enHealth (2012) provides a list of

¹⁰ Threshold toxicity effects are assessed on the basis that there is a dose of the chemical below which toxic effects will not occur (i.e., the threshold).

¹¹ Non-threshold carcinogenic effects assume that, for some chemicals classified as carcinogenic, there is no threshold below which there will be no increased risk of a toxic effect. Hence, assessment of these chemicals is based on the use of a slope factor, which assumes that any exposure to the chemicals will result in an increased incremental risk or probability of developing cancer over a lifetime.

toxicological data sources. These are classified as Level 1 or 2 data, with Level 1 sources recommended. In order of preference, the Level 1 sources are:

1. National Health and Medical Research Council documents and documents from other joint Commonwealth, State and Territory organisations.
2. ADI List from the Therapeutic Goods Administration.
3. World Health Organisation (WHO) documents.
4. enHealth Council documents.
5. National Environmental Health Forum documents.
6. International Agency for Research on Cancer (IARC) monographs.
7. WHO/FAO Joint Meeting on Pesticides (JMPR) monographs.
8. NICNAS Priority Existing Chemical (PEC) reports.
9. US Agency for Toxic Substances and Disease Registry (ATSDR) documents.
10. National Toxicology Program (NTP) carcinogenicity appraisals.
11. OECD Standard Information Data Sets (SIDS) and SID Initial Assessment Reports (SIAR).
12. USEPA Reference Doses.
13. TOXNET toxicological databases maintained by US National Library of Medicine.
14. The International Toxicity Estimates for Risk Assessment (ITER) database.
15. Dutch National Institute for Public Health and the Environment (RIVM) reports and databases.

Level 2 sources include peer-reviewed journals and industry publications and reference to Level 2 sources is considered warranted where Level 1 sources do not provide applicable criteria.

The following types of toxicity values may therefore be applicable:

- Acceptable or Tolerable Daily Intakes (ADIs or TDIs), for assessment of non-cancer effects (ANZECC, NHMRC and WHO)
- Benchmark doses, for assessment of cancer effects (ANZECC)
- Reference Concentrations (RfC), for inhalation assessment of non-cancer effects (USEPA)
- Reference Doses (RfD), for oral assessment of non-cancer effects (USEPA)
- Cancer slope factors, for assessment of cancer effects (WHO and USEPA).

Potential threshold effects are characterised by comparing the estimated chemical intakes with the ADIs, TDIs or RfDs, that represent the threshold intake for adverse health effects. Threshold toxicity effects are assessed on the basis that there is a dose of the chemical below which toxic effects will not occur (i.e., the threshold).

Potential non-threshold carcinogenic effects are the estimated incremental probabilities that an individual will develop cancer over a lifetime as a result of the estimated exposure to the COPC. When a carcinogenic slope factor is used to evaluate health risk, it is assumed that any exposure to the chemical will, in theory, result in an increased risk or probability of developing cancer. The higher the carcinogenic slope factor, the more potent the chemical, and the greater the calculated cancer risk for a given exposure.

In reviewing relevant toxicity information for the COPC identified in this HHRA, the following has also been considered in the approach adopted:

- **Assessment of Dermal Exposures:** If no dermal toxicity values are available for the COPC identified, dermal exposures will be assessed on the basis of oral data, where available
- **Assessment of Oral Exposures:** In relation to potential exposure and risk issues identified and evaluated in this assessment, a potential route of exposure is via ingestion and direct contact with COPC in water. Hence, the oral TRV is utilised for the purpose of establishing drinking water (or

recreational water) guidelines. Existing oral TRVs and drinking water guideline values were used when applicable. Otherwise, information on mammalian toxicity was acquired primarily from reported data that had already been through a screening process such as the OECD SIDS program, the U.S. Cosmetics Ingredient Review or the EU Scientific Committee on Consumer Safety (SCCS). The data from these programs were considered sufficiently reviewed as to not require further evaluation. Data reported as part of other equivalent peer reviewed risk assessment programs (e.g., HHRA (www.HHRAproject.com/); USEPA HPV Chemical Challenge Program) were also considered in a similar fashion, although a certain level of expert judgment was required to evaluate the quality of these programs. Toxicity information was also obtained via the ECHA CHEM database. This database provides electronic public access to information on chemical substances manufactured or imported in Europe. The information originates from the registration dossiers submitted by companies to ECHA in the framework of REACH Regulation. If no data were available from the above sources or the available data were considered insufficient for the determination of oral RfDs and drinking water guideline values, then toxicity information on SDSs were used, as well as read across from available experimental data on a structurally related substance and predicted values from QSAR models.

3.4.2.1 Derivation of oral reference dose and drinking water guideline values

Oral toxicity reference value derivation

Where required, the oral reference dose was calculated using the following equation:

$$\text{Oral TRV} = \frac{\text{NOAEL (or LOAEL)}}{UF_{\text{Total}}}$$

Where:

NOAEL = No Observed Adverse Effect Level

LOAEL = Lowest Observed Adverse Effect Level

UF_{Total} = Total uncertainty factors

When dosing regimens were 5 days/week, the NOAEL was adjusted to 7 days/week by multiplying the NOAEL by 5/7.

Uncertainty factors of 10 were used to account for the following (USEPA, 2002):

- Variation in sensitivity among members of the human population (i.e., inter-individual variability)
- Uncertainty in extrapolating animal data to humans (i.e., interspecies uncertainty)
- Uncertainty in extrapolating data obtained in a study with less-than-lifetime exposures (i.e., extrapolating from subchronic to chronic exposure)
- Uncertainty in extrapolating from a LOAEL rather than from a NOAEL.

Determination of drinking water guideline values

The ADWG (2018) values were used when applicable. The WHO, and then USEPA, were also consulted for any additional drinking water standards when there were no ADWGs.

For those chemicals where there are no regulatory drinking water guidelines, and for which a threshold exists, the guideline value was derived from animal toxicity data using the following equation (ADWG, 2017):

Drinking Water Criteria

$$= \frac{\text{NOAEL (or LOAEL)} \times \text{Body Weight} \times \text{Proportion intake from water}}{\text{volume of water consumed} \times UF_{\text{Total}}}$$

Where:

NOAEL = No Observed Adverse Effect Level

LOAEL = Lowest Observed Adverse Effect Level

Body weight = 78 kg

Proportion of intake from water = 10%

Volume of water consumed = 2 L/day
 UF_{Total} = Total Uncertainty Factors

3.4.3 Risk characterisation

3.4.3.1 Risks to human health

Risk characterisation is the final step in a quantitative risk assessment. It involves the incorporation of the exposure assessment and toxicity assessment to provide a quantitative assessment of non-threshold carcinogenic risk and threshold risk. In the assessment presented, evaluation of exposures to the COPC involves an assessment of threshold and non-threshold risks.

The calculation of risks has been undertaken using an in-house spreadsheet model, RiskE. The equations utilised within RiskE follow risk assessment methodology as outlined in **Section 3.0** following protocols established by ANZECC, NHMRC, NEPM, and CRC CARE.

3.4.3.2 Hazard index for threshold effects

The potential for adverse threshold effects, resulting from exposure to an individual COPC, has been evaluated by comparing an exposure level, expressed as a daily chemical intake, with the ADI/TDI or RfD. The resulting ratio is referred to as the hazard quotient, and is derived in the following manner for oral/dermal and inhalation exposures:

$$\text{Hazard Quotient (oral or dermal)} = \frac{\text{Daily Chemical Intake}}{(\text{ADI, TDI, RfD} - \text{Background})}$$

Where

ADI = acceptable daily intake (mg/kg/day)

TDI = tolerable daily intake (mg/kg/day)

RfD = Reference dose (mg/kg/day)

If the daily chemical intake for the individual COPC exceeds the ADI, TDI or RfD (i.e., if the hazard quotient exceeds one), then this would indicate potentially unacceptable chemical intakes. The hazard quotient does not represent a statistical probability of an effect occurring.

To assess the overall potential for adverse health effects posed by simultaneous exposure to multiple chemicals, the hazard quotients for each chemical and exposure pathway have been summed. The resulting sum is referred to as the hazard index (HI). The HI approach assumes that multiple sub-threshold exposures to several chemicals could result in a cumulative adverse health effect, and exposures are summed over all intake routes.

Acceptable Risk

An “acceptable” risk in this assessment has been defined as a Hazard Index of 1 (as per risk assessment industry practice, supported by protocols outlined in NEPM (2013) and USEPA guidance.

If the Hazard Index is less than one, cumulative exposure to the site chemicals is judged unlikely to result in an adverse effect. If the index is greater than one, a more detailed and critical evaluation of the risks (including consideration of specific target organs affected and mechanisms of toxic action of the chemicals of concern) would be required to ascertain if the cumulative exposure would, in fact, be likely to harm exposed individuals. All hazard quotient and hazard index calculations are presented in

Appendix D.

3.4.3.3 Non-threshold carcinogenic risk

The potential for unacceptable non-threshold carcinogenic risks associated with exposure to COPC have been evaluated using US EPA (1989 and 2009) methodology.

Non-threshold carcinogenic risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential non-threshold carcinogen. The numerical estimate of excess lifetime cancer risk is calculated as follows for oral/dermal and inhalation exposures:

$$\text{Carcinogenic Risk (oral or dermal)} = \text{Daily Chemical Intake} \times \text{Cancer Slope Factor}$$

The total non-threshold carcinogenic risk is the sum of the risk for each chemical for each pathway.

Australian guidance related to the significance of non-threshold cancer risk estimates currently specifies that risks of less than 10^{-5} per lifetime is generally accepted as indicating conditions that do not warrant specific management or remedial action.

Acceptable Risk

The adopted acceptable risk is defined as a risk of less than 1×10^{-5} incremental lifetime risk of cancer.

3.5 Environmental risk assessment

The objective of undertaking an Environmental Risk Assessment (ERA) is to investigate the potential risks to the environment associated with the concentrations of chemicals of potential environmental concern (COPEC) that may be present in the flowback fluid (in the event there is a leak or spill from aboveground infrastructure).

With regards to the assessment of potential environmental risks, the requirements of the ASC NEPM Schedule B5a, Guideline on Ecological Risk Assessment (NEPC 2013) were considered.

Similar to the HHRA, the ERA consists of the four basic components:

- Issue Identification/Problem Formulation:
 - Identification of COPECs;
 - Identification of receptors of concern; and
 - Identification of operable exposure pathways warranting quantification of risk.
- Toxicity Assessment:
 - Present the doses or concentrations of COPECs below which risks are assumed to be negligible or low (toxicological reference values, TRVs);
- Exposure Assessment:
 - Determination of exposure concentrations for the site's various receptors (i.e. concentrations used to quantify risks); and
 - Estimation of contaminant intake (dose entering body, mg/kg-day) for operable exposure pathways.
- Risk Characterisation:
 - Quantify risks as magnitude of exceedance of the TRVs (i.e. hazard quotients, dose divided by TRV) and derivation of species sensitivity distributions.

It is noted that the ERA approach presented in this report provides a methodology for assessment of the risks posed by mixtures that meet the requirement in the EA consent conditions. This approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total effluent toxicity and ecotoxicity, which is consistent with the National Water Quality Management Strategy (NWQMS) and the principles outlined in the ANZECC & ARMCANZ (2000) guidelines. The NEPC (2013) also addresses the mixture of constituents and has adopted the hazard quotient approach for the Guideline for ERA.

Similar to the human health risk assessment approach, the estimated exposure to the flowback fluid was based on a theoretical EPC that was developed from knowledge of the chemicals and quantities used in the hydraulic fracture stimulation process.

3.5.1 Exposure assessment

The exposure setting provides important information regarding the current site use and physical attributes of the site. The information herein will form the basis for determining applicable exposure pathways between sources of contamination and receptors of concern (assessment endpoints). The objective of the environmental risk assessment is to assess the typical potential exposures that may occur in any of the operational areas in the TGS fields. As such, the exposure assumptions for the environmental receptors were based on a typical operational layout and adjacent land use that includes agricultural land and a flowing surface water body.

3.5.2 Potential exposure pathways and receptors

Environmental surveys have been conducted for QGC that identified flora and fauna that may inhabit the local and regional environments associated with the gas fields. In general, the potential environmental receptors include domesticated livestock, agricultural and native plants, local and regional wildlife, and aquatic fish and invertebrates. However, as previously noted, the objective of this ERA is to evaluate the potential risks from a typical gas well field; therefore, the selection of environmental receptors for this ERA is based on understanding that the selected environmental receptors may have an equal opportunity to be exposed to residual hydraulic fracture stimulation flowback fluid at any of the TGS fields within the project area.

Considering the environment at and within the vicinity of the TGS operations evaluated in this assessment, the scope of the risk assessment, the potential receptors, and pathways (significant and less significant) will be identified.

3.5.3 Toxicity assessment

3.5.3.1 General

The purpose of toxicity assessment is to identify concentrations or doses of COPECs at which adverse effects may occur to receptors.

The risk characterisation performed in this ERA relies on toxicity data and screening level guidelines as toxicity reference values (TRVs). The TRVs are derived based on COPEC levels that imply no adverse effects or levels that represent the lowest concentrations at which adverse effects may occur. To evaluate the concentration of the COPEC in the surface water and direct exposure by the aquatic environmental receptor, a concentration based TRV was derived.

3.5.3.2 Concentration based on TRV

The existing water quality guidelines for protection of aquatic life were researched and compiled using the following sources of ecotoxicological information:

- Australian and New Zealand Environment and Conservation Council (ANZECC) guidelines for fresh and marine water quality.
- National Industrial Chemicals Notification and Assessment Scheme (NICNAS), National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia, 2017.
- International Guidance (USEPA, American Petroleum Institute, Oak Ridge National Laboratory/Risk Assessment Information System (ORNL/RAIS)).

If water quality guidelines were not available, information on aquatic toxicity was acquired from reported values that had already been through a screening process such as the following:

- AICIS Chemical Assessment Reports (includes those previously published by NICNAS)
- OECD-SIDS program
- EU existing substances risk assessment
- HHRA (www.HHRAproject.com)
- USEPA HPVC Challenge Program
- ECHA CHEM database

The data from these programs were considered sufficiently reviewed as to not require further evaluation. If no data were available from the above sources or the available data were considered insufficient for TRV determinations, then toxicity information on SDSs were used, as well as read across from available experimental data on a structurally related substances, and predicted values from QSAR models.

3.5.3.3 Calculation of PNEC for freshwater

The determination of TRVs for freshwater was conducted according to the predicted no-effects concentration (PNEC) guidance in the Environmental Risk Assessment Guidance Manual for Industrial Chemicals prepared by the Australian Environmental Agency (AEA, 2009).

A PNEC is calculated using toxicity test data such as LC50, EC50, other L(E)Cx values, NOEC (no observed effect concentration) and LOEC (lowest observed effect concentration). Derivation of a PNEC commonly relies on using assessment or safety factors. Assessment factors reflect the following uncertainties inherent in most datasets, and the extrapolations that can be required:

1. Intra-species and inter-species variations
2. Extrapolation of short-term toxicity towards long-term toxicity
3. Extrapolation of laboratory results towards the field.

Table 9 lists the assessment factors used to adjust the effect concentration and to estimate a PNEC.

Table 9 Summary of assessment factors for estimating a PNEC (AEA 2009)

Data	Data Available	Range of assessment factors	Comments
When only acute toxicity data are available, an assessment factor of between 100 and 1000 is applied to the lowest L(E)C50			
Acute	• EC50 algae (72h) • EC50 <i>Daphnia</i> (24-48 h acute test) • LC50 fish (96h)	100-1000	A factor of 1000 is a conservative and protective factor and applied when only limited data are available. A factor of 100 can be applied if the following evidence is available: • Availability of data from a wide variety of species including those which are considered to represent sensitive species • Information from structurally similar compounds or QSAR, to suggest that the acute to chronic ratio is likely to be low • Information to suggest that the chemical acts in a non-specific or narcotic manner, with little inter-species variation in toxicity • Information to suggest that the release of the chemical is short-term or intermittent, and that the chemical would not be persistent in the environment.
When chronic toxicity data are available in addition to acute data, often an assessment factor of between 10 and 100 is applied to the lowest NOEC			
Chronic	• NOEC <i>Daphnia</i> (14-21d chronic toxicity test) • NOEC algae (72h) NOEC fish (chronic toxicity test)	10-100	• If a chronic NOEC is available from one or two species representing one or two trophic levels (i.e., fish, <i>Daphnia</i> or algae), a factor of 100 or 50 is applied to the lowest NOEC. In this case, a PNEC value derived from chronic data should be compared to that derived from the lowest acute data. It is then the lowest value that is used in the assessment. • If chronic NOECs are available from three species representing three trophic levels (i.e. fish, <i>Daphnia</i> and algae), a factor of 10 is applied to the lowest NOEC. If there is convincing evidence that the most sensitive species for which acute toxicity data are available have been tested chronically, a factor of 10 may also be applied to the lowest NOEC from two

Data	Data Available	Range of assessment factors	Comments
			species representing two trophic levels (i.e. fish and/or <i>Daphnia</i> and/or algae).

It should be noted that in the case of algae studies, which are actually multigenerational studies, it is generally accepted that a 72-hour (or longer) EC50 value may be considered as equivalent to a short-term result and that a 72-hour (or longer) EC10 or NOEC value can be considered as long-term results. It is noted that Shell QGC does not perform any testing on vertebrates for the purpose of chemical selection.

3.6 Quantification of exposure

3.6.1 Source point concentrations

Similar to the human health risk assessment, the exposure point concentrations for the environmental risk assessment were based on a theoretical data set (assuming 20% and 60% mass recovery in flowback fluid).

3.7 Screening level environmental risk characterisation

Risk characterisation is the process of quantifying and characterising risk using the selected measurement endpoints or lines of evidence. The NEPC (2013) and USEPA (1997) have recommended protection goals for interpreting the risks associated with individual hazard quotients (HQ) and toxicity test results.

The use of HQs has been common practice in human health risk assessments and has been carried over and used in most screening level ERAs. In this screening level ERA for aquatic receptors, calculation for HQs was used in assessing the risk of COPECs where limited species-specific toxicity data exists.

3.7.1 Estimation of risk

The source point concentrations have been conservatively considered as exposure point concentrations (EPC) for this screening level assessment and are compared to TRVs (or PNEC aquatic) to estimate the potential for adverse environmental effects. When exposure is greater than TRVs there is a potential for adverse impacts. To assess potential adverse environmental effects HQs were calculated. Hazard quotient calculations were calculated using the derived TRVs. HQs were calculated as follows:

$$\text{HQ aquatic} = \frac{\text{EPC}}{\text{TRV (or PNEC aquatic)}}$$

HQaquatic = Hazard Quotient

EPC = COPEC exposure point concentration in surface water (mg/L)

TRV = Concentration based TRV (or PNEC aquatic) (mg/L)

To assess the overall potential for adverse environmental effects posed by simultaneous exposure to multiple chemicals, the hazard quotients for each chemical and exposure pathway have been summed. The resulting sum is referred to as the hazard index (HI).

The risk classification system used to qualify the potential for environmental risk based on HI results was as follows:

- HI less or equal to 1 indicates acceptable low risk
- HI greater than 1 indicates potential risk or adverse effect and that further evaluation is warranted to refine the calculation of potential risk to environmental receptors.

This HI system was considered appropriate given the conservative approach to estimating environmental exposure levels using the maximum measured COPEC concentrations and provide a tool by which the potential for impacts in surface water can be assessed.

3.8 Noise and vibration

The existing noise environment of ATP645 is typical of a remote, largely unpopulated area, with low levels of background noise dominated by natural sources (e.g., wind, animals, and insects) and intermittent noise from vehicular traffic and grazing activities (e.g., utilities, heavy vehicles, mustering) from the surrounding agricultural activities.

Shell QGC undertook long-term noise monitoring within the project area and deemed background noise levels to be:

- 7.00am - 6.00pm 35 dBA
- 6.00pm - 10.00pm 30 dBA
- 10.00pm - 6.00am 25 dBA
- 6.00am - 7.00am 30 dBA

The monitoring indicated that background noise levels at night can fall below 25 dB(A) during certain times of the year. Consistent with DES's Guideline *Prescribing noise conditions for petroleum activities*, (DES, 2022) where background noise levels are less than 25 dB(A) at night, a deemed background noise level of 25 dB(A) is to apply.

Based on the deemed background noise levels, the Project EA Permit EPPG00839513 has set noise nuisance limits as outlined in Table 10.

Table 10 Protecting acoustic values – Noise nuisance limits

Time period	Metric	Short term noise event	Medium term noise event	Long term noise event
7.00am - 6.00pm	L _{Aeq,adj,15min}	45 dBA	43 dBA	40 dBA
6.00pm - 10.00pm	L _{Aeq,adj,15min}	40 dBA	38 dBA	35 dBA
10.00pm - 6.00am	L _{Aeq,adj,15min}	28 dBA	28 dBA	28 dBA
	Max L _{pA,15,min}	55 dBA	55 dBA	55 dBA
6.00am - 7.00am	L _{Aeq,adj,15min}	40 dBA	38 dBA	35 dBA

The noise environmental values relevant to ATP 645 include environmental values for the acoustic environment provided in Section 6 of the *Environmental Protection (Noise) Policy 2019* as follows:

- The qualities of the acoustic environment that are conducive to protecting the health and biodiversity of ecosystems, and
- The qualities of the acoustic environment that are conducive to human health and wellbeing, including by ensuring a suitable acoustic environment for individuals to do any of the following—
 - sleep
 - study or learn
 - be involved in recreation, including relaxation and conversation, and
- the qualities of the acoustic environment that are conducive to protecting the amenity of the community

Dependent on the location and nature of the hydraulic fracture stimulation activities, there is potential for noise impacts on sensitive receptors within the operational area. However, noise emissions from hydraulic fracture stimulation are of a relatively short duration, occurring at a given wellsite on a continuous basis for only a number of weeks at a time. While it is noted that some receptors may experience extended exposure due to noise emissions from hydraulic fracture stimulation at multiple

well sites, the noise emissions are not likely to contribute to long-term background noise creep and therefore are unlikely to have a significant impact on acoustic amenity.

Noise impacts to sensitive receptors from hydraulic fracture stimulation are assessed on a case-by-case basis and managed in accordance with the Environmental Authority requirements.

3.9 Regional ecosystems

Native remnant vegetation occurs throughout the tenure, with areas of endangered vegetation communities and of concern vegetation communities associated with drainage lines. Environmental constraints and regional ecosystems are mapped in Figure 19.

The TGS wells have been located across ATP645 based on geological and constraints data (including regional ecosystems, groundwater bores, surface water drainages), as included in Figure 20.

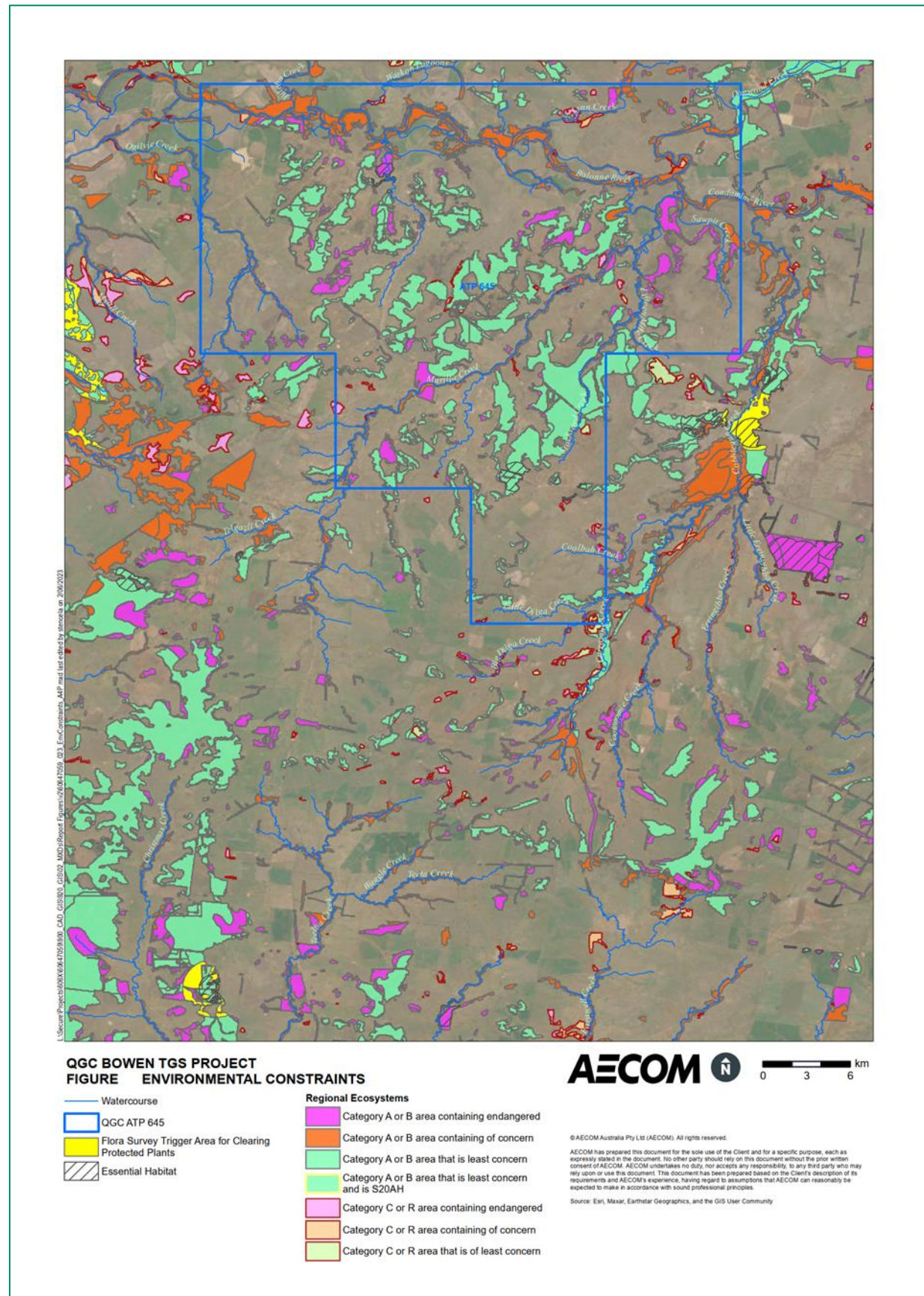


Figure 19 Regional ecosystems

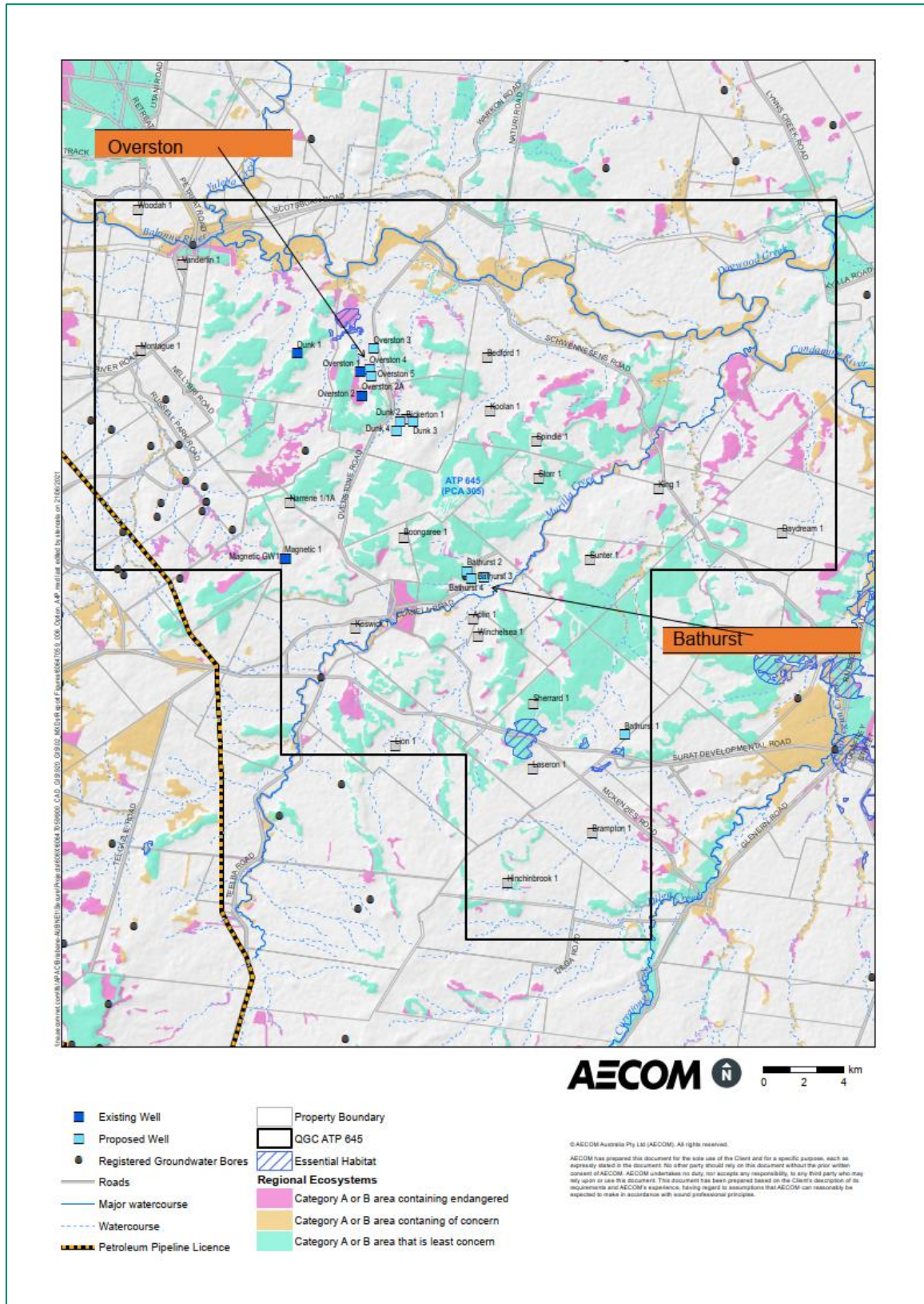


Figure 20 Drilling targets

3.10 Uncertainty assessment

In general, the uncertainties and limitations of the human health and environmental risk assessment can be classified into the following categories:

- Receptor exposure assessment; and
- Toxicological assessment.

The risk assessment process, following both Australian and international guidance, provides a systematic means for organising, analysing, and presenting information on the nature and magnitude of risks to public health posed by chemical exposures. Despite the advanced state of the current risk assessment methodology, uncertainties and limitations are inherent in the risk assessment process. The uncertainties associated with each of these categories are discussed in the sections above.

3.10.1 Exposure uncertainties

Risk assessments require the adoption of several assumptions in order to assess potential human exposure. This risk assessment includes assumptions about general characteristics and patterns of human exposure relevant to the receptor groups. These assumptions are conservative and developed to provide an estimate of maximum possible exposures rather than the actual exposures. This approach is expected to overestimate the risks.

More specifically, the presence and concentrations of COPC assumed in the calculations are based on a worst-case assumption that the COPC present in hydraulic fracture stimulation fluids do not degrade or sorb significantly in the sub-surface, and that these chemicals may all be present in the water to which trespassers, aquatic receptors and terrestrial species are exposed. In addition, it is assumed that a range of hydraulic fracture stimulation fluids are used in the same area of operation at the same time.

3.10.2 Toxicity uncertainties

In general, the available scientific information is insufficient to provide a thorough understanding of all of the potential toxic properties of chemicals to which humans may be exposed. It is necessary, therefore, to extrapolate these properties from data obtained under other conditions of exposure which generally involve experimental laboratory animals.

Although there may be interspecies differences in chemical absorption, metabolism, excretion and toxic response, there may also be uncertainties concerning the relevance of animal studies using exposure routes that differ from human exposure routes. In addition, the frequent necessity to extrapolate results of short term or sub-chronic animal studies to humans exposed over a lifetime has inherent uncertainty. In order to adjust for these uncertainties, published toxicity values generally incorporate safety factors that may vary from 10 to 1000. The uncertainties inherent in the toxicological values adopted are considered likely to result in an overestimation of actual risk.

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Appendix A

TGS Campaign

Appendix A TGS Campaign

A.1 Introduction

To conduct a risk assessment of hydraulic fracture stimulation activities within the TGS project area, an understanding of the surface and subsurface environment is required. A conceptual model of the existing environment within the TGS project area is developed in the subsequent sections of this report, to facilitate the assessment of the risks associated with the proposed hydraulic fracture stimulation.

Furthermore, an understanding of the existing environmental values allows for the development of appropriate risk management systems through impact mitigation and minimisation and for the design of a robust hydraulic fracture stimulation verification and validation (monitoring) program.

A.1.1 Locations and schedule

The QGC gas exploration area lies approximately 400 km north-west of Brisbane in the Darling Downs region of Queensland. The study area for this report focuses on Authority to Prospect (ATP) 645 (PCA 305¹²). Three previous exploration wells, Daydream 1, Dunk 1, and Magnetic 1, are located across ATP645, these wells all targeted the deeper sediments of the Bowen Basin, with total drill depths of between 3,095 m and 4,140 m. These wells provided detailed site-specific geological data across ATP645.

The major towns near ATP645 include Surat, Wallumbilla, and Tara (see Figure 21). The major land use across the study area is agricultural with grazing and dry land cropping. In these drier areas, agriculture is often supported by irrigation. However, agricultural production in the east of the study area, toward the Great Dividing Ranges does not require irrigation due to higher rainfalls.

Irrigation water is mainly sourced from surface water from the major rivers running through the area; however, some irrigation water is drawn from aquifers within the Great Artesian Basin that includes the Bowen Basin, which underlies the Surat Basin. The Surat Basin provides most groundwater extracted in the study area.

The major catchment zone in the study area is the Condamine – Balonne Catchment. This catchment extends to the south-west into NSW and feeds the Murray Darling Basin. This river system drains to the south-west.

The Bowen Basin extends northward toward the coast and also includes other catchments such as the Fitzroy River Basin, part of Dawson's River, Bellayando and Suttor, Nagoa and Mackenzie and the Burdekin River Catchment areas according to the Australian Natural Resources Atlas, based on the 2000 - 2002 National Land and Water Resources Audit. (Queensland Government, DAFF, online cotton industry overview, 2012, http://www.daff.qld.gov.au/26_3431.htm). These rivers drain to the north and east toward the coast.

There are no RAMSAR protected wetlands, nor are there nationally important wetlands, within 100 km of the study area outlined by the petroleum leases (see as detailed in Section A.1.2).

Schedule

The TGS project, comprising two drilling phases, is scheduled as follows:

- The first phase (phase-1 wells) includes 3 wells, approximately 2-week clean-up and up to a 2-week flow test.
- The second phase includes 4 additional wells and conducting long term 6-month test on all wells.

¹² Potential Commercial Area (PCA) - A PCA enables the holder of an authority to prospect (ATP) who has discovered petroleum or a natural underground reservoir suitable for the storage of petroleum, the opportunity to retain an interest in and later develop the discovery if it is not currently commercially viable.

A.1.2 Receiving environment

A.1.2.1 Surface setting

A.1.2.1.1 Location and land use

ATP645 is located within a rural setting, typical of the Central Queensland region. The largest nearby town is Roma, which is located approximately 100 km north-west, while Surat is less than 50 km to the west. The small township of Glenmorgan is located more than 20 km to the north-east (Figure 21).

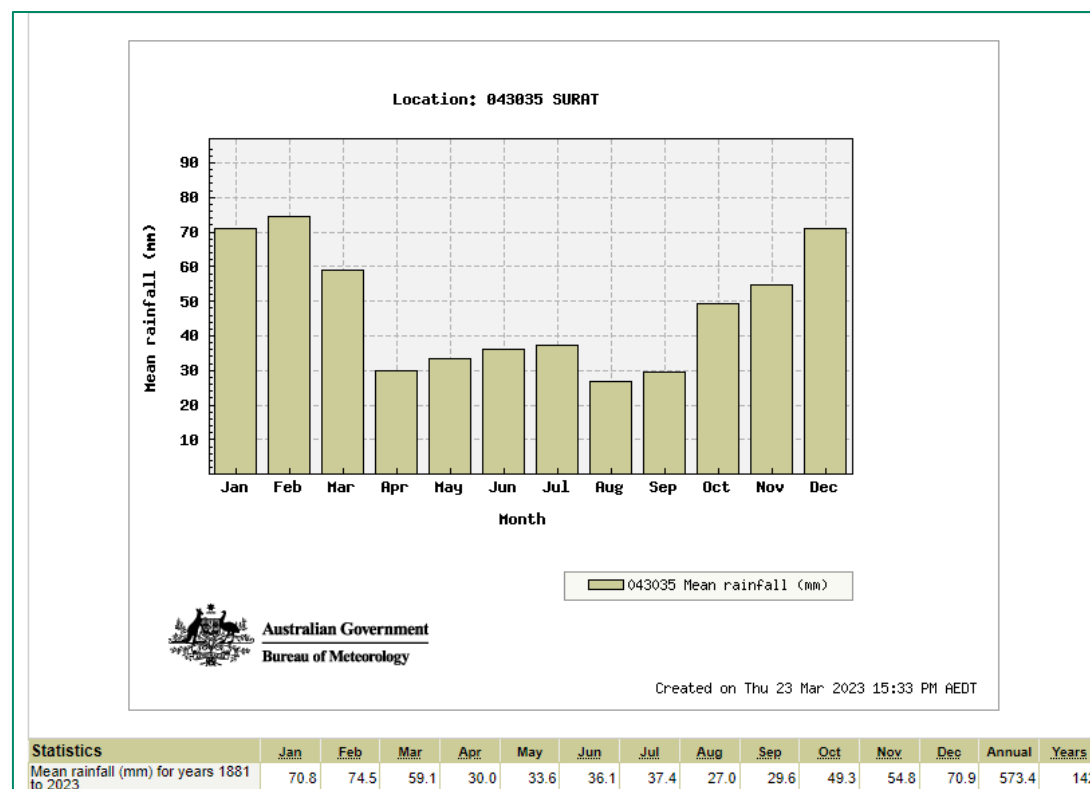
The predominant land uses within ATP645, and the wider region include agricultural (cropping and grazing), resource activities (petroleum and mining), and nature conservation plus waterways with fringing riparian vegetation. Yuleba State Forest is located directly north of the ATP645.

A.1.2.1.2 Climate

Climate data collected since 1881 from the Bureau of Meteorology weather station 043035¹³ in Surat, the closest town to ATP645, indicates:

- Hot summers (> 30 °C) and moderate winters (~20 °C)
- Mean annual rainfall is 573.4 mm (142-year data)
- Distinct wet and dry seasons (Plate 3).

Plate 3 Surat rainfall data (1881 to 2023)



No evaporation is available for weather station 043035, however, the average evaporation for the Surat Basin (using data from Miles) is approximately 1,750 mm/year. This indicates a negative climate balance within the study area.

¹³ <http://www.bom.gov.au/qld/observations/index.shtml>

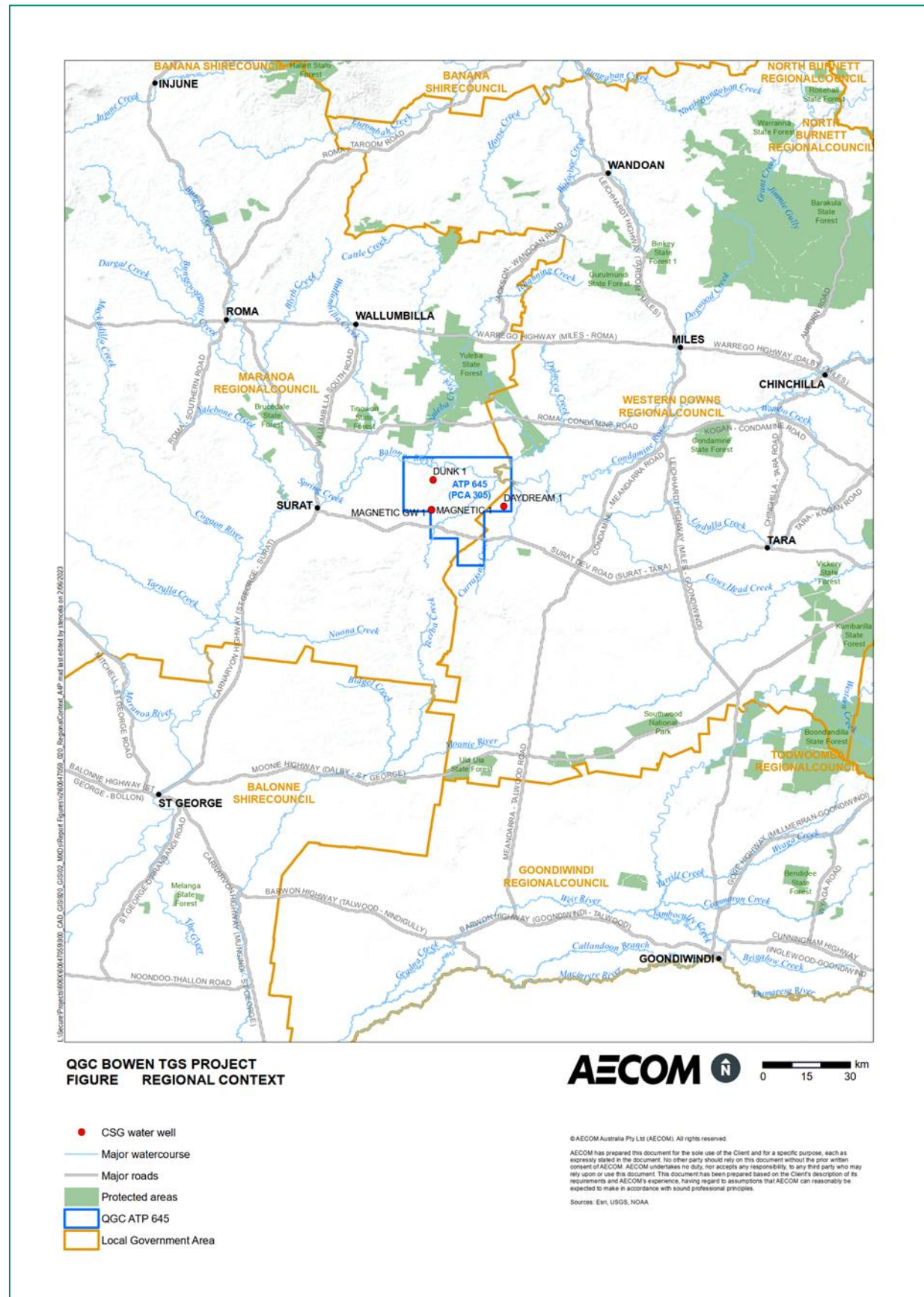


Figure 21 Regional context

A.1.2.1.3 Topography

With the study area, terrain elevation ranges from approximately 240 m to 390 m Australian Height Datum (AHD). Northern parts of ATP645 sits within flat floodplain country intersected by a complex system of rivers, creeks, and drainage lines. Balonne is a network of channels, waterholes, and floodplains.

Native remnant vegetation occurs throughout the tenure, with areas of endangered vegetation communities and of concern vegetation communities associated with drainage lines.

A.1.2.1.4 Hydrology

The Murray–Darling Basin is a large area of south-eastern Australia where water flows through a system of interconnected rivers and lakes. The two main rivers are the River Murray and the Darling River. The Darling begins in Southern Queensland where the Culgoa and Barwon rivers meet. It flows into the Murray at the border of New South Wales and Victoria, and the Murray eventually reaches the sea to the south-east of Adelaide. The Basin includes most of New South Wales, some of southern Queensland, the east of South Australia, northern Victoria, and all the Australian Capital Territory

ATP645 falls within the Condamine and Balonne rivers catchment, which is one of the largest in the Murray-Darling Basin. From the northeast of ATP645, the Condamine River flows southwest to the plains, where it meets the Dogwood Creek and becomes the Balonne River. The Balonne River increasingly transforms into a network of channels, waterholes, and floodplains before crossing the border into New South Wales. The southern part of ATP645 occurs within the Border Rivers and Moonie catchment.

A search for mapped watercourses as defined by the Water Act was completed, with a search envelope surrounding ATP645 set to approximately 60 km from the lease perimeter. The search identified 28 watercourses with several unnamed tributaries attached throughout the network.

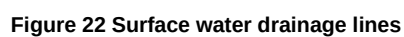
The search also identified that the five longest tributaries of the Balonne River are the Condamine River, the Maranoa River, Dogwood Creek, Yuleba Creek and Tartulla Creek.

Table 11 Watercourses as defined by the Water Act

Name	Office	Latitude	Longitude	
Balonne River	Toowoomba	-27.01458	149.4340315	Runs E-W along northern end of ATP
Bendiboi Creek	Toowoomba	-27.4562185	148.9217375	
Bidgel Creek	Toowoomba	-27.7153045	149.249348	
Brigalow Creek	Toowoomba	-27.3307665	149.8748	
Bungil Creek	Toowoomba	-26.7265195	148.834905	
Charmana Creek	Toowoomba	-26.569429	149.5893685	
Cobblegun Creek	Toowoomba	-27.248872	149.664745	Runs along eastern border of ATP
Cogoon River	Toowoomba	-26.978669	148.524207	
Condamine River	Toowoomba	-27.0748415	149.685263	Located to the west of the ATP
Cooloomala Creek	Toowoomba	-26.9582	150.192838	
Dogwood Creek	Toowoomba	-26.9771435	149.7375525	NE corner of the ATP
Dulacca Creek	Toowoomba	-26.641718	149.7519585	
Griman Creek	Toowoomba	-27.2035145	149.221624	
Horse Creek	Toowoomba	-27.2549085	149.1658645	
Little Erringibba Creek	Toowoomba	-27.310031	149.6872815	

Name	Office	Latitude	Longitude	
Maier Creek	Toowoomba	-26.7783575	149.8203105	
Murilla Creek	Toowoomba	-27.339948	149.4066605	Branch Condamine running NE-SW through ATP
Range Creek	Toowoomba	-26.748955	149.910814	
Rocky Creek	Toowoomba	-26.63231	149.3991315	
Spring Creek	Toowoomba	-27.125987	149.0964305	
Tchanning Creek	Toowoomba	-26.4988065	149.6957295	
Teelba Creek	Toowoomba	-27.475458	149.40744	
Undulla Creek	Toowoomba	-27.274558	150.470069	
Warkon Lagoons	Toowoomba	-26.993778	149.4601475	
Weribone Creek	Toowoomba	-27.2739015	148.9252295	
Wongle Wongle Creek	Toowoomba	-27.585426	149.7154175	
Yalebone Creek	Toowoomba	-26.890005	148.837698	
Yuleba Creek	Toowoomba	-26.6081675	149.383319	

The surface water drainages across ATP645 are included in Figure 22.



Land use within the area of interest and surrounds is primarily agricultural, and resources and mining. Multiple farm dams are situated within the agricultural region.

A search for existing water management infrastructure such as water storage dams was completed within a search envelope of approximately 60 km around the perimeter of ATP645. The search did not identify any dams and identified 24 pondage areas.

The 24 existing water pondage areas (farm and other dams) were identified from aerial photography (Figure 23). The surface area for these water storages varies from approximately 1 ha to 30 ha, and the distances to the centroid of the tenement vary from 5 km to approximately 80 km.

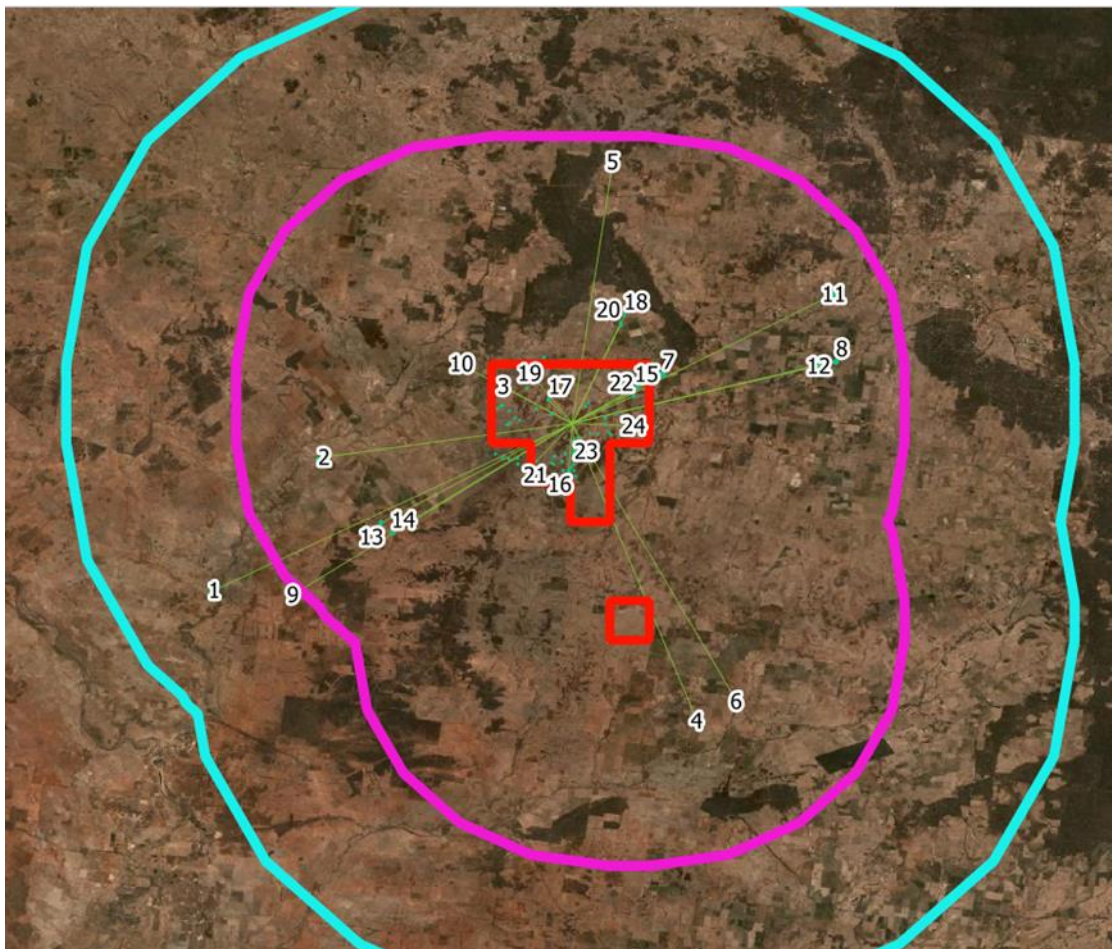


Figure 23 Existing local water storages identified via aerial photo (purple: 60 km buffer, blue: 100 km buffer)

No weirs are located within a 100 km buffer from ATP645 boundaries. The nearest weir is the Chinchilla Weir, approximately 112 km from the centre of the site.

A.1.2.1.4.1 Surface features at each Appraisal well

Based on the location of the Appraisal wells (Table 2) an assessment of the well locations and sensitive ecosystems was conducted, for consideration in the Risk Assessment.

Bathurst 5 is located some 200 m from the registered bore RN58538, which intersects the shallow (32 m) Tertiary sediments. This Appraisal well is located some 750 m from a reservoir and approximately 1 km from the nearest non-perennial creek (

Plate 4).

Plate 4 Bathurst 5 location (Google Earth)

This well is considered sufficient far to have limited risk to surface water drainages should the above ground tank burst / lose containment.

Appraisal well Dunk 5 is located on a surface water divide, with a creek some 1 km to the west and a creek 2 km to the east (Plate 5).

This well is considered sufficient far to have limited risk to surface water drainages should the above ground tank burst / lose containment.

Plate 5 Dunk 5 location (Google Earth)



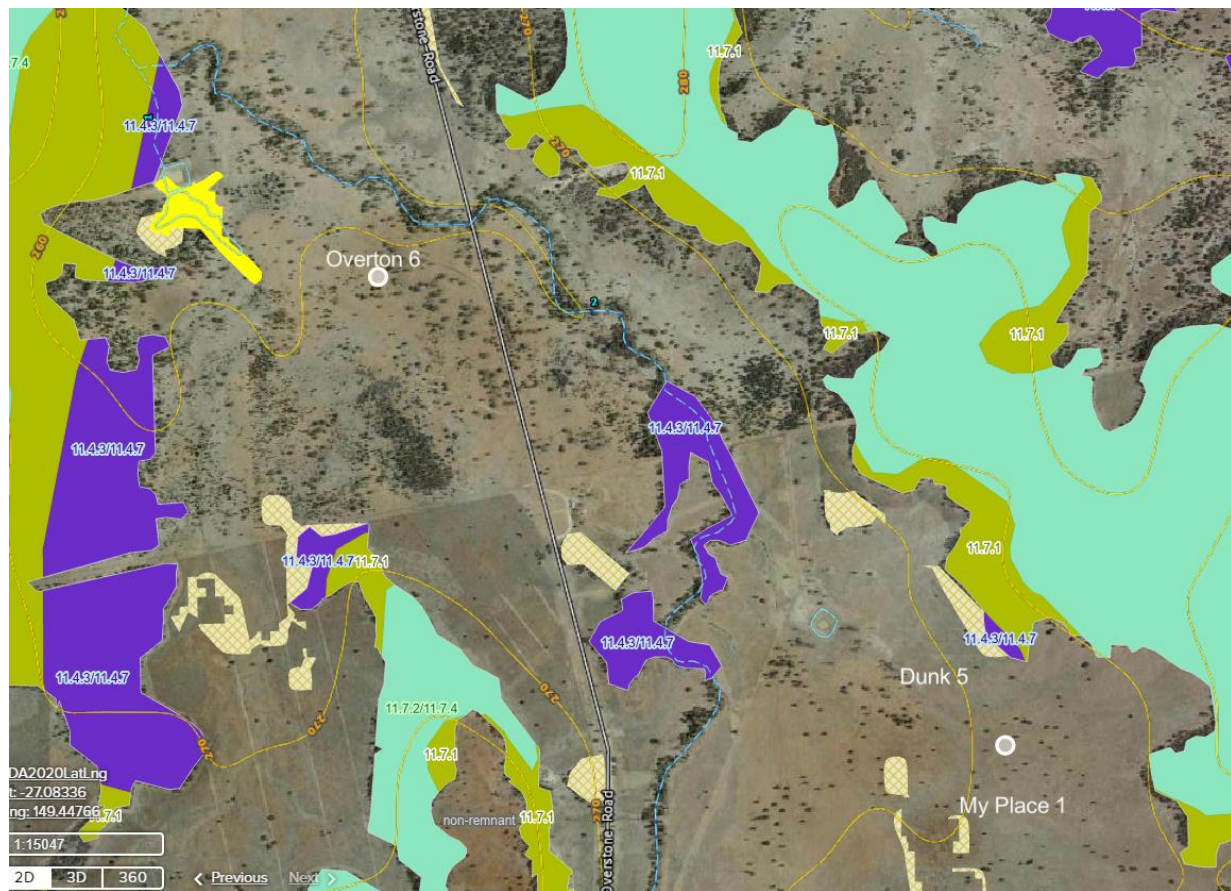
Appraisal well Overton 6 is in close proximity (230 m) from the nearest creek, and approximately 750 m from a farm dam (Plate 6).

Plate 6 Overton 6 location (Google Earth)



An assessment of remnant vegetation, Matters of State Significance (MSES), and wetland mapping was conducted within the area enveloping Overton 6 (Plate 7).

Plate 7 Overton 6 location (QGlobe)



The available mapping (QGlobe) indicates:

- There are no mapped MSES conservation areas, wetlands, wildlife habitat or vegetation
- No surface expression or terrestrial Groundwater Dependent Ecosystems (GDEs) mapped
- Artificial wetlands are mapped within the farm dam (yellow) identified as highly modified wetlands (which include dams, ring tanks, irrigation channel)
- Subdominant wetlands (beige hatched areas) are mapped, which include non-floodplain tree swamps (*Melaleuca* and *Eucalypt*)
- The well pad is located on mapped non-remnant regional ecosystem (RE)
- Adjacent RE 11.4.3/11.4.7 (purple) includes:
 - *Acacia harpophylla* and/or *Casuarina cristata* shrubby open forest on Cainozoic clay plains
 - *Eucalyptus populnea* with *Acacia harpophylla* and/or *Casuarina cristata* open forest to woodland on Cainozoic clay plains (RE 11.4.7).

Environmental risks are discussed in **Section A.1.9**.

A.1.2.2 Geological setting

According to the 1:100 000 geology maps (Meandarra Sheet 8843 and Surat Sheet 8743) the surface geology within the groundwater study area includes:

- Quaternary age alluvium comprising clay, silt, sand, and gravel
- Tertiary age sediments, comprising mudstone, sandstone, laminated siltstone, and local conglomerate
- Cretaceous Griman Creek Formation comprising fine- to medium grained sandstone, laminated to massive siltstone, and mudstone.

These geological units form part of the Surat Basin, a geological basin which comprises Jurassic through to Cretaceous aged sediments and are underlain by units of the Great Artesian Basin (GAB).

A.1.2.2.1 Regional geology

The Bowen Basin covers over 160,000 km² of southern and central Queensland and has a maximum sediment thickness of about 10,000 m concentrated in two north-south trending depocentres, the Taroom Trough in the east and the Denison Trough in the west. The basin first opened as a result of an Early Permian extensional tectonic phase. This set up a series of grabens and half- grabens into which fluvial-lacustrine sediments were deposited. This episode was also accompanied by extensive volcanics throughout the basin, but particularly along its eastern margin.

Following this extensional phase, a more passive thermal sagging phase occurred. This resulted in a basin wide marine transgression, which saw a temporary cessation of volcanic activity along the eastern margin of the basin. Sediment was dominantly sourced from the west and deposited eastward over the antecedent grabens and half-grabens. Deltaic sediments prograded into the basin from the west, filling in the various depocentres that are associated with coal deposition.

By the Late Permian, a compressional phase led to foreland loading on the eastern margin of the basin. This event cut the basin off from the open sea and resulted in rapid infilling of early to middle Triassic sediments which were deposited predominantly in coastal plain to alluvial plain systems. By the middle to late Triassic, the basin was infilled with sediments although continued tectonic compression was experienced resulting in further deformation of the rocks.

The Surat Basin is a large intracratonic basin of Mesozoic age covering approximately 300,000 km² of south-eastern Queensland and northern New South Wales. The basin forms part of the GAB, and interfingers westward across the Nebine Ridge with the Eromanga Basin, and eastward across the Kumberilla Ridge with the Clarence-Moreton Basin. Basement blocks consisting of the Central West Fold Belt and the New England Fold Belt limit the basin to the south, while in the north the basin has been eroded and unconformably overlies Triassic and Permian sediments of the Bowen Basin. The Surat Basin contains up to 2,500 m of sedimentary rocks deposited during the Latest Triassic to Early Cretaceous periods. The Latest Triassic to Earliest Cretaceous succession in the basin consists of five fining-upwards sedimentary cycles dominated by fluvio-lacustrine deposits. The lower part of each cycle typically comprises coarse-grained mature sandstone, grading up into more labile sandstone and siltstone, mudstone, and coal in the upper part. In the Cretaceous, inundation of the land through an increase in sea level led to deposition of predominantly coastal plain and shallow marine sediments in two cycles (Scott, et al, 2004).

Surface geology

The surface geology in the TGS project area consists primarily of unconsolidated Tertiary alluvial sediments comprising sand, gravel, and silts. These are generally infill alluvium and their distributions are associated with current topography or palaeo-topography (Figure 24).

Target geology

The target formations in ATP645 are tight hydrocarbon gas-bearing reservoirs located within the Tinowon Formation in the Bowen Basin.

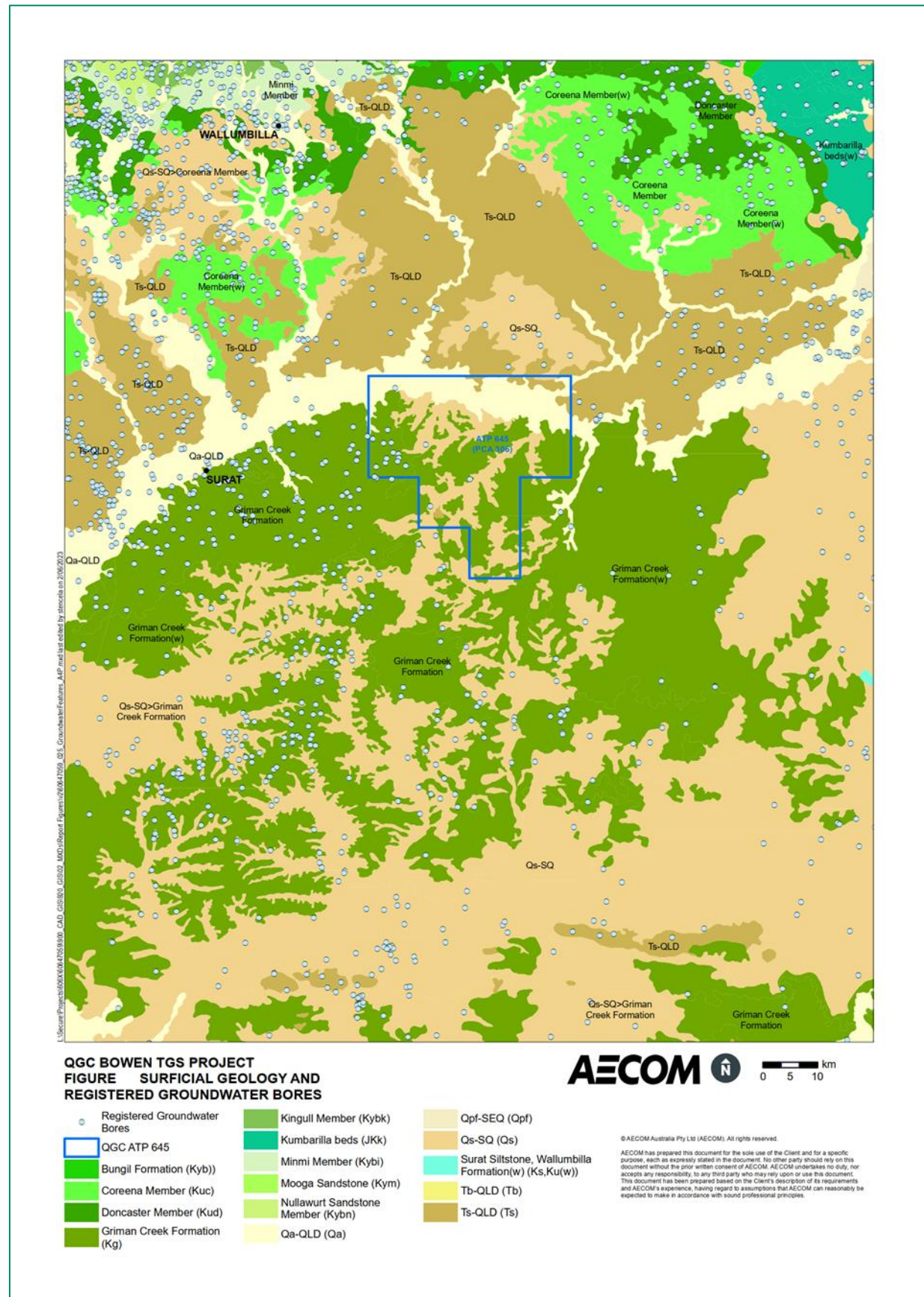


Figure 24 Surficial geology and registered groundwater bores

A.1.2.2.2 Site specific geology

Stratigraphy

A review of exploration wells and registered bores (with detailed geological logs) across ATP645 allowed for the identification of the geological units underlying the tenements.

As ATP645 is in the southern half of the Bowen Basin, which is unconformably overlain by the Surat Basin, the selected bore logs (Table 13) allowed for the evaluation of the geological contacts and unit thicknesses within both the Surat Basin and the deeper Bowen Basin.

The selected bores indicated the lithology is relatively consistent across the ATP645 area. Geological contact depths were converted to mAHD (approximately) using local topographical contour mapping (topographical mapping QLD Globe 2020).

The bore logs from the well completion reports were used to identify depth and thicknesses of geological units intersected within and adjacent to ATP645. The units logged within the well completion reports are included in Table 13.

Petroleum hydrocarbon accumulations occur throughout the sediments in the Bowen Basin, but the most significant reservoirs are in the Early Permian and Middle Triassic sediments. Source rocks for the petroleum hydrocarbon accumulations have been identified throughout the Permian and in the Middle Triassic formations and are mostly non-marine sediments (Geoscience Australia, 2012b).

Figure 36 presents the generalised stratigraphic chart of the ATP645 area relevant to the TGS project. This figure clearly shows the Surat Basin units, which are shallower than the Bowen Basin units that are the target.

A summary of the main geological units of interest (from a groundwater perspective) underlying the lease area ATP645 is included in Table 12.

Table 12 Summary of the geological units underlying ATP645

Geological unit	Description
Griman Creek Formation	The Griman Creek Formation comprises; grey, weathering to white, fine- to medium-grained sandstone, laminated to massive siltstone, and mudstone.
Wallumbilla Formation	The Wallumbilla Formation comprises; marine grey mudstone and siltstone with minor interbeds of fine-grained glauconitic and calcareous sandstone, local thin micritic limestone beds and heavy mineral strandline accumulations; down-sequence glacial ice-rafted erratics.
Bungil Formation	The Bungil Formation comprises; Glauconitic, labile to quartzose, siltstone, mudstone. Subdominant coarse-grained quartzose sandstone in some areas. Minor thin coal seams.
Mooga Sandstone	The Mooga Sandstone comprises; quartzose, sub-labile sandstone; minor siltstone, shale, mudstone, and coal. Generally considered Cretaceous age but is grouped with Jurassic-Cretaceous aged units in compilations. It is noted that this unit can be artesian in the Surat Basin.
Orallo Formation	The Orallo Formation comprises; Medium-grained, sub-lithic sandstone and interbedded siltstone and mudstone with minor coal and fossil wood.
Gubberamunda Formation	The Gubberamunda Sandstone comprises medium to coarse-grained, largely quartzose, poorly sorted sandstone with minor conglomerates and siltstone.
Westbourne Formation	The Westbourne Formation comprises; Fluvial-lacustrine sediments: fine-grained sandstone interbedded with siltstone, claystone, minor coal.
Springbok Sandstone	The Springbok Sandstone comprises; Clayey lithic sublabile to very lithic sandstone; calcareous in part; interbedded with carbonaceous mudstone and siltstone.
Walloon Coal Measures	The Walloon Coal Measures comprise; Thin-bedded, claystone, shale, siltstone, lithic and sublithic to feldspathic arenites, coal seams and partings; minor limestone.

Geological unit	Description
Hutton Sandstone	The Hutton Sandstone comprises; Poorly sorted, coarse to medium-grained, feldspathic sublabile sandstone (at base) and fine-grained, well-sorted quartzose sandstone (at top); minor carbonaceous siltstone, mudstone, coal, and rare pebble conglomerate.
Evergreen Formation	The Evergreen Formation comprises; Labile and sublabile, sandstone overlain by carbonaceous mudstone, siltstone, and minor coal; local oolitic ironstone.
Precipice Sandstone	The Australian Stratigraphic Units Database indicates that the Precipice Sandstone comprises thickly bedded, cross-bedded, pebbly quartzose sandstone, minor lithic sub labile sandstone, siltstone, and mudstone.
Moolayember Member	The Moolayember member comprises; Dominantly interbedded olive, green-brown and green-grey mudstones and lithic to sub-labile, medium- to coarse-grained sandstones. Lesser grey to black carbonaceous shale, siltstone, mudstone, coal, conglomerate; minor tuff and limestone.
Snake Creek Mudstone Member	The Snake Creek Mudstone Member comprises; Predominantly dark grey to black mudstone with minor laminae and thin beds of very fine-grained sandstone.
Showgrounds Sandstone	The Showgrounds Sandstone comprises; white coarse quartzose sandstone.

Lithological units below the Showgrounds Sandstone, as discussed in **A.1.3**, including the Rewan Group and Back Creek Group, have negligible groundwater potential.

A.1.2.2.3 Structural geology

The structural geology of the Surat Basin in the area of interest comprises the area of maximum deposition, the Mimosa Syncline, overlying the thickest Permian-Triassic rocks in the Taroom Trough of the underlying Bowen Basin.

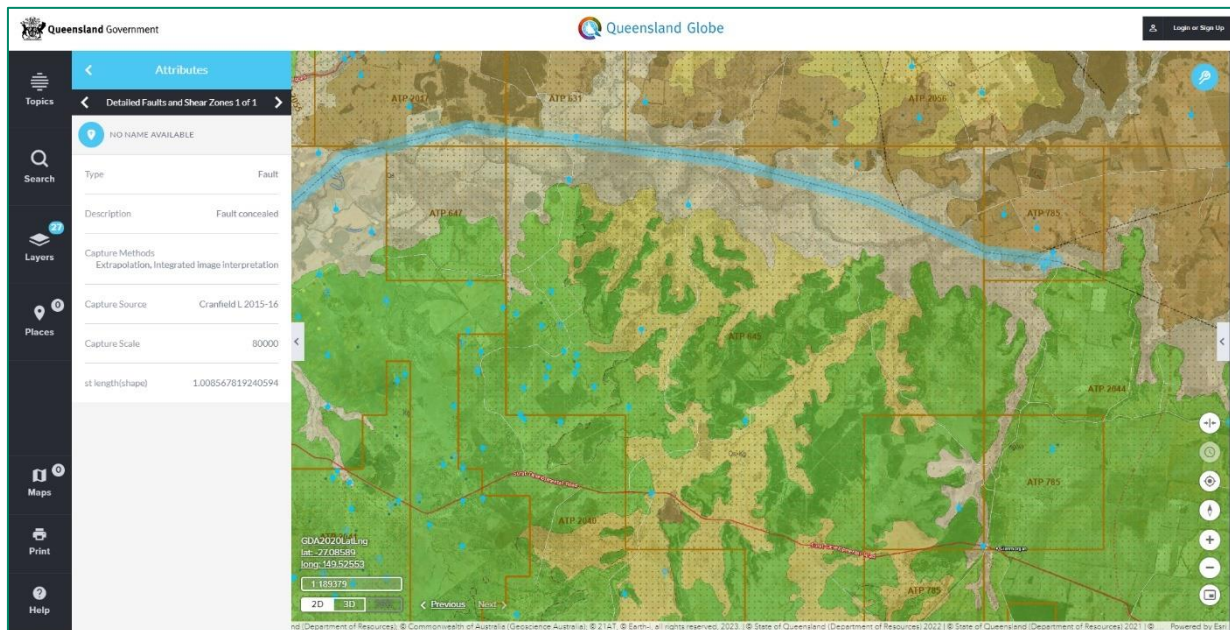
Major faulting in the Surat Basin predominantly mirrors basinal boundary faults of the Bowen Basin. There is substantial folding across the Surat Basin and formations outcrop along the northern erosional boundary and dip gently to the south at less than 5 degrees¹⁴.

Mapped structures within and adjacent to ATP645 are included in Figure 25.

One lineation, which appears to influence surface water drainage, is mapped along the northern portion of ATP645. The lineation is mapped at a concealed fault on the QGlobe mapping (Plate 8). This fault is sufficiently far from the proposed Appraisal wells (> 2 km) that negates any potential influence the fault may have on the planned hydraulic stimulation activities.

¹⁴ QGC Daydream 1 Well Completion Report, ATP 645, 16/07/2013

Plate 8 Mapped fault across ATP645 (QGlobe)



Faults

Displacements associated with these fault complexes are generally restricted to the deeper formations of the Bowen Basin and have a lesser effect on the overlying Surat Basin formations (OGIA, 2016). Estimated throws on normal faults identified in the eastern Surat Basin range from less than 10 m to about 90 m, with 77 percent of the faults having throws of less than 20 m (Silwa, 2013).

Faults may function as either barriers or conduits to groundwater flow and this may change along a relatively short strike length. Furthermore, faults can have relatively low permeability in the horizontal direction, thereby restricting flow within units, but can also have relatively high permeability in the vertical direction, thereby supporting flow between units (OGIA, 2016). In general, most faults are likely to restrict groundwater flow, especially in the horizontal direction (OGIA, 2016).

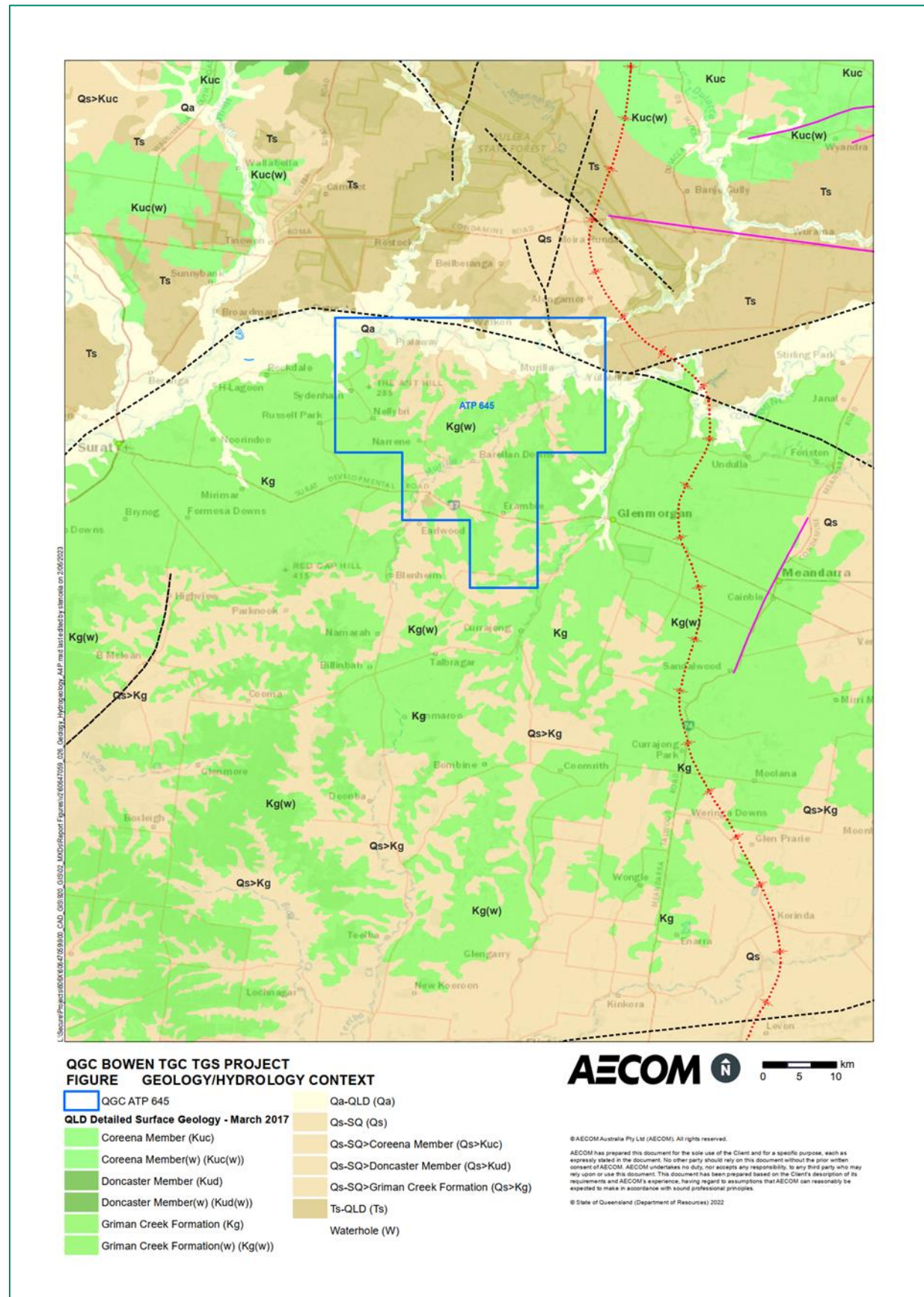


Figure 25 Mapped structures

Exploration bores, discussed in Section A.1.1 and included in Figure 34, were included in a stratigraphic cross-section, which includes structural geology (Figure 26).

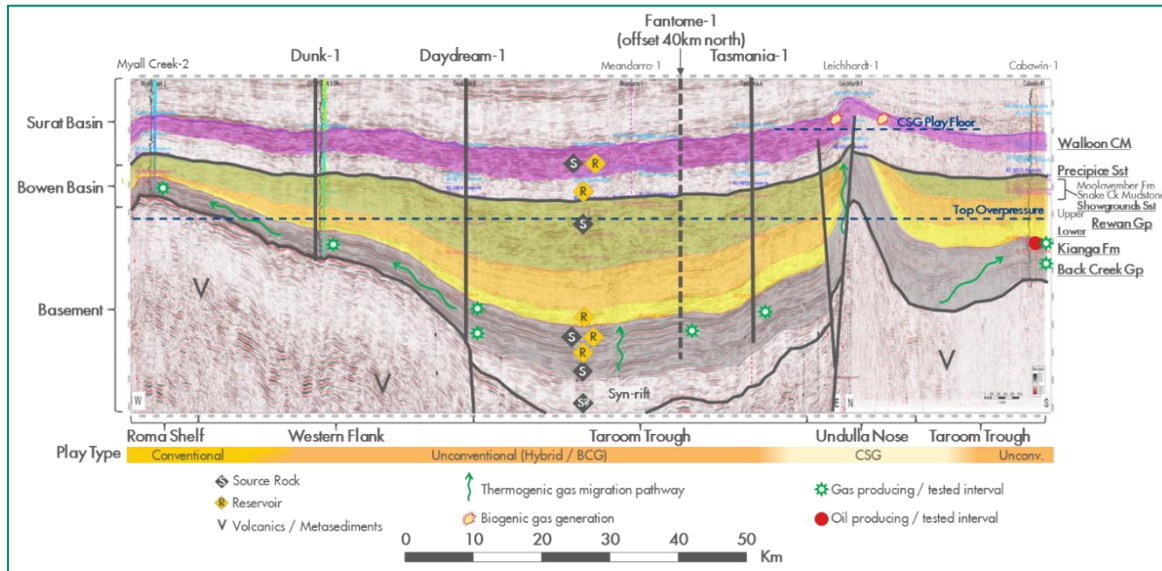


Figure 26 Stratigraphic cross-section across ATP645

Preferential flow paths or barriers

Geological faults and structures can provide preferential pathways for groundwater movement. At the depths considered in the project, the chances of faults acting as conduits for potential harmful fluids used during fracturing are very low. This is due to the depths of the target formations and the very low permeabilities of the sedimentary units being targeted for fracturing.

The presence of faults is indicated by interpretations of seismic surveys across the basin, including in the project area, and in some cases appear to have contributed to the thickening of basinal sequences. However, the same surveys show the limited extent of these faults, with little anomalism and disruptions in reflection in the sediments above. There is nothing in the existing QGC documentation available to suggest a fault could provide preferential groundwater movement.

ATP645 Fault Traces

3D seismic surveys across the TGS project area (Figure 27), allowed for the evaluation of geological structures, including faulting.

Fault traces identified by QGC within the Upper Tinowon Formation sandstone across ATP645 are included in Figure 28. Note the stratigraphy of the underlying geology is included in Figure 36 and Table 13 and exploration bore locations are included in Table 2.

The evaluation of the faulting by QGC indicated:

- Little or no observable Tinowon Sand offset.
- Seismic geophysical data shows a structural dip change at Tinowon target Sand level
- Deeper fault(s) observable on seismic geophysical data
- Fault mapping conducted on legacy Overston 3D indicated no major faults with significant offset in the area
- N-S fault (red on map) was active at time of Tinowon target Sand deposition and connects to the basement units.

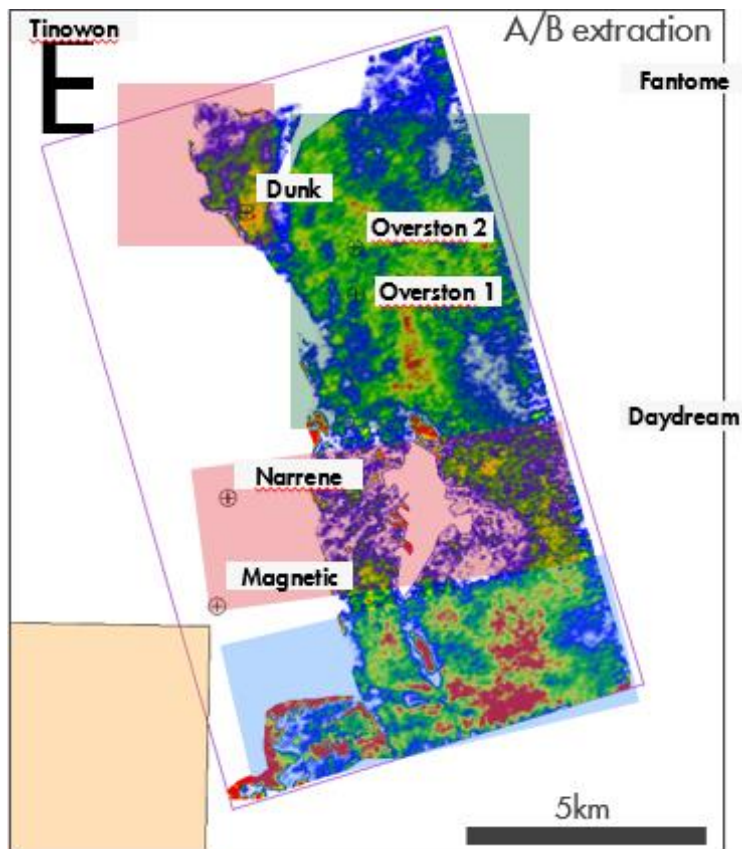


Figure 27 3D mapped Tinowon target Sand

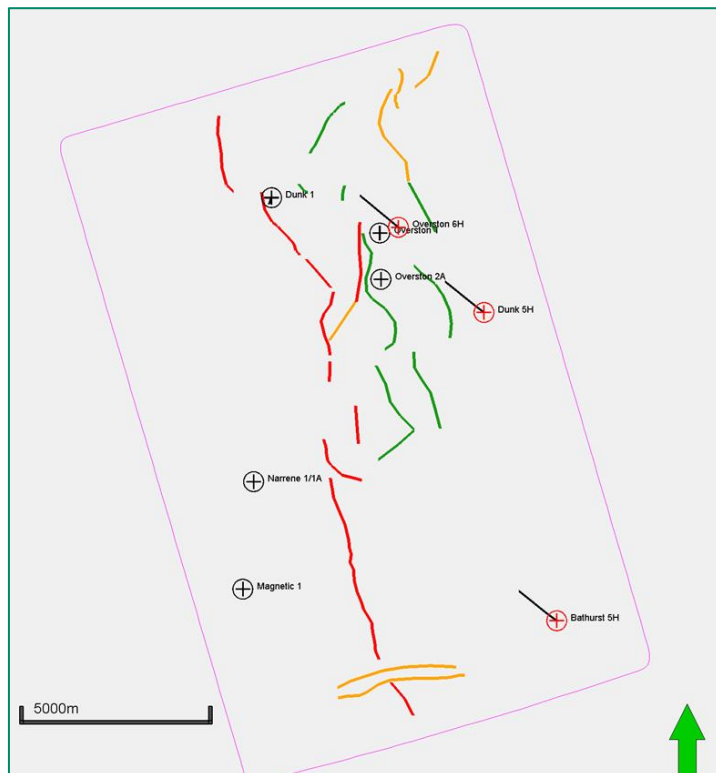
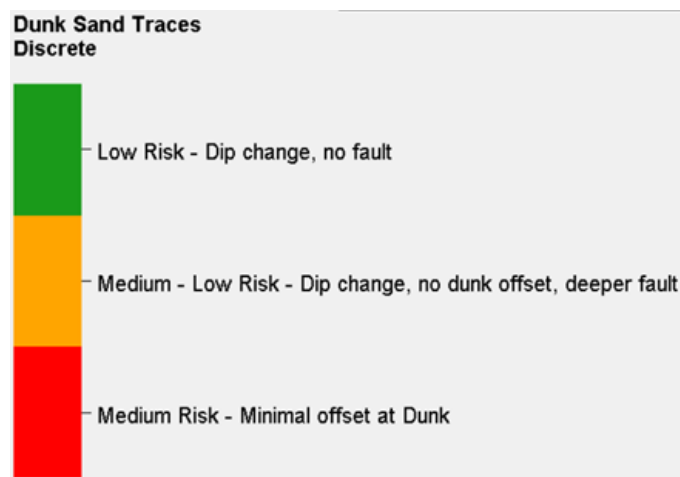


Figure 28 Tinowon target Sand level faulting

Risks associated with faulting and fracturing was evaluated and rated by QGC. These risks vary due to multiple factors such as formation offset at target level, stress orientation, connection of fault to shallower/deeper levels. The fault colour codes identify differing risk levels relate to structural risk and fault slip potential, are included in Plate 9.

Plate 9 Risk levels



The fault risks include:

- The medium (red) risk faults have minimal observable offset at Tinowon target Sand level <20 m.
- The medium low (orange) risk faults have no observable offset at the Dunk Sand level.
- The low (green) risk lineations indicate no seismically observable faulting, the seismic data indicates a structural dip change, which could have sub-seismic faulting / fracturing.

Note: All planned appraisal wells standoff from any mapped fault.

Mapping of the top of the Wallabella Coal Member of the Tinowon Formation, which directly underlies the Tinowon target Sand (Upper Tinowon Formation sandstone), Figure 29 indicates limited fault displacement, dip changes, and depth to the coal member.

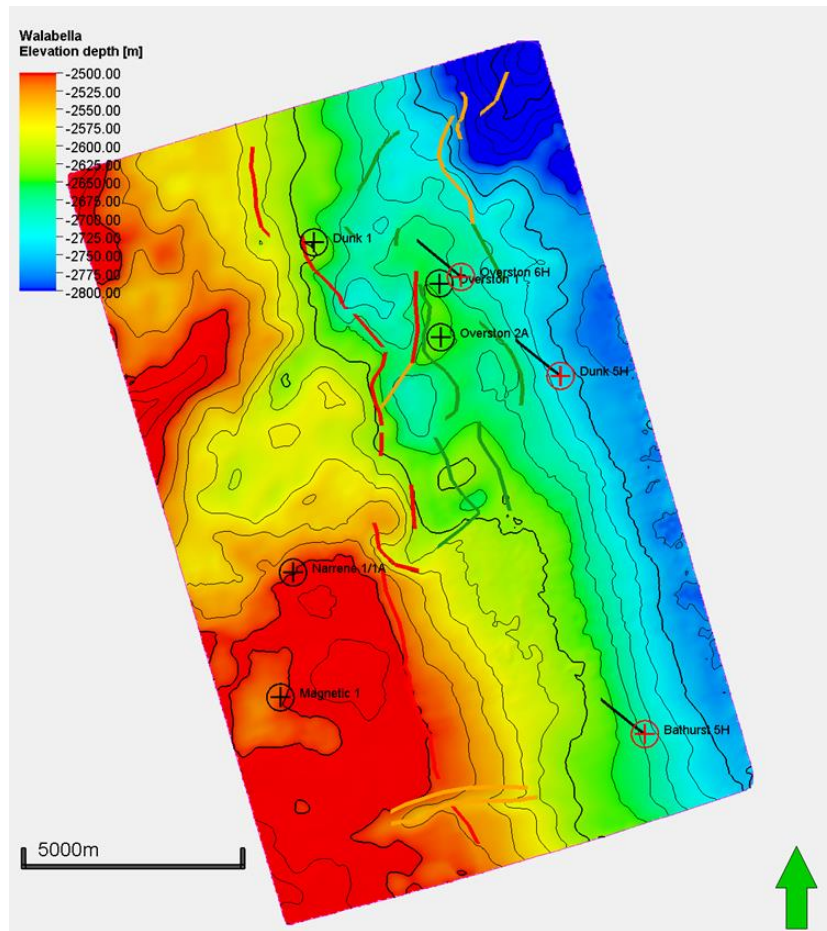


Figure 29 Walabella Coal Member depth and structures

A.1.2.2.3.1 Stress-field setting

At depth, geological formations are compressed by the weight of overlying strata and laterally constricted by the adjacent geological material. These compressive forces create stresses within the formation in three dimensions; defining a major stress field direction, an intermediate stress field direction, and minor stress field direction. The orientation and magnitude of the stress fields is of relevance to hydraulic fracture stimulation as they influence the direction of hydraulically induced fracture propagation.

On a regional scale, Australia forms part of the Indo-Australian tectonic plate which undergoes absolute movement of approximately 7 cm per year north-northeast (N-NE). This is reflected in the general N-NE to S-SW orientation of the regional major horizontal stress field in eastern Queensland, as depicted on the Australasian Stress Map, Figure 30.

The minor horizontal stress field is approximately perpendicular to the major horizontal stress direction; that is, regionally in eastern Queensland the minor horizontal stress is typically oriented in an N-NW to S-SE direction. The horizontal in situ stress can be relatively high and anisotropic and exceed the vertical stress due to gravity.

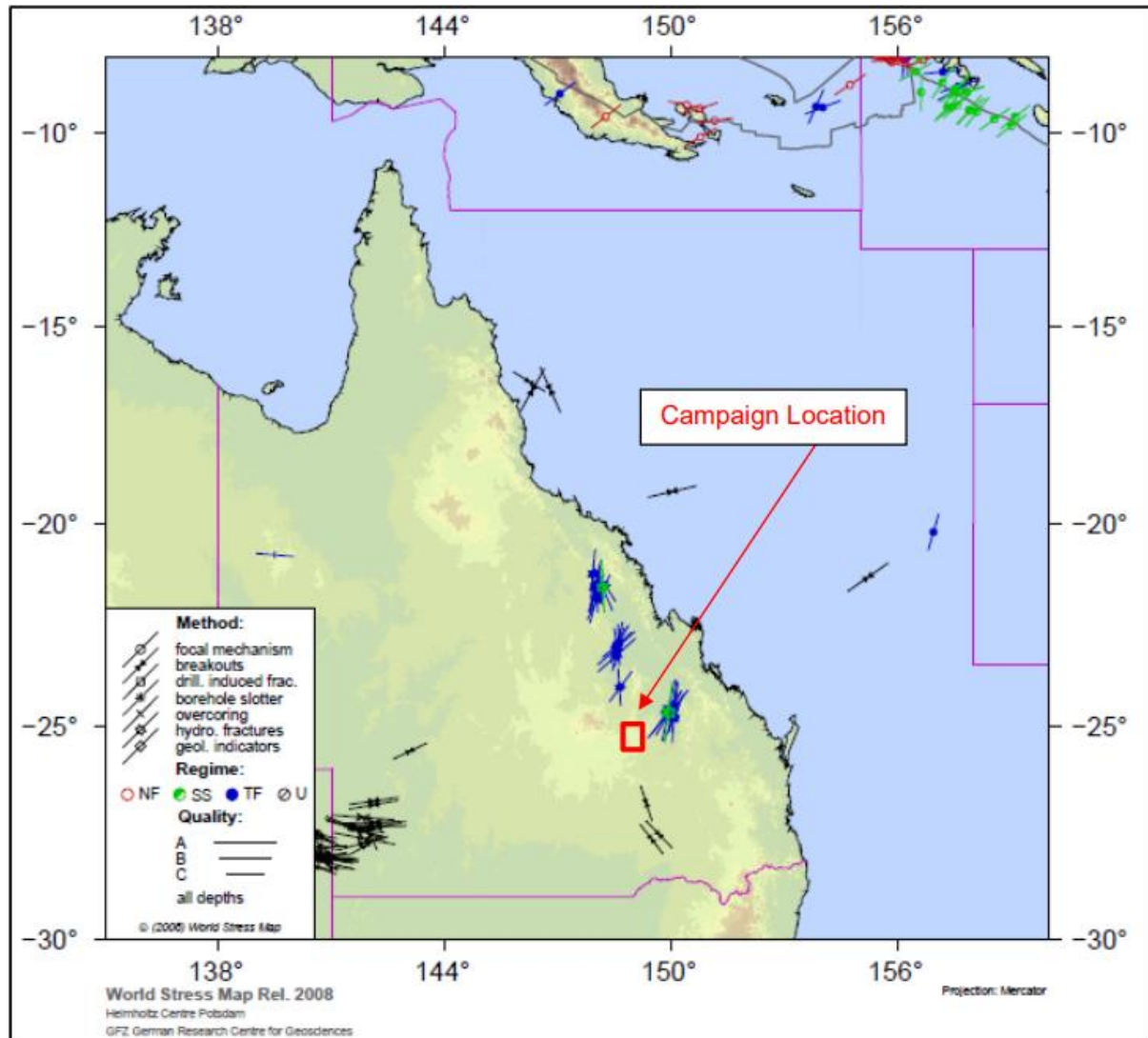


Figure 30 Queensland stress map

On the TGS project area scale, stress fields within the targeted tight sands can be affected by the local structural geology such as faults and folds. The propensity of geological material to fracture under stress (either natural or applied) is dependent on the physical properties of the rock material.

At the local scale, the regional stress field (magnitude and orientation) will be affected by discontinuities in the rock mass such as faults, and close to the surface by topography. The magnitude of horizontal stress will also be influenced by the geotechnical properties of the layered sedimentary rocks. The stiffer the rock layers, such as sandstone with few discontinuities, will attract a higher stress magnitude relative to more jointed or fractured rock layers, such as coal which will have a lower horizontal stress.

Analysis of stress and rock strength in the TGS project area has been undertaken through in-house and contractor services. Borehole studies have utilised image log data, wireline log data, rock strength testing and drilling experience to model the stress variation between the geological rock units from surface to the target formations.

The horizontal stress data from the exploration wells across the TGS Project is included in Figure 31. The maximum horizontal stress is ~ 40 degrees.

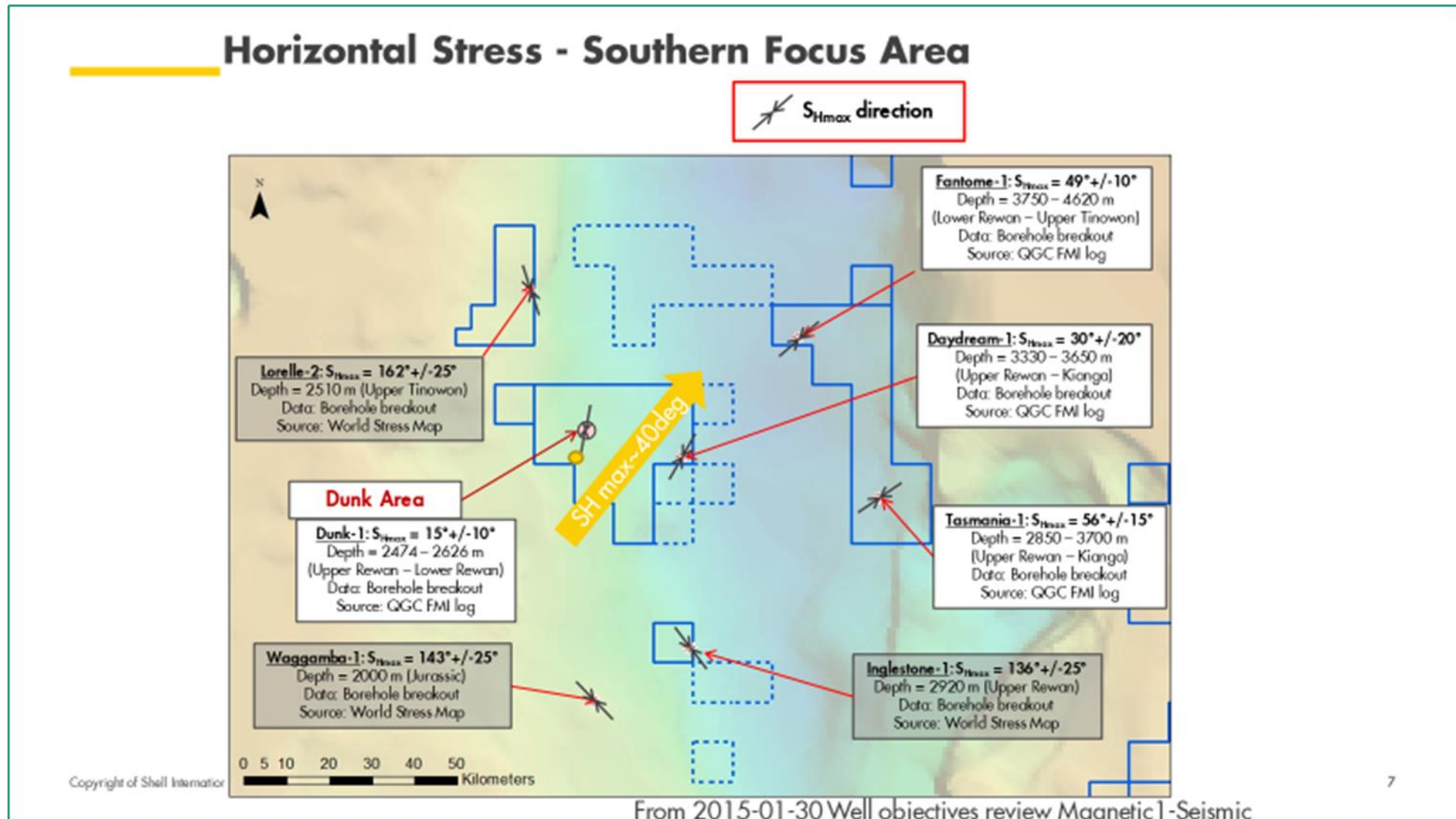


Figure 31 Local scale horizontal stress data

A.1.2.2.3.2 Seismic history of the project area

Earthquakes in the northern Australia are generally caused by the release of built-up stress in the Indo-Australian continental plate, as a result of its drift N-NE (see **Appendix A.1.2.2.3.1**).

The minimal number and magnitude of seismic events in the surrounds of the project area (Figure 32) suggest the area currently has low seismic activity. No seismic events have been recorded within the project tenements; the few seismic events that have been recorded in the surrounds of the project area were small in magnitude (less than 3 on the Richter scale).

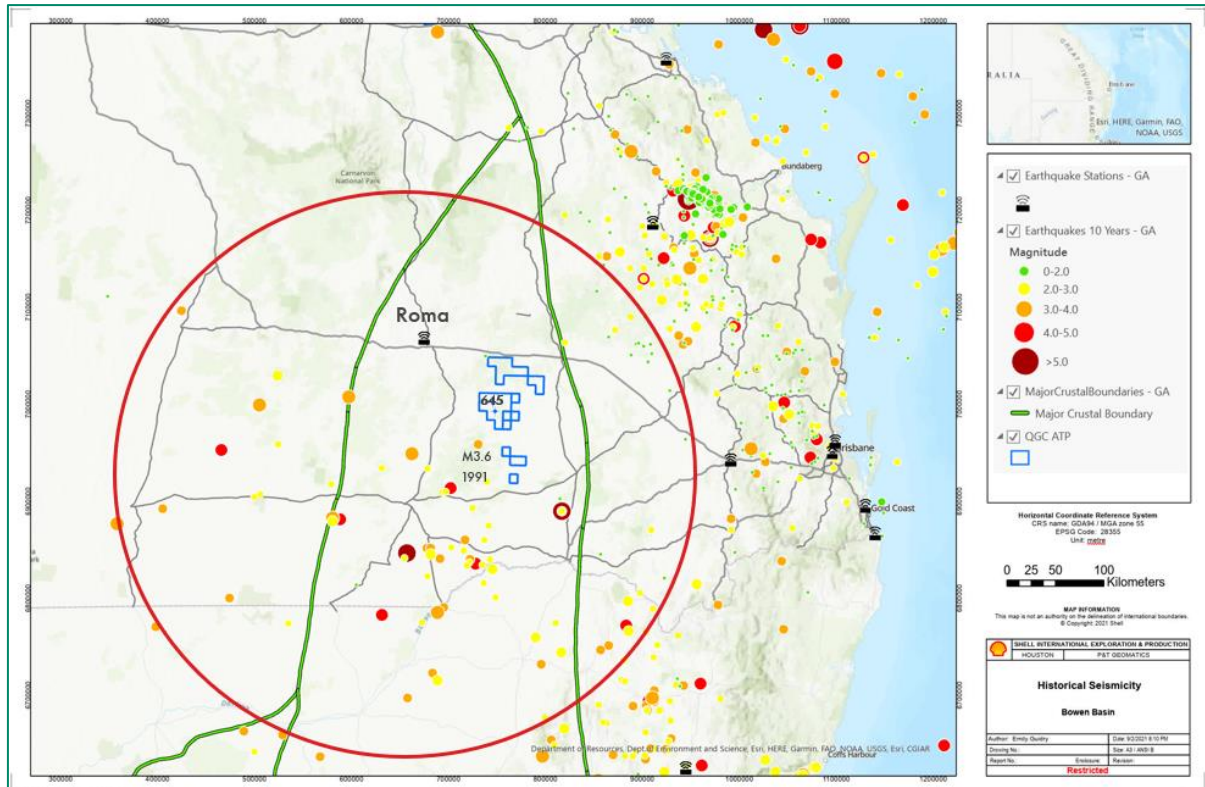


Figure 32 Historic seismicity

Closes event to ATP645 was M3.6 approximately 48 km to the southwest.

Recorded earthquakes, and magnitudes, in the project area (red circle on Figure 32) is included in Figure 33.

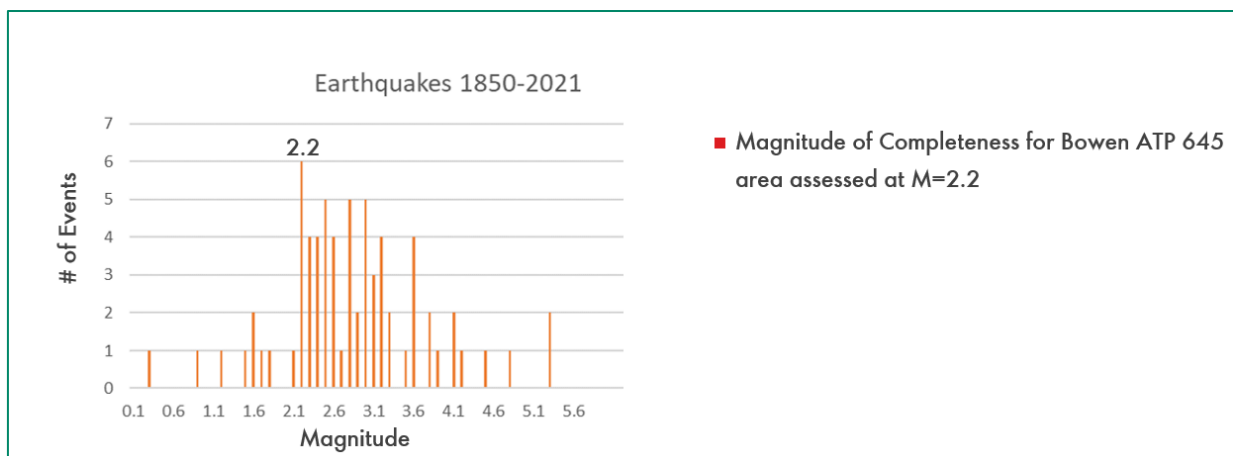


Figure 33 Earthquake summary (1850 to 2021)

Within the vicinity of the TGS project area, there are no neotectonic geological faults (faults which have been active within the 5-10 Myr (million years)) and are, therefore, not considered capable of hosting future displacement or re-activation (Machette, 2002)) (GA, 2014).

A.1.2.3 Gas Targets

The ATP645 area is in the portion of the Southern Bowen Basin (Taroom Trough). It has seen several discoveries and developments from the Tinowon Formation, including the Myall Creek Field, Churchie Field (both West of the Overston area), and The Waggamba Field (Southwest of the Overston area). There are also several other Triassic fields west as well as southwest of the Overston area targeting the Lower Rewan Group and Showgrounds Sandstone¹⁵.

Exploration of the Permian aged formations began within the Overston in the early 2000's with the Overston-1 (Sunshine O&G), Overston-2 (Sunshine and Samson), and Narrene-1/1A (Sunshine O&G) wells. The mapped wells, within and adjacent to ATP645, are included in Figure 34.

QGC (prior to the Shell and BG Group merger in 2016) actively explored for tight gas sands across the Taroom Trough with seven wells drilled in two campaigns in 2011/12 and 2014/15. Three of those wells are within ATP645. The Dunk #1 discovery provides the impetus for further appraisal in ATP645. Furthermore, the Magnetic-1 well located very close to the ATP2040 boundary, provides encouragement to further explore for the Lorelle Sandstone.

Dunk #1 and Magnetic-1 wells both encountered gas-charged sandstone units within the Permian Back Creek Group. In Dunk #1, the Upper Tinowon Sandstone within the Tinowon Formation was best developed, comprising a ~40 m thick gross interval with a Net: Gross of almost 100%. At the time of the production logging, the Upper Tinowon Sandstone provided the greatest flow contribution (62%), followed by the Lorelle Sandstone (33%), and the Overston Sandstone (5%).

The primary target in Magnetic-1, ~10 km to the south of Dunk-1, was the Lorelle Sandstone (part of the Muggleton Formation), found to be similarly well-developed as in the Narrene-1A offset well. Additional wells have also been drilled by QGC in the ATP645 and surrounding areas which include Fantome-1 and Tasmania-1. Both of these wells penetrated the Back Creek Group.

A.1.2.3.1 Geological targets at ATP645

The horizons proposed by QGC to be fracture stimulated to facilitate extraction of deep tight gas are in the Permian (Back Creek Group) sediments of the Bowen Basin, being the Tinowon Formation and potentially the Muggleton Formation (primarily the Lorelle Sandstone).

The target formations comprise a complex sequence of interbedded tight, low porosity sandstone, siltstone, shale, and coal. The estimated thickness of the sandstone sequences in the proposed fracture area ranges from tens of metres to hundreds of metres (QGC, 2012b).

A particularly large layer of “sand”, comprised of approximately 40 m of continuous higher porosity sandstone, was intersected in Dunk #1.

¹⁵ Informal status, there are facies-relationship grounds for considering Showgrounds Sandstone to be a member of Moolayember Formation rather than a formation of Clematis Group (<https://asud.ga.gov.au/search-stratigraphic-units/results/77473>)

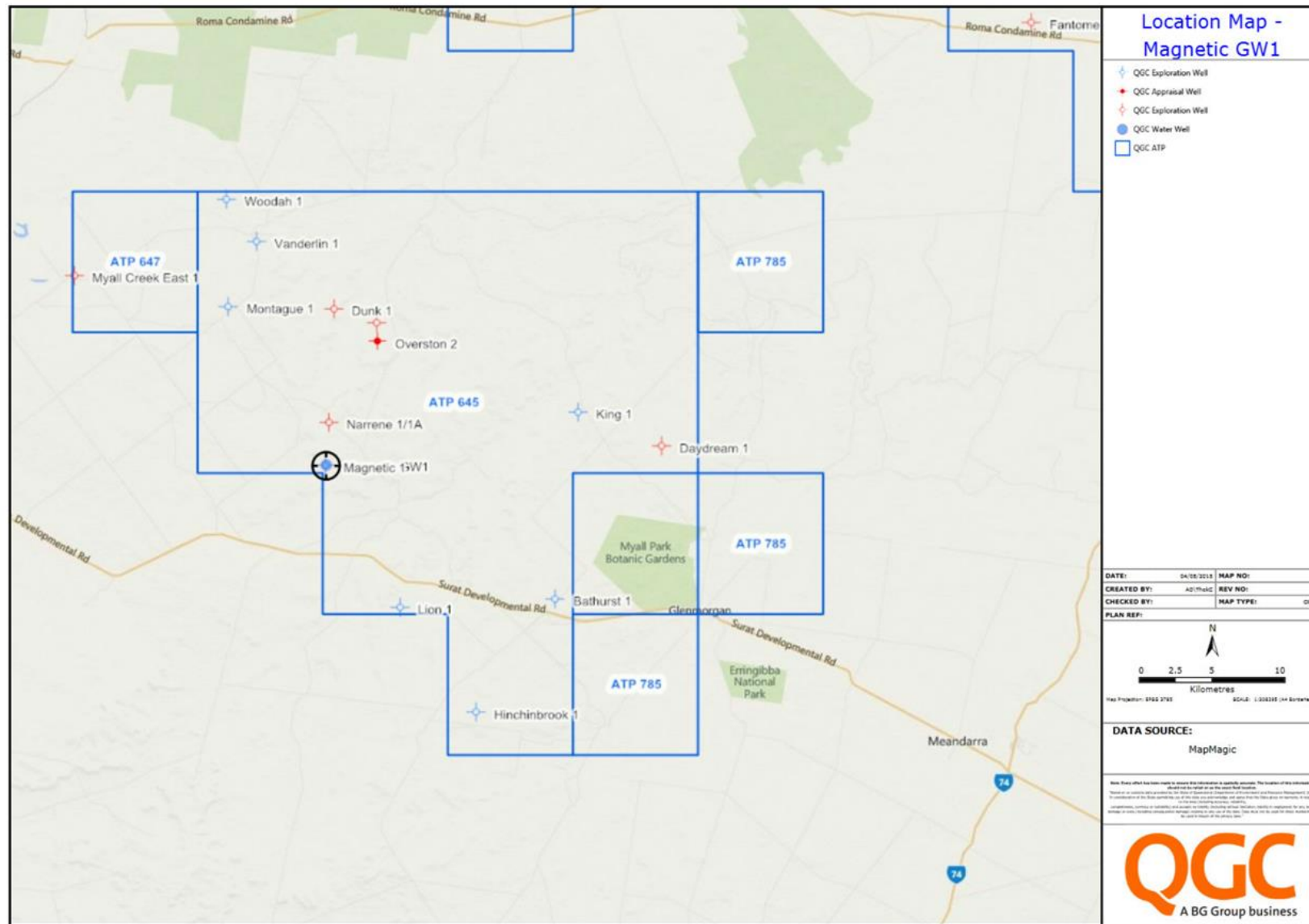
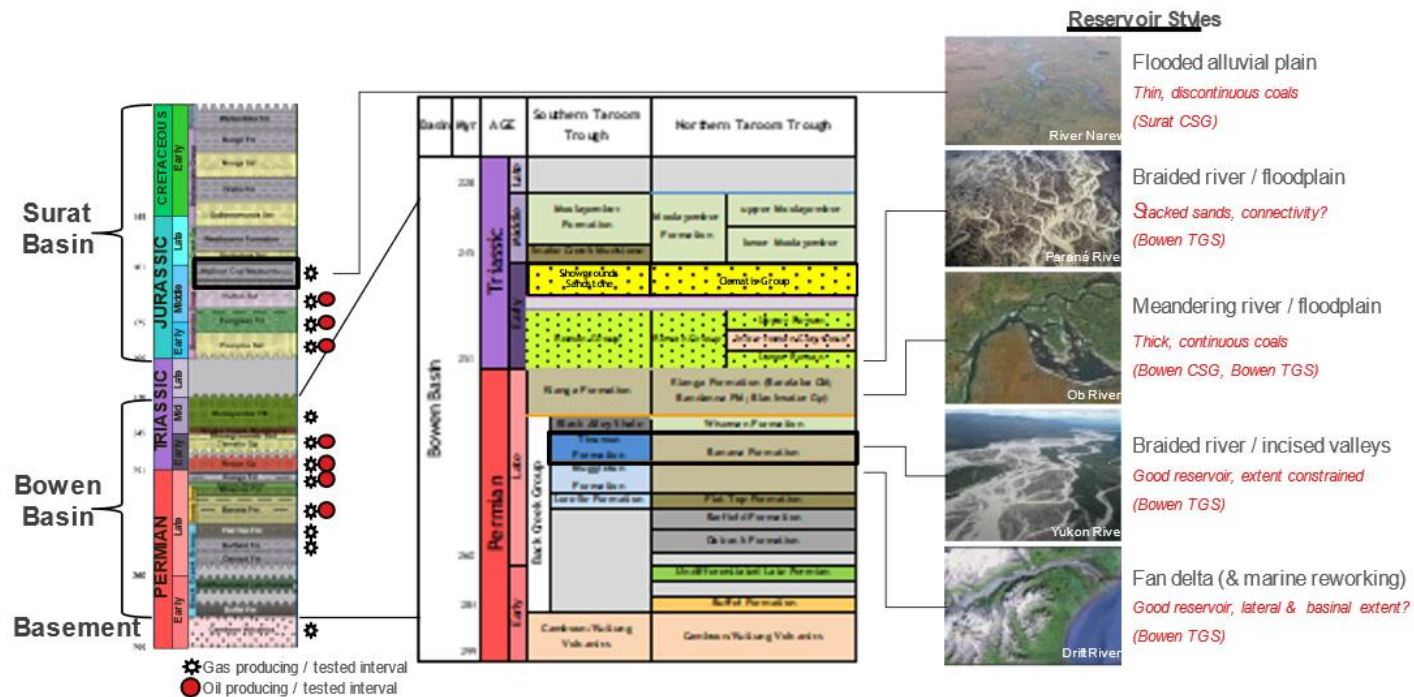


Figure 34 Mapped wells at ATP645

Stratigraphy & Targets



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Figure 35 Gas targets

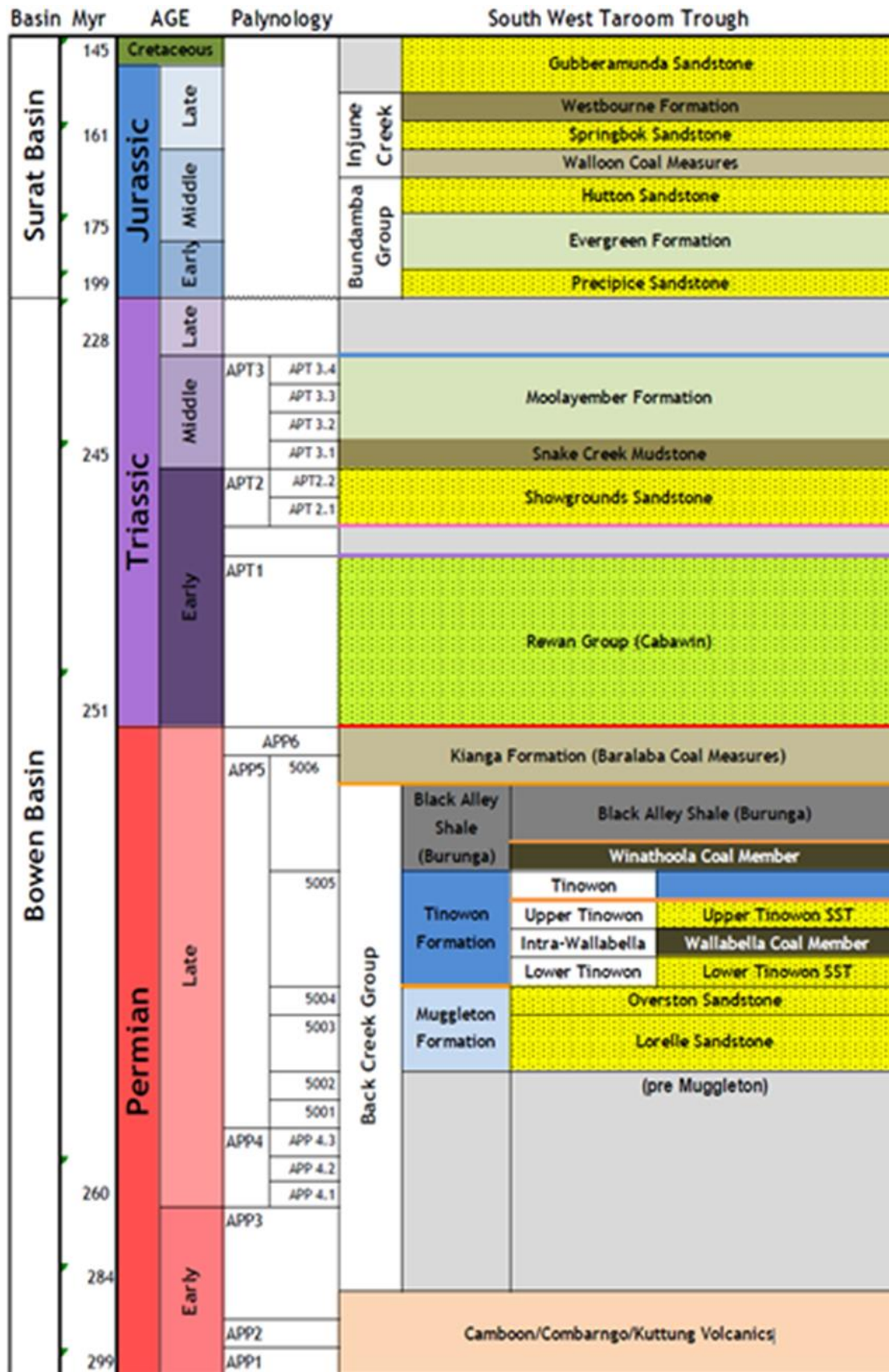


Figure 36 Generalised stratigraphic chart of the ATP645 area

Table 13 Stratigraphic data at the TGS project

Bore / Well ID	Basin	Magnetic 1		Overston 1		Daydream 1		Coalbah (RN23182)		Paloma 1 (RN22656)		Weribone 1 (RN22171)		Tinowon 1 (RN22622)	
Location		On ATP645 central west		On ATP645 central north		On ATP645 central east		6.5km south-east		Off Lease 10km south-east		Off Lease 16km south-west		Off Lease 7km north-west	
Geological Unit		Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)
Sediments		5.2	8.71									5.2	?		
Griman Creek Formation								5	210	4.3	?				
Wallumbilla Formation	Surat	8.71	360			7.7	548							3.9	291.1
Surat Siltstone								210	317						
Coreena Member								317	418	363.9	448.7	331.9	382.5		
Doncaster Member								418	590	448.7	694.9	382.5	557.5		
Bungil Formation		2021)	513			548	705	590	759	694.9	854.4	557.5	696.5	291.1	69.4
Mooga Sandstone		513	667			705	849	759	899	854.4	930.6	696.5	864.1	469.4	543.2
Orallo Formation		667	996.37	634	-374	849	1005	899	1047	930.6	1166.2	864.1	1039.4	543.2	715.7
Gubberamunda Sandstone		996.37	1161.92	870	-610	1005	1187	1047	1240	1166.2	1338.7	1039.4	1210.4	715.7	848.3
Injune Creek Group															
Westbourne Formation		1161.92	1275.48	1024.5	1160	1187	1315	1240	1347	1338.7	1521.9	1210.4	1318.3	848.3	923.5
Springbok Sandstone		1275.41	1357.12	1160	1237.5	1315	1420	1347	1456	1521.9	1584.7	1318.3	1386.2	923.5	1048.5
Walloon Coal Measures		1357.12	1607.95	1237.5	1526	1420	1783	1456	1826	1584.7	1913.2	1386.2	1633.7	1048.5	1252.7
Eurombah Formation										1913.2	1948.3			1252.7	1322.8
Hutton Sandstone		1607.95	1666	1526	1678	1783	2021	1826	2048	1948.3	2154.3	1633.7	1809.9	1322.8	1520.3

Bore / Well ID	Basin	Magnetic 1		Overston 1		Daydream 1		Coalbah (RN23182)		Paloma 1 (RN22656)		Weribone 1 (RN22171)		Tinowon 1 (RN22622)	
Location		On ATP645 central west		On ATP645 central north		On ATP645 central east		6.5km south-east		Off Lease 10km south-east		Off Lease 16km south-west		Off Lease 7km north-west	
Geological Unit		Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)
Evergreen Formation		1666	1955.57	1678	1811.5	2021	2168	2048	2172	2154.3	2279.3	1809.9	1914.1	1520.3	1624.6
Precipice Sandstone		1955.57	1975.47	1811.5	1904	2168	2248.5			2279.3	2300.6	1914.1	1919	1624.6	1644.4
Upper								2172	2203						
Lower								2203	2237						
Moolayember Formation	B o w e n	1975.47	2304	1904	2280.9	2248.5	2842.5	2237	2438 (EOH)	2300.6	2337.2 (EOH)	1919	2122.9	1644.4	1865.4
Snake Creek Mudstone Member		2304	2337	2280.9	2321.7	2842.5	2882.5					2122.9	2152.5	1865.4	1888.2
Showgrounds Sandstone		2337	2373.48	2321.7	2355.6	2882.5	3041.5					2152.5	2169.6	1888.2	1902.6
Rewan Group		2373.48	2611.14	2355.6	2701.1	3041.5	3592.5					2169.6	2271.1	1902.6	2090.1
Kianga Formation		2611.14	2728.97	2701.1	2790.5	3592.5	3743					2271.1	2365.9	2090.1	2167.1
Back Creek Group						3743	4111							2167.1	2300.9 (EOH)
Combargno Volcanics						4111	4140 (EOH)								
Black Alley Shale		2728.97	2750.01	2790.5	2820.6										
Scotia Coal Cycle		2750.01	2763.24												
Winathoola Coal Member				2820.6	2830										
Tinowon Formation		2763.11	2791	2830	2928.8										

Bore / Well ID	Basin	Magnetic 1		Overston 1		Daydream 1		Coalbah (RN23182)		Paloma 1 (RN22656)		Weribone 1 (RN22171)		Tinowon 1 (RN22622)	
Location		On ATP645 central west		On ATP645 central north		On ATP645 central east		6.5km south-east		Off Lease 10km south-east		Off Lease 16km south-west		Off Lease 7km north-west	
Geological Unit		Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)	Top (mbgl)	Bottom (mbgl)
Upper Tinowon Sandstone		2791	2827												
Wallabella Coal Member		2827	2863	2928.8	2980 (EOH)										
Lower Tinowon Sandstone		2863	2890.73												
Overston Formation															
Overston Sandstone		2890.73	2930.5												
Lorelle Sandstone		2930.5	3024.41												
Timbury Hills Formation		3024.41	3095 (EOH)									2365.9	2437 (EOH)		

mbgl – metres below ground level

EOH – End of hole

A.1.3 Hydrogeological setting

The Surat Basin and the upper sedimentary sequences (of Triassic age) of the Bowen Basin form part of the Great Artesian Basin (GAB). The GAB aquifers are underlain at depth by the Rewan Group, which is widely recognised as the basal confining unit for the GAB (Queensland Department of Natural Resources and Mines, 2005; Queensland Water Commission; 2012). The Rewan Group is part of the Bowen Basin.

The underlying Permian age units that are targeted for fracture stimulation in the incumbent risk assessed project, including the Back Creek Group, are not part of the GAB.

The GAB is a hydrogeological basin consisting of a multi-layered confined aquifer system, were alternating layers of permeable sandstone form aquifers and less permeable siltstone and mudstone act as aquitards. Individual sandstone, siltstone, and mudstone layers range in thickness from less than 100 m to more than 600 m, and the sedimentary deposits generally dip in a south-westerly direction (Queensland Water Commission, 2012).

The major aquifer systems which are in the Surat Basin within the study area include the Jurassic-aged Springbok Sandstone, Hutton Sandstone, and Precipice Sandstone. Major confining beds in the Surat Basin include the Evergreen Formation, Westbourne Formation, and Wallumbilla Formation (Habermehl, 2001a). All of these aquifer systems and confining beds are within the Surat Basin, which is above the Bowen Basin that is the target of the TGS project.

A number of literature sources cite the Triassic-aged Clematis Sandstone and equivalents as major aquifers in the Bowen Basin (Habermehl, 2001a; Queensland Department of Natural Resources and Mines, 2005, and the Queensland Water Commission, 2012). The Hydrogeological Framework Report for the GAB water resource plan area (Queensland Department of Natural Resources and Mines, 2005) lists the Clematis Sandstone and equivalents as the only aquifer of significance within the Triassic age sequence, specifying that good yields and water quality are extracted from bores dominantly on the eastern margins of the GAB in and close to outcrop areas, whilst the unit is deep elsewhere and rarely utilised.

The Clematis Sandstone and equivalents form the deepest aquifer in the GAB (Queensland Department of Natural Resources and Mines, 2005; SKM, 2012). The Clematis Sandstone and equivalents are overlain by the confining Moolayember Formation and Snake Creek Mudstone, and are underlain by the confining Rewan Group, which forms the lower boundary of the GAB (Habermehl, 2001a). Based on the lithology logged within the exploration wells (Table 13) this aligns with the Showgrounds Sandstone in the TGS project area.

The Australian Stratigraphic Units Database indicates that the Showgrounds Sandstone is considered a member of the Moolayember Formation rather than the Clematis Group and that the University of Southern Queensland (2011), classified the Clematis Sandstone as a confining unit along with the Moolayember Formation. The Showgrounds Sandstone is, however, included in the Water Plan (Great Artesian Basin and other Regional Aquifers) 2017 (GABORA) as part of the Clematis Groundwater Unit.

Most of the individual aquifers within the GAB are relatively uniform in their hydrogeological characteristics over large areas and are typically continuous and hydraulically connected across constituent sedimentary basins (Habermehl, 2001a).

Based on aquifer hydraulic properties the Showgrounds Sandstone is the closest GAB aquifer to the target tight gas sands reservoir. There is some 500 m separation between the Showgrounds Sandstone and the target Tinowon Formation (Table 13). It is noted that the Rewan Formation¹⁶ forms part of the (Bowen) Clematis Groundwater Unit in the GABORA water plan. As such, from a legislative perspective the closest groundwater unit to the target Tinowon Formation is the Rewan Formation.

¹⁶ Rewan Formation is the used for this unit within the Galilee Basin as it is not subdivided in this basin. In the Bowen Basin it is elevated to Group status as it is divided into formations. It is assumed that the Rewan Formation name in the GABORA is used as an equivalent to the Rewan Group used in the Bowen Basin based on the mapped groundwater units (<https://asud.ga.gov.au/search-stratigraphic-units>).

The risks of hydraulic stimulation impacting on the viable groundwater resource, the Showgrounds Sandstone, is included in Section 1.7.2.1. The legislative risk of impacting the lowermost stratigraphic unit of the deepest GABORA groundwater unit (the Rewan Formation of the Clematis Groundwater Unit) is considered low due to the Rewan Formation and the Tinowon Formation being separated by the Kianga Formation and the Black Alley Shale aquitard (Figure 36), a thickness of some 150 m (Table 13).

A.1.3.1.1 Hydrogeological context of TGS project

Tight gas reservoirs are similar to conventional gas reservoirs, where the gas originates from a source rock and migrates into the reservoir formation, where it is "trapped" by the presence of low permeable capping formation. Tight gas is differentiated from conventional gas resources by the low permeability of the reservoir formation (typically low permeability sandstone formation), for which stimulation of the reservoir is necessary for economic production of the gas resource (Golder, 2017).

Production of tight gas differs from Coal Seam Gas (CSG) in that the gas is not bound to the reservoir matrix in the same manner that CSG is adsorbed to coal surfaces (i.e., bound by weak molecular bonds), and once the reservoir has been stimulated it does not require depressurisation (to the extent that a CSG target would require) for gas production to occur. In addition, the presence of a very low permeability capping formation above the tight gas reservoirs inherently limits the hydraulic connection with shallower (overlying) formations.

A.1.3.1.2 Major aquifers and proximity to tight sands

The major aquifer systems which are in the Surat Basin within the TGS project area include the Jurassic-aged Springbok Sandstone, Hutton Sandstone, and Precipice Sandstone. The Triassic-aged Clematis Sandstone (Showgrounds Sandstone) is (for the purposes of the Risk Assessment) assumed to be a major aquifer system in the Bowen Basin. The target TGS tight sands, includes the Tinowon Formation and Muggleton Formation of the Back Creek Group. The Back Creek Group underlies all of the aforementioned formations.

The major aquifers are separated by thick aquitard confining units. The deepest major aquifer, the Showgrounds Sandstone (according to GABORA Water Plan), is separated from the target tight sands by more than 500 vertical meters. Table 13 indicates that the Showgrounds Sandstone is some 2,300 m below surface and the Tinowon Formation is some 2,800 m below surface at ATP645.

Historic and model predictions of fracture extent due to hydraulic stimulation indicate frac heights of ~ 50 m or frac length in the current well designs are approximately 70 to 400 m with a high confidence (Section 2.4.3).

A.1.3.1.3 Hydraulic properties of geological formations in the TGS project area

Drill stem testing (DST) and modular dynamics formation testing (MDT) are performed during the drilling of gas wells. This data is biased towards higher permeability measurements of formation permeability as DSTs typically assess only the permeability of the target sands, rather than interburden material.

Available data from the historic exploration wells within the TGS Project area, as included in. Figure 37, allowed for the assessment of rock properties.

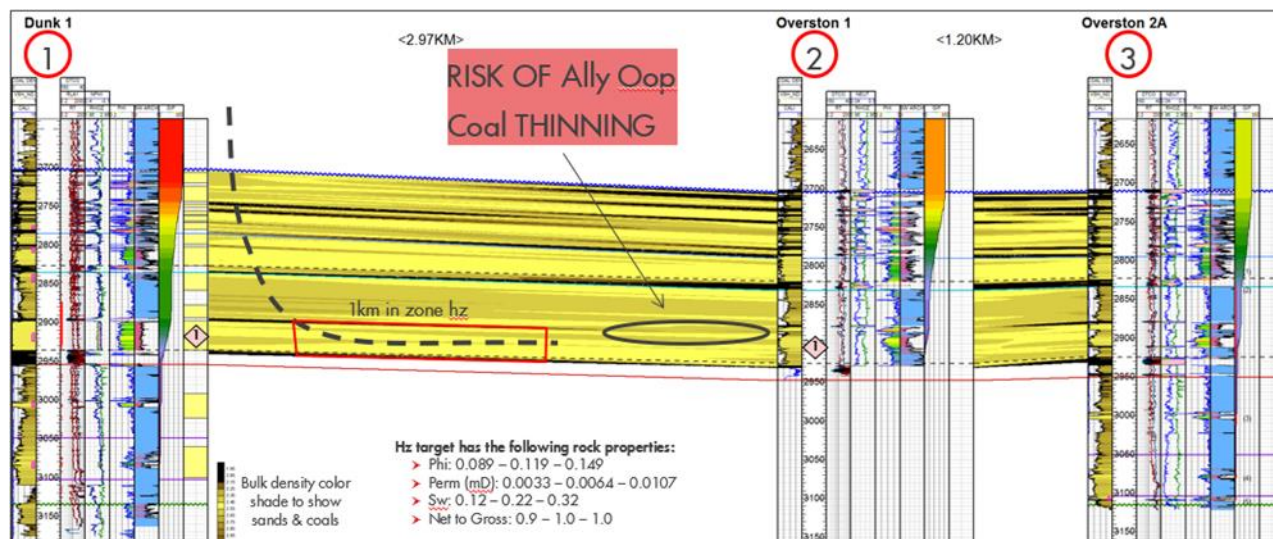


Figure 37 Target rock properties

The data indicates that the hydraulic conductivity (permeability) of the Tinowon target sand ranges from 0.0033 to 0.0107 mD¹⁷ (2.85×10^{-6} to 9.24×10^{-6} m/day).

A.1.3.1.3.1 Aquifer and Aquitard Hydraulic Properties

Hydrogeological parameters (primarily, thickness, porosity, hydraulic conductivity and storativity, and typical water yield) for the major Surat and Bowen basins aquifer and aquitard units, present in the TGS project area, have been compiled in Table 14.

The hydraulic parameters presented in this table are based on field measurements and an extensive literature review, sourced from government agency reports, publications, and investigation reports and datasets made available by QGC as compiled by Golder (Golder, 2014).

The geological processes involved in the creation of these GAB sedimentary units have given rise to laterally and vertically heterogeneous hydrogeological systems, both locally and regionally. The parameter values presented in Table 14 reflect the heterogeneity of the units which are mapped within the TGS project area (Golder, 2014).

Table 14 Aquifer hydraulic parameters in the TGS project

Unit	Average Hydraulic Conductivity (m/day)	Porosity (%)	Transmissivity (m ² /day)	Storage ¹⁸	Bore yields (L/s)
Griman Creek Formation	1.8×10^{-4}	10 - 30	6 - 15	$S_y = 5 \times 10^{-6}$	0.17 to 13.29
Wallumbilla Formation	0.06	10 - 30	50	$S = 5 \times 10^{-3}$	< 5
Bungil Formation	4.1×10^{-5}	10 - 30	50	$S = 5 \times 10^{-3}$	0.6 - 6
Mooga Sandstone	4.1×10^{-2}	10 - 30	50	$S = 5 \times 10^{-3}$	Up to 35 Average 1.3
Orallo Formation	3.0×10^{-1}	10 - 30	50	$S = 5 \times 10^{-3}$	0.08 - 2.28
Gubberamunda Formation	8.5×10^{-1}	10 - 30	50	$S = 5 \times 10^{-3}$ $S_y = 0.03$	– 22 Average 4.6
Westbourne Formation	1.0×10^{-2}	10 - 30	150	$S = 5 \times 10^{-3}$	No data
Springbok Sandstone	4.1×10^{-3}	10 - 30	150	$S = 5 \times 10^{-4}$	No data
Walloon Coal Measures	1.4 (coals)	< 1 coal	50	$S = 5 \times 10^{-4}$	0.03 - 19

¹⁷ For hydraulic conductivity (permeability) 1 m/day = 1157 mD or 8.64×10^{-4} m/day per millidarcy (mD)

¹⁸ Specific yield (S_y) and Storativity (S)

Unit	Average Hydraulic Conductivity (m/day)	Porosity (%)	Transmissivity (m ² /day)	Storage ¹⁸	Bore yields (L/s)
	1×10^{-2} (interburden)	10 – 30 (interburden)			
Hutton Sandstone	0.1 - 2	18 - 26	100 – 150	$S = 5 \times 10^{-4}$	0.1 - 50
Evergreen Formation	3.4×10^{-3}	15	No data	$S = 5 \times 10^{-4}$	0.01 – 0.44
Precipice Sandstone	2×10^{-2}	15 - 20	150	$S = 5 \times 10^{-4}$	0.1 - 30
Moolayember Member	1.6×10^{-3}	No data	No data	No data	0.1 – 24.7
Snake Creek Mudstone Member	No data	No data	No data	No data	No data
Showgrounds Sandstone / Clematis Sandstone	2.7×10^{-2}	21	No data	No data	Up to 25 Average 3.65
Back Creek Formations	0.01 to 1×10^{-3}	No data	No data	$S = 5 \times 10^{-6}$	No data

A.1.3.2 Groundwater resources

The Condamine–Balonne catchment is above an extensive and deep groundwater system, the Great Artesian Basin (GAB) underlying more than 1.7 million km² of Queensland, New South Wales, South Australia, and Northern Territory.

There is some interaction between water of the GAB and overlying surface water, or shallow groundwater contained in near-surface aquifers. Shallow groundwater exists in alluvial aquifers that are associated with the major rivers and creeks of the region. Basalt and sandstone aquifers exist in the upper and mid catchment. Groundwater also exists in sand beds and gravel layers in the mid to lower catchment. Recharge to the aquifers occurs through rainfall throughout the catchment, flooding in the lower catchment, and lateral flow between the different groundwater systems.

The GAB is the largest groundwater basin in Australia and contains a vast volume of underground water (estimated at 64,900 million ML) that supply pastoral, agricultural and extractive industries as well as domestic purposes, and supports Indigenous cultural values and groundwater dependent ecosystems (GDE).

A review of registered groundwater bores, within and adjacent to ATP645 indicated:

- Most groundwater used is sourced from the Griman Creek Formation, a layered sandstone and mudstone unit above the GAB.
- Additional groundwater is extracted from the GAB aquifers including the Mooga Sandstone, Gubberamunda Sandstone, and the Springbok Sandstone.

A review of available groundwater yield, licensed extraction, water quality, and location data related to the registered bores indicate good groundwater yield potential, variable groundwater quality, and the availability of water entitlements within and adjacent to ATP645.

Bowen Basin geology and hydrogeology

Little is known about the hydrogeology of the deep sediments of the Bowen Basin within the Queensland Murray-Darling Basin (DNRME, 2018), and information about geology and hydrogeology is mainly derived from resources sector (mining, petroleum, conventional gas and CSG) investigations.

Figure 38 shows the extent and strata of the Bowen Basin and the overlying Surat Basin and GAB formations in the Murray-Darling Basin (MDB) area (Warrego through to Border Rivers catchments).

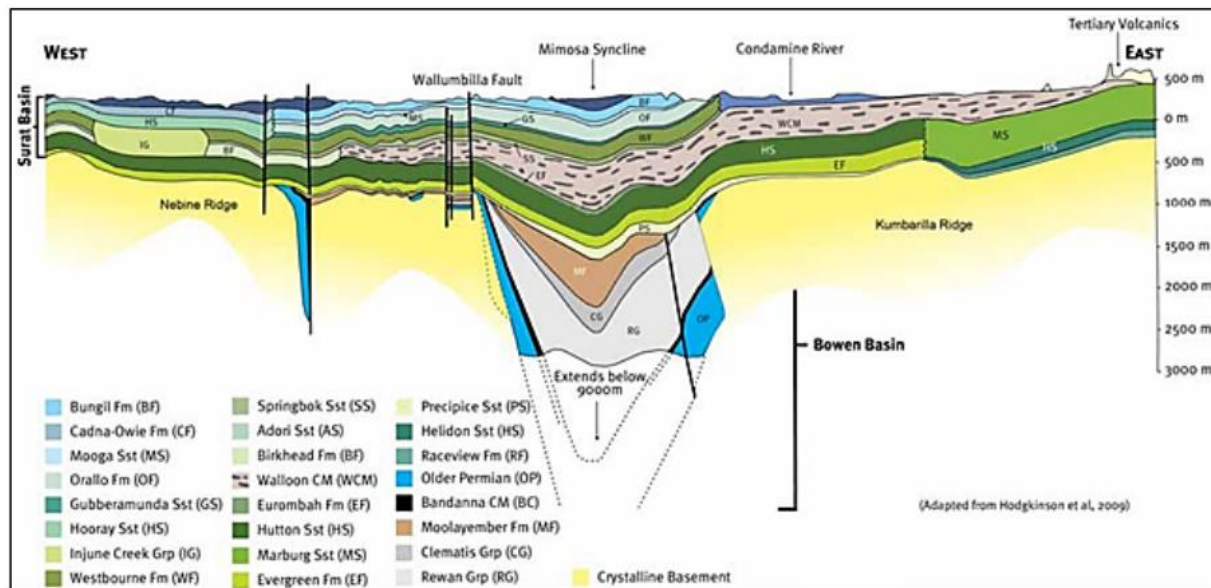


Figure 38 Geological formations in the MDB area

The hydrogeology (aquifer types) of these deep Bowen Basin sediments is considered in Figure 39. Units below the Clematis Group are aquitards.

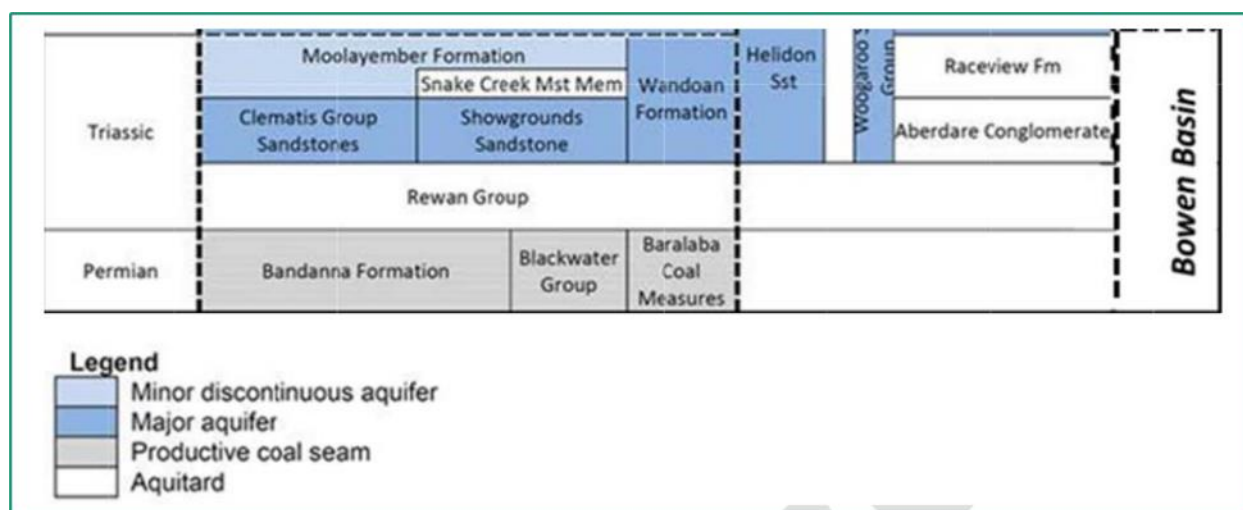


Figure 39 Deep Bowen Basin sediments hydrostratigraphy (DNRME, 2018)

A.1.3.2.1 Groundwater flow

Groundwater movement within both the Surat Basin and the Bowen Basin is controlled by the shallow dipping nature of the layered sequence, hydraulic conductivity, and structural overprints. Recharge to the Surat Basin occurs mainly through infiltration of rainfall via creeks into the outcropping aquifer sandstones, and through unconsolidated sediments overlying the sandstone aquifers along the eastern, elevated margins of the basin (Habermehl, 2001a). The Bowen Basin is recharged mainly from the exposures of aquifers in the north.

In the study area, groundwater is inferred to flow towards the south-west, predominantly parallel to bedding planes and sedimentary contacts. Vertical groundwater flow within aquifers is considered to be limited, as is cross formational or inter-formational flow. Cross formational flow is likely to be restricted by the natural bedding plane alignment of the sedimentary grains, parallel to the bedding planes and the presence of low permeability units that act as confining layers.

Vertical flow

Vertical flow from or through one layer into another (upwards or downwards), sometimes referred to as “inter-aquifer” flows or vertical leakage, occurs naturally to some extent where there is a hydraulic connection between adjacent water-bearing formations (i.e., in porous media systems, a component of vertical hydraulic conductivity, K_v , always exists) and a sufficient vertical hydraulic gradient exists. The extent to which vertical flow occurs (or has the potential to occur) between two formations can be significantly limited by the presence of an intervening low permeability aquitard (e.g., a mudstone, claystone, or siltstone), or low permeability interbeds within a formation. For example, a mudstone or claystone band (with a low K_v) separating two aquifers would restrict, but not entirely eliminate water flow between the aquifers.

Inter-aquifer flow can be enhanced by the presence of structural features (e.g., joints, fractures, or faults) that crosscut the bedding within a sedimentary sequence. This occurs more frequently at basin margins, where the rocks are folded, and along fault lines, where a zone of increased fracturing may be present in the vicinity of the fault. In addition, inter-aquifer flow can be initiated or enhanced by groundwater extraction that induces increased pressure gradients between the formation from which extraction occurs and surrounding formations.

Vertical leakage is thought to account for a considerable portion of groundwater discharge in the GAB (estimated at around 42%; Habermehl 2002), suggesting inter-aquifer connectivity to be relatively widespread.

The upper units of the Bowen Basin (Rewan Group, Clematis Sandstone, and the Moolayember Formation), while generally considered to be hydraulically separated from the overlying Surat Basin, do display similar hydrochemical characteristics, supporting the idea that there is connectivity between the overlying and adjoining aquifers of the GAB (Habermehl 1980).

Preferential flow paths

Vertical hydraulic connection can occur through man-made features, such as vertical bores. Deep exploration wells within ATP645 can, due to current casing and construction status or due to proximity to proposed hydraulic stimulation activities, could act as preferential flow paths for groundwater and/or frac fluids.

The four remaining Legacy TGS wells (Fantome 1, Dunk 1, Daydream 1, and Magnetic 1) on ATP645, which were drilled between 2012 and 2014, are awaiting abandonment. The schedule for the abandonments is currently aligned to the upcoming TGS “Examine” drilling campaign (targeting Q1 2023 to Q1 2024) with abandonment priority placed on Fantome 1 due to the previously identified barrier integrity issues.

Process

The Legacy TGS wells are appraisal wells that were drilled, tested, and then subsequently suspended. A suspended well is shut-off from the reservoir using a normally closed device or devices (e.g., a deep-set plug, either permanent or retrievable) with cement or a hydrostatic column above if required. The suspension plug should be designed to maintain integrity for the duration of the planned suspension.

A suspended well should be tested as leak tight. The well must be considered flow wetted when a suspension plug is not leak-tight and should be maintained as such (i.e., Wellhead Integrity Test (WIT) and Subsurface Integrity test (SIT) re-instated as per an Operated well).

Components of a barrier or barrier element should be inflow tested in the direction of flow, when possible, at the required closed-in tubing head pressure (CITHP) or working pressure. Legacy TGS wells are required to be monitored and maintained despite being suspended (with or without barrier failures) and not connected to production facilities.

A.1.3.2.2 Groundwater yields

A review of registered bore data on the Groundwater Database (GWDB) allowed for an initial assessment of groundwater yield (and potential) noting that dry bores are not always recorded on the GWDB. The yield information is summarised in Table 15.

Table 15 Flow rate information

Geological unit	Yield information
Griman Creek Formation	Four registered groundwater bores had flow rate information recorded. Maximum discharge rates varied from 7.5 – 10.98 L/s, with a mean of 9 L/s.
Mooga Sandstone	19 registered groundwater bores had flow rate information recorded. Maximum discharge rates varied from 0.17 – 13.29 L/s, with a mean of 3.1 L/s.
Gubberamunda Sandstone	Three registered groundwater bores had flow rate information recorded. Maximum discharge rates varied from 0.31 – 5.99 L/s, with a mean of 2.2 L/s.
Springbok Sandstone	No flow rate information was available for any of the Springbok Sandstone bores in the data set.
Hutton Sandstone	No flow rate information was available for any of the Hutton Sandstone bores in the data set.
Precipice Sandstone	No flow rate information was available for any of the Precipice Sandstone bores in the data set.
Clematis Sandstone / Showgrounds Sandstone	No flow rate information was available for any of the Clematis Sandstone bores in the data set.

A.1.3.2.3 Groundwater recharge and discharge

Surat Basin aquifers

Recharge to the groundwater regime(s) is understood to occur within the outcrop areas in the north, north-east and east along the western slopes of the Great Dividing Range (OGIA, 2019). The exception is recharge to the Hutton Sandstone and Precipice Sandstone units north of Great Dividing Range, recent investigations (OGIA, 2019) have suggested north of the divide groundwater in these formations may flow towards the north and northeast.

The GAB aquifers are recharged by infiltration (rainfall), and leakage from streams into outcropping sandstone formations. Rates of recharge from direct rainfall or diffuse recharge are small, generally less than 2.5 mm per year. However, recharge rates from preferred pathway flow during high intensity rainfall events, and localised leakage from watercourses can be up to 30 mm/year (Kellett et al. 2003).

Anthropogenic groundwater abstraction accounts for a substantial portion of the discharge from the Surat basin aquifers.

Natural groundwater discharge from the major GAB aquifers manifests in the form of groundwater springs.

Bowen Basin – deep sediments

Recharge to the Bowen Basin occurs by infiltration of rainfall into the outcropping sandstone aquifers and leakage through unconsolidated sediments overlying the aquifers from the north in Roma in a southwest direction towards St George and the Queensland/New South Wales border.

Groundwater is expected to be broadly topographically controlled, away from the outcropping recharge zones (DNRM 2012, OGIA 2016). The Bowen Basin deep sediments are generally isolated from overlying aquifers and are non-artesian.

Discharge from the Queensland Bowen Basins has not been estimated but is expected to be small and generally restricted to connected Bowen sub-basins, with a trend towards to the southern Basins including the Gunnedah-Oxley Basin in NSW.

Due to the degree of uncertainty about the extent, depth (depths of up to 9,000 m) layering, connectivity, and potential production from the basins for water extraction, there is insufficient information to report on the transmissivity and yield of the basins for commercial purposes.

Holland et al. (2017) noted that there is minimal interference with this low-quality groundwater resources from non-petroleum and gas production activities. What is known is that there are several deep non-artesian sedimentary and coal layers below the GAB that often vary from 70 m to 250 m thick which have very low permeability and flow rates (OGIA 2016).

A.1.3.2.4 Groundwater quality

A.1.3.2.4.1 Griman Creek Formation

Hydrochemistry data for this unit was available from ten registered groundwater bores identified during the registered bore search. Seven of these bores are located within ATP645 and three are located 5 to 7 km outside the ATP645 area.

Hydrochemistry data for this unit is summarised in Table 16.

Table 16 Griman Creek Formation hydrochemistry summary

Analyte	Calcium	Chloride	EC	Fluoride	Magnesium	pH	Potassium	Sodium	SAR	Sulphate
Units	mg/L	mg/L	µS/cm	mg/L	mg/L		mg/L	mg/L	mg/L	mg/L
No.	10	10	13	8	10	10	8	10	13	10
Min	9.5	35.0	479.0	0.06	7.5	6.6	1.4	163.7	5.4	6.0
Max	775.8	10,949.0	29,580.0	1.0	758.3	8.6	20.2	5,546.2	78.9	1,100.5
Mean	214.4	3651.7	9452.2	0.4	226.5	7.8	6.3	2053.1	25.5	366.5
Median	37.8	528.4	1895.0	0.3	22.0	8.0	2.0	610.2	26.5	87.6
20th%	22	81.6	1002.8	0.24	15.18	7.24	1.68	253.4	8.2	17.2
80th%	557.04	10288	25960	0.488	687.4	8.14	11.3	5204.72	33.9	1014.24

A.1.3.2.4.2 Mooga Sandstone

Hydrochemistry data was available from nine registered groundwater bores located approximately 5 km to the north-northeast of the ATP645 area.

Registered bores, which specify Mooga Sandstone as the contributing aquifer unit indicate the unit is located at depths of between 520 m and 700 m below surface in the vicinity of ATP645. Hydrochemistry data for this unit is summarised in Table 17.

Table 17 Mooga Sandstone hydrochemistry summary

	Calcium	Chloride	EC	Fluoride	Magnesium	pH	Potassium	Sodium	SAR	Sulphate
Units	mg/L	mg/L	µS/cm	mg/L	mg/L		mg/L	mg/L	mg/L	mg/L
No.	32	35	33	22	32	34	25	35	31	22
Min	1.3	45.4	1,740	0.21	0.0	7.4	1.0	441.4	48.1	0.0
Max	4.0	140.0	2,120	3.8	4.0	8.9	4.0	581.0	117.4	10.0
Mean	1.9	95.3	1980	2.4	1.4	8.3	1.7	509.6	73.5	3.0
Median	1.8	94.0	2000	2.5	1.4	8.4	1.7	519.1	67.3	2.0
20 th %	1.4	79.6	1898	2.128	0.32	8.16	1.5	486.4	62	1
80 th %	2	116.6	2050	3.04	2	8.6	1.8	530.4	91	5

Magnetic GW1

Source water for the hydraulic stimulation activities, as detailed in Section 2.4.8.3, was identified as Magnetic GW1, a water supply bore which intersects the Mooga Sandstone. A summary of the available groundwater quality data for Magnetic GW1 is included in Table 18.

It is noted that trace hydrocarbon compounds were reported within the water sample. Based on the limited water quality results and the use at the bore (the neighbouring landholder had installed a pipe to take water from this bore) it is considered that these trace hydrocarbon results may be erroneous (i.e., not naturally occurring within the Mooga Sandstone).

Table 18 Magnetic GW1 hydrochemistry summary

Parameter	Units	LOR	2011 NHMRC Australian Drinking Water Health	ANZECC 1992 Livestock Drinking Water Quality	Magnetic GW1
Sample Date					10/02/2022
Physical Parameters					
pH (field)	pH units	-	-	-	-
pH (lab)	pH units	0.01	-	-	8.52
Temperature (field)	°C	-	-	-	-
Electrical Conductivity (specific) (field)	µS/cm	1	-	-	-
Electrical Conductivity (specific) (lab)	µS/cm	1	-	-	2,230
Total Dissolved Solids (Calc.)	mg/L	1	600	2,000 – 13,000	1,440
Ions					
Calcium	mg/L	1	-	1,000	2
Chloride	mg/L	1	-	-	203
Fluoride	mg/L	0.1	1.5	2	1.7
Magnesium	mg/L	1	-	-	<1
Potassium	mg/L	1	-	-	2
Sodium	mg/L	1	-	-	638
Sulfate as SO ₄	mg/L	1	-	1,000 – 2,000	<1
Alkalinity and Hardness					
Bicarbonate Alkalinity as CaCO ₃	mg/L	1	-	-	874
Carbonate Alkalinity as CaCO ₃	mg/L	1	-	-	48
Hydroxide Alkalinity as CaCO ₃	mg/L	1	-	-	<1
Total Alkalinity as CaCO ₃	mg/L	1	-	-	922
Total Hardness as CaCO ₃	mg/L	1	-	-	5
Dissolved Metals					
Aluminium	mg/L	0.01	-	5	<0.01
Arsenic	mg/L	0.001	0.01	0.5	<0.001
Barium	mg/L	0.001	2	-	0.020
Beryllium	mg/L	0.001	0.06	-	<0.001
Boron	mg/L	0.001	4	5	5.16
Cadmium	mg/L	0.0001	0.002	0.01	<0.0001
Chromium	mg/L	0.001	0.05	1	<0.001

Parameter	Units	LOR	2011 NHMRC Australian Drinking Water Health	ANZECC 1992 Livestock Drinking Water Quality	Magnetic GW1
Sample Date					10/02/2022
Cobalt	mg/L	0.001	-	1	<0.001
Copper	mg/L	0.001	2	0.4	<0.001
Iron	mg/L	0.05	-	-	<0.05
Lead	mg/L	0.001	0.01	0.1	<0.001
Manganese	mg/L	0.001	0.5	-	0.001
Mercury	mg/L	0.0001	0.001	0.002	<0.0001
Molybdenum	mg/L	0.001	0.05	0.15	0.002
Nickel	mg/L	0.001	0.02	1	<0.001
Selenium	mg/L	0.01	0.01	0.02	<0.01
Uranium	mg/L	0.001	0.017	0.2	<0.001
Vanadium	mg/L	0.01	-	-	<0.01
Zinc	mg/L	0.005	-	20	<0.005
Total Metals					
Aluminium	mg/L	0.01	-	5	0.02
Arsenic	mg/L	0.001	0.01	0.5	<0.001
Barium	mg/L	0.001	2	-	0.040
Beryllium	mg/L	0.001	0.06	-	<0.001
Boron	mg/L	0.001	4	5	5.92
Cadmium	mg/L	0.0001	0.002	0.01	<0.0001
Chromium	mg/L	0.001	0.05	1	<0.001
Cobalt	mg/L	0.001	-	1	<0.001
Copper	mg/L	0.001	2	0.4	<0.001
Iron	mg/L	0.05	-	-	0.23
Lead	mg/L	0.001	0.01	0.1	<0.001
Manganese	mg/L	0.001	0.5	-	0.004
Mercury	mg/L	0.0001	0.001	0.002	<0.0001
Molybdenum	mg/L	0.001	0.05	0.15	0.002
Nickel	mg/L	0.001	0.02	1	<0.001
Selenium	mg/L	0.01	0.01	0.02	<0.01
Uranium	mg/L	0.001	0.017	0.2	<0.001
Vanadium	mg/L	0.01	-	-	<0.01
Zinc	mg/L	0.005	-	20	0.007
Dissolved Gases					
Unionized Hydrogen Sulfide	mg/L	0.1	-	-	<0.1
Methane	µg/L	10		-	8,060
Ionic Balance					
Total Anions	meq/L	0.01	-	-	24.1

Parameter	Units	LOR	2011 NHMRC Australian Drinking Water Health	ANZECC 1992 Livestock Drinking Water Quality	Magnetic GW1
Sample Date					10/02/2022
Total Cations	meq/L	0.01		-	27.9
Ionic Balance	%	0.01		-	7.21
Miscellaneous					
Oil & Grease	mg/L	5			<5
Glycols	mg/L	2			<2
Monocyclic Aromatic Hydrocarbons	µg/L	1 - 5			<LOR
Fumigants	µg/L	5			<5
Halogenated Aliphatic Compounds	µg/L	5 - 50			<LOR
Halogenated Aromatic Compounds	µg/L	5			<5
Trihalomethanes	µg/L	5			<5
Phenolic Compounds	µg/L	1 - 2			<LOR
Polynuclear Aromatic Hydrocarbons	µg/L	1			<1
Total Petroleum Hydrocarbons					
C6-C9 Fraction	µg/L	20			<20
C6-C14 Fraction	µg/L	50			90
C15 – C28 Fraction	µg/L	100			100
C29 – C36 Fraction	µg/L	50			60
C10 – C36 Fraction (sum)	µg/L	50			250
Total Recoverable Hydrocarbons					
C6-C10 Fraction	µg/L	20			<20
C6-C10 Fraction minus BTEX	µg/L	20			<20
>C10 – C16 Fraction	µg/L	100			<100
>C16-C34 Fraction	µg/L	100			140
>C34 – C40 Fraction	µg/L	100			<100
>C10 – C40 Fraction (sum)	µg/L	100			140
>C10 – C16 Fraction minus Naphthalene	µg/L	100			<100

LOR – limit of reporting

No alcohols or PFAS were detected above LOR

A.1.3.2.4.3 Gubberamunda Sandstone

Most of the Gubberamunda Sandstone data reviewed was supplied by QGC. The water quality data was compiled from the QGC bores located approximately 70 km northeast of the ATP645.

Hydrochemistry was available from one registered groundwater bore (RN22622), located some 6 km to the northeast of ATP645 (Figure 40).

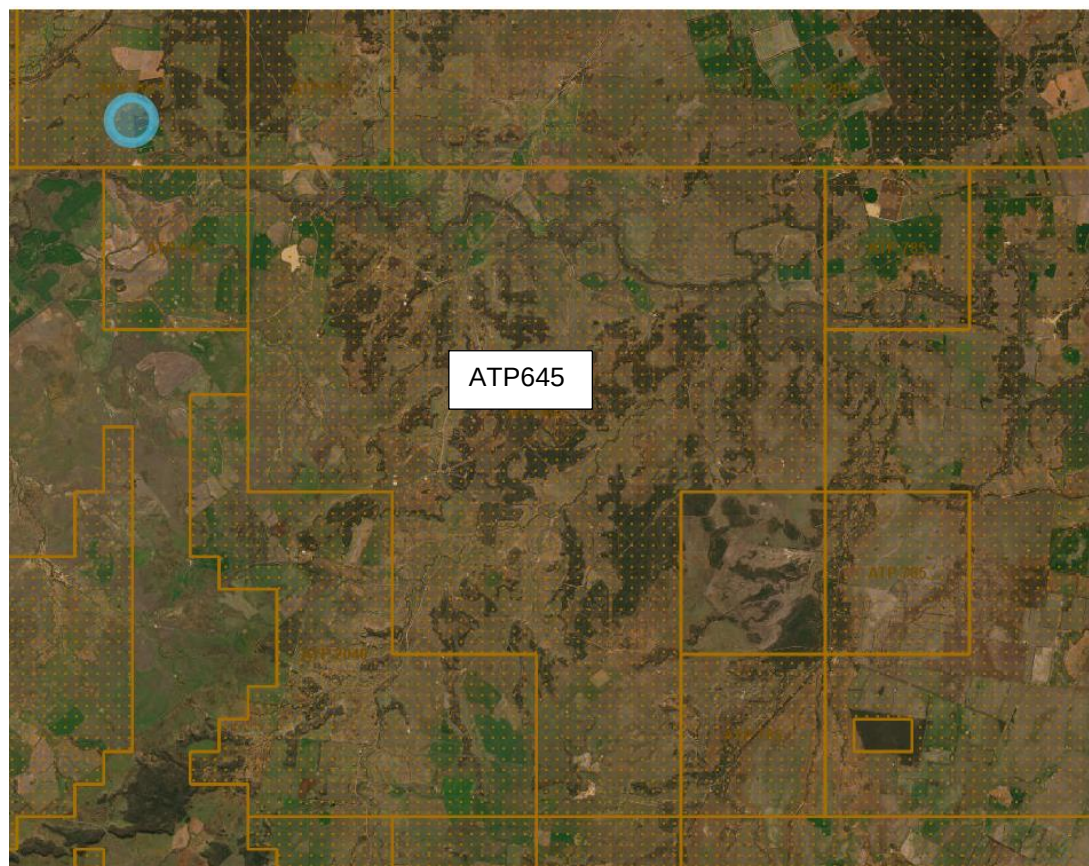


Figure 40 RN22622 locality plan

Registered bore RN23182 indicates the Gubberamunda Sandstone to be between 1,100 m and 1,240 m below ground level (mbgl) in the vicinity of ATP645. Hydrochemistry data for this unit from the available reports is summarised in Table 19.

Table 19 Gubberamunda Sandstone hydrochemistry summary

	Calcium	Chloride	EC	Fluoride	Magnesium	pH	Potassium	Sodium	SAR	Sulphate
Units	mg/L	mg/L	µS/cm	mg/L	mg/L		mg/L	mg/L	mg/L	mg/L
No.	73	24	75	24	74	75	72	74	67	24
Min	0.4	100.0	4.0	0.1	0.1	5.25	0.2	69.2	7.52	1.0
Max	35.1	1,220.0	4,642.0	1.4	14.5	9.85	13.6	1,040.0	97.5	52.0
Mean	7.6	543.4	2362.0	0.4	4.4	7.9	3.1	521.1	53.9	10.5
Median	2.3	260.5	1730.0	0.2	0.5	8.2	2.0	444.3	55.0	1.0
20 th %	1.7	250.8	1496	0.2	0.18	7.072	1	310	32.76	1
80 th %	11.24	1026.6	4274	0.3	12	8.632	3.2	896.6	74.4	6.4

A.1.3.2.4.4 Springbok Sandstone

All the Springbok Sandstone chemistry data was supplied by QGC. The water quality data was compiled from the QGC bores located approximately 70 km northeast of the ATP645.

On lease ATP645 exploration bore Magnetic-1, indicates the Springbok Sandstone to be between 1,275 m and 1,357 mbgl beneath lease ATP645.

Hydrochemistry data for this unit from the available reports is summarised in Table 20.

Table 20 Springbok Sandstone hydrochemistry summary

	Calcium	Chloride	EC	Fluoride	Magnesium	pH	Potassium	Sodium	SAR	Sulphate
Units	mg/L	mg/L	µS/cm	mg/L	mg/L		mg/L	mg/L	mg/L	mg/L
No.	51	123	48	128	124	128	128	113	48	51
Min	110.0	1,770.0	0.1	0.05	7.31	0.99	156.0	13.4	1.0	110.0
Max	7,110.0	19,100.0	4.0	50.4	12.2	44.0	4,250.0	182.0	29.0	7,110.0
Mean	1473.4	4037.3	1.5	5.2	8.7	4.6	844.7	83.3	2.9	1,473.4
Median	969.0	3100.0	1.5	0.4	8.6	2.8	616.0	88.0	1.0	969.0
20 th %	285	1950	0.52	0.1	7.956	1.3	454.2	70.64	1	285
80 th %	2230	4692	2.3	1.8	8.9	5.6	1040	96.96	2.6	2230

A.1.3.2.4.5 Hutton Sandstone

All the Hutton Sandstone data was supplied by QGC. The water quality data was compiled from the QGC bores located approximately 70 km northeast of the ATP 645.

On lease ATP645 exploration bore Magnetic 1, indicates the Hutton Sandstone to be between 1,600 m and 1,665 mbgl beneath lease ATP645. Hydrochemistry data for this unit from the available reports is summarised in Table 21.

Table 21 Hutton Sandstone hydrochemistry summary

	Calcium	Chloride	EC	Fluoride	Magnesium	pH	Potassium	Sodium	SAR	Sulphate
Units	mg/L	mg/L	µS/cm	mg/L	mg/L		mg/L	mg/L	mg/L	mg/L
No.	44	28	42	28	44	41	44	44	41	28
Min	1.0	104.0	1,000.0	0.1	0.1	7.11	0.8	237.0	29.9	1.0
Max	50.3	1,170.0	4,500.0	8.8	9.9	8.71	46.3	972.0	126.0	81.0
Mean	14.5	398.7	2400.8	2.3	2.5	7.9	11.0	540.5	61.7	21.9
Median	2.3	130.5	1825.0	1.4	0.2	8.0	3.6	449.0	57.7	3.0
20 th %	1.48	121.2	1430	0.1	0.1	7.47	1.36	333.2	32.4	1
80 th %	42.04	1106	4266	3.26	7.6	8.27	27.8	845	88.6	71.8

A.1.3.2.4.6 Precipice Sandstone

The majority of Precipice Sandstone hydrochemistry data was supplied by QGC, and these bores are located approximately 70 km northeast (up dip) of the ATP645 lease area.

Data from seven bores (Mahlbacher, A, 2019) located in the Moonie Oil Field area was also reviewed and these are located approximately 35 km south of the ATP645 lease and intersect the Precipice Sandstone at a depth > 1,700 m.

No Precipice Sandstone groundwater chemistry data was available from the registered bores within the ATP645 lease or within up to 7 km of the lease.

The Precipice Sandstone is a deep, high-quality aquifer in the GAB. The hydrochemistry study has split the Precipice Sandstone bores into two groups based on the hydrochemistry, the depth of the screened interval, and the bore location in relation to ATP645.

This is due to the deeper Moonie Oil Field bores ('Lower Precipice') to the south of the ATP645 had markedly different hydrochemistry to the shallower ('Upper Precipice') bores to the north of the ATP645.

Hydrochemistry data for this unit (Lower and Upper Precipice) from the available reports is summarised in Table 22 and Table 23.

RN23182 indicates the Precipice Sandstone to be between 2,180 m and 2,230 mbgl in the vicinity of ATP645 (noting this GAB aquifer has limited thickness, of approximately 50 m).

Table 22 'Lower' Precipice Sandstone hydrochemistry summary

	Calcium	Chloride	EC	Fluoride	Magnesium	pH	Potassium	Sodium	Sulphate
Units	mg/L	mg/L	µS/cm	mg/L	mg/L		mg/L	mg/L	mg/L
No.	7	7	7	7	7	7	7	7	7
Min	11.0	180	1,211	2.9	1.0	7.88	17.0	657	2.0
Max	22.0	196	2,462	8.5	3.0	8.4	32.0	779	4.0
Mean	15.3	191.1	1724.6	6.1	1.6	8.2	25.3	709.1	3.0
Median	15.0	193	1341	6.9	1.0	8.1	24.0	688	3.0
20 th %	11.8	188.4	1255.2	4.52	1	8.084	23	681.2	2
80 th %	16.8	195.8	2289.4	7.38	2	8.342	30.8	752	4

Table 23 'Upper' Precipice Sandstone hydrochemistry summary

	Calcium	Chloride	EC	Fluoride	Magnesium	pH	Potassium	Sodium	SAR	Sulphate
Units	mg/L	mg/L	µS/cm	mg/L	mg/L		mg/L	mg/L	mg/L	mg/L
No.	31	30	29	20	31	30	31	31	30	20
Min	0.6	7.0	112.0	0.1	0.1	6.3	1.7	23.6	4.22	1.0
Max	24.3	1,205	1,200	0.3	1.8	8.23	98.2	272.0	25.5	9.0
Mean	5.2	159.9	438.2	0.2	0.7	7.1	23.1	83.2	9.0	2.6
Median	5.0	21.0	281	0.2	0.6	7.1	12.5	54.8	6.9	1.0
20 th %	0.9	11.8	130.8	0.1	0.2	6.62	2	28.3	6.112	1
80 th %	6.5	333.8	911.6	0.2	1.2	7.58	48.9	106	9.456	5

A.1.3.2.4.7 Deep sediments of the Bowen Basin

Water quality is generally poor, with salinity reaching 9,000 mg/L in some places (OGIA 2016), which is not suitable for agricultural or commercial uses.

There are no known connections between the deep sediments of the Bowen Basin and surface water (including with GAB springs sourced from the above water resources), and no risks to environmental assets have been identified (DNRME, 2018).

A.1.3.2.5 Suitability of analytical limits of reporting for stimulation monitoring

The understanding of the source aquifer of groundwater chemistry described in the section above is useful from the perspective of assessing the possible sub-surface impact of hydraulic fracture stimulation. If a hydraulic connection were to be established between the well and an aquifer adjacent to the target sands:

- i. There may be a change in the chemistry of groundwater sampled from a bore screened in an aquifer overlying or underlying a target formation; and/or
- ii. There may be a change in the chemistry of the water flowing back from the gas well. Though this may take some time to become apparent, depending on the distance of the hydraulic connection from the well. A more immediate indicator is an increase in the yield of water flowing back from the well and/or a change in water pressure in the gas well; this coincides with the establishment of a hydraulic connection with an aquifer that is more permeable than the target formation or has a different formation pressure. Hence a change in water chemistry would be used as a secondary potential indicator, which warrants further investigation.

The concentration of potassium and chloride in the hydraulic fracturing fluid is typically markedly higher in groundwater from the aquifers above the target sands, such that they can be used as indicators of scenario (i) or (ii) having occurred.

Laboratory limits of reporting for chloride and potassium (1 mg/L) are appropriate for accurately assessing the difference between hydraulic fracturing fluid and aquifer groundwater. This analytical data could be used to inform an assessment of whether the hydraulic fracturing process has altered the environmental value of groundwater, for example, whether there has been chemical alteration to groundwater accessed by landholder bores.

A.1.3.3 Groundwater use

A desktop census of water bores was conducted through a review of the Queensland Government Globe registered water bore database (GWDB). No bores were registered that were at a depth deeper than 150 metres on or close to ATP645.

A review of registered groundwater bores, within ATP645 (Figure 41), indicate that groundwater is sourced from:

- 17 registered groundwater bores within lease ATP645
- 32 registered bores within a 5 km envelope of the ATP645.

Most groundwater used is sourced from the Griman Creek Formation, a layered sandstone and mudstone unit above the GAB. Additional groundwater is extracted from the GAB aquifers including the Mooga Sandstone, Gubberamunda Sandstone, and the Springbok Sandstone.

Most of the groundwater in the area used for domestic and farming is reportedly extracted from the shallower Griman Creek Formation (which overlies the Surat Sandstone). 15 groundwater bores were identified as being present or operated to access the Griman Creek Formation groundwater.

The Wallumbilla Formation is not targeted as a water source in the area. The Orallo Formation, which underlies the Mooga Sandstone, provides up to 200 m vertical separation from the underlying Gubberamunda Sandstone aquifer, which is a major GAB aquifer in the Surat Basin.

A.1.3.3.1 Water supply bores (P&G Act)

There were 12 water supply bores, constructed under the P&G Act for exploration purposes, recorded within and adjacent to ATP645. The majority of these wells have no available information regarding screened depth, yield, or water quality (Table 24).

Table 24 ATP645 Water Supply bore summary

Well ID	Bore Name	Type	Date	Total Depth (m)	Detail
30702	No.2	Water Supply	1/01/1949	69.5	None
29469	House		Unknown	47.5	None
29466	29466		Unknown	106.7	None
29468	House		Unknown	62.2	None
29476	Brigalow		1/01/1946	21.3	None
29467	29467		Unknown	59.7	None
29475	Cow Paddock		1/01/1946	45.7	None
29464	29464		Unknown	73.2	None
29465	29465		1/01/1900	24.4	None
1517	Kinkabilla Creek 1		22/08/1987	3103	The well was drilled to target TGS within the Moolayember Formation, Showgrounds Sandstone and Rewan Group, however indicated poor reservoirs so was plugged back to the Blythesdale Group (Bungil Formation, Mooga Sandstone, Orallo Fm) for use as a water supply bore.
1024	Inglestone 1		06/04/1982	3874	Inglestone 1 well was drilled 1.5 km east of Kinkabilla 1 to test stratigraphic variation. The well completion report notes that water for both camp and rig was pumped from a nearby shallow water bore. The bore

Well ID	Bore Name	Type	Date	Total Depth (m)	Detail
					was plugged and abandoned; however, the Blythesdale Sands were left open for conversion to a water well.
71351	Magnetic GW 1		13/04/2015	692.8	Targeted the more developed sandstone at the base of the Mooga Sandstone aquifer to supply water for the drilling operations at the Magnetic 1 well. On completion was cased and suspended.

Groundwater use comments

A single bore, located approximately 8 km south of well Daydream 1, was drilled to 2,430 m depth. It is not clear what the purpose of the well was, either a conventional gas or unconventional gas well.

Note: There may be bores not listed on the Queensland Globe database, including unregistered groundwater bores in the TGS project area. However, Shell QGCs considers the likelihood of these bores to be unregistered and at depths of the target formation to be extremely low.

At the upper portion of the Surat Basin, the Cretaceous aged Mooga Sandstone (depth of approximately 470 m to 500 m) will be used as the groundwater source for use in the Shell QGC operations. This aquifer is not used in the TGS project area as a water source.

Overall, the deepest unit that potentially could be targeted for groundwater use in the area is the Clematis Sandstone / Showgrounds Sandstone. This unit is separated from the target reservoir (Back Creek Group) by more than 500 vertical meters. Table 13 indicates that the Showgrounds Sandstone is some 2,300 m below surface and the Tinowon Formation is some 2,800 m below surface at ATP645.

There are no licenced entitlements in the deep sediments of the Bowen Basin (DNRME, 2018). CSG and conventional gas and petroleum extraction and coal mining are the principal users of groundwater in the QMBDD (DNRME, 2018). It is anticipated that CSG and coal mining activities will grow over the lifespan of the MDB water plans, which may impact groundwater resources due to dewatering and water releases. The impacts will, however, occur primarily in the overlying and unconnected Surat Basin (OGIA 2016; Sander et al. 2014). The interference with groundwater levels from non-petroleum and gas production activities is minimal (Holland et al., 2017).

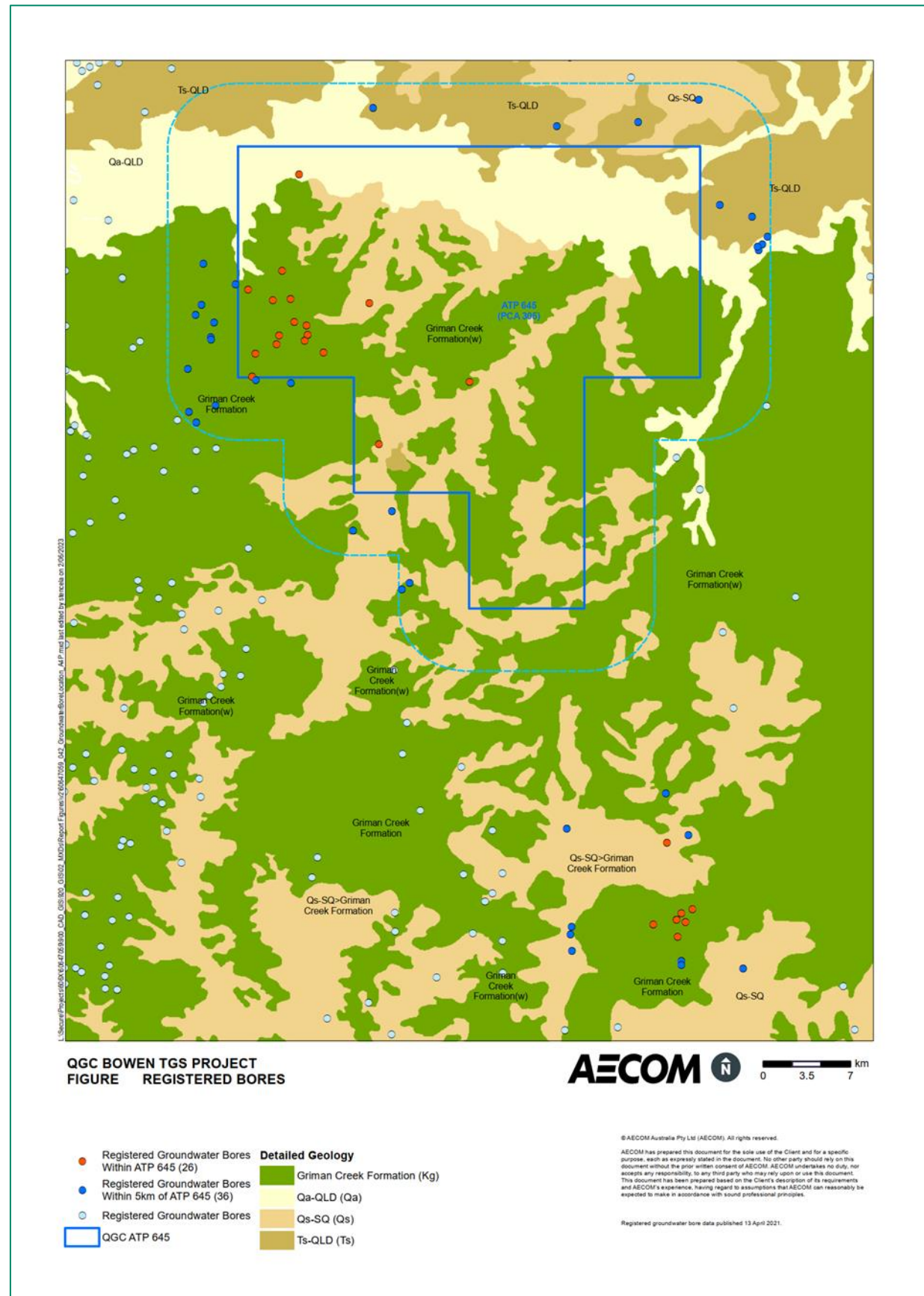


Figure 41 Registered bores

A.1.3.3.2 Water entitlements

Water entitlement data was reviewed from the DRDMW Queensland Open Data Portal¹⁹. The findings from this search are summarised below.

Water licenses

A summary of the water license search for registered groundwater bores within the groundwater study area is provided in Table 25.

No water permits were identified for any of the registered groundwater bores within the search area.

No interim water permits were identified for any of the registered groundwater bores within the search area.

No seasonal interim water permits were identified for any of the registered groundwater bores within the search area.

All water entitlements, groundwater, and surface water, within and adjacent to ATP645 are included in Figure 42. The planned drilling locations are identified to be located within or immediately adjacent to surface water entitlements only.

¹⁹ ¹⁹ <https://www.data.qld.gov.au/dataset/water-entitlements>

Table 25 Water license search summary

Registered Bore	Distance from ATP645	Licence No.	Statutory Class	Expiry	Water Authorisation	Water Allocation	Water Source	Purpose
15101	<5km	15101R	WL	30/06/2111	Yes	No	Mooga Sandstone	Stock
16687	<5km	187499	WL	30/06/2111	Yes	No	Mooga Sandstone	Stock
123353	<5km	607184	WL	30/06/2111	Yes	No	Mooga Sandstone	Stock
36336	<5km	36336N	WL	30/06/2111	Yes	No	Mooga Sandstone	Stock
14826	<5km	14826N	WL	30/06/2111	Yes	No	Mooga Sandstone	Stock
14964	<5km	14964N	WL	30/06/2111	Yes	No	Mooga Sandstone	Stock
43966	<5km	43966N	WL	30/06/2111	Yes	No	Mooga Sandstone	Stock
4051	<5km	04051N	WL	30/06/2111	Yes	No	Gubberamunda	Stock
58564	<5km	189950	WL	30/06/2111	Yes	No	Griman Creek	Stock Intensive
49209	<5km	405382	WL	30/06/2111	Yes	No	Gubberamunda	Stock
14489	>5km	14489N	WL	30/06/2111	Yes	No	Mooga Sandstone	Stock
22622	>5km	22622N	WL	30/06/2111	Yes	No	Injune Creek Group	Stock
16174	>5km	16174N	WL	30/06/2111	Yes	No	Gubberamunda	Stock
22656	>5km	22656R	WL	30/06/2111	Yes	No	Gubberamunda	Stock
4053	>5km	04053N	WL	30/06/2111	Yes	No	Gubberamunda	Stock
10487	>5km	400225	WL	30/06/2111	Yes	No	Hooray Sandstone	Stock
10841	>5km	615141	WL	30/06/2111	Yes	No	Mooga Sandstone	Stock
11410	>5km	101154	WL	30/06/2111	Yes	No	Mooga Sandstone	Stock
14813	>5km	14813R	WL	30/06/2111	Yes	No	Orallo Formation	Stock
100944	>5km	178662	WL	30/06/2111	Yes	No	Gubberamunda	Stock
137506	>5km	403519	WL	30/06/2111	Yes	No	Gubberamunda	Stock

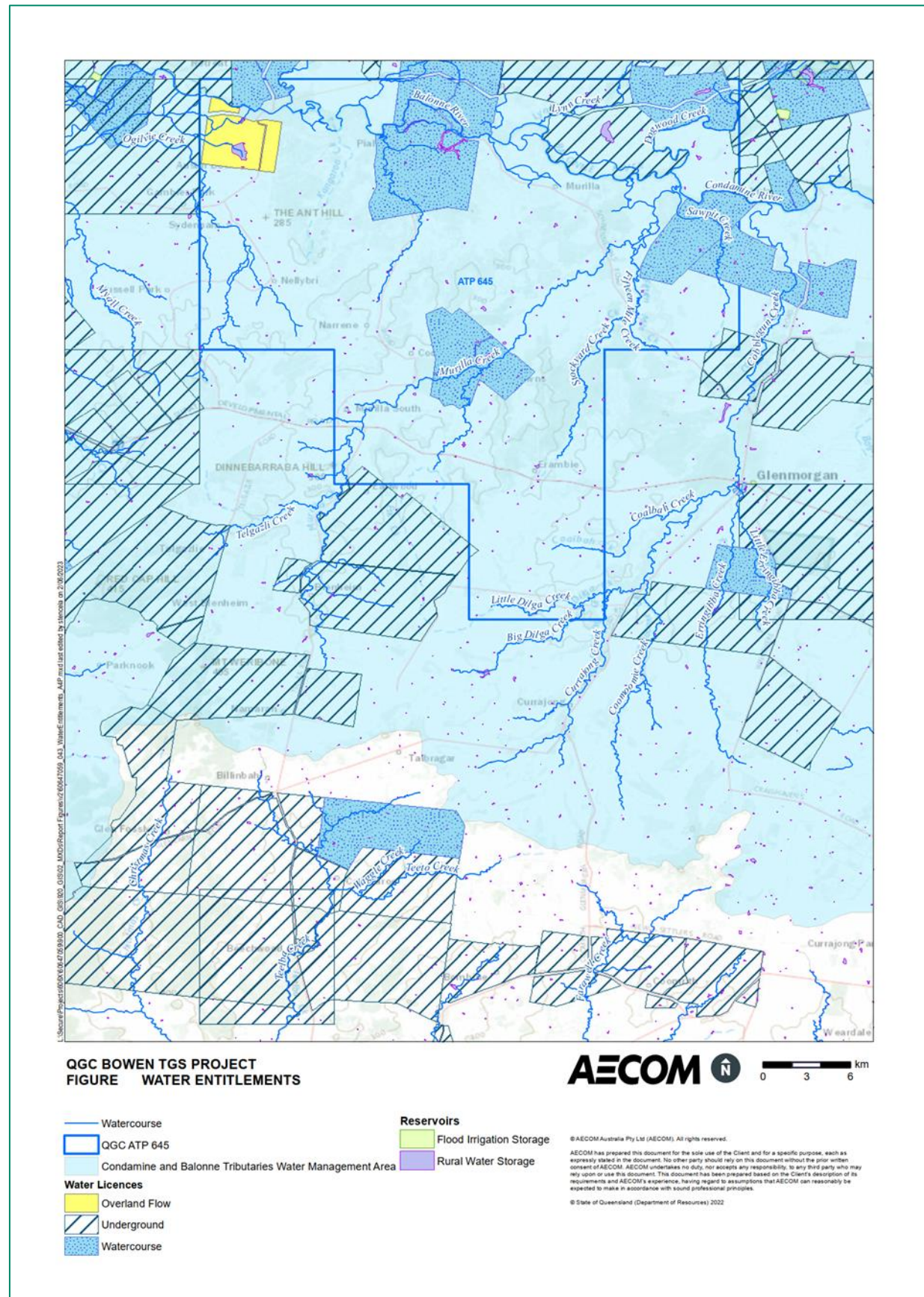


Figure 42 Water entitlements

A.1.3.4 Groundwater environmental values

The environmental values of groundwater considered of the TGS project area are assessed in accordance with the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP, 2019), specifically for groundwater Queensland Murray-Darling and Bulloo River Basins – Groundwater Environmental Values and Water Quality Objectives (DES, 2020).

Aquifer systems included in the EPP (Water and Wetland Biodiversity) and on site are presented in Table 26.

Table 26 Aquifer systems included in the EPP

System	Description
Sediments overlying the GAB	The overlying sediments consist of Tertiary sediments, weathered Cainozoic alluvium surrounding and underlying recent alluvium. Based on few data, the water quality is moderate to highly saline NaCl, with lower salinity and higher HCO ₃ near streams.
Mid GAB aquifers	This represents the main confined GAB aquifers, particularly the Bungil, Mooga, Orallo, and Gubberamunda (Kumbarilla Beds). Water quality is complex and variable, particularly around the outcrops in the north and east. Data sufficiency is poor, but the water quality appears to be moderately saline NaHCO ₃ , over most of the west and southern central area, but more variable around the north and eastern outcrops, with saline NaCl to the east, mainly around outcrops and thicker sequences of Bungil and Mooga, or sometimes associated with the Gubberamunda. High fluoride levels may also occur in the southeast, away from the outcrop areas.
Lower GAB	This is a thick sequence of important aquifers and aquitards, including the Hutton, Springbok and Boxvale aquifers, and the Injune Creek, Westbourne, and Walloon aquitards. Although data sufficiency is poor for most zones, it appears that most of the west and central area, away from the outcrops, has a fairly uniform, moderately saline NaHCO ₃ water type. However, the outcrop areas in the north and east are much more variable, with those on the eastern edge are mostly high salinity NaCl, probably influenced by underlying or overlying Walloons.
Basal GAB	This division represents the lowest beds in the GAB, mainly the Evergreen aquitard and underlying Precipice Sandstone. The GABORA equivalents are the Precipice Unit, and the Evergreen Fm. from the Hutton Unit. The groundwater is generally moderately saline, dominated by HCO ₃ with either Na, or mixed cations in northern outcrop area near basaltic remnants. Instances of high fluoride have been recorded in the central Surat area.
Earlier basins partially underlying the GAB	These Permian-Triassic basins represent hydrological networks that pre-date the GAB and were eroded before GAB sedimentation commenced. The QMDB includes the Bowen Basin underlying the Surat. The corresponding GABORA unit is the Clematis. The available data indicates NaHCO ₃ groundwater of relatively high salinity, with high fluoride occurrences.

As stipulated in these policy documents, the following groundwater environmental values in the Maranoa-Balonne River Basin are to be enhanced or protected:

- Surat Basin
 - Aquatic ecosystems
 - Farm supplies
 - Stock water
 - Drinking water
 - Cultural, spiritual, and ceremonial values.
- Bowen Basin
 - Aquatic ecosystems

- Stock water
- Cultural, spiritual, and ceremonial values.

The environmental values for groundwater within the project area that are to be enhanced or protected, through appropriate management and mitigation throughout the TGS project are expanded upon below.

A.1.3.4.1 Aquatic ecosystem environmental value

Management to ensure the physical, chemical (and where available), biological water quality objectives (WQOs) to support and protect the aquatic ecosystem EV is to be adopted. The WQOs are listed in the Queensland Murray-Darling and Bulloo River Basins – Groundwater Environmental Values and Water Quality Objectives (DES, 2020), including:

- Queensland Murray-Darling and Bulloo River basins Groundwater Water Quality Objectives: Physicochemical (nutrients, minerals, ions)
- Queensland Murray-Darling and Bulloo River basins Groundwater Water Quality Objectives: Additional indicators.

Any discharge of groundwater, including TGS associated water or hydraulic fracture stimulation flowback fluid, could potentially affect the biological integrity of any receiving surface water system.

Discharge of untreated hydraulic fracture stimulation flowback fluid to surface water systems will not intentionally occur during any period of Shell QGC operations, and hence, such impacts are not expected.

A.1.3.4.2 Farm supply use

The management goal for farm supply use is that the quality of water provided for farm use is suitable for produce preparation and for domestic household uses other than drinking.

As groundwater for domestic supply, in remote arid areas, is an important environmental value in the TGS project area, discharge of untreated hydraulic fracture stimulation flowback fluid to artificially recharge shallow groundwater systems will not intentionally occur during any period of QGC operations.

A.1.3.4.3 Stock water

The management goal for stock watering is that the quality of water provided to stock watering does not cause deterioration in stock health or condition (noting that water quality requirements may differ by stock type).

As for farm supply use, to maintain the groundwater resources used for stock watering discharge of untreated hydraulic fracture stimulation flowback fluid to artificially recharge shallow groundwater systems will not intentionally occur during any period of QGC operations.

A.1.3.4.4 Raw water for drinking water consumption

Management and mitigation will be adopted during the QGC operations to:

- Minimise the risk that the quality of raw water taken for treatment for human consumption results in adverse human health effects.
- Maintain the palatability rating of water taken for treatment for human consumption at the level of 'good' as set out in the ADWG (Table 18).
- Minimise the risk that the quality of raw water taken for treatment for human consumption results in the odour of drinking water being offensive to consumers.

A.1.3.4.5 Cultural and spiritual values and uses of water

The management goal for the TGS Project is that water resources remain fit for purpose in relation to cultural, spiritual, and ceremonial values and uses of water.

A.1.3.4.6 Surface water – groundwater interaction

There is some interaction between water of the GAB and overlying surface water, or shallow groundwater contained in near-surface aquifers. Shallow groundwater exists in alluvial aquifers that are associated with the major rivers and creeks of the region.

Basalt and sandstone aquifers exist in the upper and mid catchment. Groundwater also exists in sand beds and gravel layers in the mid to lower catchment. Recharge to the aquifers occurs through rainfall throughout the catchment, flooding in the lower catchment, and lateral flow between the different groundwater systems.

Risks associated with surface-water groundwater interactions were assessed. These entail impact of any surface activities to affect environments in communication with shallow aquifers.

Discharge of untreated hydraulic fracture stimulation flowback fluid or TGS associated water to surface water systems will not intentionally occur during any period of QGC operations.

A.1.4 Hydraulic fracture stimulation process

Hydraulic fracture stimulation is a process for improving and/or inducing hydrocarbon gas inflow into a well by hydraulically creating a narrow fissure (or fracture) in the reservoir rock providing a large surface area for gas to flow from and adequate fracture permeability and conductivity to allow the gas to flow.

Following the drilling, casing, and cementing of the well, the well casing consists of cemented sleeves that are hydraulically shifted open sequentially at the target intervals within the tight gas reservoirs. This is to ensure that the downhole pressures will only be applied on the target zones, via these cemented sleeves in the casing string.

Fractures are created by using high-pressure pumps to inject hydraulic fracturing fluids (mostly water) through the wells into selected horizons creating a fissure with a “wedge” of viscous fluid. The viscous fluid is also used to place natural or man-made, inert, round granular materials (proppant) into the fracture to hold it open and to connect and hold open tiny natural cracks within the gas bearing reservoirs.

The proppant (sand) is selected and sized to create a highly permeable flow path for the gas from the tight rocks into the established well bore. By creating larger fractures or fracture networks within the target zone, the surface area exposed to the borehole is greatly increased, allowing commercial gas production rates to be achieved from what is termed “tight” reservoirs or from hydrocarbon source rocks, such as deeply buried coals or organic shales.

Fracturing fluid is formulated with chemicals or additives that aid the fracture creation, proppant transport and fluid recovery processes. Other additives protect the formation and well bore from damage or contamination. The fracturing fluids are required to be sufficiently viscous to:

- Create a fracture of adequate width in the target reservoir
- Be able to migrate to a sufficient distance to extend the fracture length in the target reservoir
- Transport the sand (proppant) into the created fracture.

Fracture geometry (i.e., width and length) is generated by pumped fluid volumes and rates, more than fluid leak-off into the formation.

It is noted that there have been developments in the fracturing fluid technology in recent years also to consider the HSSE profiles of previous crosslinkers and their associated breakers. The primary fluid system consists of a slickwater HVFR fluid chemistry designed to start with maximum viscosity at surface and break over time at downhole temperatures post-fracture treatment typically without the need for breakers.

A.1.4.1 Well cleanout and well completion

During the well completion procedure, the brine residual in the well after the hydraulic fracture stimulation operation is displaced from the well pH-controlled permeate water. The permeate water is less dense than the brine previously in the well; hence the hydrostatic pressure in the well is reduced.

The reduction in hydrostatic pressure in the well enables formation fluid and any loose proppant to flow to surface in the circulated volume. This fluid is stored on the well pad in a flowback tank (Figure 13).

Flowback tank dimensions are approximately 13.5 m [L] x 2.4 m [W] x 2.2 m [H].

The well is then equipped with a bottom hole pump to artificially lift formation fluids to surface during the production phase of the well.

A.1.4.2 Fluid system mass balance

The campaign hydraulic fracture stimulation fluid chemicals are presented Table 27 (HVFR_A), Table 28(HVFR_B) and Table 29(HVFR_Hybrid). Their SDS are presented in **Appendix C**. The stimulation fluid compositions are sourced from the Contractor's fluid disclosure reports. It is noted that HVFR_A is the preferred stimulation fluid to be used in the campaign. HVFR_B and HVFR_Hybrid are assessed as the alternative fluids.

A PBT assessment of the chemicals is presented in A.1.6.4.

Table 27 Chemicals used in the HVFR_A hydraulic fracture stimulation fluid

Chemical name	CAS Number
Petroleum Distillates (Hydrotreated, Light)	64742-47-8
Quartz or Organophilic phyllosilicate (crystalline silica, quartz)	14808-60-7
Hydrochloric acid	7647-01-0
Glutaraldehyde	111-30-8
Isopropanol	67-63-0
Ethoxylated C12-C16 Alcohol	68551-12-2
Cinnamaldehyde	104-55-2
Ethoxylated Decanol	26183-52-8
Sodium erythorbate	6381-77-7
Ethoxylated Tallow Alkyl Amine	61791-26-2
Methanol	67-56-1
Hepta sodium phosphonate	22042-96-2
Polyacrylamide	9003-05-08
Polyethylene glycol trimethylnonyl ether	127087-87-0

Table 28 Chemicals used in the HVFR_B hydraulic fracture stimulation fluid

Chemical name	CAS Number
Petroleum Distillates (Hydrotreated, Light)	64742-47-8
Quartz or Organophilic phyllosilicate (crystalline silica, quartz)	14808-60-7
Hydrochloric acid	7647-01-0
Glutaraldehyde	111-30-8

Chemical name	CAS Number
Sodium erythorbate	6381-77-7
Hepta sodium phosphonate	22042-96-2
Polyacrylamide	9003-05-08
Polyethylene glycol trimethylnonyl ether	127087-87-0
Didecyldimethyl ammonium chloride	7173-51-5
Ethyl alcohol (Ethanol)	64-17-5

Table 29 Chemicals used in the HVFR_Hybrid hydraulic fracture stimulation fluid

Chemical name	CAS Number
Petroleum Distillates (Hydrotreated, Light)	64742-47-8
Quartz or Organophilic phyllosilicate (crystalline silica, quartz)	14808-60-7
Hydrochloric acid	7647-01-0
Glutaraldehyde	111-30-8
Isopropanol	67-63-0
Ethoxylated C12-C16 Alcohol	68551-12-2
Cinnamaldehyde	104-55-2
Ethoxylated Decanol	26183-52-8
Sodium erythorbate	6381-77-7
Ethoxylated Tallow Alkyl Amine	61791-26-2
Methanol	67-56-1
Hepta sodium phosphonate	22042-96-2
Polyacrylamide	9003-05-08
Polyethylene glycol trimethylnonyl ether	127087-87-0
Guar gum	9000-30-0
Polyoxyethylene nonylphenol ether	9016-45-9
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2
Potassium hydroxide	1310-58-3
1,6-Hexanediol	629-11-8
Ammonium Persulphate	7727-54-0
Sodium chloride	7647-14-5
Boric acid	10043-35-3
Talc, Magnesium Silicate	14807-96-6
Mannanase	37288-54-3
Sorbitol	50-70-4
Phenoxy ethanol	122-99-6

Chemical name	CAS Number
1,2-Benzisothiazonlin-3(2H)	2634-33-5
Sodium Gluconate	527-07-1
Propylene glycol	57-55-6

Mass balance of the fluid systems are presented **Appendix B**. The mass balance describes the concentration of the chemical components of each fluid system, in terms of weight and volume. The concentration of each chemical injected into the tight sands is calculated, in terms of:

- Weight for weight (w/w), i.e., kg/kg
- Volume for volume (v/v), i.e., L/L
- Weight per volume (w/v), i.e., mg/L

For the (w/w) and (v/v) calculation the weight/volume of the proppant material is included in the total weight/volume of the fluid system. In the (w/v) calculation, the volume of the proppant is not included in the total volume, to not under-represent the concentration of each chemical relative to the overall fluid system; instead, the total volume used to calculate chemical concentration (w/v) includes only liquids.

The mass balance also estimates the concentration of each chemical that will be returned to surface during the flowback of the hydraulically fractured well, based on an upper and lower estimate of 20% and 60% mass recovery.

A.1.5 Qualitative risk assessment

A.1.5.1 Overall approach

The campaign hydraulic fracture stimulation campaign will be carried out using the hydraulic fracture stimulation design, operation, monitoring, and assessment procedures described in **Section 2.3**. The risk assessment approach and source-receptor pathways remain similar to that as described in **Section 3.0**.

A.1.5.2 Problem formulation

The potential risks to the project area receiving environments associated with the campaign hydraulic fracture stimulation campaign is considered to be the following:

- The exposure of workers, trespassers or the environment to potentially hazardous concentrations of hydraulic fracture stimulation chemicals as a result of the loss of containment, operational spills and leaks.
- The potential for release of hazardous gases from the TGS well following hydraulic fracture stimulation.
- The potential release of dust from hydraulic fracture stimulation activities.
- Contamination of groundwater in aquifers overlying or underlying the target TGS.
- Contamination of groundwater in the target TGS that is accessed by landholder bores.
- Migration of remnant hydraulic fracture stimulation fluid or chemicals to springs, adversely affecting water quality.
- Hydraulic fracture stimulation triggering earthquakes and/or reactivation of geological faults.

A.1.5.3 Risks and mitigation measures

Table 30 below discusses the potential risks with regard to their potential consequences and the mechanisms by which adverse impacts are proposed to be controlled/managed.

Table 30 Qualitative human health and environmental risk assessment and consideration of the need for Quantitative risk assessment for the campaigns

	Identified Potential Hazard	Hazard Causes and Consequences	Risk Mitigation Measures	Warrants further consideration in this Risk Assessment	Reason for carrying forward the potential hazard into the subsequent Quantitative Risk Assessment
Surface Environment	The loss of containment of chemicals used for hydraulic fracture stimulation	Exposure of workers, residents, or the environment to potentially hazardous hydraulic fracture stimulation chemicals, resulting from loss of containment occurring: - While in transit to site - During the mixing of hydraulic fracture stimulation fluid on site; or (In diluted form) during the storage and transport of well flowback fluid.	QGC implements a range of engineering and operational control measures to ensure the risk of hydraulic fracture stimulation fluid spills are minimised during hydraulic fracture stimulation operations, including during transport to and from the wellsite and during the flowback of hydraulic fracture stimulation chemicals from the well. These control measures include: - Adherence to the material storage and transport requirements as stipulated on the chemical Safety Data Sheets (SDS). - Adherence to the Transport of Dangerous Goods by Road Regulations (for chemicals classified as a 'Dangerous Goods'). - Ensuring chemicals remain in their original containers and are not decanted into smaller containers which may not be fit for purpose. - During hydraulic fracture stimulation operations, the use of secondary containment beneath all equipment holding or pumping chemicals. - Using fit for purpose flowback fluid storage tanks. Conducting regular integrity checks of fluid storage tanks, during commissioning and use. Ensure adequate freeboard is maintained at all times.	Yes	The evaluation of the risk to workers involved in the operation of well hydraulic fracture stimulation activities (including transportation of the COPC to the site) is not considered warranted in the subsequent sections of this risk assessment, as it is addressed via the implementation of appropriate occupational health and safety procedures and management plans. Further consideration is warranted regarding the risk of above ground exposure relating to the handling and storage of hydraulic fracture stimulation chemicals and flowback fluid. This is addressed in Section 3.4.3. Further assessment is warranted regarding the risk associated with the potential and actual concentrations of COPC in flowback fluid; and the presence of other COPC that may have been liberated during the hydraulic fracture stimulation operations. This is addressed in Section 3.4.3. Further assessment is warranted regarding the chemical and physical properties of the constituents used in hydraulic fracture stimulation fluids that result in the potential for these chemicals to be present in flowback fluid and to be of concern in relation to potential acute or chronic risks. This is addressed in Section 3.4.3.
	Harm to the environment due to the release of fugitive emissions from hydraulically fractured wells.	Release of hazardous gases from the TGS well at surface following the hydraulic fracture stimulation of a well; e.g. if the hydraulic fracture stimulation injection pressure were to open a micro annulus in the production casing annular cement seal, from the TGS to surface.	QGC's Well Design protocols mandate the use of both surface and production casing sections. In the unlikely event that a micro annulus was opened in the production casing annular cement seal from a target TGS to ground surface, any gas that migrated through that pathway would be contained by the wellhead which is fastened to the top of the surface casing, encapsulating the top of the production casing and production casing annular seal (see Section 2.2). Prior to hydraulic fracture stimulation, QGC evaluates the quality of the cement seal around the production casing of every well by reviewing CBLs performed on the wells. If QGC considers the cement seal of a well to be inadequate for hydraulic fracture stimulation, that well is not hydraulically fractured. If there is uncertainty within QGC as to the suitability of the cement seal of a well, the CBL is reviewed by an independent third party, if they consider the cement seal of a well to be inadequate for hydraulic fracture stimulation, that well is not hydraulically fractured.	No	Risk is identical to that reviewed in the body of the report, see Table 6. No further risk assessment necessary.
	Harm to residents or fauna/flora due release of dust from hydraulic fracture stimulation activities	During the hydraulic fracture stimulation process, certain fluid additives may be present which pose a human health risk due to inhalation due to dust generation. Crystalline silica (sand) is an example of a potential risk additive.	Chemical blending operations are carried out using dust covers, minimising exposure to workers onsite and the potential for creating windblown dust, which could impact residents or flora/fauna. In addition Shell QGC have administrative controls such as placing a temporary hold on work during excessive dust and windblowing in the direction of the sensitive receivers. With these controls in place, the risk for dust created by hydraulic fracture stimulation to harm residents or fauna/flora is considered as low.	No	Risk is identical to that reviewed in the body of the report, see Table 6. No further risk assessment necessary.
	Harm to residents or fauna due to noise or vibrations from hydraulic fracture stimulation operations	Significant noise and vibrations can be created during hydraulic fracture stimulation operations by the pumps, blenders, generators used to conduct the operation. This noise has the potential to harm residents or fauna in the short or long term.	During the hydraulic fracture stimulation planning phase, Shell QGC models the noise that will be produced during hydraulic fracture stimulation operations. QGC will also conduct ongoing assurance monitoring at the well locations to validate the noise emissions. Alternative arrangements will also be recommended based on predicted noise impacts from stimulation activities.	No	Risk is identical to that reviewed in the body of the report, see Table 6. No further risk assessment necessary.

	Identified Potential Hazard	Hazard Causes and Consequences	Risk Mitigation Measures	Warrants further consideration in this Risk Assessment	Reason for carrying forward the potential hazard into the subsequent Quantitative Risk Assessment
Subsurface Environment	Hydraulic fracture stimulation resulting in seismic activity due to the reactivation of geological faults or alteration of tectonic stresses	Opening of fractures within geological material in the surrounds of dormant geological faults, potentially resulting in fault reactivation.	QGC has a detailed understanding of the geological faults and stress fields (see Section A.1.2.2.3) within the project area, established using the following the techniques: - Development of a mechanical earth model (see Section 2.3.3), incorporating QGC's understanding of the local geological stress regime at each location to be hydraulically fractured. This understanding allows QGC to design hydraulic fracture stimulation considerate of the local geological stress regime. - Seismic surveys (to inform understanding of subsurface geometric relationships). - Widespread geological drilling programs (to inform subsurface stratigraphic understanding).	No	Risk is identical to that reviewed in the body of the report, see Table 6 . No further risk assessment necessary.
	Alteration of groundwater quality in aquifers overlying or underlying the target TGS	Contamination of groundwater in aquifers overlying or underlying the target TGS with either TGS groundwater or hydraulic fracture stimulation chemicals due to: - Hydraulic fracture stimulation creating a hydraulic connection between the target TGS and overlying or underlying aquifers - Failure of the integrity of the TGS well, resulting in a connection forming between fluid inside the well and the aquifers overlying the target TGS. - Loss of hydraulic fracture stimulation fluids into the over- or under-lying aquifers.	The TGS targeted by QGC hydraulic fracture stimulation operations are separated by low permeability aquitards, made of high strength, ductile rock (see Section A.1.3). Hydraulic fracture stimulation operations are designed so as not to propagate outside of the target TGS; through part of this design is the establishment of a safe injection pressure operating envelope (see Section 2.3.5). This operating envelope is developed based on consideration of: - CBL results - Mechanical earth model (see Section 2.2.3) - Hydraulic fracture stimulation models (see Section 2.3.3) - Historical tracer results - Relevant legislation - Internal and external standards	No	Risk is identical to that reviewed in the body of the report, see Table 6 . No further risk assessment necessary.
	Contamination of groundwater in the target TGS, which is then accessed by landholder bores	Previous hydraulic fracture stimulation pilot campaigns have demonstrated that not all hydraulic fracture stimulation chemicals are recovered from the well (hence TGS) during the flow-back period. Based on the hydrogeological setting within the project area (Section A.1.3), in order for the pathway to be valid in the context of exposure to hydraulic fracture stimulation fluids, a groundwater supply bore would need to source groundwater from directly within the hydraulically fractured zone of the TGS.	QGC have protocols in place which preclude hydraulic fracture stimulation operations impacting landholder bores. Prior to commencing a hydraulic fracture stimulation campaign, QGC performs field assessments of all groundwater bores 200m above or below the target gas producing formation and are spatially located with a two (2) kilometre radius from the location of the stimulation initiation point (i.e., the TGS well). Part of this assessment is to understand the precise location of bores and their likely source aquifer. If a landholder bore is potentially screened within the radius of influence of a hydraulic fracture stimulation operation (both horizontally and vertically), that gas well is not hydraulically fractured. Hence this scenario becomes invalid.	Yes	The protocols that QGC has in place to prevent hydraulic fracture stimulation occurring near landholder bores screened in target TGS, negate the requirement for further consideration of the risks of this scenario. A quantitative understanding of the potential for chemicals remaining in the TGS to migrate in groundwater is achieved with a fate and transport assessment (see Section A.1.7).

On the basis of the assessment presented above, the following presents a summary of the key issues that will be considered further:

1. Loss of containment of chemicals used for hydraulic fracture stimulation, causing harm to workers, residents, or the environment (to be assessed in **Section A.1.6** to **Section A.1.11**).
2. Contamination of groundwater in the target TGS that is accessed by landholder bores (to be assessed in **Section A.1.7**)

A.1.6 Identification of contaminants of potential concern

A.1.6.1 Introduction

Section A.1.6 presents the hydraulic fracture stimulation fluid system that will be used for the campaign. The risk assessment for the campaigns will focus on the theoretical datasets.

The identification of the COPCs will consider the following:

- Screening of chemicals for low human health concern
- Comparison of chemical concentrations with screening criteria for human health
- Comparison of chemical concentrations with screening criteria for environmental impacts
- Their Persistence, Bioaccumulation and Toxicity (PBT assessment).

A.1.6.2 Screening of chemicals for low human health concern

The following chemicals have already been assessed under the National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia using the adapted IMAP screening process (NICNAS 2017) and have been identified to be of low concern because of low hazard. **Table 31** presents the chemicals of low human health concern that do not require further assessment.

Table 31 Chemicals of low human health concern

CAS#	Chemical
6381-77-7	Sodium erythorbate
22042-96-2	Hepta sodium phosphonate
9003-05-08	Polyacrylamide
50-70-4	Sorbitol
629-11-8	1,6-Hexanediol
7647-14-5	Sodium chloride
9000-30-0	Guar gum
14807-96-6	Talc, Magnesium Silicate
68953-58-2	Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite
527-07-1	Sodium Gluconate
57-55-6	Propylene glycol

A.1.6.3 Identification of human health COPC

The theoretical dataset calculated EPCs based on theoretical calculations of exposure using the mass balance data for the hydraulic fracture stimulation fluid systems. It was assumed that between 20% and 60% of the mass of chemicals injected into the well will be present in the flowback fluid. The theoretical concentrations of the frac chemicals in flowback fluid are presented in **Table 32** for HVFR_A, **Table 33** for HVFR_B and **Table 34** for HVFR Hybrid below. The determination of COPC from the theoretical datasets were based on a comparison of the estimated concentrations with human health-based screening level guidelines. Where available, the Australian Drinking Water Guidelines (i.e., concentrations in water that are safe for all members of the population to consume every day for a lifetime) have been identified and considered in this assessment. Where these guidelines are not available, and the available published reviews have identified a suitable TDI or NOAEL this value has been presented and used to derive a preliminary drinking water guideline following guidance provided by the National Health and Medical Research Council (refer to **Section 3.4.2.1** for further discussion).

Table 32 Theoretical concentrations of COPC in flowback fluid – HVFR_A Fluid System

COPC	Mass Injected in Stimulation Fluid (mg/L)	Flowback Concentration		Adopted Screening Level Guideline (mg/L)	Selected as COPC?
		20% mass recovery (mg/L)	60% mass recovery (mg/L)		
64742-47-8	Petroleum Distillates (Hydrotreated, Light)	294	882	39 (D)	Yes
14808-60-7	Crystalline silica, quartz	28	84	NA. Not toxic via oral exposure as not absorbed via GI tract	No
7647-01-0	Hydrochloric acid	238	713	NA. Acute toxicity only (irritant and corrosive)	No
111-30-8	Glutaraldehyde	46	139	0.156 (D)	Yes
67-63-0	Isopropanol	0.33	0.98	9.95 (D)	No
68551-12-2	Ethoxylated C12-C16 Alcohol	0.26	0.77	1.95 (D)	No
104-55-2	Cinnamaldehyde	0.10	0.30	7.8 (D)	No
26183-52-8	Ethoxylated Decanol	0.09	0.28	1.95 (D)	No
61791-26-2	Ethoxylated Tallow Alkyl Amine	0.04	0.13	3.9 (D)	No
67-56-1	Methanol	0.01	0.02	0.145 (D)	No
127087-87-0	Polyethylene glycol trimethylnonyl ether	0.91	2.73	0.2 (D)	Yes

D – Derived (refer to individual Toxicity Profiles in Appendix C)

Table 33 Theoretical concentrations of COPC in flowback fluid – HVFR_B Fluid System

COPC	Mass Injected in Stimulation Fluid (mg/L)	Flowback Concentration		Adopted Screening Level Guideline (mg/L)	Selected as COPC?
		20% mass recovery (mg/L)	60% mass recovery (mg/L)		
64742-47-8	Petroleum Distillates (Hydrotreated, Light)	326	979	39 (D)	Yes

COPC	Mass Injected in Stimulation Fluid (mg/L)	Flowback Concentration		Adopted Screening Level Guideline (mg/L)	Selected as COPC?
		20% mass recovery (mg/L)	60% mass recovery (mg/L)		
14808-60-7	Crystalline silica, quartz	31	93	NA. Not toxic via oral exposure as not absorbed via GI tract	No
7647-01-0	Hydrochloric acid	264	791	NA. Acute toxicity only (irritant and corrosive)	No
111-30-8	Glutaraldehyde	51	154	0.156 (D)	Yes
127087-87-0	Polyethylene glycol trimethylnonyl ether	1.01	3.03	0.2 (D)	Yes
7173-51-5	Didecyldimethyl ammonium chloride	0.73	2.20	0.39 (D)	Yes
64-17-5	Ethyl alcohol (Ethanol)	0.08	0.25	93.6 (D)	No

D – Derived (refer to individual Toxicity Profiles in Appendix C)

Table 34 Theoretical concentrations of COPC in flowback fluid – HVFR Hybrid Fluid System

COPC	Mass Injected in Stimulation Fluid (mg/L)	Flowback Concentration		Adopted Screening Level Guideline (mg/L)	Selected as COPC?
		20% mass recovery (mg/L)	60% mass recovery (mg/L)		
64742-47-8	Petroleum Distillates (Hydrotreated, Light)	380	1140	39 (D)	Yes
14808-60-7	Crystalline silica, quartz	14	42	NA. Not toxic via oral exposure as not absorbed via GI tract	No
7647-01-0	Hydrochloric acid	264	791	NA. Acute toxicity only (irritant and corrosive)	No
111-30-8	Glutaraldehyde	47	142	0.156 (D)	Yes
67-63-0	Isopropanol	0.36	1.09	9.95 (D)	No
68551-12-2	Ethoxylated C12-C16 Alcohol	0.28	0.85	1.95 (D)	No
104-55-2	Cinnamaldehyde	0.11	0.33	7.8 (D)	No
26183-52-8	Ethoxylated Decanol	0.11	0.32	1.95 (D)	No
61791-26-2	Ethoxylated Tallow Alkyl Amine	0.05	0.15	3.9 (D)	No
67-56-1	Methanol	0.01	0.02	0.145 (D)	No
127087-87-0	Polyethylene glycol trimethylnonyl ether	0.39	1.18	0.2 (D)	Yes
9016-45-9	Polyoxyethylene nonylphenol ether	84	251	0.2 (D)	Yes
1310-58-3	Potassium hydroxide	268	805	NA. Acute toxicity only	No
7727-54-0	Ammonium Persulphate	27	80	0.082 (D)	Yes
10043-35-3	Boric acid	92	276	3.5 (A)*	Yes

COPC	Mass Injected in Stimulation Fluid (mg/L)	Flowback Concentration		Adopted Screening Level Guideline (mg/L)	Selected as COPC?
		20% mass recovery (mg/L)	60% mass recovery (mg/L)		
37288-54-3	Mannanase	0.05	0.16	5.0 (D)	No
122-99-6	Phenoxy ethanol	0.01	0.02	2.73 (D)	No
2634-33-5	1,2-Benzisothiazonlin-3(2H)	0.01	0.02	0.99 (D)	No

D – Derived (refer to individual Toxicity Profiles in Appendix C); A – ADWG; *as boron

A.1.6.4 Persistence, bioaccumulation, and environmental toxicity – identification of environmental COPCs

The PBT assessment approach outlined in **Section 3.2.4.2** was undertaken to rank the chemicals based on persistence (P), bioaccumulation (B) and toxicity (T). Based on this approach, the chemicals proposed to be used in hydraulic fracture stimulation fluid have been evaluated, with the outcomes of the assessment conducted summarised in **Table 35** and in **Appendix C**

Table 35 PBT assessment of the hydraulic fracture stimulation fluid system chemicals to be used by QGC for the Campaign

Substance	P/vP Criteria Fulfilled	B/vB Criteria Fulfilled	T Criteria Fulfilled?	Overall Conclusion
Methanol 67-56-1	No. Methanol is expected to be readily biodegradable.	No. The Log Kow for methanol is -0.77. Thus, methanol does not meet the screening criteria for bioaccumulation.	No. The EC50s from the acute aquatic toxicity data on methanol are >1 mg/L, hence does not meet the screening criteria for toxicity.	Not PBT
Propan-2-ol (Isopropanol) 67-63-0	No. Isopropanol is readily biodegradable and thus it does not meet the screening criteria for persistence.	Based on a measured log Kow of 0.05 and a calculated BCF of 1, isopropanol does not meet the screening criteria for bioaccumulation.	The chronic toxicity data on isopropanol show NOECs of >0.01 mg/L. Thus, isopropanol does not meet the screening criteria for toxicity.	Not PBT
Cinnamaldehyde 104-55-2	No. Based on the results of the ready biodegradability studies, cinnamaldehyde is categorised as Not Persistent.	Based on low log K values and/or expected natural metabolism and regulation of internal concentrations, the chemical is categorised as Not Bioaccumulative	Based on measured acute toxicity endpoints of greater than 1 mg/L cinnamaldehyde is categorised as Not Toxic.	Not PBT
Glutaraldehyde 111-30-8	No. Readily biodegradable and as such not persistent in the environment.	No. As the Log Pow is -0.01 (Log Pow < 4.5), it is not expected to be bioaccumulative.	No. Chronic toxicity data >1 mg/L in invertebrates, thus glutaraldehyde does not meet the screening criteria for toxicity.	Not PBT
Sodium Erythorbate 6381-77-7	No. The chemical readily biodegradable (based on modelled data).	No. The Log Pow is -3.29 (Log Pow < 4.5) which does not meet the screening criteria for bioaccumulation.	No. Based on measured acute toxicity endpoints of greater than 1 mg/L Sodium erythorbate does not meet the screening criteria for toxicity.	Not PBT
Hydrochloric acid 7647-01-0	No. Hydrochloric acid is an organic salt that dissociates completely to hydrogen and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both hydrogen and chloride ions are also ubiquitous and are present in most water, soil and sediment. Thus, the	Hydrogen and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, hydrochloric acid is not expected to bioaccumulate.	No chronic toxicity data exist on hydrochloric acid; however, the acute EC(L)50s are >0.1 mg/L in fish, invertebrates and algae. Thus, hydrochloric acid does not meet the screening criteria for toxicity.	Not PBT

Substance	P/vP Criteria Fulfilled	B/vB Criteria Fulfilled	T Criteria Fulfilled?	Overall Conclusion
	persistent criterion is not considered applicable to this inorganic salt.			
Polyacrylamide 9003-05-8	Yes. Anionic polyacrylamide is a large molecular weight, water-soluble polymer. It is not expected to be readily biodegradable; thus, it meets the screening criteria for persistence. A Tier 1 Human Health and Environmental Assessment for this chemical has been conducted by NICNAS which concluded that it was low concern to human health and the environment and thus required no further assessment.	No. Pharmacokinetic studies showed that anionic polyacrylamide was not bioavailable to rats when ingested; this is most likely due to its large size (high molecular weight) and presumed resistance to break down in the gastrointestinal tract. Anionic polyacrylamide is thus not expected to be bioavailable to aquatic or terrestrial organisms. It is not expected to meet the criteria for bioaccumulation.	No. The acute LC50 values in fish and invertebrates are >1 mg/L. Thus, it does not meet the criteria for toxicity.	Not BT. Potentially P.
Crystalline silica 14808-60-7	No. Not applicable, inorganic substance, ubiquitous in environment.	No. Not applicable, inorganic substance, ubiquitous in environment.	No. Long term data not available (acute data >0.1 mg/L).	Not PBT
Ethoxylated Tallow Alkyl Amine 61791-26-2	No. Based on the results from the read-across substance, Fatty acids, tall oil, ethoxylated (EO > 1 < 2.5) (CAS 61791-00-2) is considered to be readily biodegradable.	No. Low BCF values of < 100 L/kg ww indicate that chemical does not meet the criteria for bioaccumulation.	No. Available short-term and long-term toxicity tests with aquatic organisms resulted in effect values > 1 mg/L. Thus, this substance does not meet the screening criteria for toxicity.	Not PBT
Petroleum Distillates (Hydrotreated, Light) 64742-47-8	No. This chemical is expected to be biodegradable. The ready biodegradability of SHELLSOL NF a solvent naphtha (petroleum), heavy aromatics (consists predominantly of C9 aromatics 25%w/w; C10 aromatics 65%, and indanes 10%) was studied in mineral nutrient medium inoculated with activated sludge (mixed liquor suspended solids 100-101 mg/L, pH 6.9) and incubated for 28 days at 20°C. SHELLSOL	Category members have a potential to bioaccumulate, based on calculated log BCF values for constituents that range from 2.78 to 4.06, and calculated BCF values of 598 to 11,430 L/kg wet-weight, based on the Arnot and Gobas model, that take into account biotransformation of the chemicals in fish tissue. This chemical also has a log Kow of 6.025.	Yes. The lowest acute endpoint is <1 mg/L.	Not P. Potentially B and T.

Substance	P/vP Criteria Fulfilled	B/vB Criteria Fulfilled	T Criteria Fulfilled?	Overall Conclusion
	NF is readily biodegrade after 28 days but not within the 10-day window.			
Ethoxylated C12-C16 Alcohol 68551-12-2	No. These chemicals were found to be readily biodegradable. Thus, it does not meet the screening criteria for persistence.	No. Bioaccumulation in organisms is expected to be negligible, due to biotransformation and excretion of alcohol ethoxylates.	No. The NOECs from the chronic aquatic toxicity data are >0.01 mg/L, hence does not meet the screening criteria for toxicity.	Not PBT
Ethanol 64-17-5	No. Ethanol is readily biodegradable (74% after 5 days).	No. Ethanol is not likely to bioaccumulate (calculated logBCF=0.5).	No. Chronic aquatic toxicity (NOEC) >1mg/l, thus ethanol does not meet the screening criteria for toxicity.	Not PBT
Didecyltrimethyl ammonium chloride 7173-51-5	No. Based on biodegradation studies, this chemical is categorised as Not Persistent.	No. Based on the available measured bioconcentration data, all chemicals in this group are categorised as Not Bioaccumulative.	Yes. Based on available acute ecotoxicity values below 1 mg/L and/or chronic ecotoxicity values below 0.1 mg/L, this chemical is categorised as Toxic.	Not PB. Potentially T.
Guar gum 9000-30-0	No biodegradation information was found on guar gum. However, guar gum is a naturally occurring polysaccharide which would be expected to readily biodegrade. Thus, it is not expected to meet the screening criteria for persistence.	The molecular weight of guar gum ranges from 200,000 to 300,000 daltons, and it is also water soluble. Thus, guar gum is not expected to meet the criteria for bioaccumulation	The acute aquatic toxicity of guar gum is >0.1 mg/L. Thus, guar gum is not expected to meet the screening criteria for toxicity	Not PBT
Polyoxyethylene nonylphenol ether 9016-45-9	No. It achieved 96% degradation in 30 days thus is expected to be readily biodegradable which does not meet the screening criteria for persistence.	No. The reported BCF for this chemical in the fish Cyprinus carpio after 42 days was less than 0.2 L/kg at a test concentration of 2 mg/L and less than 1.4 L/kg at a test concentration of 0.2 mg/L (NITE, 2014) which does not meet the screening criteria for bioaccumulation.	No. Based on available acute ecotoxicity values above 1 mg/L and chronic ecotoxicity values above 0.1 mg/L, nonylphenol ethoxylate does not meet the screening criteria for toxicity.	Not PBT
Quaternary ammonium compounds, bis(hydrogenated	Not applicable. Inorganic substance.	Not applicable. Inorganic substance.	No. Based on measured acute toxicity endpoints of greater than 1 mg/L this	Not PBT

Substance	P/vP Criteria Fulfilled	B/vB Criteria Fulfilled	T Criteria Fulfilled?	Overall Conclusion
tallow alkyl)dimethyl, salts with bentonite 68953-58-2			substance does not meet the screening criteria for toxicity.	
Potassium hydroxide 1310-58-3	Not applicable (ionic species ubiquitous in environment)	Not applicable (ionic species ubiquitous in environment)	No chronic toxicity data exist on potassium hydroxide; however, the acute EC(L)50s for KCl are >0.1 mg/L in fish, invertebrates and algae. Thus, potassium hydroxide does not meet the screening criteria for toxicity.	Not PBT
1,6-Hexanediol 629-11-8	No. Based on test guideline OECD 301C, 1,6-Hexanediol is readily biodegradable.	No. The substance has no considerable potential for bioaccumulation.	No. The acute EC(L)50 are >0.1 mg/L in fish, invertebrates and algae for 1, 6-Hexanediol. Therefore, it does not meet the screening criteria for toxicity.	Not PBT
Ammonium Persulphate 7727-54-0	No. Not applicable, inorganic salt, ionic species ubiquitous in environment.	No. Not applicable, inorganic salt, ionic species ubiquitous in environment	No chronic toxicity data exist; however, the acute EC(L)50s are >0.1 mg/L in fish, invertebrates and algae. Thus does not meet the screening criteria for toxicity.	Not PBT
Sodium chloride 7647-14-5	Sodium chloride is an organic salt that dissociates completely to sodium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and chloride ions are also ubiquitous and are present in most water, soil and sediment. The persistent criteria is not considered applicable to this inorganic salt.	Sodium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium chloride is not expected to bioaccumulate.	The measured chronic toxicity data for sodium chloride was 314 mg/L for Daphnia. Thus, sodium chloride does not meet the screening criteria for toxicity.	Not PBT
Boric acid 10043-35-3	For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic substance.	For the purposes of this PBT assessment, the bioaccumulation criteria is not considered applicable to this inorganic substance.	No. The chronic toxicity data is >1 mg/L.	Not PBT

Substance	P/vP Criteria Fulfilled	B/vB Criteria Fulfilled	T Criteria Fulfilled?	Overall Conclusion
Talc, Magnesium Silicate 14807-96-6	For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic substance.	For the purposes of this PBT assessment, the bioaccumulation criteria is not considered applicable to this inorganic substance.	Talc is not expected to be bioavailable to aquatic organisms; thus, it does not meet the criteria for toxicity.	Not PBT
Mannanase 37288-54-3	No. Mannanase has been tested for ready biodegradation in the 'Ready Biodegradability, Modified Sturm Test' (OECD 301B), and was found to be readily biodegradable.	No. Mannanase has no considerable potential for bioaccumulation (log Kow -1.3).	No. The NOECs from the acute aquatic toxicity data are >1 mg/L, hence does not meet the screening criteria for toxicity.	Not PBT
Sorbitol 50-70-4	No. Utilizing the Japanese MITI test, 81% of the Theoretical BOD was reached in 2 weeks indicating that biodegradation is an important environmental fate process in soil.	No. Sorbitol has no considerable potential for bioaccumulation (log Kow -2.2).	No data available. Sorbitol poses no unreasonable risk to the environment based on Tier I assessment under the NICNAS IMAP assessment framework.	Not PBT
Phenoxy ethanol 122-99-6	No. The substance is readily biodegradable.	No. Based on the log partition coefficient of 1.16, phenoxyethanol has a very low potential to bioaccumulate.	No. Long term data not available (acute data >0.1 mg/L); potentially not toxic.	Not PBT
1,2-Benzisothiazolin-3(2H) 2634-33-5	No. The substance is reported to readily biodegrade in soil.	No. Based on the log Kow of 0.4, the chemical has a very low potential to bioaccumulate.	No. Long term data not available (acute data >0.1 mg/L); potentially not toxic.	Not PBT
Sodium Gluconate 527-07-1	No. Sodium gluconate is readily biodegradable.	No. The estimated log Kow for sodium gluconate is -5.99.	No. The acute E(L)C50 values are >1 mg/L.	Not PBT
Propylene glycol 57-55-6	No. Propylene glycol is readily biodegradable.	No. The calculated BCF value is 1.4 l/kg and the log10 Pow is 1.07.	No. Experimental data on acute toxicity to aquatic organisms values are > 0.1 mg/l and the chronic NOEC values are > 0.01 mg/l.	Not PBT

As Table 35 above indicates, all the compounds utilised in hydraulic fracture stimulation fluids are not considered to be PBT (i.e., none of the chemicals meet all three criteria of being persistent *and* bioaccumulative *and* toxic, refer to **Section 3.2.4.2** for further information). As such, the compounds are expected to degrade in the sub-surface, or where these compounds are present in flowback fluid, they will subsequently readily degrade or dissociate in the environment and will not bioaccumulate in terrestrial or aquatic species.

Polyacrylamide has limited biodegradation potential however, it is not bioaccumulative and is essentially non-toxic to aquatic species. Petroleum distillates meet the screening criteria for bioaccumulation and toxicity; however, the chemical is expected to be biodegradable and adverse chronic outcomes are not evident based on its lack of persistence in the environment. Didecyldimethyl ammonium chloride meet the screening criteria for toxicity, however adverse chronic outcomes are not evident based on their lack of persistence and bioaccumulation potential in the environment. A quantitative evaluation of the environmental risk posed by the COPCs above is presented in **Section A.1.9**.

It is to be noted that some constituents used in hydraulic fracture stimulation fluid, such as sand, are solids that once injected into the well are used to prop open fractures in the TGS. These constituents are not sufficiently mobile such that they are extracted in flowback fluid. Hence the presence of these constituents in hydraulic fracture stimulation fluid does not warrant any further evaluation in this risk assessment.

A.1.7 Residual chemical fate and transport modelling

As part of the risk identification process (see **Section 3.2.4**), Chemicals of Potential Concern (COPC) were identified amongst the chemicals used by QGC for hydraulic fracture stimulation. Chemicals which were deemed to be of potential concern are those known or suspected to be present at concentrations and quantities high enough to warrant inclusion in an assessment of risks to human health. The identification of COPC is based on the assessment of the nature, magnitude, and extent of these chemicals in the environment on-site.

The potential of the COPC to migrate has been considered below, based on a conservative scenario informed by the site conceptual model.

A.1.7.1 Environmental fate of inorganic COPC

When hydrated, inorganic COPC either rapidly dissociate into salts or have restricted mobility based on their physical properties hydrated (i.e., they are the consistency of a gel). On this basis, the migration of inorganic hydraulic fracture stimulation chemicals is likely to result in a change in the alkalinity and/or salinity of groundwater within the immediate vicinity of the hydraulically fractured zone. As the quality of the groundwater within the receiving TGS is already high in salinity (see **Section 3.2.4**), a localised change in the alkalinity and salinity from dissociated inorganic COPC is considered a low risk in an aquifer environment (as there are no inorganic COPC that will contribute to the toxicity of groundwater) and thus did not warrant further assessment using modelling.

A.1.7.2 Fate and transport modelling of COPC

It is likely that 20-60% of the hydraulic fracturing fluids will return to the surface via the production bore after fracturing, clean-up, and production testing. In deep tight formations, it is extremely difficult to recover fluids as they are held in the formation by capillary forces.

Transport of the chemicals in the formation beyond the fracture is likely to be very limited, since outside the fractures the lack of connected pore space means the permeability of the rocks will be very low. Except in a circumstance where a fracture created a pathway to an aquifer, it is not likely that significant migration of fracturing chemicals would occur.

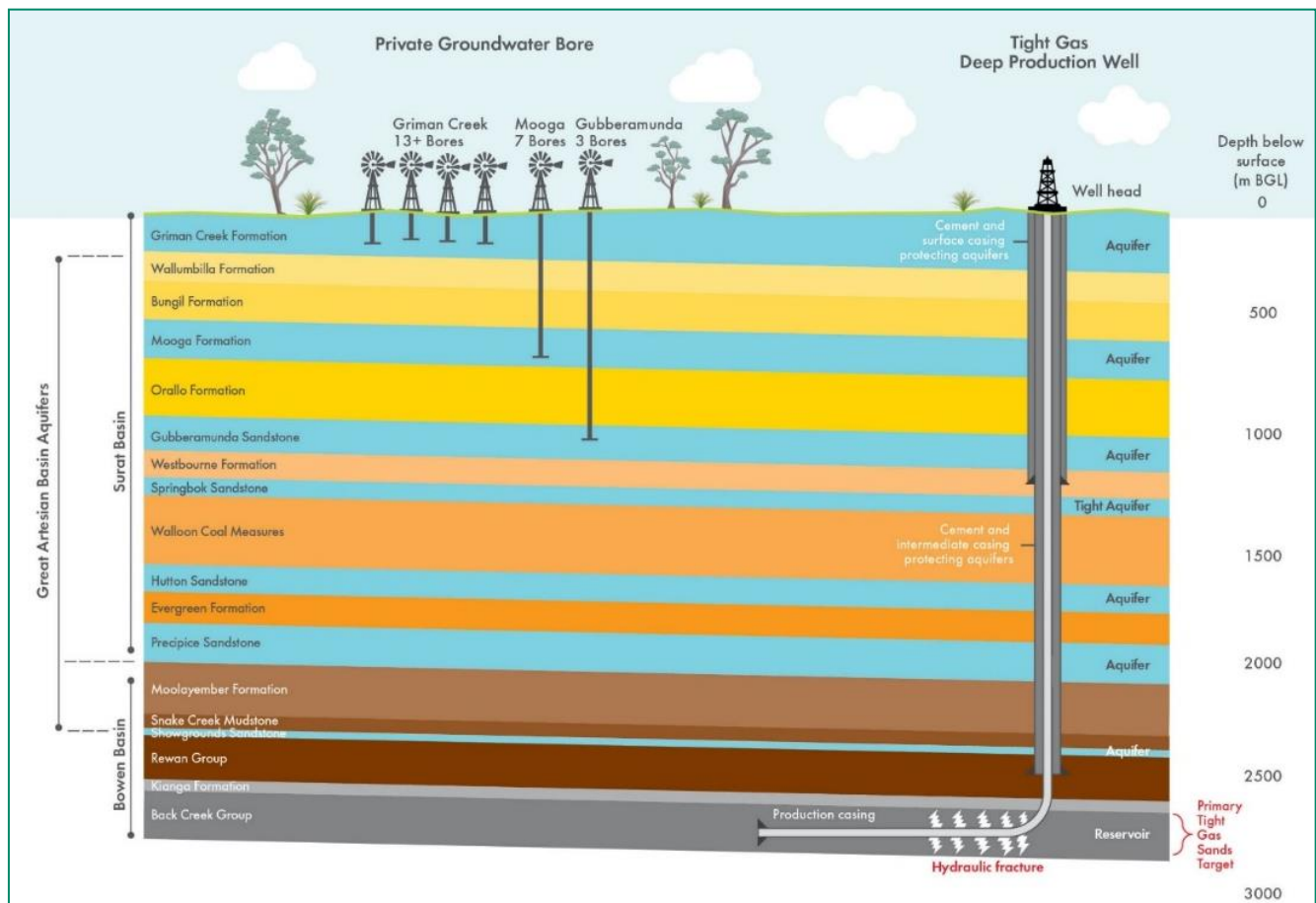
A.1.7.2.1 Vertical distance to the nearest aquifer

The Clematis Sandstone / Showgrounds Sandstone is considered to be the only aquifer (from an aquifer hydraulic properties perspective) where a direct connection between the fractured horizon (Back Creek Group) and the aquifer requires assessment, as it is one nearest to the reservoir in vertical distance. The Clematis Sandstone / Showgrounds Sandstone directly overlies the Rewan Group, which forms the lower boundary of the GAB (Habermehl, 2001a).

The target reservoir is the Back Creek Group, which is further separated from the Rewan Group by the Kianga Formation and the Black Alley Shale. The Back Creek Group is 1,050 m below the Clematis Sandstone, suggesting negligible potential for connectivity and low risk to the Clematis Sandstone / Showgrounds Sandstone.

This separation of aquifers and target reservoir formations is included in Plate 10.

Plate 10 Typical TGS Production Well and hydrostratigraphic units



A.1.7.2.1 Horizontal transport distance

Horizontal transport of chemicals in the fractured horizons is unlikely to be significant outside the fractures, due to the very low permeability of the rocks.

The critical lateral pathway for transport of hydraulic fracturing fluids is therefore within the resource aquifer (i.e., the Clematis Sandstone) in the event that a vertical connection is made. Under normal conditions (i.e., not an accidental casing failure or surface spillage) the release of hydraulic fracturing fluids will be at depths exceeding 2,500 m. At these depths, away from its outcrop area, the Clematis Sandstone aquifer will have low permeability, and flow rates are likely to be slow. Potential travel times will be site specific, and quantitative prediction is not considered meaningful on a generic basis.

DES has previously specified a lateral radius of 2 km from a fracture stimulation within which groundwater extraction wells must be monitored as a condition of an Environmental Authority. Whilst it is not clear that this distance has a quantitative basis, it does provide a potential screening measure to decide when additional consideration of risks to groundwater bores is appropriate.

In the absence of information to derive an alternative horizontal screening distance, QGC has adopted 2 km as the distance from a hydraulically fractured well within which groundwater extraction wells should be considered on a site-specific basis

A.1.7.2.2 Screening existing wells for potential sub-surface connection

To evaluate the likelihood that gas wells might be located in a position where a groundwater extraction well could theoretically be affected, Shell QGC has carried out a baseline survey and GIS proximity analysis in which the existing identified groundwater wells have been screened for depth relative to the top of the Back Creek Group. This has identified no groundwater wells deeper than 150 m, within the petroleum tenures and for a 2 km radius around the boundary of the tenures.

The majority of identified bores are separated by a vertical distance of more than 1,600 m from the Back Creek Group.

Three bores were identified within a vertical distance of 1,050 m of the Back Creek Group in petroleum tenure ATP 645. The use of these bores is also unknown.

A.1.7.2.3 Qualitative fate and transport assessment summary

The target horizon has very low permeability, and horizontal transport within the target horizon outside the fractures is likely to be negligible. Therefore, to create a pathway to an aquifer, a direct connection via a fracture to an aquifer is needed.

Fracture propagation is likely to be a maximum of 50 m vertically (no coals) and fractures will normally propagate horizontally within the target horizons (1,400 m). To account for uncertainty, QGC has conservatively selected 240 m as a screening distance for potential vertical connection.

Horizontal transport radius within aquifers can only be estimated site specifically, and therefore no generic quantitative estimate can be meaningfully made. DES selected 2 km for QGC's Environmental Authority for the Surat Basin, and QGC have therefore used 2 km as a screening radius for lateral transport for this assessment of the Bowen Basin.

Using the screening distances above, groundwater extraction wells within 2 km laterally of any gas well could be considered potentially within the radius of influence for accidental surface spillage and casing failure accidents. It is noted that casing failure is very rare, as are surface spills of sufficient scale to result in contamination of an aquifer.

To create a subsurface connection, two very unlikely events have to come together. Firstly, a vertical connection to an overlying aquifer must be created, and secondly there must be a groundwater extraction well close enough that the chemicals can reach the well before they are diluted, degraded, or otherwise attenuated in the aquifer. This lateral distance is a site-specific consideration, and in most parts of the petroleum tenures there will be no groundwater wells which could even theoretically be affected.

Based on the data discussed above and the conceptual understanding of the hydraulic fracturing process, it is considered that the subsurface pathways via fractures or pre-existing hydraulic connectivity are generally not likely to be viable.

A.1.8 Quantitative human health risk assessment

A.1.8.1 Exposure assessment

As indicated in **Section A.1.5.1**, the fracture stimulation campaign will be carried out using the same operation, monitoring and assessment procedures as for the general campaign as described in **Section 2.0**, using the campaign fluid systems HVFR_A, HVFR_B and HVFR_Hybrid. HVFR_A will be the preferred fluid system for this campaign. HVFR_B and HVFR_Hybrid will be assessed as the alternative fluid systems. As such, based on the available information the following points have been considered:

- No further assessment is considered warranted for groundwater as there are no potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracture stimulation fluids within the TGS, and no connection exists between groundwater in the TGS and surface-water, aquifers utilised for the purpose of extraction (for any beneficial use), or springs.
- Potential risks to workers involved with the hydraulic fracture stimulation process, where the COPC are handled on and off-site (i.e., during transportation of the COPC to the site), have not been considered as detailed Health and Safety (H&S) procedures are employed to manage these exposures. It is noted that potentially complete pathways to workers would include dermal contact and incidental ingestion.
- It is noted that none of the COPC identified for consideration in this HHRA are persistent and bioaccumulative and toxic, hence secondary pathways (such as accumulation in crops and produce, and subsequent human consumption) were not quantified.
- The flowback fluid recovered during completion operations will be stored in a flowback tank where it will be held on-site for a maximum period of 3 years, after which the fluid will be trucked off-site to a disposal facility authorised to receive this waste stream.

These flowback tanks are double lined with galvanised steel frame. Flowback tanks are inspected and monitored for leaks during the operational periods when they are used for holding fluid. The tanks are also covered with a floating cover to reduce evaporation losses.

While it is expected that the flowback tanks are not accessible to the public, exposure may occur if trespassers enter the tanks, or if there is a leak in the pipelines or flowback tank and water from this infrastructure is released to the local environment.

Based on the available information, the key receptors (and exposures that are considered significant) who may be exposed to the COPC identified on and off the site includes the following:

Trespassers

- Direct contact (ingestion and dermal contact) with COPC identified in flowback fluid contained within the flowback holding tanks. It is noted that this is a conservative scenario as the drill pad is fenced with signage and the holding tanks are covered with a floating cover to limit trespasser access.

A.1.8.2 Potential exposure pathways and receptors

A summary of AECOM's decision tree evaluating the receptors and pathways is present in Table 36.

Table 36 Identification of Potential Human Receptors and Pathways

Source	Exposure Scenario	Receptors (On and Off-site)	Pathway	Pathway Potentially Complete?	Comment
Hydraulic fracture stimulation Chemicals	Handling of chemicals either on or off-site (i.e. during transportation of chemicals to the site), spills and leaks.	On and off-site workers	Ingestion, dermal	No	Potential risks to workers have not been considered in this assessment as detailed Health and Safety (H&S) procedures are employed to manage these exposures. OH&S procedures and spill containment adequately address this exposure.
Hydraulic fracture stimulation fluids	Fracturing fluid escapes into aquifer (well casing failure, fault, and fracture, unconformity in seam or strata) and enters a water bore used for beneficial use.	Off-site residents	Ingestion, dermal	No	QGC has detailed operational procedures that are designed to contain hydraulic fracture stimulation fluids within the TGS. No direct connection is understood to exist between groundwater in the TGS and surface-water, aquifers utilised for the purpose of extraction. Large vertical separation distances between TGS and over/underlying aquifers, coupled with the presence of aquitards. Furthermore, fate and transport assessment indicate COPC migration is minimal within the TGS (refer Section A.1.7).
Flowback Fluid	Deliberate entry into flowback tanks	Trespassers	Ingestion, dermal	Yes	Trespassers entry is limited via fencing and signage around the drill pad areas. The tanks are covered with a floating cover. In addition, the walls of the flowback tanks are at least 3 m high. Access ladders on the side of the flowback tanks exist. As such, this pathway has been conservatively evaluated as part of this assessment.
	Working with the flowback tanks (i.e. drainage of flowback tanks)	Workers	Ingestion, dermal	No	OH&S procedures limit workers exposure to flowback fluid.
	Spills and leaks, flowback tanks overflow system failure	Workers	Ingestion, dermal	No	OH&S procedures limit workers exposure to flowback fluid.

A.1.8.3 Exposure parameters

Exposure parameters which are considered representative of RME have been selected for the receptor groups evaluated, namely trespassers. Where available, exposure parameters have been obtained from Australian sources (CRC care 2011; enHealth 2012; NEPC 2013). As required, this has been supplemented with data from the US EPA (2008 and 2009).

The exposure assumptions adopted are consistent with the typical exposure assumptions utilised by enHealth (2012) for recreational exposure. The exposure parameters adopted also partially reflect that storage of flowback fluid at individual well pad sites will be only a temporary activity, with operational controls and activities at the well sites likely limiting the occurrence of trespasser entry and exposures.

The following **Table 37** presents an overview of the parameters selected. These parameters, as well as relevant references, are utilised in the exposure models presented in **Appendix D**, the equations used to estimate exposure are also provided in **Appendix D**.

Table 37 Exposure Parameters – Trespassers

Exposure Factor	Units	Trespasser	Reference / Source
Exposure Frequency	Days/year	Assume direct contact with flowback fluid occurs over 1 day within the period that the flowback pond is on-site	Professional judgement
Exposure Duration	Year	The maximum duration of a flowback fluid on-site is 3 years.	QGC
Exposure Time Outdoors	Hours/day	Assumes adults/children get completely wet for 1 hour each time	Professional judgement
Surface Area	cm ²	20,000 cm ² for adults, 15,900 cm ² for children. Exposure is assumed to be equal to that of swimming, where the whole body gets wet	enHealth 2012
Body Weight	kg	78 kg for adults, 39 kg for children	enHealth 2012

A.1.8.4 Exposure Point Concentrations

Exposure Point Concentrations (EPC) of COPC requiring further assessment, as identified based on theoretical data are presented in **Section A.1.6.3**.

A.1.8.5 Human Health Toxicity Assessment

The COPC in the campaign fluid systems were reviewed and quantitative toxicity values were identified/derived, and the drinking water guidelines identified/derived in accordance with guidance available from enHealth (2012), ADWG (2022) and NEPM (2013). Detailed discussion regarding the methodology is presented in Section A.1.5. **Appendix C** provides further toxicity information on each of the COPC.

Table 38 provides a summary of the quantitative toxicity values for oral and dermal exposures and the drinking water criteria for the COPC identified.

Table 38 Toxicity Data for Chronic Oral/Dermal Exposures and Drinking Water Screening Criteria for COPC in all Fluid Systems

CAS	Chemical	Non-Threshold Slope Factor (mg/kg/day) ⁻¹	Threshold Chronic TDI (mg/kg/day)		Dermal Permeability* (cm/hr)	Drinking Water Guideline (mg/L)	
64742-47-8	Hydrotreated light petroleum distillate	--	1.00E+01	D	1.96E+00	39	D
111-30-8	Glutaraldehyde	--	4.00E-02	D	3.25E-04	0.2	D

CAS	Chemical	Non-Threshold Slope Factor (mg/kg/day) ⁻¹	Threshold Chronic TDI (mg/kg/day)		Dermal Permeability* (cm/hr)	Drinking Water Guideline (mg/L)	
127087-87-0	Polyethylene glycol trimethylnonyl ether	--	5.00E-02	D	5.00E-03	0.2	D
7173-51-5	Didecyldimethyl ammonium chloride		1.00E-01	D	1.81E-02	0.39	D
9016-45-9	Polyoxyethylene nonylphenol ether		5.00E-02	D	5.00E-03	0.2	D
7727-54-0	Diammonium peroxodisulphate		2.10E-02	D	1.00E-03	0.082	D
10043-35-3	Boric acid		5.50E-02	A	1.00E-03	3.5	A

Notes: D – Derived, A – ADWG (as boron), *USEPA DERWIN v2.02

A.1.8.6 Risk Characterisation

The risk characterisation was performed in accordance with the methodologies outlined in **Section 3.4.3**.

No carcinogenic compounds were present in the hydraulic fracture stimulation fluids injected into the subsurface and as a result only non-carcinogenic risks were calculated. The target hazard index (HI) for non-threshold effects is less or equal to 1. A summary of the calculated risks for the trespassers that are relevant to the assessment of potential exposure to COPCs on-site, based on the available data is presented in **Table 39** (HVFR_A), **Table 40** (HVFR_B) and **Table 41** (HVFR Hybrid).

Table 39 Risk associated with potential exposure to trespassers – HVFR_A (theoretical data)

Receptor and Pathway	Non-Threshold Carcinogenic Risk	Threshold Hazard Index	Non-Threshold Carcinogenic Risk	Threshold Hazard Index
	20% Mass Return		60% Mass Return	
Hydraulic fracture stimulation fluid system - COPC associated with theoretical data				
Adult Trespassers				
Ingestion of chemicals via incidental contact with flowback fluid	NA	0.002	NA	0.006
Dermal exposure to chemicals via incidental contact with flowback fluid	NA	0.04	NA	0.1
Total Risk	NA	0.04	NA	0.1
Child Trespassers				
Ingestion of chemicals via incidental contact with flowback fluid	NA	0.004	NA	0.01
Dermal exposure to chemicals via incidental contact with flowback fluid	NA	0.06	NA	0.2
Total Risk	NA	0.07	NA	0.2

Notes:

Risk values have been rounded to two significant figures with totals rounded to one significant figure; hence, the sum of individual risks may not add up exactly to the total presented. NA = Not Assessed as there are no non-threshold COPC in the media of concern

The following can be noted from the table above:

- The calculated risks associated with potential exposure to COPC identified in flowback fluid, where the HVFR_A hydraulic fracture stimulation fluid is used and assuming 20% or 60% mass recovery are below the target 1, hence, risks are considered to be low and acceptable.

Table 40 Risk associated with potential exposure to trespassers – HVFR_B hydraulic fracture stimulation fluid system (theoretical data)

Receptor and Pathway	Non-Threshold Carcinogenic Risk	Threshold Hazard Index	Non-Threshold Carcinogenic Risk	Threshold Hazard Index
	20% Mass Return		60% Mass Return	
Hydraulic fracture stimulation fluid system - COPC associated with theoretical data				
Adult Trespassers				
Ingestion of chemicals via incidental contact with flowback fluid	NA	0.002	NA	0.007
Dermal exposure to chemicals via incidental contact with flowback fluid	NA	0.05	NA	0.1
Total Risk	NA	0.05	NA	0.1
Child Trespassers				
Ingestion of chemicals via incidental contact with flowback fluid	NA	0.005	NA	0.01
Dermal exposure to chemicals via incidental contact with flowback fluid	NA	0.07	NA	0.2
Total Risk	NA	0.08	NA	0.2

Notes:

Risk values have been rounded to two significant figures with totals rounded to one significant figure; hence, the sum of individual risks may not add up exactly to the total presented.

NA = Not Assessed as there are no non-threshold COPC in the media of concern

The following can be noted from the table above:

- The calculated risks associated with potential exposure to COPC identified in flowback fluid, where the HVFR_B hydraulic fracture stimulation fluid is used and assuming 20% or 60% mass recovery are below the target 1, hence, risks are considered to be low and acceptable.

Table 41 Risk associated with potential exposure to trespassers – HVFR_Hybrid (theoretical data)

Receptor and Pathway	Non-Threshold Carcinogenic Risk	Threshold Hazard Index	Non-Threshold Carcinogenic Risk	Threshold Hazard Index
	20% Mass Return		60% Mass Return	
Hydraulic fracture stimulation fluid system - COPC associated with theoretical data				
Adult Trespassers				
Ingestion of chemicals via incidental contact with flowback fluid	NA	0.01	NA	0.03
Dermal exposure to chemicals via incidental contact with flowback fluid	NA	0.06	NA	0.2
Total Risk	NA	0.07	NA	0.2

Receptor and Pathway	Non-Threshold Carcinogenic Risk	Threshold Hazard Index	Non-Threshold Carcinogenic Risk	Threshold Hazard Index
	20% Mass Return		60% Mass Return	
Child Trespassers				
Ingestion of chemicals via incidental contact with flowback fluid	NA	0.02	NA	0.06
Dermal exposure to chemicals via incidental contact with flowback fluid	NA	0.10	NA	0.3
Total Risk	NA	0.1	NA	0.4

Notes:

Risk values have been rounded to two significant figures with totals rounded to one significant figure; hence, the sum of individual risks may not add up exactly to the total presented.

NA = Not Assessed as there are no non-threshold COPC in the media of concern

The following can be noted from the table above:

- The calculated risks associated with potential exposure to COPC identified in flowback fluid, where the HVFR_Hybrid hydraulic fracture stimulation fluid is used and assuming 20% or 60% mass recovery are below the target 1, hence, risks are low and acceptable

A.1.8.7 Conclusions

The quantification of potential risks to human health associated with the use of chemicals in well simulation activities conducted by QGC within the campaign project area has involved the assessment of potential exposures to compounds used or formed in the simulation activities. Based on the conceptual site model, operational controls and management practices implemented by QGC, the potentially complete exposure pathway identified and assessed in the risk assessment was the incidental ingestion and dermal contact by trespassers at the flowback tank.

On the basis of the conservative assessment undertaken with consideration of the uncertainties identified in Section A.1.10, the following can be concluded in relation to potential exposures to flowback fluid from well simulation activities:

- No unacceptable risks to trespassers were identified

A.1.9 Environmental risk assessment

A.1.9.1 General

A qualitative environmental risk assessment (ERA) was conducted to evaluate the potential for adverse environmental effects to environmental receptors that may be exposed to residual levels of hydraulic fracture stimulation fluids. The hydraulic fracture stimulation campaign will be carried out using the same hydraulic fracture stimulation design, operation, monitoring and assessment procedures as for the general campaign as described in **Section 2.3**. As such, the environmental risk assessment approach remains similar to that as described in **Section 3.5**.

A.1.9.2 Identification of Chemicals of Potential Environmental Concern (COPEC)

The potential COPEC in the hydraulic fracture stimulation fluid recipe were reviewed and quantitative toxicity values were identified / derived in accordance with guidance in the Environmental Risk Assessment Guidance Manual for Industrial Chemicals prepared by the Australian Environmental Agency (AEA, 2009). Detailed discussion regarding the methodology is presented in **Section 3.5.3**.

Table 42 (HVFR_A), **Table 43** (HVFR_B), and **Table 44** (HVFR_Hybrid) below presents the summary of derived TRVs for the Protection of Aquatic Species (PNECs). **Appendix C** presents the environmental reviews of the COPEC identified in the hydraulic fracture stimulation fluid and includes further details on the endpoints selected and PNEC values calculated for each potential COPEC.

Table 42 Summary of derived TRVs for protection of aquatic species (PNECs) for the HVFR_A Fluid System

CAS #	Chemical	Endpoint	E(L)C50 or NOEC (mg/L)	Assessment Factor	PNEC Aquatic (mg/L)
111-30-8	Glutaraldehyde	48 h acute Daphnia	2.1	10	2.10E-01
7647-01-0	Hydrochloric Acid	Chronic Daphnia	62	10	6.20E+00
64742-47-8	Hydrotreated light petroleum distillate	Acute Daphnia	0.018	100	1.80E-04
68551-12-2	Ethoxylated C12-C16 Alcohol	Chronic daphnia	0.11	10	1.10E-02
104-55-2	Cinnamaldehyde	72 hr Algae	2	10	2.00E-01
26183-52-8	Ethoxylated Decanol	Chronic daphnia	0.11	10	1.10E-02
61791-26-2	Ethoxylated Tallow Alkyl Amine	Acute daphnia	12.41	1000	1.24E-02
127087-87-0	Polyethylene glycol trimethylnonyl ether	Chronic fish	0.048	100	4.80E-04
22042-96-2	Hepta sodium phosphonate	Chronic fish	25.6	100	2.56E-01
6381-77-7	Sodium erythorbate	Acute Algae	1020	100	1.02E+01
67-63-0	Propan-2-ol	Chronic Daphnia	5000	10	5.00E+02
14808-60-7	Crystalline silica, quartz	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			
9003-05-08	Polyacrylamide	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			
67-56-1	Methanol	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			

Table 43 Summary of derived TRVs for protection of aquatic species (PNECs) for the HVFR_B Fluid System

CAS #	Chemical	Endpoint	E(L)C50 or NOEC (mg/L)	Assessment Factor	PNEC Aquatic (mg/L)
111-30-8	Glutaraldehyde	48 h acute Daphnia	2.1	10	2.10E-01
7647-01-0	Hydrochloric Acid	Chronic Daphnia	62	10	6.20E+00
64742-47-8	Hydrotreated light petroleum distillate	Acute Daphnia	0.018	100	1.80E-04
127087-87-0	Polyethylene glycol trimethylnonyl ether	Chronic fish	0.048	100	4.80E-04
22042-96-2	Hepta sodium phosphonate	Chronic fish	25.6	100	2.56E-01
6381-77-7	Sodium erythorbate	Acute Algae	1020	100	1.02E+01
7173-51-5	Didecyldimethyl ammonium chloride	Acute Algae	0.014	5	2.80E-03
64-17-5	Ethyl alcohol (Ethanol)	Chronic Daphnia	7800	10	7.80E+02
14808-60-7	Crystalline silica, quartz	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			

CAS #	Chemical	Endpoint	E(L)C50 or NOEC (mg/L)	Assessment Factor	PNEC Aquatic (mg/L)
9003-05-08	Polyacrylamide	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			

Table 44 Summary of derived TRVs for protection of aquatic species (PNECs) for the HVFR_Hybrid Fluid System

CAS #	Chemical	Endpoint	E(L)C50 or NOEC (mg/L)	Assessment Factor	PNEC Aquatic (mg/L)
64742-47-8	Hydrotreated light petroleum distillate	Acute Daphnia	0.018	100	6.33E+06
7647-01-0	Hydrochloric Acid	Chronic Daphnia	62	10	1.28E+02
111-30-8	Glutaraldehyde	48 h acute Daphnia	2.1	10	6.78E+02
67-63-0	Propan-2-ol	Chronic Daphnia	5000	10	2.18E-03
68551-12-2	Ethoxylated C12-C16 Alcohol	Chronic daphnia	0.11	10	7.74E+01
104-55-2	Cinnamaldehyde	72 hr Algae	2	10	1.66E+00
26183-52-8	Ethoxylated Decanol	Chronic daphnia	0.11	10	2.86E+01
6381-77-7	Sodium erythorbate	Acute Algae	1020	100	1.06E+00
61791-26-2	Ethoxylated Tallow Alkyl Amine*	Acute daphnia	12.41	1000	1.20E+01
22042-96-2	Hepta sodium phosphonate	Chronic fish	25.6	100	3.06E+02
127087-87-0	Polyethylene glycol trimethylnonyl ether	Chronic fish	0.048	100	2.47E+03
9000-30-0	Guar gum	Acute fish	218	1000	2.58E+03
9016-45-9	Polyoxyethylene nonylphenol ether	Chronic fish	0.048	100	5.23E+05
68953-58-2	Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	Acute daphnia	100	1000	3.79E+03
7727-54-0	Diammonium peroxodisulphate	Acute Daphnia	92	100	8.72E+01
10043-35-3	Boric acid	Chronic fish	2.1	100	1.31E+04
122-99-6	Phenoxy ethanol	Fish	344	1000	4.45E-02
2634-33-5	1,2-Benzisothiazonlin-3(2H)	Algae	0.283	100	6.00E+00
67-56-1	Methanol	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			
9003-05-08	Polyacrylamide	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			
1310-58-3	Potassium hydroxide	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			
629-11-8	1,6-Hexanediol	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			
7647-14-5	Sodium chloride	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			

CAS #	Chemical	Endpoint	E(L)C50 or NOEC (mg/L)	Assessment Factor	PNEC Aquatic (mg/L)
14807-96-6	Talc, Magnesium Silicate	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			
37288-54-3	Mannanase	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			
50-70-4	Sorbitol	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			
14808-60-7	Crystalline silica, quartz	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			
527-07-1	Sodium Gluconate	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			
57-55-6	Propylene glycol	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the IMAP assessment framework.			

A.1.9.3 Tier 1 Environmental Screening Assessment

The potential for chemicals in the hydraulic fracture stimulation fluid recipe to represent a potential environmental hazard was characterised in accordance with the methodologies discussed in **Section 3.7**. If the environmental hazard quotient was less than or equal to 1.0, then the chemical was not considered to be a COPEC and was not carried forward in the assessment. A summary of the Environmental Tier 1 Screening Assessment and the identification of the COPECs are presented in Table 45 (HVFR_A), Table 46 (HVFR_B) and Table 47 (HVFR_Hybrid). The hazard calculations are presented in **Appendix D**.

The source concentrations for the Tier 1 Screen were based on a theoretical data set (assuming 20% and 60% mass recovery in flowback fluid). The theoretical COPEC concentrations for the theoretical scenarios for the identified receptor group (aquatic invertebrates and fish) are presented in Table 45, Table 46 and Table 47.

The environmental hazard calculations presented in **Appendix D** do not consider the significant dilution that is expected to occur where flowback fluid is discharged to a surface water body in the event of a significant spill or leak. In addition, processes such as sorption and biodegradation have not been considered.

Table 45 Summary of COPEC for the HVFR_A Fluid System

CAS	Chemical	Flowback Concentration 20% mass recovery (mg/L)	Flowback Concentration 60% mass recovery (mg/L)	HI >1	Selected as COPEC?
111-30-8	Glutaraldehyde	221	663	Yes	Yes
7647-01-0	Hydrochloric Acid	38	115	Yes	Yes
64742-47-8	Hydrotreated light petroleum distillate	1634251	4902753	Yes	Yes
68551-12-2	Ethoxylated C12-C16 Alcohol	23	70	Yes	Yes
104-55-2	Cinnamaldehyde	0.50	1.5	Yes	Yes
26183-52-8	Ethoxylated Decanol	9	26	Yes	Yes
61791-26-2	Ethoxylated Tallow Alkyl Amine*	4	11	Yes	Yes
127087-87-0	Polyethylene glycol trimethylnonyl ether	1897	5691	Yes	Yes
22042-96-2	Hepta sodium phosphonate	100	299	Yes	Yes
6381-77-7	Sodium erythorbate	0.32	0.96	No	No
67-63-0	Propan-2-ol	0.00065	0.0020	No	No

Table 46 Summary of COPEC for the HVFR_B Fluid System

CAS	Chemical	Flowback Concentration 20% mass recovery (mg/L)	Flowback Concentration 60% mass recovery (mg/L)	HI >1	Selected as COPEC?
64742-47-8	Hydrotreated light petroleum distillate	3.26E+02	9.79E+02	Yes	Yes
7647-01-0	Hydrochloric Acid	2.64E+02	7.91E+02	Yes	Yes
111-30-8	Glutaraldehyde	5.15E+01	1.54E+02	Yes	Yes
6381-77-7	Sodium erythorbate	3.60E+00	1.08E+01	Yes	Yes
22042-96-2	Hepta sodium phosphonate	2.83E+01	8.50E+01	Yes	Yes
127087-87-0	Polyethylene glycol trimethylnonyl ether	1.01E+00	3.03E+00	Yes	Yes
7173-51-5	Didecyldimethyl ammonium chloride	7.32E-01	2.20E+00	Yes	Yes
64-17-5	Ethanol	8.27E-02	2.48E-01	No	No

Table 47 Summary of COPEC for the HVFR_Hybrid Fluid System

CAS	Chemical	Flowback Concentration 20% mass recovery (mg/L)	Flowback Concentration 60% mass recovery (mg/L)	HI >1	Selected as COPEC?
64742-47-8	Hydrotreated light petroleum distillate	3.80E+02	1.14E+03	Yes	Yes
7647-01-0	Hydrochloric Acid	2.64E+02	7.91E+02	Yes	Yes
111-30-8	Glutaraldehyde	4.74E+01	1.42E+02	Yes	Yes

CAS	Chemical	Flowback Concentration 20% mass recovery (mg/L)	Flowback Concentration 60% mass recovery (mg/L)	HI >1	Selected as COPEC?
67-63-0	Propan-2-ol	3.63E-01	1.09E+00	No	No
68551-12-2	Ethoxylated C12-C16 Alcohol	2.84E-01	8.52E-01	Yes	Yes
104-55-2	Cinnamaldehyde	1.10E-01	3.31E-01	Yes	Yes
26183-52-8	Ethoxylated Decanol	1.05E-01	3.15E-01	Yes	Yes
6381-77-7	Sodium erythorbate	3.60E+00	1.08E+01	No	No
61791-26-2	Ethoxylated Tallow Alkyl Amine*	4.97E-02	1.49E-01	Yes	Yes
22042-96-2	Hepta sodium phosphonate	2.61E+01	7.83E+01	Yes	Yes
127087-87-0	Polyethylene glycol trimethylnonyl ether	3.95E-01	1.18E+00	Yes	Yes
9000-30-0	Guar gum	1.87E+02	5.62E+02	Yes	Yes
9016-45-9	Polyoxyethylene nonylphenol ether	8.36E+01	2.51E+02	Yes	Yes
68953-58-2	Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	1.26E+02	3.79E+02	Yes	Yes
7727-54-0	Diammonium peroxodisulphate	2.68E+01	8.03E+01	Yes	Yes
10043-35-3	Boric acid	9.20E+01	2.76E+02	Yes	Yes
122-99-6	Phenoxy ethanol	5.11E-03	1.53E-02	No	No
2634-33-5	1,2-Benzisothiazolin-3(2H)	5.66E-03	1.70E-02	Yes	Yes

A.1.9.4 Exposure Assessment

The operational area for the campaign is considered a highly modified system that has minimal wildlife habitat to support a functioning aquatic or terrestrial ecosystem. The adjacent areas comprise unimproved pastures and remnant native vegetation, both of which are used for cattle grazing purposes. A range of surface water systems that include streams, creeks, dams, and rivers also exist nearby.

The security and management practices implemented by QGC as described in **Section 3.3.1** will be carried out for the stimulation of the campaign. The flowback fluid will be contained inside a flowback tank (with at least 3 m high walls), there would be minimal opportunity for environmental receptors to come into contact with the with the flowback fluid.

As the objective of this qualitative ERA is to evaluate the potential risks from a typical gas well field, the selection of environmental receptors for this ERA is based on understanding that the selected environmental receptors all have an equal opportunity to be exposed to residual hydraulic fracture stimulation flowback fluid within the project area. In reviewing and considering the potential significance of exposure pathways, the following points have been considered:

- No further assessment is considered warranted for groundwater as there are no potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracture stimulation fluids within the target formation, and no connection exists between groundwater in the target formation and surface-water, aquifers utilised for the purpose of extraction (for any beneficial use), or springs.
- Due to the engineered controls and barriers that QGC has implemented to contain the flowback fluid; no material exposure pathway is considered to exist for terrestrial environmental receptors. The site is fenced and the flowback fluid is contained in aboveground tanks, with walls of up to 3

metres in height. Terrestrial receptors identified to exist near the site and surrounds include domesticated livestock (cattle), large mammalian wildlife (kangaroos) and small mammalian wildlife (dingos). The fencing and the height of the above ground holding ponds will effectively limit their access to the flowback fluid. As such, the risk to terrestrial receptors has not been further assessed.

- The holding tanks are covered with a floating roof, limiting access for birds or bats to fly in and drink the flowback fluid or become trapped in the tank. As such, this exposure pathway is not considered to be of significance and has not been further assessed.
- It is noted that three COPEC for consideration in this ERA were either persistent, or bioaccumulative or toxic. However, none of the compounds utilised in hydraulic fracture stimulation fluids were persistent and bioaccumulative and toxic (PBT) in the environment. Polyacrylamide has limited biodegradation potential however, it is not bioaccumulative and is essentially non-toxic to aquatic species. Petroleum distillates meet the screening criteria for bioaccumulation and toxicity; however, the chemical is expected to be biodegradable and adverse chronic outcomes are not evident based on its lack of persistence in the environment. Didecyldimethyl ammonium chloride meet the screening criteria for toxicity, however adverse chronic outcomes are not evident based on their lack of persistence and bioaccumulation potential in the environment.
- Whilst considered minimal, there is the potential for a release of stored hydraulic fracture stimulation flowback fluid to surface water systems located near the gas well pads in the situation of an accidental release, such as from piping, leaks, or failure of overflow system in the event of heavy rainfall. The flowback tanks are held on-site for a maximum period of 3 years, after which the fluid will be trucked off-site to a disposal facility authorised to receive this waste stream. It is considered that the likelihood of a substantial release of flowback fluid from the tank during this period is low.

Based on the available information, the key receptors (and exposures that are considered significant) who may be exposed to the COPEC identified on and off the site includes the following:

Aquatic invertebrates and fish

- Direct contact (ingestion and dermal contact) with residual hydraulic fracture stimulation chemicals identified in surface water in the event of a release of stored flowback fluid.

The assessment endpoints, or environmental values selected was the survival and reproduction of aquatic invertebrates. The assessment endpoints are sensitive to the residual hydraulic fracture stimulation flowback fluid COPEC identified and have the toxicological and life history databases to support their use as representatives of the study area ecosystem.

A.1.9.5 Potential exposure pathways and receptors

A summary of AECOM's decision tree evaluating the environmental receptors and pathways is presented in Table 48.

Table 48 Identification of Potential Environmental Receptors and Pathways

Source	Exposure Scenario	Receptors (on and off-site)	Pathway	Pathway Potentially Complete?	Comment
Hydraulic fracture stimulation chemicals	Spills and leaks occur while handling of chemicals either on or off-site (i.e., during transportation of chemicals to the site)	Indigenous fauna and flora	Ingestion, dermal	No	OH&S procedures and spill containment adequately address this exposure.
Flowback Fluid	Leaks, above ground flowback overflow system failure	Aquatic invertebrates, fish	Ingestion, dermal	Yes	There is the potential for a release of stored hydraulic fracture stimulation flowback fluid to surface water systems located near the TGS areas in the situation of an accidental release, such as from piping, leaks or failure of overflow system in the event of heavy rainfall. However, this exposure scenario unlikely due to robust flowback tank design and overflow controls implemented by QGC. Nevertheless, this pathway has been evaluated as part of this assessment.
		Indigenous fauna and flora	Ingestion, dermal, uptake	No	The potential for an accidental release of flowback fluid from leaking flowback tanks or piping does exist (although is considered unlikely due to the operational controls and robust designs implemented by QGC), however as the operational area is considered a highly modified environment (normal operational activities, infrastructure, gravel and compacted soil cover on the well pad sites and around infrastructure would significantly inhibit the establishment/function of wildlife habitat in the immediate vicinity), the exposure pathway to indigenous flora is deemed incomplete for minor leaks and spills. The probability of such an accidental release is further reduced due to the temporary duration that the flowback fluids are stored in the flowback tanks. In considering this, the likelihood that exposure to spilled or leaked flowback fluid to domestic livestock and mammalian wildlife is considered insignificant, as their exposure is not habitat driven (i.e., they would not normally forage and breed in the operational areas) and operational controls (i.e., signage and fencing) and activities at the site limiting the occurrence of livestock and wildlife entry and exposures. The potential for terrestrial receptors obtaining drinking water from leaked flowback fluid only on occasions were they to inadvertently enter onto the operational area is considered highly unlikely

Source	Exposure Scenario	Receptors (on and off-site)	Pathway	Pathway Potentially Complete?	Comment
					(i.e., the exposure frequency and duration is deemed insignificant) and hence this exposure pathway is considered effectively incomplete.
	Entry into flowback tanks	Indigenous fauna	Ingestion, dermal	No	Entry is limited via signage and fencing around the operational areas. In addition, the walls of the flowback tanks are at least 3 m high, which prevents access into the tanks.
Hydraulic fracture stimulation Fluids	Fracturing fluid escapes into aquifer (well casing failure, fault, fracture, unconformity in strata) used for stock water supply and discharges to surface water.	Stock animals, Aquatic invertebrates, fish	Ingestion, dermal	No	QGC has detailed operational procedures that are designed to contain hydraulic fracture stimulation fluids within the TGS. No direct connection is understood to exist between groundwater in the TGS and surface-water, aquifers utilised for the purpose of extraction. Furthermore, fate and transport assessment indicate COPEC migration is minimal (refer to Section A.1.7).

Shaded cells indicate potentially complete exposure pathway, assessed as part of this ERA

A.1.9.6 Interpretation of environmental significance

The estimated environmental hazards have been qualitatively evaluated via a hazard index approach to determine their environmental significance for the operations evaluated in this assessment. The Tier 1 screen results show that most chemicals from the theoretical data for the campaign fluid systems exceed the acceptable hazard threshold of 1.0 for aquatic receptors and were considered potential COPEC.

It is noted that the Tier 1 Screen is a conservative approach and estimates potential “worst case scenario” environmental hazard. This worst-case scenario is based on a significant spill or release event directly to an adjacent surface water body, with no operational or spill management controls. The campaign wells are located in the Condamine and Balonne rivers catchment. The southern part of ATP645 occurs within the Border Rivers and Moonie catchment. There are no springs considered to be potentially affected by TGS development located within 10 km of campaign TGS wells (OGIA, 2019).

In reviewing and considering the significance of the potentially complete exposure pathways, the following points have been considered:

- It is noted that this estimated potential risk is based on a significant spill or release event directly to an adjacent surface water body.
- The environmental risk calculations presented in this assessment do not take into account dilution that could occur where flowback fluid is discharged to a surface water body in the event of a significant spill or leak. Processes such as sorption and biodegradation have not been considered. During normal operation procedures there are no discharges to surface waterbodies.
- Furthermore, the lack of a robust aquatic toxicological database resulted in aquatic screening values for the theoretical exposure scenario COPEC to be highly conservative, which is expected to significantly overestimate the actual risk.

Notwithstanding this conservative approach to estimating environmental exposure levels, risk management measures are routinely implemented by QGC which effectively minimise or removes the risk of accidental spills and releases of flowback fluid. These include:

1. Layout design development criteria are followed for placement of petroleum activity infrastructure, to minimise activities that require earthworks, vegetation clearing and/or placing fill (other than that is associated with the construction of linear infrastructure) in or within watercourses, wetlands, lakes, and springs.
2. Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals, and if a spill was to occur, rectification measures would be taken immediately and notification to DES of any unauthorised releases would be made. Secondary containment bunds will be added to the drill pads as a spill containment measure.
3. Routine integrity inspections are undertaken of equipment and storage tanks prior, during and post stimulation. Continuous monitoring and evaluation of well production data versus fluid storage and transfer during the production test phase.
4. Routine inspection of the flowback tank(s) and associated equipment (e.g., blender, hoses, pumps) to check for leakage of flowback fluid
5. Flowback tank and equipment is manned during the hydraulic fracture stimulation operation and as required, fluid is transferred to vacuum truck for disposal to ensure freeboard in the tank is maintained.
6. Pre-job inspection of the flowback tank and fluid connections to confirm integrity.
7. A vacuum truck with 20,000 L capacity and a front-end loader excavator located permanently on the site, available to assist in emergency spill situations, if required.

On every wellsite included in the campaign, a QGC representative inspects the site to verify controls 3 to 7 from the above list are occurring. The operational controls are routinely evaluated by Shell QGC and modifications and revisions made, where necessary.

With consideration of the above engineered controls and mitigation measures, while potential impacts to aquatic receptors could occur if releases of flowback fluid reach adjacent surface waterbodies, the likelihood that any of these chemicals may be discharged to an environment where any level of exposure may occur is considered highly unlikely. Therefore, it is considered that due to the engineered controls and routine implementation of existing operational management measures by QGC, no material pathway is considered to exist for aquatic environmental receptors.

A.1.9.7 Conclusions

The qualitative evaluation of potential risks to the environment associated with the use of chemicals in well simulation activities conducted by QGC within the project area has involved the assessment of potential exposures to compounds used or formed in the simulation activities. Based on the operational controls, security and management practices implemented by QGC, the design of the flowback tanks and groundwater fate and transport assessment, no complete exposure pathways have been identified for environmental receptors and the potential risks to the environment are considered to be low and acceptable.

A.1.10 Uncertainty assessment

In general, the uncertainties and limitations of the human health and environmental risk assessment can be classified into the following categories:

- Receptor exposure assessment; and
- Toxicological assessment.

The risk assessment process, following both Australian and international guidance, provides a systematic means for organising, analysing, and presenting information on the nature and magnitude of risks to public health posed by chemical exposures. Despite the advanced state of the current risk assessment methodology, uncertainties and limitations are inherent in the risk assessment process. The uncertainties associated with each of these categories are discussed in the sections below.

A.1.10.1 Exposure uncertainties

Risk assessments require the adoption of several assumptions to assess potential human exposure. This risk assessment includes assumptions about general characteristics and patterns of human exposure relevant to the receptor groups. These assumptions are conservative and developed to provide an estimate of maximum possible exposures rather than the actual exposures. This approach is expected to overestimate the risks.

More specifically, the presence and concentrations of COPC assumed in the calculations are based on a worst-case assumption that the COPC present in stimulation fluids do not degrade or sorb significantly in the sub-surface, and that these chemicals may all be present in the water to which trespassers, aquatic receptors and terrestrial species are exposed. In addition, it is assumed that a range of hydraulic fracture stimulation fluids are used in the same area of operation at the same time.

A.1.10.2 Toxicity uncertainties

In general, the available scientific information is insufficient to provide a thorough understanding of all of the potential toxic properties of chemicals to which humans may be exposed. It is necessary, therefore, to extrapolate these properties from data obtained under other conditions of exposure which generally involve experimental laboratory animals.

Although there may be interspecies differences in chemical absorption, metabolism, excretion and toxic response, there may also be uncertainties concerning the relevance of animal studies using exposure routes that differ from human exposure routes. In addition, the frequent necessity to extrapolate results of short term or sub-chronic animal studies to humans exposed over a lifetime has inherent uncertainty. In order to adjust for these uncertainties, published toxicity values generally incorporate safety factors that may vary from 10 to 1000. The uncertainties inherent in the toxicological values adopted are considered likely to result in an overestimation of actual risk.

A.1.11 Conclusions

The potential risks to human health and the environment associated with hydraulic fracture stimulation for the upcoming campaign were undertaken in accordance with enHealth, NEPM and ANZECC guidance, with reference to peer-reviewed international guidance where relevant.

Detailed operational procedures have been developed that are designed to contain the hydraulic fracture stimulation fluids within the TGS, such that groundwater utilised for the purpose of extraction (for any beneficial use), or springs is not impacted by hydraulic fracture stimulation chemicals.

The risk of chemical exposure to workers involved in the operation of hydraulic fracture stimulation activities (including the transportation of chemicals) was not quantitatively evaluated as this risk is addressed through the implementation of appropriate occupational health and safety procedures and management plans.

Potential exposures to hydraulic fracture stimulation chemicals were therefore assessed to be limited to the above ground storage and handling of flowback fluid. Management of TGS water involves temporary storage of flowback fluid in above ground fluid flowback tanks, after which the fluid will be transported to an off-site disposal facility. Exposure point concentrations were developed for each of the hydraulic fracture stimulation fluid systems using a combination of theoretical calculations (where it was assumed that between 20% and 60% of the mass of the chemicals injected into the well will be present in the flowback water).

The toxicity of the chemicals used in the hydraulic fracture stimulation process has been assessed for persistence, bioaccumulation, and aquatic toxicity (PBT), and human health toxicity. The chemicals used in the hydraulic fracture stimulation process do not contain BTEX or polycyclic aromatic hydrocarbons as additives. It is noted that none of the COPC identified for consideration in this HHRA are persistent and bioaccumulative and toxic, hence there are no secondary pathways of concern (such as accumulation in crops and produce, and subsequent human consumption) that require quantification.

Based on the operational controls and management practices implemented by QGC, the design of the flowback tanks and groundwater fate and transport assessment, the potentially complete exposure pathways identified and assessed in the risk assessment comprised the following:

- Incidental ingestion and dermal contact by trespassers at the flowback fluid flowback tank; and
- Potential releases of water to aquatic environments.

On the basis of the risk calculations taken, with consideration of the uncertainties identified, the following can be concluded in relation to potential exposures to flowback fluid from well hydraulic fracture stimulation activities:

- No unacceptable risks to trespassers were identified. Conservative risk scenarios assessed included regular access to the flowback tank, where swimming type activities were undertaken, with exposures to high theoretical concentrations of COPC in the flowback fluid. It is noted that this scenario is highly unlikely as the flowback tank is covered with a floating cover, further limiting trespassers access into the tank.
- Potential impacts to aquatic receptors could occur if releases of flowback fluid reach surface waterbodies. The worst-case scenario was assumed where the assessed water body was located adjacent to the flowback tank.
- The likelihood that any of these chemicals may be discharged to an environment where any level of exposure may occur is managed via the implementation of existing operational management measures consistent with API guidance and 'Best Practice' specifications for the design and implementation of all hydraulic fracture stimulation operations that are conducted for the Project. The flowback tanks are held on-site for a maximum period of 3 years, after which the fluid will be trucked off-site to a disposal facility. It is considered that the likelihood of a substantial release of flowback fluid from the tank during this period is low.

Effective operational controls and management implemented by QGC further minimises the potential for exposures. These operational controls include:

8. Layout design development criteria are followed for placement of petroleum activity infrastructure, to minimise activities that require earthworks, vegetation clearing and/or placing fill (other than that is associated with the construction of linear infrastructure) in or within watercourses, wetlands, lakes and springs.
9. Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals, and if a spill was to occur, rectification measures would be taken immediately and notification to DES of any unauthorised releases would be made.
10. Routine integrity inspections are undertaken of equipment and storage tanks prior, during and post stimulation. Continuous monitoring and evaluation of well production data versus fluid storage and transfer during the production test phase.
11. Routine inspection of the flowback tank(s) and associated equipment (e.g., blender, hoses, pumps) to check for leakage of flowback fluid.
12. Flowback tank and equipment is manned during the hydraulic fracture stimulation operation and as required, fluid is transferred to vacuum truck for disposal to ensure freeboard in the tank is maintained.
13. Pre-job inspection of the flowback tank and fluid connections to confirm integrity.
14. A vacuum truck with 20,000 L capacity and a front-end loader excavator located permanently on the site, available to assist in emergency spill situations, if required.

On every wellsite included in the campaign, a QGC representative inspects the site to verify controls 3 to 7 from the above list are occurring. The operational controls are routinely evaluated by Shell QGC and modifications and revisions made, where necessary.

The summary of the results from the human health and environmental risk assessment and associated risk mitigation measures is presented in Table 49 below.

In summary, QGC's operational and management controls can be further supported by the following recommendations:

- Maintain compliance with QGC's Stimulation Impact Monitoring Plan, which will be developed to monitor the impact of hydraulic fracture stimulation in the project area.

Table 49 Results from quantitative human health and environmental risk assessment for the campaign

	Identified Potential Hazard	Hazard Causes and Consequences	Risk Mitigation Measures	Reason for carrying forward the potential hazard into the subsequent Quantitative Risk Assessment	Results of Quantitative Risk Assessment	Recommended Mitigation to Address Residual Risk
Surface Environment	The loss of containment of chemicals used for hydraulic fracture stimulation	Exposure of workers, residents or the environment to potentially hazardous hydraulic fracture stimulation chemicals, resulting from loss of containment occurring: Whilst in transit to site During the mixing of hydraulic fracture stimulation fluid on site; or (In diluted form) during the storage and transport of well flowback fluid.	QGC implement a range of engineering and operational control measures to ensure the risk of hydraulic fracture stimulation fluid spills are minimised during hydraulic fracture stimulation operations, including during transport to and from the wellsite and during the flowback of hydraulic fracture stimulation chemicals from the well. These control measures include: Adherence to the material storage and transport requirements as stipulated on the chemical Safety Data Sheets (SDS). Adherence to the Transport of Dangerous Goods by Road Regulations (for chemicals classified as a 'Dangerous Goods'). Ensuring chemicals remain in their original containers and are not decanted into smaller containers which may not be fit for purpose. During hydraulic fracture stimulation operations, the use of secondary containment beneath all equipment holding or pumping chemicals. Using fit for purpose flowback fluid storage tanks. Conducting regular integrity checks of fluid storage tanks, during commissioning and use. Ensure adequate freeboard is maintained at all times.	The evaluation of the risk to workers involved in the operation of well hydraulic fracture stimulation activities (including transportation of the COPC to the site) is not considered warranted in the subsequent sections of this risk assessment, as it is addressed via the implementation of appropriate occupational health and safety procedures and management plans. Further consideration is warranted regarding the risk of above ground exposure relating to the handling and storage of hydraulic fracture stimulation chemicals and flowback fluid. This is addressed in Section 3.4.3 Further assessment is warranted regarding the chemical and physical properties of the constituents used in hydraulic fracture stimulation fluids that result in the potential for these chemicals to be present in flowback fluid and to be of concern in relation to potential acute or chronic risks. This is addressed in Section 3.4.3.	Exposures by workers involved in the operation of well hydraulic fracture stimulation activities have not been evaluated as their exposures are addressed through the implementation of appropriate occupational health and safety procedures and management plans. The PBT assessment of the chemicals indicated that none of the COPCs identified for consideration in this HHRA are persistent and bioaccumulative and toxic, hence secondary pathways (such as accumulation in crops and produce, and subsequent human consumption) were not quantified. Polyacrylamide has limited biodegradation potential however, it is not bioaccumulative and is essentially non-toxic to aquatic species. Petroleum distillates meet the screening criteria for bioaccumulation and toxicity; however, the chemical is expected to be biodegradable and adverse chronic outcomes are not evident based on its lack of persistence in the environment. Didecyldimethyl ammonium chloride meet the screening criteria for toxicity, however adverse chronic outcomes are not evident based on their lack of persistence and bioaccumulation potential in the environment. The assessment has focused on the theoretical dataset, assuming between 20% and 60% of the mass of chemicals injected into the well will be present in the flowback fluid. Based on the conceptual site model, the potentially complete exposure pathways identified and assessed in the risk assessment comprised the following: - Incidental ingestion and dermal contact by trespassers at the flowback tanks; and - Potential releases of water to aquatic environments. The results of the risk assessment indicated the following: - No unacceptable risks to trespassers were identified. Conservative risk scenarios considered included exposures that involved regular access to the flowback tanks, where swimming type activities were undertaken, with exposures to high theoretical concentrations of COPC in the flowback fluid. It is noted that this scenario is highly unlikely as the flowback tanks are covered with a floating cover.	Operational controls which could further minimise the potential for exposure include monitoring weather forecast and implementing flowback tank over-flow prevention measures, as required. If the flowback tanks are to be left unattended for an extended period whilst containing residual flowed-back material, perform routine flowback tank inspections to confirm adequate freeboard and to check for leakage of flowback fluid.

	Identified Potential Hazard	Hazard Causes and Consequences	Risk Mitigation Measures	Reason for carrying forward the potential hazard into the subsequent Quantitative Risk Assessment	Results of Quantitative Risk Assessment	Recommended Mitigation to Address Residual Risk
Subsurface Environment	Contamination of groundwater in the target TGS, which is then accessed by landholder bores	Based on the hydrogeological setting within the project area (Section 2.2.3), in order for the pathway to be valid in the context of exposure to hydraulic fracture stimulation fluids, a potential landholder groundwater supply bore would need to source groundwater from directly within the hydraulically fractured zone of the TGS.	QGC have protocols in place which preclude hydraulic fracture stimulation operations impacting landholder bores. Prior to commencing a hydraulic fracture stimulation campaign, QGC perform Baseline Assessments of all groundwater bores within 2 km of horizontal separation from a target well. Part of this assessment is to understand the precise location of bores and their likely source aquifer. If a landholder bore is potentially screened within the radius of influence of a hydraulic fracture stimulation operation (both horizontally and vertically), that gas well is not hydraulically fractured. Hence this scenario becomes invalid.	The protocols that QGC has in place to prevent hydraulic fracture stimulation occurring near landholder bores screened in target TGS, negate the requirement for further consideration of the risks of this scenario.	To evaluate the likelihood that gas wells might be located in a position where a groundwater extraction well could theoretically be affected, QGC has carried out a baseline survey and GIS proximity analysis in which the existing identified groundwater wells have been screened for depth relative to the top of the Back Creek Group. This has identified no groundwater wells deeper than 150 m, within the petroleum tenures and for a 2 km radius around the boundary of the tenures. The majority of identified bores are separated by a vertical distance of more than 1600 m from the Back Creek Group. Three bores were identified within a vertical distance of 1050 m of the Back Creek Group in petroleum tenure ATP 645. The use of these bores is unknown. The qualitative assessment of the fate and transport of COPCs residual in the TGS after hydraulic fracture stimulation (see Section A.1.7) determined minimal potential for COPC migration beyond the hydraulically fractured zone. There are no landholder bores installed within both 750 m horizontal separation and 100 vertical metres of the top of the TGS.	Risk mitigation achieved via QGC's existing operational controls described in Section 2.3 and Stimulation Impact Monitoring Plan.

Appendix B

Hydraulic Fracture Stimulation Fluid Mass Balance

Contractor HVFR_A Fluid Recipe									
Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%v/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% w/w)	Concentration in Injected Fluid (mg/L)	Flowback Concentration Assuming 20% Mass Recovery (mg/L)	Flowback Concentration Assuming 60% Mass Recovery (mg/L)
Petroleum Distillates (Hydrotreated, Light)	64742-47-8	0.8	11598.595	0.168760%	9279	0.1%	1471	294	882
Quartz or Organophilic phyllosilicate (crystalline silica, quartz)	14808-60-7	2.65	331.388	0.004822%	878	0.0%	139	28	84
Hydrochloric acid	7647-01-0	1.15	6505.606	0.094657%	7494	0.1%	1188	238	713
Glutataldehyde	111-30-8	1.1	1380.918	0.020092%	1464	0.0%	232	46	139
Isopropanol	67-63-0	0.79	13.158	0.000191%	10	0.000%	1.6	0.33	0.98
Ethoxylated C12-C16 Alcohol	68551-12-2	0.9	8.971	0.000131%	8	0.000%	1.3	0.26	0.77
Cinnamaldehyde	104-55-2	1.05	2.99	0.000044%	3	0.000%	0.50	0.10	0.30
Ethoxylated Decanol	26183-52-8	0.999	2.99	0.000044%	3	0.000%	0.47	0.09	0.28
Sodium erythorbate	6381-77-7	1.95	52.456	0.000763%	102	0.001%	16.2	3.25	9.75
Ethoxylated Tallow Alkyl Amine	61791-26-2	0.946	1.495	0.000022%	1	0.0000%	0.22	0.04	0.13
Methanol	67-56-1	0.79	0.299	0.000004%	0	0.0000%	0.04	0.01	0.02
Hepta sodium phosphonate	22042-96-2	1.945	414.2	0.006027%	806	0.010%	128	26	77
Polyacrylamide	9003-05-08	1.189	15658.103	0.227826%	18617	0.239%	2951	590	1771
Polyethylene glycol trimethylnonyl ether	127087-87-0	1.04	27.616	0.000402%	29	0.000%	4.6	0.91	2.73
Proppants									
Silicon Dioxide (quartz / sand)	14808-60-7	2.65	564222.928		1495191	19.2%			
Water									
Water in additives	7732-18-5	1	1656.798	0.024%	1657	0.0%			
Water	7732-18-5	1	6270960.34	91.2%	6270960	80.3%			
Total Chemical Additives			35999		38,957	0.5%			
Total Proppant			564223		1495191	19.2%			
Total Make Up Water			6272617		6270960	80.3%			

The mass balance also estimates the concentration of each chemical that will be returned to surface during the flowback of the hydraulically fractured well, based on an upper and lower estimate of 20% and 60% mass recovery

Contractor HVFR_B Fluid Recipe									
Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%v/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% w/w)	Concentration in Injected Fluid (mg/L)	Flowback Concentration Assuming 20% Mass Recovery (mg/L)	Flowback Concentration Assuming 60% Mass Recovery (mg/L)
Petroleum Distillates (Hydrotreated, Light)	64742-47-8	0.8	11598.595	0.185526%	9279	0.1291605%	1631	326	979
Quartz or Organophilic phyllosilicate (crystalline silica, quartz)	14808-60-7	2.65	331.388	0.005301%	878	0.0122241%	154	31	93
Hydrochloric acid	7647-01-0	1.15	6505.606	0.104061%	7494	0.1043217%	1318	264	791
Glutataldehyde	111-30-8	1.1	1380.918	0.022089%	1464	0.0203755%	257	51	154
Sodium erythorbate	6381-77-7	1.95	52.456	0.000839%	102	0.0014268%	18.0	3.60	10.81
Hepta sodium phosphonate	22042-96-2	1.945	414.2	0.006625%	806	0.0112141%	142	28	85
Polyacrylamide	9003-05-08	1.189	15658.103	0.250461%	18617	0.2591525%	3273	655	1964
Polyethylene glycol trimethylnonyl ether	127087-87-0	1.04	27.616	0.000442%	29	0.0003998%	5.0	1.01	3.03
Didecyldimethyl ammonium chloride	7173-51-5	0.870	23.924	0.000383%	21	0.0002897%	3.7	0.73	2.20
Ethyl alcohol (Ethanol)	64-17-5	0.7864	2.99	0.000048%	2	0.0000327%	0.4	0.08	0.25
Proppants									
Silicon Dioxide (quartz / sand)	14808-60-7	2.65	564222.928		1495191	20.8%			
Water									
Water in additives	7732-18-5	1	1659.789	0.027%	1660	0.0%			
Water	7732-18-5	1	5649843.46	90.4%	5649843	78.6%			
Total Chemical Additives			35996		38,954	0.5%			
Total Proppant			564223		1495191	20.8%			
Total Make Up Water			5651503		5649843	78.6%			

The mass balance also estimates the concentration of each chemical that will be returned to surface during the flowback of the hydraulically fractured well, based on an upper and lower estimate of 20% and 60% mass recovery

Contractor HVFR Hybrid Fluid Recipe									
Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%v/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% w/w)	Concentration in Injected Fluid (mg/L)	Flowback Concentration Assuming 20% Mass Recovery (mg/L)	Flowback Concentration Assuming 60% Mass Recovery (mg/L)
Petroleum Distillates (Hydrotreated, Light)	64742-47-8	0.8	13509.311	0.216089%	10807	0.15037%	1900	380.04	1140.13
Quartz or Organophilic phyllosilicate (crystalline silica, quartz)	14808-60-7	2.65	151.956	0.002431%	403	0.00560%	71	14.16	42.48
Guar gum	9000-30-0	0.7	7607.386	0.121685%	5325	0.07409%	936	187.26	561.78
Hydrochloric acid	7647-01-0	1.15	6505.606	0.104061%	7494	0.10427%	1318	263.54	790.62
Glutaldehyde	111-30-8	1.1	1272.655	0.020357%	1349	0.01877%	237	47.44	142.31
Polyoxyethylene nonylphenol ether	9016-45-9	1.06	2244.067	0.035895%	2379	0.03310%	418	83.65	250.94
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2	1.6	2244.067	0.035895%	3591	0.04996%	631	126.26	378.78
Potassium hydroxide	1310-58-3	2.1	3632.934	0.058111%	7629	0.10615%	1341	268.28	804.83
1,6-Hexanediol	629-11-8	0.96	224.407	0.003590%	215	0.00300%	38	7.58	22.73
Isopropanol	67-63-0	0.79	13.158	0.000210%	10	0.00014%	1.8	0.36	1.09
Ammonium Persulphate	7727-54-0	2.0	380.422	0.006085%	761	0.01059%	134	26.75	80.26
Ethoxylated C12-C16 Alcohol	68551-12-2	0.9	8.971	0.000143%	8	0.00011%	1.4	0.28	0.85
Cinnamaldehyde	104-55-2	1.05	2.99	0.000048%	3	0.00004%	0.55	0.11	0.33
Ethoxylated Decanol	26183-52-8	0.999	2.99	0.000048%	3	0.00004%	0.53	0.11	0.32
Sodium erythorbate	6381-77-7	1.95	52.456	0.000839%	102	0.00143%	18	3.60	10.81
Ethoxylated Tallow Alkyl Amine	61791-26-2	0.946	1.495	0.000024%	1	0.00002%	0.25	0.05	0.15
Methanol	67-56-1	0.79	0.299	0.000005%	0	0.000003%	0.042	0.01	0.02
Hepta sodium phosphonate	22042-96-2	1.945	381.796	0.006107%	743	0.01033%	131	26.11	78.34
Polyacrylamide	9003-05-08	1.189	6119.609	0.097887%	7276	0.10124%	1279	255.87	767.60
Sodium chloride	7647-14-5	2.17	26.498	0.000424%	57	0.00080%	10	2.02	6.05
Boric acid	10043-35-3	1.44	1816.467	0.029055%	2616	0.03639%	460	91.98	275.94
Talc, Magnesium Silicate	14807-96-6	2	20.022	0.000320%	40	0.00056%	7	1.41	4.22
Polyethylene glycol trimethylnonyl ether	127087-87-0	1.04	10.793	0.000173%	11	0.00016%	2.0	0.39	1.18
Mannanase	37288-54-3	1.12	1.325	0.000021%	1	0.00002%	0.3	0.05	0.16
Sorbitol	50-70-4	1.49	1.325	0.000021%	2	0.00003%	0.3	0.07	0.21
Phenoxy ethanol	122-99-6	1.10	0.132	0.000002%	0	0.000002%	0.026	0.01	0.02
1,2-Benzisothiazonlin-3(2H)	2634-33-5	1.22	0.132	0.000002%	0	0.000002%	0.028	0.01	0.02
Sodium Gluconate	527-07-1	1.8	3632.934	0.058111%	6502.95	0.09%	1143	228.68	686.03
Propylene glycol	57-55-6	1.036	1.325	0.000021%	1	0.00002%	0.24	0.05	0.14
Proppants									
Silicon Dioxide (quartz / sand)	14808-60-7	2.65	564222.928		1495191	20.8%			
Water									
Water in additives	7732-18-5	1	2750.971	0.044%	2751	0.0%			
Water	7732-18-5	1	5634880.54	90.1%	5634881	78.4%			
Total Chemical Additives			49868		57,333	0.8%			
Total Proppant			564223		1495191	20.8%			
Total Make Up Water			5637632		5634881	78.4%			

The mass balance also estimates the concentration of each chemical that will be returned to surface during the flowback of the hydraulically fractured well, based on an upper and lower estimate of 20% and 60% mass recovery

Appendix C

Hydraulic Fracture Stimulation Fluid Toxicological Profiles

Toxicity Summary - Potassium Hydroxide

Chemical and Physical Properties ^{1,2,3}	
CAS number	1310-58-3
Molecular formula	KOH
Molecular weight	56.11
Solubility in water	1100 g/l at 25°C
Melting point	406°C
Boiling point	1327°C
Vapour pressure	1.3 hPa at 719°C
Henrys law constant	No data available.
Explosive potential	The solution in water is a strong base. It reacts violently with acid and is corrosive to metals such as aluminium, tin, lead and zinc. This produces a combustible / explosive gas. Reacts with ammonium salts. This produces ammonia. This generates fire hazard. Contact with moisture and water may generate heat.
Flammability potential	Not combustible. Contact with moisture or water may generate sufficient heat to ignite combustible materials.
Colour/Form	White or slightly yellow odourless lumps, rods, pellets.
Overview	Potassium hydroxide is a strong alkaline substance that dissociates completely in water to K ⁺ and OH ⁻ ions. KOH is commercialised as a solid or as solutions with varying concentrations. It has many industrial uses; less than 2% is for wide dispersive use. It is used in paint and varnish removers, drain cleaners, degreasing agents and dairy pipeline cleaners.
Environmental Fate ⁴	
Soil/Water/Air	The high water solubility and low vapour pressure indicate that KOH will be found predominantly in the aquatic environment. KOH is present in the environment as potassium and hydroxyl ions, which implies that it will not adsorb on particulate matter or surfaces and will not accumulate in living tissues.
Human Health Toxicity Summary ^{1,3,4}	
Chronic Repeated Dose Toxicity	No studies were identified regarding the repeated dose toxicity of KOH in animals
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	There is no evidence for a mutagenic activity. K ⁺ and OH ⁻ are not expected to be systemically available in the body over the normal limits, under non-irritating conditions. A genotoxic effect is also not very likely because both the K ⁺ and OH ⁻ ions are naturally present in the human body.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Studies to the reproduction of KOH are not available. Based on the results of corresponding potassium salts like KCl and K ₂ CO ₃ , effects in non-irritating doses/concentrations to reproduction or development are not expected for KOH. The calculated NOAEL for the potassium ion is approximately 164 mg/kg bw.
Acute Toxicity	Potassium hydroxide has moderate acute toxicity based on results from three animal studies in rats following oral exposure. The median lethal dose (LD₅₀) in rats is reported as 273–1230 mg/kg bw. The concentrations used in these tests were not reported. Observed sub-lethal effects included hyperexcitability, followed by apathy and weakness. Haemorrhaging of the stomach and intestine, and adhesions of abdominal organs (stomach, pancreas, spleen, liver and small intestine) were seen following administration of both lethal and sub-lethal doses (OECD, 2002). In contrast, the LD₅₀ value in rats of potassium chloride, 3000 mg/kg bw, is much higher than that of potassium hydroxide, indicating low toxicity of the potassium ion (OECD, 2002).

Irritation	Solid KOH is corrosive. Depending on the concentration, solutions of KOH are non-irritating, irritating or corrosive and they cause direct local effects on the skin, eyes and gastrointestinal tract. Systemic effects are not to be expected. Solutions with concentrations higher than 2% are corrosive, while concentrations of about 0.5 to about 2.0 % are irritating.												
Sensitisation	Based on the reported negative results in a guinea pig study and human experience, potassium hydroxide is not considered to be a skin sensitiser (OECD, 2002). Potassium hydroxide has been used extensively for many decades by industry and by consumers. However, skin sensitisation has never been described as secondary to skin irritation or burns. As discussed previously, both the potassium and the hydroxide constituents are ions that are naturally present in the body. For this reason, it is very unlikely that skin sensitisation would result from exposure to the chemical (OECD, 2002)												
Health Effects Summary	Potassium hydroxide is corrosive to the skin, eyes, and gastrointestinal and respiratory tracts. Based on human data, concentrations of 0.5–2.0 % are irritating to the skin, while a concentration greater than 2.0 % is corrosive (OECD, 2002).												
Key Study/Critical Effect for Screening Criteria	No oral TRV apply. Acute toxicity only (irritant and corrosive). Systemic effects are not to be expected. The Australian drinking water guideline value for pH may apply to potassium hydroxide.												
Ecological Toxicity ⁴													
Aquatic Toxicity	The hazard of KOH for the environment is caused by the hydroxyl ion (pH effect). For this reason the effect of KOH on the organisms depends on the buffer capacity of the aquatic or terrestrial ecosystem. Also the variation in acute toxicity for aquatic organisms can be explained for a significant extent by the variation in buffer capacity of the test medium. The LC50 value of acute fish toxicity was in the order of 80 mg/l. It was 880 mg/l for KCl and ranged between 125-189 mg/l for NaOH. The LC50 values of acute invertebrate toxicity for KCl was 660 mg/l (Daphnia magna) and 630 mg/l (Ceriodaphnia dubia), and for NaOH 40 mg/l (Ceriodaphnia dubia). The EC50 algae value (Nitscheria linearis) was 1337 mg/l for KCl. This chemical poses no unreasonable risk to the environment based on Tier I assessment under the NICNAS IMAP assessment framework. It is a reactive substance which rapidly converts into species of low ecotoxicological concern. This chemical, and its degradant species, are not expected to pose an unreasonable risk to the environment provided that ANZECC water quality guidelines for physical and chemical stressors are not exceeded.												
Determination of PNEC aquatic	It is not considered useful to calculate a PNEC for potassium hydroxide because factors such as the buffer capacity, the natural pH, and the fluctuation of the pH are very specific for a certain ecosystem. Based on the information above, a PNECaquatic was not derived for potassium hydroxide.												
Current Regulatory Controls¹													
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	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dccew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	The chemical is classified as hazardous, with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): Xn; R22 (acute toxicity) C; R35 (corrosivity)	
Australian Occupational Exposure Standards	TWA: 2 mg/m ³ (peak limitation), Safe Work Australia	
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica): An exposure limit of 0.5–2 mg/m ³ time weighted average (TWA) in different countries such as Bulgaria, Chile, Denmark, Poland and Sweden and 1–2 mg/m ³ short-term exposure limit (STEL) in countries such as the United Kingdom, Spain, South Africa and Poland.	
Australian Food Standards	No data available.	
Australian Drinking Water Guidelines	No data available.	
Aquatic Toxicity Guidelines	No data available.	
PBT Assessment		
P/vP Criteria fulfilled?	Not applicable (ionic species ubiquitous in environment)	
B/vB criteria fulfilled?	Not applicable (ionic species ubiquitous in environment)	
T criteria fulfilled?	No chronic toxicity data exist on potassium hydroxide; however, the acute EC(L)50s for KCl are >0.1 mg/L in fish, invertebrates and algae. Thus, potassium hydroxide does not meet the screening criteria for toxicity.	
Overall conclusion	Not PBT	

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier II Assessment for Potassium hydroxide: Retrieved 2019: <https://www.nicnas.gov.au>
2. HSDB (n.d.). Hazardous Substances Data Bank. Retrieved 2015, from Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>
3. IPCS Potassium Hydroxide, Retrieved 2015: <http://www.inchem.org>
4. OECD (2008). Screening Information Dataset (SIDS) Initial Assessment Report for Potassium Hydroxide (CAS No. 1310-58-3)
5. Safe Work Australia Workplace Exposure Standards for Airborne Contaminants, 2013.
6. ECHA REACH, Potassium Hydroxide, Retrieved 2015: <http://echa.europa.eu>

Toxicity Summary - 1,2-Benzisothiazolin-3(2H)

Chemical and Physical Properties ^{1,2,3}	
CAS number	2634-33-5
Molecular formula	C ₇ H ₅ NOS
Molecular weight	151.19
Solubility in water	1.1 g/L at 20 °C
Melting point	156.6 °C
Boiling point	327.6 °C
Vapour pressure	3.7 x 10 ⁻⁷ kPa at 25 °C
Henry's law constant	5X10 ⁻¹⁰ atm-cu m/mole
Explosive potential	Non-explosive
Flammability potential	Non-flammable
Colour/Form	Off-white to yellowish solid
Overview	Benzo[d]isothiazol-3-one is an organic heterobicyclic compound based on a fused 1,2-thiazole and benzene bicyclic ring skeleton, with the S atom positioned adjacent to one of the positions of ring fusion. It has a role as a disinfectant, a platelet aggregation inhibitor, an environmental contaminant, a xenobiotic, a drug allergen and a sensitizer. It is an organonitrogen heterocyclic compound and an organic heterobicyclic compound.
Environmental Fate ³	
Soil/Water/Air	If released to air, a vapour pressure of 2.78X10 ⁻⁶ mm Hg at 25 °C indicates benzisothiazolinone will exist in both the vapor and particulate phases in the atmosphere. Vapour-phase benzisothiazolinone will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 23 days. Particulate-phase benzisothiazolinone will be removed from the atmosphere by wet and dry deposition. Benzisothiazolinone is susceptible to photolysis under aqueous conditions and may photodegrade under other environmental conditions. If released to soil, Benzisothiazolinone is expected to have very high mobility based upon an estimated K _{oc} of 34. Volatilization from moist soil surfaces is not expected to be an important fate process based upon an estimated Henry's Law constant of 5X10 ⁻¹⁰ atm-cu m/mole. Benzisothiazolinone is not expected to volatilize from dry soil surfaces based upon its vapour pressure. Benzisothiazolinone is reported to readily biodegrade in soil. Results of an aerobic study found a half-life of less than 24 hours in a sandy loam soil. Benzisothiazolinone is a biocide, and a 0% theoretical BOD in the Japanese MITI suggests that the compound may be toxic to microorganisms at high concentrations. If released into water, benzisothiazolinone is not expected to adsorb to suspended solids and sediment based upon the estimated K _{oc} . Volatilization from water surfaces is not expected to be an important fate process based upon this compound's estimated Henry's Law constant. 1,2-Benzisothiazolin-3-one has been shown to be hydrolytically stable with a hydrolysis half-life of >30 days.
Human Health Toxicity Summary ^{1,2,3}	
Chronic Repeated Dose Toxicity	Repeated oral exposure to benzisothiazolinone in rats was consistently associated with increased incidence of histopathological lesions on the non-glandular stomach such as hyperkeratosis, epithelial hyperplasia, ulceration, and keratin cysts. These effects are attributed to local irritant effects of the chemical. A NOAEL of 25.26 mg/kg bw/day was established from the 90-day study based on systemic effects at the Lowest-Observed- Adverse-Effect-Level (LOAEL) of 63.15 mg/kg bw/day
Carcinogenicity	No data were available.
Mutagenicity/ Genotoxicity	An in vitro mammalian cell gene mutation test (OECD TG 476) showed that

	benzothiazolinone was not mutagenic up to 5.2 µg/mL with and without metabolic activation. The chemical was not clastogenic to Chinese hamster ovary (CHO) cells with and without metabolic activation in an in vitro mammalian chromosome aberration test conducted to OECD TG 473 at levels up to 6.4 µg/mL. Benzothiazolinone was not clastogenic in Swiss albino mice in an in vivo mammalian erythrocyte micronucleus test conducted to OECD TG 474 at doses up to 210.5 mg/kg. In an unscheduled DNA synthesis (UDS) test with mammalian liver cells in vivo conducted to OECD TG 486, the chemical did not induce UDS in Wistar rat hepatocytes at concentrations up to 750 mg/kg. Benzothiazolinone is not considered to be genotoxic.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	The reproductive study shows that dietary exposure to benzothiazolinone in rats showed no fertility effects. The NOAEL for local effect of the parent generation is 50 mg/kg bw/day.
Acute Toxicity	Sprague-Dawley rats were administered 82.3% benzothiazolinone by gavage at doses of 823, 1646, or 4115 mg/kg bw. This study was conducted according to the United States Environmental Protection Agency Office of Pesticide Programs (EPA OPP) 81-1. The effects observed at any of the doses were not specified. The reported acute oral median lethal dose (LD50), calculated using Probit Analysis, was 2100 mg/kg bw for males. The reported acute oral LD50 for females, estimated graphically, was 1050 mg/kg bw (Product Safety Labs 1996a). The study shows that benzothiazolinone has low to moderate acute toxicity by the oral route in rats. Topical application of a single dose of 4115 mg/kg bw of 82.3% benzothiazolinone to Sprague-Dawley rats showed no gross toxicity, adverse effects, or abnormal behaviour (details not provided). This study was conducted in accordance with EPA OPP 81-2. The acute dermal LD50 was >4115 mg/kg bw. The study shows that benzothiazolinone has low acute toxicity by the dermal route in rats.
Irritation	In a skin irritation test in New Zealand albino rabbits conducted in accordance with EPA OPP 81-5, 82.3% benzothiazolinone was applied by semi-occlusion. Well-defined moderate erythema and oedema were observed at all treated sites one hour after patch removal. The chemical was found to be a skin irritant based on the conditions of the test. The effects observed in this test demonstrate that benzothiazolinone is a skin irritant in animals. In an eye irritation test in New Zealand albino rabbits conducted in accordance with EPA OPP 81-4, 82.3% benzothiazolinone was instilled undiluted to the eyes. All of the treated eyes showed severe to maximal irritation with corneal opacity, iritis and conjunctivitis from 1 to 48 hours with the severity of irritation increasing with time. The chemical was found to be severely irritating to the rabbit eye. An in vitro assessment of the eye irritancy potential of benzothiazolinone using the bovine corneal opacity and permeability assay is available. Bovine eyes were exposed to up to 7500 ppm aqueous solution of the chemical and corneal opacity and permeability were determined to give an in vitro score. The chemical was considered to be non-irritating to the eyes at all dose levels under the conditions of the test. The effects observed in the in vivo test demonstrate the severe eye irritation potential of benzothiazolinone. Benzothiazolinone is also a skin irritant in humans.
Sensitisation	In a guinea pig maximisation test (GPMT) (OECD TG 406), benzothiazolinone at 79.8% was found to be a moderate contact sensitiser. In a Buehler test in accordance with EPA OPP 81-6 in Hartley albino guinea pigs, the chemical (at 82.3%) was not a sensitiser based on the test conditions. An EC3 (the effective concentration required to produce a three-fold increase in stimulation index) of 2.3% was identified for benzothiazolinone in a local lymph node assay (LLNA) dataset review; however, the experimental details were not provided. These studies show benzothiazolinone causes skin sensitisation in animals. Benzothiazolinone may also cause skin sensitisation in humans
Key Study/Critical Effect for Screening Criteria	Benzothiazolinone demonstrates acute oral toxicity effects, irritation of the skin, corrosive effects in the eyes, and skin sensitisation. Repeated oral exposure caused increased incidence of histopathological lesions on the non-glandular stomach which are attributed to the local irritant effects of the

	chemical. These effects are consistent with the two-generation reproductive toxicity study, with the most appropriate NOAEL for risk assessment purposes of 25.26 mg/kg bw/day based on decrease in bodyweight gain and salivation at the LOAEL of 63.15 mg/kg bw/day. The chemical is not genotoxic. Benzisothiazolinone shows no fertility effects.																				
Ecological Toxicity ^{1,2,3}																					
Aquatic Toxicity	Acute toxicity: Algae = 0.283 mg/L Daphnia = 1.175 mg/L Fish = 1.6 mg/L																				
Determination of PNEC aquatic	Lowest endpoint Algae = 0.283 mg/L Uncertainty factor = 100 PNEC _{aqua} = 2.80E-03																				
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Australian Hazard Classification	The chemical is classified as hazardous for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia 2013) with the following risk phrases: • Xn (Harmful); R22 • Xi (Irritant); R38, R41, R43 Mixtures containing the chemical are classified as hazardous with the following risk phrases based on the concentration of the chemicals in the mixtures. The risk phrases for different concentration (Conc) ranges are: Conc ≥25%: Xn, N: R22 (Harmful if swallowed), R38 (Irritating to skin), R41 (Risk of serious eye damage), R43 (May cause sensitisation by skin contact) • 20% ≤Conc <25%: Xi: R38, R41, R43 • 10% ≤Conc <20%: Xi: R41, R43 • 5% ≤Conc <10%: Xi: R36 (Irritating to eyes), R43 • 0.05% ≤Conc <5%: Xi: R4																				

Australian Occupational Exposure Standards	No specific exposure standards were available.
International Occupational Exposure Standards	No specific exposure standards were available.
Australian Food Standards	No Australian food standards were identified.
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified for this chemical in the Australian drinking water guidelines (National Health and Medical Research Council (NHMRC, 2011).
Aquatic Toxicity Guidelines	No data available.
PBT Assessment^{2,3}	
P/vP Criteria fulfilled?	No. The substance is reported to readily biodegrade in soil.
B/vB criteria fulfilled?	No. Based on the log Kow of 0.4, the chemical has a very low potential to bioaccumulate.
T criteria fulfilled?	No. Long term data not available (acute data >0.1 mg/L); potentially not toxic.
Overall conclusion	Not PBT

References

1. Department of the Environment and Energy 2017, National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme
2. ECHA REACH, 1,2-benzisothiazol-3(2H)-one, Retrieved 2021: <https://echa.europa.eu/>
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Toxicity Summary - Sodium Erythorbate

Chemical and Physical Properties ^{1,2}	
CAS number	6381-77-7
Molecular formula	C ₆ H ₇ NaO ₆
Molecular weight	199.13
Solubility in water	Soluble; 146 g/L at 20 °C and pH 6
Melting point	160 °C at 101.3 kPa
Boiling point	No data available.
Vapour pressure	No data available.
Henry's law constant	No data available.
Explosive potential	No data available.
Flammability potential	Non-flammable (100%)
Colour/Form	White, free-flowing crystals
Overview	Sodium erythorbate is a synthetic antioxidant used in food and cosmetic formulations. Foliar application of sodium erythorbate sprays and dusts are used to control young tree decline in citrus trees and to reduce ozone damage to Thompson seedless grapes. It is also used in hydraulic fracturing mixtures to prevent precipitation of metal oxides (iron control). This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate ¹	
Soil/Water/Air	Limited environmental fate information is available for this chemical. Sodium erythorbate is expected to be readily biodegradable based on modelled predictions (USEPA BIOWIN).
Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	Male 6-week-old F344 rats were given doses of 5% Sodium Erythorbate in feed for 168 days. Parameters of urinary excretion were investigated and the urinary bladder epithelium was examined using light and scanning electron microscopy at weeks 8, 16, and 24. The urine of rats fed Sodium Erythorbate had increased pH, elevated content of crystals and sodium, and decreased osmolality; however, no morphological alterations such as hyperplasia were detected in the mucosa. The urine values and urinary bladder mucosa were similar to controls at doses below 5 g/kg/day.
Carcinogenicity	F344/DuCrj rats of both sexes (6-week-old) were given 1.25% or 2.5% Sodium Erythorbate in drinking water for 104 weeks and untreated water for 8 additional weeks. Rats of the control group were given untreated water only. Each group consisted of 52 male and 50 female rats. Cumulative consumption of Sodium Erythorbate by male rats was 217 g/rat (1.25%) and 430 g/rat (2.5%). Consumption by females was 206 g/rat (1.25%) and 583 g/rat (2.5%). Body weight of rats given 2.5% Sodium Erythorbate was reduced by 8.5% for males and 15.5% for females at weeks 88 and 85, respectively, compared to controls. Body weight gain was normal in rats of the low dose group. All male treated and control rats (except two of the high-dose group) had testicular interstitial cell tumours. Various tumours occurred in 80% of control males, 69% of males given the low dose, and 78% of males given the high dose. A 6-18% incidence of leukaemia, pheochromocytoma, mammary fibroadenoma, and mesothelioma was observed. Of the females of the control, 1.25%, and 2.5% dose groups, 94%, 88%, and 78% had tumours, respectively. Twenty to 43% of females (all groups) had leukaemia, mammary fibroadenoma, endometrial stromal polyp and/or pituitary adenoma. Females given 2.5% Sodium Erythorbate had significantly fewer tumours than control females. The pattern of occurrence of the various

	types of tumours was similar among the groups. Sodium Erythorbate did not enhance the development of rare spontaneous tumours or transform benign tumours (e.g., solid adenoma of the thyroid) to carcinomas. The investigators concluded that Sodium Erythorbate was not carcinogenic in F344 rats.										
Mutagenicity/ Genotoxicity	Sodium Erythorbate (99.8% pure; 5.0 mg/plate) was non-mutagenic in <i>S. typhimurium</i> strains TA92, TA94, TA98, TA100, TA1535, and TA1537 with and without S9 activation. Sodium Erythorbate (0.25 mg/mL plate) was also negative in the chromosomal aberration assay using Chinese hamster fibroblasts; Sodium Erythorbate did not induce the formation of polyploid cells after 48 hours, and caused 1 % chromosomal breaks after 24 hours.										
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Sodium erythorbate did not cause maternal or fetal toxicity when administered to female rats and mice during gestation by oral intubation at dosages up to 1,030 mg/kg/day. Developmental toxicity did not occur after pregnant rats were given up to 5% sodium erythorbate in feed during a 13-week teratogenesis study. It produced negative results in the Ames test, the host-mediated assay using <i>S. typhimurium</i>, chromosomal aberration tests using Chinese hamster ovary fibroblasts, the dominant lethal test using rats, and the <i>B. subtilis</i> rec assay.										
Acute Toxicity	Sodium erythorbate powder was applied to the intact and abraded skin of six rabbits as a single 2 g/kg dose. A substantial amount of residual compound was observed 24 hours after dosing. No erythema, edema, or other signs of dermal irritation were observed at five of six test sites. One rabbit (abraded skin) had slight (1+) erythema at 24 hours that cleared by 48 hours.										
Irritation	Sodium erythorbate powder did not cause signs of dermal irritation when applied to the intact and abraded skin of rabbits. Instillation of sodium erythorbate powder to the conjunctival sac of rabbits caused slight and transient reddening of the conjunctiva that cleared within 24 hours.										
Sensitisation	In a dermal sensitization study (according to OECD 429) with Sodium erythorbate (5, 10, 25% w/w in propylene glycol), young adult female CBA/Ca (CBA/CaOlaHsd) mice (4/group) were tested using the local lymph node assay (LLNA). In this study, Sodium erythorbate was not considered a potential skin sensitizer.										
Health Effects Summary	Sodium erythorbate did not show signs of toxicity, carcinogenicity, mutagenicity, irritation and sensitisation in the studies reported. This chemical has been identified by NICNAS to be of low concern to human health.										
Key Study/Critical Effect for Screening Criteria	The Australian drinking water guideline value for sodium may apply.										
Ecological Toxicity ⁴											
Aquatic Toxicity	The acute toxicity of sodium erythorbate to Algae was 1020 mg/L										
Determination of PNEC aquatic	A PNECaquatic of 10.2 mg/L was calculated using an assessment factor of 100.										
Current Regulatory Controls ⁴											
Listed as a Chemical of Concern on International Databases	<table><tr><th>International Database</th><th>Listed?</th></tr><tr><td>European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table</td><td>No</td></tr><tr><td>International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications</td><td>No</td></tr><tr><td>National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html</td><td>No</td></tr><tr><td>US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2</td><td>No</td></tr></table>	International Database	Listed?	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2	No
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	Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIICChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	No data available.	
Australian Occupational Exposure Standards	No data available.	
International Occupational Exposure Standards	No data available.	
Australian Food Standards	No data available.	
Australian Drinking Water Guidelines	No data available.	
Aquatic Toxicity Guidelines	No data available.	
PBT Assessment		
P/vP Criteria fulfilled?	No. The chemical readily biodegradable (based on modelled data).	
B/vB criteria fulfilled?	No. The Log Pow is -3.29 (Log Pow < 4.5) which does not meet the screening criteria for bioaccumulation.	
T criteria fulfilled?	No. Based on measured acute toxicity endpoints of greater than 1 mg/L Sodium erythorbate does not meet the screening criteria for toxicity.	
Overall conclusion	Not PBT	

References

1. HSDB (n.d.). *Hazardous Substances Data Bank*. Retrieved 2015, from Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>
2. ECHA REACH, 2,3-didehydro-3-O-sodio-D-erythro-hexono-1,4-lactone, Retrieved 2019: <https://echa.europa.eu/>
3. Department of the Environment and Energy 2017, National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme
4. National Industrial Chemicals Notification and Assessment Scheme (NICNAS, 2017). National assessment of chemicals associated with coal seam gas extraction in Australia. Human health hazards of chemicals associated with coal seam gas extraction in Australia.

Toxicity Summary - Didecyl dimethyl ammonium chloride

Chemical and Physical Properties ^{1,2,3}	
CAS number	7173-51-5
Molecular formula	C ₂₂ H ₄₈ NCl
Molecular weight	362.08 g/mol
Solubility in water	0.39 g/L at 25 °C
Density	0.87 to 0.902 kg/L at 20 °C
Melting point	94 °C
Boiling point	No boiling point at atmospheric pressure (1013 hPa). It decomposes before boiling at a temperature of >180 °C.
Vapour pressure	6.0 x 10 ⁻⁶ kPa at 25 °C
Henry's law constant	8.5 x 10 ⁻⁷ Pa m ³ /mol
Explosive potential	Non-explosive
Flammability potential	Flammable
Colour/Form	Solid powder/particulate of white or slight yellowish colour with a moderate mushroom-like odour.
Overview	This chemical is categorised as a cationic quaternary ammonium surfactant with reported cosmetic use, home maintenance use, and industrial use. Industrially it is used in oil and gas field drilling and production operations; paper industry processing; in washing, cleaning and disinfecting products; and for water treatment. It is also used in consumer cleaning and washing products as well as biocides. The main route of public exposure is expected to be through the skin and eyes, inhalation from products applied as cosmetics and from using domestic products.
Environmental Fate ²	
Soil/Water/Air	If discharged into natural waters, the chemical is expected to dissociate and release its quaternary ammonium cations, which can adsorb to clays and natural organic materials, such as humic substances and remain in soil. It is not expected to undergo long-range transport based on low volatility its biodegradability in the environment. This chemical has low to moderate bioaccumulation potential in aquatic organisms. Reported bioconcentration factor (BCF) in the fish <i>Cyprinus carpio</i> is 63 L/kg at a test concentration of 0.005 mg/L and in the range of 47 to 95 L/kg at a test concentration of 0.0005 mg/L.
Human Health Toxicity Summary ^{1,3,4,5}	
Chronic Repeated Dose Toxicity	In a repeated dose oral toxicity study, didecyl dimethyl ammonium chloride (CAS No. 7173-51-5) was administered to rats (10/sex/dose) in the diet at 0, 6.2, 18.5, 36.8, 60.7 and 175.4 mg/kg bw/day for males and 0, 7.5, 22.3, 44.4, 74.3 and 225.5 mg/kg bw/day for females for 13 weeks. High-dose animals showed increased mortality; decreased mean body weights, body weight gain, and food consumption; and increased incidence of gross pathological observations and non-neoplastic lesions, including higher incidence of glycogen depletion in the liver and contracted spleens. Sinus erythrocytosis and lymphoid hyperplasia of mesenteric lymph nodes were also noted in high-dose females. The NOAEL was established as 60.7 mg/kg bw/day and 74.3 mg/kg bw/day in males and females, respectively, based on increased mortality and effects on body weights, liver and spleen at the next highest dose. In another combined chronic toxicity/carcinogenicity study, didecyl dimethyl ammonium chloride (CAS No. 7173-51-5) was administered to SD rats (60/sex/dose) in the diet at approximately 0, 13, 32 or 64 mg/kg bw/day for males and 0, 16, 41 or 83 mg/kg bw/day for females for two years (see Carcinogenicity). Treatment-related effects in the high-dose

	animals included decreased mean body weight, increased incidence of sinusoidal blood, haemosiderosis, and histiocytosis in the mesenteric lymph nodes (US EPA, 2008). In a repeated dose oral toxicity study, didecyl dimethyl ammonium chloride (CAS No. 7173-51-5) was administered to CD-1 mice (60/sex/dose) in the diet at 0, 100, 500 or 1000 ppm (approximately 0, 15.0, 76.3 or 155.5 mg/kg bw day for males and 0, 18.6, 93.1 or 193.1 mg/kg bw/day for females) for 78 weeks. Decreased mean body weights and body weight gains were the only treatment-related effects noted at the highest tested dose. The NOAEL was established as 76.3/93.1 mg/kg bw/day for males/females (US EPA, 2008). In a chronic, 1-year toxicity study (Schulze, G 1991), males and female beagle dogs were administered DDAC (80.8% a.i.) at dosage levels of 0, 3, 10 and 20/30 mg/kg/day (dosing at 30 mg/kg/day was not tolerated well and was discontinued on day 31; dosing was resumed at day 36 at 20mg/kg/day). No treatment-related deaths occurred during the study. The treatment-related clinical signs (soft/mucoid feces, emesis) were observed frequently in high-dose animals. Hematology or urinalysis results were normal. Total cholesterol levels were significantly decreased in high-dose females. Gross and histopathological findings did not reveal any treatment-related effects. Based on increased incidence of clinical observations (emesis and soft/mucoid feces) in males and females and decreased total cholesterol levels in females, the NOAEL for both male and females is 10 mg/kg/day, and the LOAEL is 20 mg/kg/day (USEPA 2017).
Carcinogenicity	The chemical is not likely to be a carcinogen. When administered to SD rats (60/sex/dose) in the diet at up to 64 mg/kg bw/day for males and 83 mg/kg bw/day for females for two years in a combined chronic toxicity/carcinogenicity study, there was no evidence of carcinogenicity even though the maximum tolerated dose was achieved in this study for carcinogenicity testing (based on a decrease in mean body weight and some histopathological changes). In a similar study, when administered to CD-1 mice (60/sex/dose) in the diet at up to 76.3 or 155.5 mg/kg bw/day for males and 193.1 mg/kg bw/day for females for 78 weeks, treatment-related mortality or clinical signs, and gross and histopathological abnormalities were not observed, and there was no evidence of carcinogenicity. Carcinogenicity was also not seen in another study where SD rats were fed this chemical at up to 55.4 mg/kg bw/day for males and 69.5 mg/kg bw/day for females for 104 weeks.
Mutagenicity/ Genotoxicity	This chemical was not mutagenic in bacterial reverse mutation assays and did not induce chromosomal aberrations in Chinese hamster ovary cells. Although data are limited for cationic quaternary ammonium surfactants, the available information indicates this chemical is not considered to have mutagenic or genotoxic potential.
Reproductive Toxicity / Developmental Toxicity/ Teratogenicity	This chemical is not considered to have specific reproductive and developmental toxicity; any reproductive and developmental effects were only observed secondary to maternal toxicity. When administered to pregnant New Zealand White rabbits (16/dose) in a developmental toxicity study by gavage at 0 - 10 mg/kg bw/day, maternal toxicity was evident at the mid and high doses. An increased maternal mortality was noted at 10 mg/kg bw/day. Developmental effects were noted at 10 mg/kg bw/day. The NOAEL for maternal toxicity was established as 1 mg/kg bw/day (based on decreased body weight gain, hypoactivity, laboured/audible respiration, and mortality) and the NOAEL for developmental toxicity was established as 3 mg/kg bw/day (based on increased mortality, decreased foetal body weight, and an increased number of dead foetuses). In another developmental toxicity study, when administered to pregnant SD rats (25/dose) by gavage at doses of 0, 1, 10 and 20 mg/kg bw/day, the NOAEL for maternal toxicity was established as 1 mg/kg bw/day (based on decreased body weight gain, low food efficiency, and audible respiration) and the NOAEL for developmental toxicity was established as 10 mg/kg bw/day (based on an increased incidence of skeletal variations at the next higher dose).
Acute Toxicity	<u>Oral</u> The chemical has moderate acute toxicity following oral exposure in animal tests. The reported oral median lethal dose (LD50) in rats was 238–262 mg/kg bw for didecyl dimethyl ammonium chloride (CAS No. 7173-51-5) <u>Dermal</u>

	The chemical is likely to have low to moderate acute dermal toxicity in animal tests. The reported dermal median lethal dose (LD50) in rats was >1000 mg/kg bw (undiluted) for didecyl dimethyl ammonium chloride (CAS No. 7173-51-5) (65 % purity).																		
Irritation	This chemical is considered to be corrosive to skin and eyes. No data are available on skin irritation in animals and. Although data on eye irritation is limited, the corrosive nature of this chemical affects the eyes.																		
Sensitisation	Based on limited information available on the skin sensitisation potential of this chemical, it is not likely to be a skin sensitiser.																		
Health Effects Summary	The results from the studies reveal a pattern of response (local irritation/corrosion followed by reduced food intake and reduction in body weight and body weight gain) that is consistent with the mode of action of a corrosive substance. Therefore, the systemic effects observed in these studies are regarded as secondary to the local irritation/corrosion caused by DDAC.																		
Key Study/Critical Effect for Screening Criteria	For the purpose of this risk assessment, the most NOAEL for risk assessment is 10 mg/kg bw/day based on the chronic oral toxicity study in dogs and using an uncertainty factor of 100 (10x inter-species extrapolation, 10x intra-species variation).																		
Ecological Toxicity ²																			
Aquatic Toxicity	Acute: Fish: 96 h LC50 = 0.19 mg/L, <i>Lepomis macrochirus</i> (Bluegill) Invertebrates: 48 h LC50 = 0.018 mg/L, <i>Daphnia magna</i> Algae: 96 h EC50 = 0.014 mg/L, <i>Pseudokirchneriella subcapitata</i> (Green algae) Chronic: Invertebrates: 21 d NOEC = 0.125 mg/L, <i>Daphnia magna</i> Algae: 72 h NOEC = 0.06 mg/L, <i>Pseudokirchneriella subcapitata</i> (Green algae)																		
Determination of PNEC aquatic	The calculated PNEC for di-alkyl quaternary ammonium compounds with C₁₀ alkyl chains is 2.8 µg/L based on a 96 h EC50 of 0.014 mg/L for algae. The laboratory endpoint value for algae was divided by an assessment factor of 100 to account for interspecies variation and the use of acute toxicity endpoint values, and the derived value was then multiplied by a factor of 20 to account for the 5% bioavailable fraction in environmental waters.																		
Current Regulatory Controls																			
Listed as a Chemical of Concern on International Databases	<table> <tr> <th>International Database</th><th>Listed?</th></tr> <tr> <td>European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table</td><td>No</td></tr> <tr> <td>International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications</td><td>No</td></tr> <tr> <td>National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html</td><td>No</td></tr> <tr> <td>US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris</td><td>No</td></tr> <tr> <td>United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and</td><td>No</td></tr> <tr> <td>Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18</td><td>No</td></tr> <tr> <td>Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol</td><td>No</td></tr> <tr> <td>Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals</td><td>No</td></tr> </table>	International Database	Listed?	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No	Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol	No	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
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Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No																		
Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol	No																		
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	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	This chemical is classified as hazardous in Safe Work Australia HCIS. - Hazard categories include: - Acute toxicity – Category 4 - Skin corrosion – Category 1B - Hazard statements include: - H302 (Harmful if swallowed) - H312 (Harmful in contact with skin) - H314 (Causes severe skin burns and eye damage)	
Australian Occupational Exposure Standards	No Australian occupational exposure standards are provided by Safe Work Australia HCIS for this chemical.	
International Occupational Exposure Standards	No exposure standards provided in NIOSH.	
Australian Food Standards	No Australian food standards were identified in FSANZ	
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified in the National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines (NHMRC, 2022).	
Aquatic Toxicity Guidelines	No Australian guidelines available.	
PBT Assessment ²		
P/vP Criteria fulfilled?	No. Based on biodegradation studies, this chemical is categorised as Not Persistent.	
B/vB criteria fulfilled?	No. Based on the available measured bioconcentration data, all chemicals in this group are categorised as Not Bioaccumulative.	
T criteria fulfilled?	Yes. Based on available acute ecotoxicity values below 1 mg/L and/or chronic ecotoxicity values below 0.1 mg/L, this chemical is categorised as Toxic.	
Overall conclusion	Overall, this chemical is not considered to be a PBT substance.	

Notes: HCIS – Hazardous Chemical Information System; NIOSH – National Institute for Occupational Safety and Health; FSANZ – Food Standards Australia New Zealand; NHMRC (2022) – National Health and Medical research Council, Australian Drinking Water Guidelines 6, 2011 (Version 3.8, Updated September 2022)

References

- AICIS (2015) Cationic surfactants: Human health Tier II assessment
- AICIS (2016) Mono- and di-alkyl quaternary ammonium surfactants: Environment Tier II assessment
- ECHA, <https://echa.europa.eu/registration-dossier/-/registered-dossier/5864>
- USEPA (2006) Reregistration Eligibility Decision for Aliphatic Alkyl Quaternaries (DDAC), August 2006
- USEPA (2017) Didecyl Dimethyl Ammonium Chloride (DDAC) Final Work Plan, March 2017

Toxicity Summary - Hydrochloric acid

Chemical and Physical Properties ^{1,2,3,4}	
CAS number	7647-01-0
Molecular formula	HCl
Molecular weight	36.46 g/mol
Solubility in water	Soluble
Melting point	-114.22 °C
Boiling point	-85.05°C
Vapour pressure	35,424 mm Hg at 25 deg C
Henry's law constant	2.04 x10 ⁶ mol/L atm
Explosive potential	Reacts with most metals producing explosive hydrogen gas
Flammability potential	Not combustible
Colour/Form	Liquid
Overview	Hydrochloric acid has demonstrated acute oral toxicity, corrosive effects to the skin and eye, and irritant effects to the respiratory system. Following absorption, the chemical dissociates rapidly into hydrogen ions (protons) and chloride ions, which are both normal, homeostatically regulated components of the human body. Hydrochloric acid is a direct acting corrosive and irritant and adverse effects are caused at the site of contact by deposition of protons (causing pH change) rather than effects of the chloride ion. Exposure by inhalation, dermal or oral route at high concentrations has therefore been considered as inappropriate. If released to water, hydrogen chloride dissociates readily in water to chloride and hydronium ions, decreasing the pH of the water. Hydrochloric acid is one of the most widely used industrial chemicals. Uses include pickling and cleaning metals, food process, and cleaning of industrial equipment.
Environmental Fate ^{5,6}	
Soil/Water/Air	Hydrochloric acid is readily dissociated in water into hydrated protons and chloride ions. The increase in the concentration of hydrochloric acid in water decreases the pH in the aquatic ecosystem. Generally, the buffer capacity to maintain the pH in the aquatic ecosystem is important and the equilibrium between CO₂, HCO₃⁻ and CO₃²⁻ in the aquatic ecosystem is mainly responsible for the buffer capacity of receiving water.

Human Health Toxicity Summary ^{1,2,3,4,9}	
Chronic Repeated Dose Toxicity	In a repeated dose study (non-guideline), rats were fed diets containing the chemical at 312, 625, 937 or 1250 millimoles/kg diet (180, 349, 366 or 466 mg/animal/day) for nine weeks. Water intake was high in all treatment groups. A no observed adverse effect level (NOAEL) of 625 mmol/kg diet (349 mg/kg bw) was determined based on mortalities (100 %) at 937 mmol/kg diet and above. The other effects reported include decreased body weight and food consumption, changes to blood pH and femur length at 937 mmol/kg diet and above (OECD, 2005). Based on the available data, the chemical is not considered to cause serious damage to health from repeated inhalation exposure. However, local irritation effects are expected due to the corrosivity of the chemical. Studies reporting exposure to hydrogen chloride gas are available. Rats and mice were exposed to the chemical gas (equivalent to OECD TG 413) at concentrations of 0, 10, 20 or 50 ppm (0, 15, 30 or 75 mg/m³), six hours/day, five days/week for 90 days. Mice showed decreased body weight gain, food consumption and liver weight (in males only) at 50 ppm. Decreased body weight gain was observed in male rats at 50 ppm and food consumption was reduced in both sexes at 20 and 50 ppm. Inflammatory histopathological changes in lips or the nasal cavity were observed in mice and rats above 10 ppm. The no observed adverse effect concentration (NOAEC) for systemic toxicity was determined to be 20 ppm for rats and mice based on the reduction in body weight gain and liver weight (in male mice) (OECD, 2005).
Carcinogenicity	HCl is not classifiable as a human carcinogen. No evidence of treatment related carcinogenicity was observed either in other animal studies performed by inhalation, oral or dermal administration. In three industry-based human case studies conducted in the U.S, no association between hydrogen chloride exposure and cancers of the lung, brain, or kidney was observed. In one U.S study of steel-pickling workers an excess risk for cancer of the lung was identified in workers exposed primarily to hydrochloric acid. Under IARC definitions, HCl is not classifiable as to its carcinogenicity to humans (Group 3).
Mutagenicity/ Genotoxicity	In single studies, HCl induced mutation and chromosomal aberrations in mammalian cells and induced chromosomal aberrations in insects and in plants. It did not induce mutation in bacteria. For genetic toxicity, a negative result has been shown in the Ames test. A positive result, which is considered to be an artefact due to the low pH, has been obtained in a chromosome aberration test using Hamster ovary cells. The effects of low pH in in vitro studies are not a problem in vivo as the proton level is regulated systemically. Hydrochloric acid is not considered to be genotoxic.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	No reliable studies have been reported regarding toxicity to reproduction and development in animals after oral, dermal or inhalation exposure to hydrogen chloride/hydrochloric acid. As protons and chloride ions are normal constituents in the body fluid of animal species, low concentrations of hydrogen chloride gas/mist or solution do not seem to cause adverse effects to animals. The cells of gastric glands secrete hydrochloric acid into the cavity of the stomach. No reliable conclusion could be drawn on the potential reproductive toxicity of hydrogen chloride/hydrochloric acid.

Acute Toxicity	Rapid evaporation of the liquid may cause frostbite. The substance is corrosive to the eyes, the skin and the respiratory tract and can cause serious skin burns and blurred/reduced vision or blindness. Inhalation of high concentrations of the gas may cause pneumonitis and lung oedema, resulting in reactive airways dysfunction syndrome. The effects may be delayed. Exposure to hydrochloric acid can produce burns on the skin and mucous membranes, with severity related to the concentration of the solution. Subsequent ulceration may occur, followed by keloid and retractile scarring. Dental decay, including yellowing, softening and breaking of teeth, and related digestive diseases have been recorded after exposures to hydrochloric acid. Mortality has been observed following ingestion of hydrochloric acid. Female rats orally administered 3.3% hydrochloric acid yielded an acute oral median lethal dose (LD50) in a range from 238 to 277 mg/kg bw (Hoechst 1966). No details of the study were available. In another study in rats, administration of a solution of undisclosed concentration induced stomach ulceration, inflammation of the intestine, discolouration of the liver and hyperaemia of the lung (Monsanto 1976). An LD50 of 700 mg/kg bw was reported. An acute dermal LD50 was established as >5010 mg/kg bw in rabbits however the dose levels administered were not reported (Monsanto 1976). Acute median lethal concentration (LC50) values of 8.3 mg/L and 3.2 mg/L were observed in rats and mice respectively after a 30 minute inhalation exposure to aerosolised hydrochloric acid (Darmer et al. 1974).
Irritation	In a skin irritation test in rabbits performed according to OECD TG 404, 37% hydrochloric acid (0.5 mL) was applied by both semi-occlusion and occlusion (Potokar 1985). The chemical was found to be corrosive under both conditions after one hour exposure. Concentrations >17% also caused corrosion in rabbits. Concentrations >3.3% caused skin irritation to rabbits after application for 5 days. Hydrochloric acid caused mild to severe eye irritation in animal studies. There were no data available for respiratory irritation however; inhalation of hydrochloric acid vapours is expected to cause irritation. In humans, the chemical was determined to be 'irritating to skin' (York et al. 1996).
Sensitisation	May cause dermatitis with frequent contact of aqueous solutions of hydrochloric acid.
Health Effects Summary	Hydrochloric acid has demonstrated acute oral toxicity, corrosive effects to the skin and eye, and irritant effects to the respiratory system. Hydrochloric acid is not a skin sensitizer based on the available studies. Only limited information on the repeated oral toxicity of hydrochloric acid is available. However, as the component ions are normal constituents of the human body (particularly the stomach), only localised effects are expected. No systemic effects from repeated exposures are expected. The chemical is not genotoxic. No evidence of treatment-related carcinogenicity was observed in animal studies performed by inhalation or dermal administration. In humans, no association between hydrogen chloride exposure and tumour incidence was observed. No reliable studies were identified regarding specific toxicity to reproduction and development in animals after exposure to hydrochloric acid/hydrogen chloride. Because protons and chloride ions are normal constituents in the body fluids, low concentrations of hydrochloric acid/hydrogen chloride would not be expected to cause adverse reproductive effects to animals. This conclusion is supported by the 90-day inhalation study of hydrogen chloride where no effects on the gonads of rodents were observed.

Key Study/Critical Effect for Screening Criteria	The Australian drinking water guideline value for pH may apply to hydrochloric acid. The critical health effects for risk characterisation include: - local effects (corrosivity); and - systemic acute effect (acute toxicity by the inhalation route of exposure). The critical health effects are different for gaseous hydrogen chloride, for which respiratory irritation and corrosion are critical, and aqueous solutions (hydrochloric acid) where dermal corrosion is the key effect. Due to corrosive nature of the chemical, even low concentrations of the chemical will also cause irritation to the eyes, skin and the respiratory tract.	
Ecological Toxicity ^{1,3,4,8}		
Aquatic Toxicity	The measured acute endpoint for: Algae = 0.492 mg/L Daphnia = 0.492 mg/L Fish = 4.92 mg/L The measured chronic endpoint for Daphnia is 62 mg/L	
Determination of PNEC aquatic	On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported Chronic endpoint of 62 mg/L for Daphnia. The PNECaquatic is 6.2 mg/L.	
Current Regulatory Controls ^{1,2,9}		
Listed as a Chemical of Concern on International Databases	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No
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	Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	Skin corrosion – category 1B; H314 (Causes severe skin burns and eye damage) STOT SE 3; H335 (May cause respiratory irritation)	
Australian Occupational Exposure Standards	There are no specific exposure standards for hydrochloric acid. However, the permissible exposure limits for hydrogen chloride gas apply (Safe Work Australia 2013): Time Weighted Average (TWA) of 7.5 mg/m ³ (5 ppm).	
International Occupational Exposure Standards	The following exposure standards were identified for hydrogen chloride (Galleria Chemical 2013). TWA: 7 to 8 mg/m ³ (5 ppm) [Austria, Belgium, Denmark, EU, Hungary, Japan, Korea, Mexico, The Netherlands, New Zealand, Norway, Sweden, Turkey] 2 to 5 mg/m ³ (1-2 ppm) [Germany, Poland, Switzerland, UK]. Short Term Exposure Limit (STEL): 15 mg/m ³ (10 ppm) [Austria, Belgium, EU, Hungary]	

Australian Food Standards	Hydrochloric acid is an additive permitted in accordance with Good Manufacturing Practice (GMP) in processed foods specified in Schedule 1 of the Australia New Zealand Food Standards Code – Standard 1.3.1 – Food Additives (Food Standards Australia New Zealand 2013).
Australian Drinking Water Guidelines	Hydrochloric acid is listed as an endorsed drinking water treatment chemical in the Australian Drinking Water Guidelines (National Health and Medical Research Council (NHMRC) 2011).
Aquatic Toxicity Guidelines	No data found
PBT Assessment	
P/vP Criteria fulfilled?	Hydrochloric acid is an organic salt that dissociates completely to hydrogen and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both hydrogen and chloride ions are also ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.
B/vB criteria fulfilled?	Hydrogen and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, hydrochloric acid is not expected to bioaccumulate.
T criteria fulfilled?	No chronic toxicity data exist on hydrochloric acid; however, the acute EC(L)50s are >0.1 mg/L in fish, invertebrates and algae. Thus, hydrochloric acid does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT. NICNAS concluded that this chemical poses no unreasonable risk to the environment based on Tier I assessment under the NICNAS IMAP assessment framework.

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier II Assessment for Hydrochloric acid: Retrieved 2020: <https://www.nicnas.gov.au>
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3. U.S. National Library of Medicine, Toxicology Data Network HSDB (Hazardous Substances Data Bank) <http://toxnet.nlm.nih.gov/>
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8. OECD (2002). Screening Information Dataset (SIDS) Initial Assessment Report for Hydrogen chloride (CAS No. 7647-01-0), UNEP Publications.
9. Safe Work Australia Workplace Exposure Standards for Airborne Contaminants, 2013.
10. Department of the Environment and Energy 2017, National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

Toxicity Summary - Sodium chloride

Chemical and Physical Properties ^{1,4}	
CAS number	7647-14-5
Molecular formula	NaCl
Molecular weight	58.44 g/mol
Solubility in water	3.57 x 10 ⁵ g/m ³ at 25°C
pH	In aqueous solution is neutral
Melting point	1 mm Hg at 865°C
Boiling point	1670 °C
Vapour pressure	No data found
Henry's law constant	No data found
Explosive potential	Not explosive
Flammability potential	Not flammable
Colour/Form	Light brown liquid or colourless crystals
Overview	Sodium, together with potassium is an essential mineral for the regulation of body fluid balance. Sodium is the most abundant cation in the extracellular fluid and sodium salts account for more than 90% of the osmotically active solute in the plasma and interstitial fluid. Consequently, sodium load is the major determinant of extracellular volume. Chloride is also important in maintaining the fluid balance and is an essential component of the gastric and intestinal secretions. Sodium chloride occurs naturally as rock salt which comprises 95% to 99% NaCl. It is also widely used in food products. The NHMRC has established dietary guidelines for the intake of sodium per day (adults should consume less than 2300 mg sodium per day). This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate ^{2,3}	
Soil/Water/Air	Due to its high solubility, sodium chloride is highly mobile in the environment. Once dissociated, chloride ions will migrate readily, however sodium ions will sorb to clay-rich materials limiting mobility. If released into the environment, sodium chloride is not likely to sorb to solid particles in the water column, is readily dissociated to form chloride and sodium ions, is not bioaccumulative in aquatic species or the food chain.

Human Health Toxicity Summary ^{2,3}	
Chronic Repeated Dose Toxicity	High sodium chloride intakes increase calcium excretion and may increase the risk of kidney stone formation. There is evidence for a causal relationship between the consumption of sodium (mainly from common salt) and both blood pressure and the age-related rise in blood pressure. Data suggest that 30% of a normotensive population may be salt sensitive. Sodium chloride has been demonstrated to be a gastric tumour promoter in experimental animals and high sodium chloride intakes have been associated with incidence of stomach cancer in human populations with traditional diets of highly concentrated, salted foods.
Carcinogenicity	Not listed with IARC.
Mutagenicity/ Genotoxicity	No data available.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	No data available.
Acute Toxicity	No data available.
Irritation	Although rare, acute toxicity may be caused by ingestion of 500 – 1000 mg sodium chloride/kg body weight. Symptoms include vomiting, ulceration of the gastrointestinal tract, muscle weakness and renal damage, leading to dehydration, metabolic acidosis and severe peripheral and central neural effects.
Sensitisation	No data available.
Health Effects Summary	This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Key Study/Critical Effect for Screening Criteria	The Australian drinking water guideline value for sodium and chloride may apply.
Ecological Toxicity ^{2,3,4}	
Aquatic Toxicity	A large number of studies are available in relation to the aquatic toxicity of sodium chloride with the USEPA ECOTOX database identifying 1712 records. The evaluation of ecological effects of sodium chloride has been evaluated in detail for the assessment of the use of rock salt in the US on roadways during the winter months. The following has been summarised from the US review: The presence of sodium chloride may result in the increased mobilisation of other contaminants (metals, nutrients etc) and a shift in the acid buffering capacity may compromise aquatic ecosystems. Most sensitive species are birds where a safe concentration of 1000 mg/L sodium chloride can be established. Salt tolerance of aquatic species varies significantly with EC50 concentrations ranging from 400 to 30000 mg/L. The measured acute endpoint for Fish was reported at 1290 mg/L. The measured NOEC for Daphnia is 314 mg/L. This chemical poses no unreasonable risk to the environment based on Tier I assessment under the NICNAS IMAP assessment framework. This inorganic substance comprising ions is of low ecotoxicological concern. This chemical is not expected to pose an unreasonable risk to the environment provided that ANZECC water quality guidelines for physical and chemical stressors are not exceeded.
Determination of PNEC aquatic	PNECaquatic: On the basis of the chronic results for Daphnia, an assessment factor of 100 has been applied to the lowest reported effect concentration of 314 mg/L. The PNECaquatic is determined to be 3.14 mg/L.
Current Regulatory Controls	

Listed as a Chemical of Concern on International Databases	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	No data available	
Australian Occupational Exposure Standards	No data available	
International Occupational Exposure Standards	No data available	
Australian Food Standards	No data available	
Australian Drinking Water Guidelines	No data available	
Aquatic Toxicity Guidelines	No data available	
PBT Assessment ⁴		
P/vP Criteria fulfilled?	Sodium chloride is an organic salt that dissociates completely to sodium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and chloride ions are also ubiquitous and are present in most water, soil and sediment. The persistent criteria is not considered applicable to this inorganic salt.	
B/vB criteria fulfilled?	Sodium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium chloride is not expected to bioaccumulate.	
T criteria fulfilled?	The measured chronic toxicity data for sodium chloride was 314 mg/L for Daphnia. Thus, sodium chloride does not meet the screening criteria for toxicity.	
Overall conclusion	Not PBT	

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1. HSDB (n.d.). *Hazardous Substances Data Bank*. Retrieved 2015, from Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>
2. UK 2003. Expert Group on Vitamins and Minerals, Risk Assessment - Sodium Chloride
3. US, 2007. Hazard Identification for Human and Ecological Effects of Sodium Chloride Rock Salt. Prepared by the New Hampshire Department of Environmental Services
4. Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

Diammonium Peroxidisulphate

Chemical and Physical Properties ²	
CAS number	7727-54-0
Molecular formula	H ₈ N ₂ O ₈ S ₂
Molecular weight	--
Solubility in water	228.2 g/mol
Melting point	Decomposition temperature 120 °C
Boiling point	Decomposes
Vapour pressure	No data available
Henry's law constant	No data available
Explosive potential	Not explosive.
Flammability potential	Not flammable.
Colour/Form	White granules
Overview	Ammonium persulfate is distributed into the water compartment in the ionic form of the ammonium cation and persulfate ion. The persulfate anion will readily hydrolyze (decompose) into sulfate ions. Diammonium peroxidisulphate is a widely used reagent in biochemistry and molecular biology for the preparation of polyacrylamide gels and is also used in hair bleach
Environmental Fate ^{1,4,5}	
Soil/Water/Air	The inorganic persulfates are soluble in water and their vapour pressures are negligible. Ammonium persulfate will be distributed into the water compartment in the ionic form of the ammonium cation and persulfate anion. Ammonium persulfate is expected to degrade in the environment mainly via hydrolysis, but metal catalyzed decomposition, and reactions with organic chemicals in the soil or water also are possible. Persulfates are not expected to adsorb to soil due to its dissociation properties, instability (hydrolysis) and high water solubility. Persulfates should behave as free ions or decompose into sulfate ions. In soils, upon decomposition, the cation could form more stable sulfate or bisulfate salts. Persulfates are not expected to bioaccumulate in the soil or in aqueous solution. They will decompose into inorganic sulfate or bisulfate
Human Health Toxicity Summary ^{1,3,4,5,6}	
Chronic Repeated Dose Toxicity	28-day repeated dose oral (dietary) toxicity studies in rats were conducted and the NOAELs for sodium and ammonium salts were 41 mg/kg bw/day and the top dose of 137 mg/kg bw/day, respectively (FMC Corporation 1979a, 1979c). A well-conducted 90-day inhalation study of ammonium persulfate revealed evidence of inflammation of the airways, reduced body weight gain, rales, increased respiratory rate and increased lung weights at the LOAEL of 25 mg/m³ (FMC 1998). A NOAEL of 5 mg/m³ was identified by the OECD (2005) based on sporadic rales and respiratory effects seen (in females only) at the NOAEL of 10.3 mg/m³. No long term dermal studies were available. In humans, pulmonary function tests conducted on employees of a persulfate production facility indicated no adverse effects on pulmonary function at workplace levels, measured at 0.5 mg/m³ (FMC Corporation 1992). Follow-up of these same employees indicated that exposure at 0.5 mg/m³ had no long-term effects on pulmonary function (Greaves 1997).
Carcinogenicity	NA - not listed on Chemical Carcinogenesis Research Information System (CCRIS) or International Agency for Research on Cancer (IARC) Databases, or documented by US EPA. In a non-guideline dermal study, female SENCAR mice were exposed twice weekly to 0.2 mL of a 200 mg/mL solution of ammonium persulfate for 51 weeks (Kurokawa et al. 1984). It was concluded that ammonium

	persulfate is neither a tumour promoter nor a complete carcinogen when applied to the skin.
Mutagenicity/ Genotoxicity	Ammonium persulfates are not genotoxic. Negative results for mutagenicity are available from Ames tests in <i>S. typhimurium</i> strains TA97 or TA102 (Ishidate 1984) for ammonium persulfate. Ammonium persulfate was not clastogenic to Chinese hamster fibroblasts in the absence of metabolic activation in a chromosome aberration test (Ishidate et al. 1988).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	In a developmental/reproduction study with ammonium persulfate in rats (OECD 421), no effects on reproductive performance, fertility, fetal anomalies, fetal viability, spermatogenesis, spermatogenic cycle were reported up to 250 mg/kg/day. Dose levels were chosen based on the acute lethality studies for the ammonium salt and on a 90-day repeat-dose study in rats with the sodium salt (high dose: 225 mg/kg/day). In the developmental/reproduction study, animals were dosed prior to and during mating through gestation until lactation day 4. There was a transient depression in pup body weight at the 250 mg/kg dose level on lactation day 0 which resolved by day 4. This effect was not considered adverse. Based on the available data, the persulfates do not show evidence of reproductive or developmental toxicity. The NOAEL is 250 mg/kg bw/day.
Acute Toxicity	The substance is irritating to the eyes, the skin and the respiratory tract. Inhalation of dust may cause asthma-like reactions. The ammonium salt gave no evidence of genotoxic activity in bacterial mutagenicity tests (including the Ames assay) or in tests for chromosomal damage with mammalian cells in culture. The acute oral LD50 for ammonium persulfate in rats is between 495 mg/kg bw to 700 mg/kg bw in females and from 600 mg/kg bw to 820 mg/kg bw in males. The acute dermal LD50s in rats and rabbits are >5,000 mg/kg. In acute inhalation studies in rats, the 4-hour LC50 was generally greater than the maximum attainable concentration (>2,950 mg/m ³ for ammonium persulfate).
Irritation	Ammonium persulfate is non-irritating to the skin in animal studies but may be slightly irritating to the eye of rabbits. There were no data available for respiratory irritation. Studies in humans indicate that aqueous solutions of 5% persulfate or higher can cause skin irritation.
Sensitisation	Results of animal skin sensitization tests (Buehler Test and Maximization Test) were negative when persulfate was applied topically, but was positive when persulfate was injected intradermally in induction and challenge phases in a non-standard Maximization Test. Ammonium persulfate at approximately 50 mg/m ³ for four hours induced airway hyper-responsiveness (AHR) (Mensing et al. 1995). Numerous dermal challenge tests indicate that all persulfates are dermal and respiratory sensitizers in humans occupationally exposed to persulfates in hairdressing salons and, in one case, in a production facility.
Health Effects Summary	Ammonium persulfate have low acute dermal and inhalation toxicity but are harmful by the oral route. The chemicals were non-irritating to slightly irritating to eyes and respiratory system and not a skin irritant in animal studies, whilst studies in humans indicate that the chemicals can cause irritation. The chemicals are capable of inducing skin and respiratory sensitisation in animals and these are also the major chronic effects observed in humans. The chemicals were not genotoxic or shown to cause tumour induction or promotion in a mouse skin model. Repeated oral exposures to ammonium persulfate provided evidence that persulfates are not reproductive or developmental toxicants. Overall, the main critical effects to human health are sensitisation and irritancy.
Key Study/Critical Effect for Screening Criteria	The most sensitive endpoint was effects on the respiratory system with a NOAEC of 10.3 mg/m ³ (equivalent to 2.1 mg/kg bw/day) in a 90-day inhalation study (FMC Corporation 1998). Local effects, including respiratory tract inflammation, increased lung weight and rales were observed in rats at the LOAEC of 25 mg/m ³ . Drinking water guideline value = 0.0819 ppm
Ecological Toxicity ⁶	

Aquatic Toxicity	Acute Aquatic – Invertebrate The measured endpoint value for Acute Daphnia magna is 92 mg/L.	
Determination of PNEC aquatic	An assessment factor of 100 has been applied the measured endpoint value for Acute Daphnia magna. The PNECaquatic is 0.92 mg/L.	
Current Regulatory Controls ⁶		
Listed as a Chemical of Concern on International Databases	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIICChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	Xn(Harmful); R22 (Harmful if swallowed) Xi (Irritant); R36/37/38 (Irritating to eyes, respiratory system and skin), R42/43 (May cause sensitisation by inhalation and skin contact).	
Australian Occupational Exposure Standards	Time Weighted Average (TWA) of 0.01 mg/m³.	
International Occupational Exposure Standards	Time Weighted Average (TWA): 0.1 mg/m³ (Belgium, Canada, Ireland, Italy, Portugal, Spain, US) 2 mg/m³ (Denmark, Iceland, Norway)	
Australian Food Standards	Ammonium persulfate is listed in Schedule 18–Processing Aids- S18.08 Permitted processing aids—Miscellaneous purposes (section 1.140): Yeast washing agent under GMP conditions (Food Standards Australia New Zealand 2013).	
Australian Drinking Water Guidelines	No data available	
Aquatic Toxicity Guidelines	No data available	
PBT Assessment		
P/vP Criteria fulfilled?	No. Not applicable, inorganic salt, ionic species ubiquitous in environment.	
B/vB criteria fulfilled?	No. Not applicable, inorganic salt, ionic species ubiquitous in environment.	
T criteria fulfilled?	No chronic toxicity data exist; however, the acute EC(L)50s are >0.1 mg/L in fish, invertebrates and algae. Thus does not meet the screening criteria for toxicity.	
Overall conclusion	Not PBT	

References

1. ECHA European Chemicals Agency, Registered Substance Database, Cellulase, <http://echa.europa.eu>
2. HSDB (n.d.). *Hazardous Substances Data Bank*. Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>
3. IPCS *Ammonium persulphate: Summary*, 2010. International Programme on Chemical Safety and the Commission of the European Communities (IPCS and CEC).
4. OECD IUCLID Data Set for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727-27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications, 2005.
5. OECD. Screening Information Dataset (SIDS) Initial Assessment Report for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727-27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications, 2005.
6. Department of the Environment and Energy 2017, National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

Toxicity Summary - Guar gum

Chemical and Physical Properties ^{1,2,7}	
CAS number	9000-30-0
Molecular formula	NA.
Molecular weight	220,000 g/mol
Solubility in water	Completely soluble in water
pH	No data were found.
Melting point	No data were found.
Boiling point	No data were found.
Vapour pressure	solid
Henry's law constant	NA
Explosive potential	NA
Flammability potential	NA
Colour/Form	NA
Overview	Guar gum is a yellowish-white free-flowing powder. It is completely soluble in water and practically insoluble in oils, greases, hydrocarbons, ketones and esters. Water solutions are tasteless, odourless and a pale, translucent grey colour and neutral. The powder has 5 to 8 times the thickening power of starch. Water solution may be converted to a gel by adding a small amount of borax and are stable to heat. Guar gum is extensively used, eg typically used as a protective colloid, stabilizer, thickening and film forming agent for cheese, salad dressing, milk products including ice cream and soups; disintegration agent in tablet formulations; in pharmaceutical jelly formulations; in suspension, emulsions, lotions, creams and toothpastes; in bulk laxatives and appetite depressants; in mining industry as a flocculent, for hydraulic fracturing aid in oil well recovery and as a filtering agent; gelling and waterproofing agent in explosive and in water treatment as a coagulant. Guar gum is approved for use as a food additive by the U.S. Food and Drug Administration and is on the list of substances "generally recognized as safe" (CFR 1974). This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate ¹	
Soil/Water/Air	No information was found. Guar gum, being a polysaccharide composed of galactomannan, would be expected to be readily biodegradable

Human Health Toxicity Summary ^{1,2,3,4,5,6}	
Chronic Repeated Dose Toxicity	F344 rats and B6C3F1 mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks (NTP, 1982). Mean body weights were decreased in male rats (100,000 ppm group) and in female mice (50,000 and 100,000 ppm). A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects. F344 rats and B6C3F1 mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). Mean body weights of the high-dose females were lower than those of the controls after week 20 for mice and week 40 for rats. No compound-related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls. There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related.
Carcinogenicity	F344 rats and B6C3F1 mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). There were increased incidences of adenomas of the pituitary in male rats and pheochromocytomas of the adrenal in female rats that were statistically significant, but these differences were considered to be unrelated to guar gum administration. When pituitary adenomas or carcinomas and when pheochromocytomas or malignant pheochromocytomas are combined, the statistical differences disappear. Hepatocellular carcinomas occurred in treated male mice at incidences that were significantly lower than that in controls. The combined incidence of male mice with either hepatocellular adenomas or carcinomas was also significantly lower in the highdose group. It was concluded that under conditions of this bioassay, guar gum was not carcinogenic for F344 rats or B6C3F1 mice.
Mutagenicity/ Genotoxicity	Guar gum induced no consistent responses in dominant lethal gene tests to suggest that it was mutagenic to the rat. Guar gum was not mutagenic to Salmonella typhimurium TA 1530 or G-46 when tested without metabolic activation; however, it was mutagenic to Saccharomyces cerevisiae D- 3 (Green, 1977). Guar gum also was reported to cause chromosomal aberrations in human embryonic lung cells WI-38 (Green, 1977). No in vivo genotoxicity studies have been conducted on guar gum.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	The developmental effects of guar gum were evaluated in groups of 20 rabbits by daily dermal administration of the test substance for 6 hours/day at dose levels of 0, 2, 10 and 50 mg/kg/day on days 6 through 18 of gestation. The number of early resorptions was significantly increased and the number of viable foetuses was correspondingly decreased at 50 mg/kg/day ($p<0.05$). The NOEL was 2 mg/kg/day. The frequency of foetal malformations and variations in the treated groups was comparable to that of the control group at all dose levels. Female rabbits were given daily (6 hours/day) dermal administration of 0, 2, 10 and 50 mg/kg guar gum during gestational days 6 through 18 (IRDC, 1988). Mortalities included 2 deaths at 50 mg/kg and 1 death at 10 mg/kg. A single animal was killed in extremis. A dose-related increase in dermal irritation (including erythema, edema, and desquamation) was observed in animals receiving 10 and 50 mg/kg. The number of early resorptions was significantly increased and the number of viable fetuses was correspondingly decreased at 50 mg/kg/day ($p<0.05$). The frequency of fetal malformations and variations in the treated groups was comparable to that of the control group at all dose levels. The NOEL for this study is 2 mg/kg/day.
Acute Toxicity	Guar gum has been blamed for causing esophageal obstruction. A death has the use of one guar gum tablet product, which apparently swelled in the esophagus, resulting in complications that caused the fatality. Mildly toxic by ingestion. The oral LD50 is 8,100 mg/kg for mice and 9,400 mg/kg for rats.
Irritation	No data were found.

Sensitisation	Occupational asthma has been reported in subjects of guar gum. A respiratory sensitizer There are reports of respiratory sensitization in workers exposed occupationally to guar gum dusts (Maio, 1986).																				
Health Effects Summary	This chemical has been identified by NICNAS to be of low concern to human health and it is listed by the US Food and Drug Administration (FDA) as a Generally Recognised as Safe (GRAS) substance.																				
Ecological Toxicity ^{1,7}																					
Aquatic Toxicity	Acute endpoint: Fish = 218 mg/L (measured)																				
Determination of PNEC aquatic	PNECaquatic: On the basis that the data consists of only one short-term result from one trophic level, an assessment factor of 1,000 has been applied to the reported effect concentration of 218 mg/L for Fish. The PNECaquatic is 0.218 mg/L.																				
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United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No																				
Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://www.cdc.gov/TSP/index.aspx?sysid=18	No																				
Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol	No																				
Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIICChemicals	No																				
Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No																				
Australian Hazard Classification	No data available																				
Australian Occupational Exposure Standards	No data available																				
International Occupational Exposure Standards	No data available																				
Australian Food Standards	No data available																				
Australian Drinking Water Guidelines	No data available																				
Aquatic Toxicity Guidelines	No data available																				
PBT Assessment ^{4,5}																					

P/vP Criteria fulfilled?	No biodegradation information was found on guar gum. However, guar gum is a naturally occurring polysaccharide which would be expected to readily biodegrade. Thus, it is not expected to meet the screening criteria for persistence
B/vB criteria fulfilled?	The molecular weight of guar gum ranges from 200,000 to 300,000 daltons, and it is also water soluble. Thus, guar gum is not expected to meet the criteria for bioaccumulation
T criteria fulfilled?	The acute aquatic toxicity of guar gum is >0.1 mg/L. Thus, guar gum is not expected to meet the screening criteria for toxicity
Overall conclusion	Not a PBT substance.

References

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4. International Research and Development Corp (1988). Teratology Study of Guar Gum in Rabbits. TSCATS database, EPA Doc. No. 88-920004924, Fiche No. OTS0542101; cited in NZ HSNO CCID. <http://www.epa.govt.nz/search-databases/Pages/cciddetails.aspx?SubstanceID=1930>
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7. Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

Toxicity Summary - Partially hydrolysed polyacrylamide

Chemical and Physical Properties ^{1,2,3,4}	
CAS number	9003-05-8
Molecular formula	(C ₃ H ₅ NO) _x
Molecular weight	1,000,000 to > 50,000,000 g/mol for polyacrylamide copolymers used as flocculants
Solubility in water	Water soluble
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henry's law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	No data available.
Overview	Polyacrylamide polymers can exist in cationic, anionic or non-ionic forms, depending on their ionic charge. The non-ionic form of polyacrylamide is generated from the basic polymerisation of acrylamide. Anionic polyacrylamide polymer can then be formed from the hydrolysis of the acrylamide homopolymer either simultaneously during the polymerisation process or as a subsequent step. Anionic polyacrylamide polymer can also be formed from the copolymerisation of acrylamide and acrylic acid. A Tier 1 Human Health and Environmental Assessment for this chemical has been conducted by NICNAS which concluded that it was low concern to human health and the environment and thus required no further assessment.
Environmental Fate ³	
Soil/Water/Air	No studies on the environmental fate of anionic polyacrylamide are available. As a high-molecular weight, water-soluble polymer, it is not expected to biodegrade or bioaccumulate. The environmental fate of anionic polyacrylamide will be determined primarily by adsorption. The polyanions in this group are expected to partition onto natural colloids in surface waters and in soil and are not expected to undergo long-range transport in the environment.
Human Health Toxicity Summary ^{1,2,4}	
Chronic Repeated Dose Toxicity	No data available.
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	No data available.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No data available.
Acute Toxicity	Mouse LD50 (oral): 12950 mg/kg Rabbit LD50 (oral): 11250 mg/kg Rat LD50 (oral): >1000 mg/kg
Irritation	No data available.
Sensitisation	No data available.
Health Effects Summary	Poses no unreasonable risk to human health based on Tier I assessment under the NICNAS IMAP assessment framework.

Key Study/Critical Effect for Screening Criteria	The oral acute toxicity in rats was considered the most sensitive endpoint with a LD50 of 1000 mg/kg.	
Ecological Toxicity ³		
Aquatic Toxicity	Fathead minnow LC50: 810 mg/L Rainbow trout LC50: > 100 mg/L Bluegill sunfish LC50: >300 mg/L Daphnia magna LC50: 470 mg/L	
Determination of PNEC aquatic	Anionic polyacrylamide has a low acute toxicity concern to aquatic organisms and thus required no further assessment.	
Current Regulatory Controls		
Listed as a Chemical of Concern on International Databases	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	No data available.	
Australian Occupational Exposure Standards	No data available.	
International Occupational Exposure Standards	No data available.	
Australian Food Standards	No data available.	
Australian Drinking Water Guidelines	No data available.	
Aquatic Toxicity Guidelines	No data available.	
PBT Assessment ³		
P/vP Criteria fulfilled?	Yes. Anionic polyacrylamide is a large molecular weight, water-soluble polymer. It is not expected to be readily biodegradable; thus, it meets the screening criteria for persistence.	

B/vB criteria fulfilled?	No. Pharmacokinetic studies showed that anionic polyacrylamide was not bioavailable to rats when ingested; this is most likely due to its large size (high molecular weight) and presumed resistance to break down in the gastrointestinal tract. Anionic polyacrylamide is thus not expected to be bioavailable to aquatic or terrestrial organisms. It is not expected to meet the criteria for bioaccumulation.
T criteria fulfilled?	No. The acute LC50 values in fish and invertebrates are >1 mg/L. Thus, it does not meet the criteria for toxicity.
Overall conclusion	Not PBT
Revised	February 2022

References

1. Department of the Environment and Energy 2017, National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme
2. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier 1 Assessment. Retrieved 2022: <https://www.industrialchemicals.gov.au/>.
3. EHS Support, Anionic Polyacrylamide. Available at: <https://www.santos.com/wp-content/uploads/2021/04/Anionic-Polyacrylamide-March-2021.pdf>. Retrieved February 2022.
4. ChemIDplus, Polyacrylamide, Retrieved February 2022: <https://chem.nlm.nih.gov/chemidplus/rn/9003-05-8>.
5. HCIS, Hazardous Chemical Information System, Safe Work Australia, Retrieved February 2022: <http://hcis.safeworkaustralia.gov.au/HazardousChemical>.
6. ILO, International Labour Organisation, International Chemical Safety Cards (ICSCs), Retrieved February 2022: http://www.ilo.org/dyn/icsc/showcard.listcards3?p_lang=en.

Toxicity Summary - Polyoxyethylene Nonylphenol Ether

Chemical and Physical Properties ^{1,2,3}	
CAS number	9016-45-9
Molecular formula	(C ₂ H ₄ O) _n C ₁₅ H ₂₄ O
Molecular weight	748.98
Solubility in water	153 g/L at 20 °C and pH 5.5
Melting point	Not applicable
Boiling point	295 - 320 °C
Vapour pressure	1.4 hPa @ 25 °C
Henry's law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	Liquid at 20°C and 1013 hPa
Overview	Nonylphenol ethoxylates (NPE) surfactants and are used in large quantities and have widespread domestic and industrial uses. The most significant industrial use for the chemicals in this group is as a detergent. They are also used as emulsifiers, wetting agents and dispersants.
Environmental Fate ¹	
Soil/Water/Air	The chemicals in this group are expected to undergo degradation in the environment. The biodegradation behaviour of the chemicals in this group depends on the environmental conditions (Patoczka and Pulliam, 1990). Recent studies on nonylphenol ethoxylate biotransformation pathways show that under aerobic conditions, nonylphenol ethoxylates undergo rapid primary biodegradation by shortening of the ethoxylate chain followed by oxidation of the terminal alcohol to form nonylphenol ethoxyacetates (Gu, et al., 2010). Under anaerobic conditions, shortening of the ethoxylate chain results in nonylphenols and shorter chain nonylphenol ethoxylate degradants (Lu, et al., 2009). The major degradants are nonylphenoxy acetates and nonylphenol mono-ethoxyacetates, nonylphenol mono- and di-ethoxylates, and to a lesser extent, nonylphenols (Coady, et al., 2010). Short chain nonylphenol ethoxylates are expected to partition between water and sediment, while longer chain nonylphenol ethoxylates are expected to remain in water when released from industrial uses. Long chain nonylphenol ethoxylates are expected to remain in water as they have high water solubility and low volatility (Nguyen, et al., 2004; Staples, et al., 2008).
Human Health Toxicity Summary ^{1,2,3}	
Chronic Repeated Dose Toxicity	Based on the available data, these chemicals are not considered to cause serious damage to health following repeated oral exposure.
Carcinogenicity	No studies on octylphenol ethoxylates (OPEs) are available. Based on the available data, NPEs are not considered to be carcinogenic.
Mutagenicity/ Genotoxicity	Based on the available in vitro genotoxicity data, NPEs and OPEs are not considered to be genotoxic. No in vivo genotoxicity data are available for NPEs.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	CAS Nos. 9016-45-9 is listed in the EC Endocrine Disruptors Priority List. Poly(oxy-1,2-ethanediyl), .alpha.-(nonylphenyl)-.omega.-hydroxy- (CAS No. 9016-45-9) is listed under Category 2, indicating at least some in vitro evidence of biological activity related to endocrine activity (EC, 2015). Studies are available only for NPE-9, NPE-10, NPE-30, OPE-9 and OPE-40. No data are available for the other chemicals in this group. The chemical NPE-9 is a known spermicide (CIR, 2015) and the studies available using NPE-9 have reported reproductive toxicity effects in rats from doses of 50 mg/kg bw/day, when administered intravaginally. However, oral studies in rats with NPE-9 showed reproductive and developmental effects only at a dose of 250 mg/kg bw/day. Based on the available data and considering the routes of exposure relevant for

	humans (excluding spermicide use), a conclusion on the reproductive and developmental toxicity of NPEs cannot be derived.
Acute Toxicity	For the chemical CAS No. 9016-45-9, the oral LD50 was reported to be 1310 mg/kg bw in rats (HSDB). The dermal LD50 for the chemical with CAS No. 9016-45-9 was reported to be 2000 mg/kg bw in rabbits (HSDB).
Irritation	Skin irritation studies in rabbits with some NPEs have shown moderate to severe irritation. The degree of irritation changes with the number of EO units (HSDB). In an eye irritation study of undiluted nonylphenol ethoxylate solution at a dose of 0.1 mL, nonylphenol ethoxylate solution was applied to the conjunctival sacs of New Zealand White rabbits and symptoms were observed. Nonylphenol ethoxylate with EO chain length of 2 to 15 induced moderate to severe irritation. Nonylphenol ethoxylate with EO chain length of 30 and more induced no irritation.
Sensitisation	A maximization study of nonylphenol ethoxylate sensitization was conducted in Hartley-Dalkin guinea pigs. A solution of 0, 1.7, 3, 9 and 27% (w/w) nonylphenol ethoxylate in propylene glycol and complete Freund's adjuvant (1:1) was injected into the shoulder at a dose of 0.1 mL. After 7 days, undiluted nonylphenol ethoxylate was applied and the application site was occluded for 48 hours for sensitization. After a 21-day interval without application, 2.7% nonylphenol ethoxylate, which induces no skin irritation, was applied and the application site was occluded for 24 hours to induce irritation, and 48 hours after, skin responses were observed. The positive response rates were 5/40, 2/5, 0/5, 1/4 and 2/5, respectively, and no significant differences were found among nonylphenol ethoxylate concentrations. From these results, it is concluded that nonylphenol ethoxylate causes no sensitization in guinea pig.
Health Effects Summary	The lowest no observed effect level (NOEL) was determined as 50 mg/kg bw/day based on reproductive and developmental effects (increased pre-implantation losses, skeletal anomalies in the litters) observed at doses ≥ 250 mg/kg bw/day
Key Study/Critical Effect for Screening Criteria	The critical health effects for risk characterisation are skin and eye irritation. The chemicals could also cause systemic acute effects from oral exposure. However, these health effects are applicable mainly for short chain length NPEs and OPEs and the effects could reduce with increasing chain lengths. The chemicals with EO chains ≥ 30 are reported to be generally non-toxic (CIR, 2015). While nonoxynol-9 is toxic to reproduction and this is expected to also apply to related NPEs, the effects appear to be specific to direct spermicidal use, which is not relevant to industrial uses of the chemicals. Reproductive and developmental effects were not observed with OPEs. Ethoxylated nonylphenol acrylate may be a potential skin sensitiser. The NPEs biodegrade to NPs in the environment and some products containing NPEs can also contain residual amounts of NPs. Therefore, critical health effects of NPs could also be applicable for risk characterisation under those situations, particularly following secondary exposure from environmental sources. This also applies to OPEs.
Ecological Toxicity^{1,2,3}	
Aquatic Toxicity	Acute: Fish: 96 h EC50 = 1.3 mg/L (<i>Lepomis macrochirus</i>) Invertebrates: 48 h LC50 = 1.821 mg/L (QSAR) Algae: 5 d EC50 = 37.4 mg/L (<i>Scenedesmus opoliensis</i>), Gallery worm: 48 h LC50 = 3.26 mg/L (<i>Capitella capitata</i>) Chronic: Fish: 21 d NOEC = 0.048 mg/L (<i>Oncorhynchus mykiss</i>) (read across from nonylphenol monoethoxylate) Invertebrates: 6 d NOEC = 1.0 mg/L (<i>Daphnia magna</i>) Algae: 96 h NOEC = 8.0 mg/L (<i>Pseudokirchneriella subcapitata</i>)
Determination of PNEC aquatic	Fish are the most sensitive taxon to toxic effects of the chemicals in this group, based on the available information. The PNEC _{aqua} derived for the most toxic chemical in this group, nonylphenol monoethoxylate, is 0.48 µg/L based on the 21 d NOEC of 0.048 mg/L for <i>Oncorhynchus mykiss</i> . The laboratory chronic toxicity value for this fish species was divided by an assessment factor of 100 to

	account for both interspecies variation and the relative lack of chronic aquatic toxicity data available for chemicals in this group.																				
Current Regulatory Controls⁴																					
Listed as a Chemical of Concern on International Databases	<table> <tr> <th>International Database</th><th>Listed?</th></tr> <tr> <td>European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table</td><td>Yes</td></tr> <tr> <td>International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications</td><td>No</td></tr> <tr> <td>National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html</td><td>No</td></tr> <tr> <td>US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris</td><td>No</td></tr> <tr> <td>United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and</td><td>No</td></tr> <tr> <td>Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18</td><td>No</td></tr> <tr> <td>Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol</td><td>No</td></tr> <tr> <td>Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIICChemicals</td><td>No</td></tr> <tr> <td>Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx</td><td>No</td></tr> </table>	International Database	Listed?	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	Yes	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No	Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol	No	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIICChemicals	No	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
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Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No																				
Australian Hazard Classification	Polyoxyethylene Nonylphenol Ether is listed in the Hazardous Chemical Information System (HCIS) (Safe Work Australia 2020) as hazardous substances. Acute toxicity – category 4 Skin irritation – category 2 Eye irritation – category 2A																				
Australian Occupational Exposure Standards	No specific exposure standards were available.																				
International Occupational Exposure Standards	No data available.																				
Australian Food Standards	No data available.																				
Australian Drinking Water Guidelines	No data available.																				
Aquatic Toxicity Guidelines	No data available.																				
PBT Assessment²																					
P/vP Criteria fulfilled?	No. It achieved 96% degradation in 30 days thus is expected to be readily biodegradable which does not meet the screening criteria for persistence.																				
B/vB criteria fulfilled?	No. The reported BCF for this chemical in the fish Cyprinus carpio after 42 days was less than 0.2 L/kg at a test concentration of 2 mg/L and less than 1.4 L/kg at a test concentration of 0.2 mg/L (NITE, 2014) which does not meet the screening criteria for bioaccumulation.																				
T criteria fulfilled?	No. Based on available acute ecotoxicity values above 1 mg/L and chronic ecotoxicity values above 0.1 mg/L, nonylphenol ethoxylate does not meet the screening criteria for toxicity.																				
Overall conclusion	Not PBT																				

References

1. NICNAS (2019) Human Health Tier II Assessment for Nonylphenol and octylphenol ethoxylates and related compounds
2. NICNAS (2006) Environment Tier II Assessment for Nonylphenol Ethoxylates and their Sulfate and Phosphate Esters
3. ECHA REACH, Nonylphenol, ethoxylated, Retrieved January 2020: <https://echa.europa.eu>
4. HCIS, Hazardous Chemical Information System, Safe Work Australia, Retrieved: <http://hcis.safeworkaustralia.gov.au/HazardousChemical>

Toxicity Summary - Boric acid/sodium tetraborate / boronatrocalcite

Chemical and Physical Properties ^{1,3,5,8}	
CAS number	Boric Acid: 10043-35-3 Sodium Tetraborate: 1330-43-4 Boronatrocalcite: 1319-33-1
Molecular formula	Boric acid: H_3BO_3 Sodium Tetraborate: $\text{Na}_2\text{B}_4\text{O}_7$ Boronatrocalcite: $\text{CaNaH}_{12}(\text{BO}_3)_5 \cdot 2\text{H}_2\text{O}$
Molecular weight	Boric acid: 61.833 g/mol Sodium Tetraborate: 201.220 g/mol Boronatrocalcite: 405.23 g/mol
Solubility in water	Boric acid: 49.20 g/l @ 20 ± 0.5 °C Sodium Tetraborate: 3.1% at 25 °C Boronatrocalcite: no data found
pH	Boric acid: 6.1 in a 0.1% (wt) solution Sodium Tetraborate: 9.3 at 20 °C (3% solution) Boronatrocalcite: no data found
Melting point	Boric Acid: 170.9 °C Sodium Tetraborate: 743 °C Boronatrocalcite: no data found
Boiling point	Boric Acid: 300 °C Sodium Tetraborate: 1,575 °C (decomposes) Boronatrocalcite: no data found
Vapour pressure	Boric acid: 9.9×10^{-6} Pa @ 25 °C Sodium Tetraborate: Negligible at 20 °C Boronatrocalcite: no data found
Henry's law constant	No data found
Explosive potential	Not explosive
Flammability potential	Not flammable
Colour/Form	Boric Acid: Colourless, transparent crystals or white granules or powder. Sodium Tetraborate: Colourless, monoclinic crystalline salt; also occurs as a white powder. Boronatrocalcite: Silky white rounded crystalline masses or parallel fibres.

Overview	Limited toxicity data is available for sodium tetraborate (Borax anhydrous) and boronatocalcite (Ulexite) as such; this toxicity profile includes data on boron and boric acid. Boric acid and borate salts exist naturally in rocks, soil, plants and water as forms of the naturally occurring element boron. Anhydrous Borax is a free flowing mixture of clear, glass-like particles and white granules formed by the crushing of relatively large masses of fused materials. Borax is a salt of boric acid. Borax occurs naturally in evaporite deposits produced by the repeated evaporation of seasonal lakes and has many applications in chemistry, mining and pharmaceuticals. Ulexite is a sodium-calcium-hydroborate and, like other borates, is a structurally complex mineral. It is composed of hydrogen (3.98 %), sodium (5.67 %), calcium (9.89 %), boron (13.34 %), and oxygen (67.12 %) There is a lack of data available in the literature to directly assess the toxicity of the chemical. The major component of the chemical is a borate ion, which is likely to be associated with human health hazards of the chemical. The other constituents are considered to be of low concern to human health (NICNAS, 2013). As the chemical will readily break down in the stomach pH to boric acid (H_3BO_3) following ingestion, the toxicokinetics and toxicity of the chemical will be driven predominantly by borate ions. Boron is a naturally occurring element that is found in the form of borates in the oceans, sedimentary rocks, coal, shale, and some soils. Boron is widely distributed in nature, with concentrations of about 10 mg/kg in the earth's crust (range 5 mg/kg in basalts to 100 mg/kg in shales) and about 4.5 mg/L in the ocean. Borates are used in glass, ceramics, detergents, wood treatment and insulation fiberglass industries. Boric acid and other borates are also used in a range of consumer products including cosmetic and personal care products and also in detergents. Moreover, borates are essential for all plants – their use as fertilizers increases crop yields (including grapes, potatoes, sugar beets, alfalfa and olives) and quality. Boron occurs in foods as borate and boric acid. Boron has not been established to be an essential nutrient for humans and no specific biochemical function for boron has been identified in higher animals or man. There is some evidence that, in humans, boron intake within the usual dietary range may influence the metabolism and utilisation of other nutrients, particularly calcium, and may have a beneficial effect on bone calcification and maintenance.
Environmental Fate^{2,4}	
Soil/Water/Air	These forms of boron are highly soluble and not easily removed from solution by natural mechanisms. Borate and boric acid are in equilibrium depending on the pH of the water. At an acidic pH, boron exists in solution mainly as undissociated boric acid, whereas at alkaline pH it is present as borate ions. Boric acid is a persistent molecule, mobile in soil and sediment, not subject to hydrolysis, photodegradation or biodegradation. Other borates yield boric acid upon dissolution in water (or borate anion in higher pH conditions).
Human Health Toxicity Summary^{2,3,4,8,9}	
Chronic Repeated Dose Toxicity	The haematological system and the testes have been identified as the major targets after oral repeat dose exposure to Boric acid. Studies after repeated dermal or inhalation exposure to boric acid are not available. A NOAEL for effects on testes and the blood system of 17.5 mg boron/kg bw/day can be derived (with a LOAEL of 58.5 mg boron/kg bw/day) from two 2-year studies in rats on boric acid. Results obtained with boric acid can be supported by findings obtained from other borates thus indicating that the boron ion is the toxicologically relevant species

Carcinogenicity	Boric acid is not listed as an IARC carcinogen. In long term feeding studies on boric acid and disodium tetraborate decahydrate in both rats and dogs, no carcinogenic effects were observed.
Mutagenicity/ Genotoxicity	Boric acid is not mutagenic either in vitro or in vivo.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	Results from animal experiments demonstrate that boric acid adversely effects fertility and development. Feeding studies in different animal species (rats, mice and dogs) have consistently demonstrated that the male reproductive system is the principle target in experimental animals, although effects on the female reproductive system have also been reported. Testicular damage ranging from mildly inhibited spermiation to complete atrophy has been demonstrated following oral administration of boric acid. Effects on fertility were observed at lower dose levels compared to dose levels, where signs of general toxicity appeared. Based on data from the two-year feeding studies with boric acid and borax in rats, 17.5 mg boron /kg bw/day (equivalent to 100 mg boric acid/kg bw/day)_ was derived as a NOAEL for male and female fertility. Developmental effects have been observed in three species, rats, mice and rabbits. The most sensitive species appears to be rats, in which the effects observed at non maternally toxic doses include a reduction in foetal body weight and minor skeletal variations which, with the exception of short rib XIII, had reversed by 21 days post-natal. The NOAEL for developmental effects is 9.6 mg boron/kg bw/day (55 mg boric acid/kg/day).
Acute Toxicity	Boric acid is of low acute toxicity. LD50 oral rat > 3765 mg/kg bw (659 mg boron/kg/bw); LD50 dermal rabbits > 2000 mg/kg bw/day; 4 hour LC50 inhalation rat ≥ 2.03 mg/L.
Irritation	In rabbits, boric acid caused no/mild skin irritation, induced reversible conjunctival redness and chemosis with minor effects on the iris. In rats and mice, boric acid acts as a sensory irritant. The substance may irritate the eyes, nasal mucous membranes, skin and the respiratory tract, and may cause effects on the gastrointestinal tract, liver and kidneys.
Sensitisation	No borate tested has displayed skin sensitisation in Bheuler studies. No evidence of skin sensitisation has been seen in humans exposed occupationally to sodium borates, or in a human patch test with a 3% aqueous boric acid solution.
Health Effects Summary	Borates are of low acute toxicity and low skin irritation potential. It may cause sensory irritant effects on animals and humans with acute exposure. Borates were shown not to be skin sensitisers, genotoxic or carcinogenic. Repeated exposures to boron as boric acid induced effects on fertility (testes), development and the blood system.
Key Study/Critical Effect for Screening Criteria	The critical lowest No Observed Adverse Effect (NOAEL) level for the purposes of risk assessment is 9.6 mg boron/kg bw/day. This NOAEL was the equivalent of 55 mg boric acid/kg bw/day; 38 mg disodium octaborate anhydrate/kg bw/day and 85 mg borax/kg bw/day), from feeding (dietary intake) studies based on developmental effects. Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability) Drinking water guideline for boron: 3.5 ppm
Ecological Toxicity ^{3,9}	
Aquatic Toxicity	The most sensitive tests report that acute effects on fish are in the range of 10-20 mg-B/L although the quality of these studies was rated low. The lowest daphnid acute value is 133 mg-B/L. Algal and microbial inhibition studies suggest less toxicity: Selenastrum growth was not affected at 93 mg-B/L and activated sludge respiration showed minimal effects at 683 mg/L boric acid (119 mg-B/L). Chronic endpoints for Boric acid were available for Daphnia (6 mg/L) and Fish (2.1 mg/L).
Determination of PNEC aquatic	Canadian Water Quality Guidelines for the Protection of Aquatic Life: Long-term Exposure to Boron is 1.5 mg/L (2009). An assessment factor of 100 has been applied to the lowest reported chronic effect concentration of 2.1 mg/L for Fish. The PNECaquatic is 0.021 mg/L.

Current Regulatory Controls ⁹		
Listed as a Chemical of Concern on International Databases	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	Yes
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dceew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIICChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	Toxic to reproduction (Repr.) Cat. 2; R60 (May impair fertility) (Safe Work Australia 2013) Repr. Cat. 2; R61 (May cause harm to the unborn child) (Safe Work Australia 2013)	
Australian Occupational Exposure Standards	There are no specific exposure standards for boric acid. However, the permissible exposure limits (as the time weighted average (TWA)) for dusts apply (10 mg/m ³ measured as inspirable dust) (Safe Work Australia 2013b).	
International Occupational Exposure Standards	Canada 2 mg/m ³ TWA, 6 mg/m ³ Short-term exposure limit (STEL) (borate compounds) Germany 10 mg/m ³ TWA; 1 mg/m ³ STEL Spain 10 mg/m ³ TWA (insoluble particles) US 2 mg/m ³ TWA; 6 mg/m ³ STEL (borate compounds), 5 mg/m ³ TWA (particulates, respirable fraction)	
Australian Food Standards	No data found.	
Australian Drinking Water Guidelines	No data found. However, boron in the environment is likely to be predominantly in the form of boric acid and that based on health considerations, the concentration of boron in drinking water should not exceed 4 mg/L (NHMRC 2011).	
Aquatic Toxicity Guidelines	For boron: 90 µg/L (ANZECC 2000 99% Freshwater)	
PBT Assessment ⁹		
P/vP Criteria fulfilled?	For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic substance.	
B/vB criteria fulfilled?	For the purposes of this PBT assessment, the bioaccumulation criteria is not considered applicable to this inorganic substance.	
T criteria fulfilled?	No. The chronic toxicity data is >1 mg/L.	
Overall conclusion	Not PBT	

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1. HSDB (n.d.). *Hazardous Substances Data Bank*. Retrieved 2015, from Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>
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3. Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: Boric Acid, 10043-35-3, 2005. <http://www.heraproject.com>
4. EFSA, Opinion of the Scientific Panel on Dietetic Products, Nutrition and Allergies on a request from the Commission related to the Tolerable Upper Intake Level of Boron (Sodium Borate and Boric Acid), 2004
5. Draft European Union Risk Assessment Report. Disodium tetraborate, Anhydrous Boric Acid, Boric Acid, Crude natural (1) Risk Assessment. 2007
6. IPCS Sodium Tetraborate, Retrieved 2016: <http://www.inchem.org>
7. EFSA, European Food Safety Authority, Scientific Opinion on the re-evaluation of boric acid (E284) and sodium tetraborate (borax) (E285) as food additives. 2013
8. NICNAS, National Industrial Chemicals Notification and Assessment Scheme, Human Health Tier II Assessment for Ulexite, CAS Number: 1319-33-1, 2015
9. Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

Toxicity Summary - Talc

Chemical and Physical Properties ^{1,4}	
CAS number	14807-96-6
Molecular formula	H ₂ O ₃ -Si 3/4Mg or Mg ₃ Si ₄ O ₁₀ (OH) ₂
Molecular weight	78.10 (estimate)
Solubility in water	Insoluble in water, cold acids or in alkalis
pH	9.0 to 9.5
Melting point	800-900°C (disintegration; WHO 2005)
Boiling point	549.7°C (estimate)
Vapour pressure	NA
Henry's law constant	NA
Explosive potential	NA
Flammability potential	Not flammable
Colour/Form	white to gray-white, fine crystalline powder.
Overview	Talc finely powdered hydrous magnesium silicate mineral sometimes found in association with asbestos. After being mined, it is processed to remove impurities and powdered. Talc is a useful commercial product due to its fragrance retention, luster, purity, softness, and whiteness as well as its chemical inertness and oil and grease adsorption. Talc is a mineral composed of hydrated magnesium silicate. Talc refers to both mineral talc and industrial mineral products that are marketed under the name talc and contain proportions of mineral talc that range from about 35% to almost 100%. Industrial talc generally refers to products that contain abundant minerals other than talc; cosmetic talc now normally contains >98% talc but the content may have been lower in the past. Pharmaceutical talc contains >99% talc. Talcum powder is cosmetic-grade talc. This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment. Further assessment of the environmental risks from the use of this chemical is also not required.
Environmental Fate ^{2,3}	
Soil/Water/Air	As a mineral, talc does not biodegrade

Human Health Toxicity Summary ^{1,2}	
Chronic Repeated Dose Toxicity Carcinogenicity	Talc-based body powder, when used perineally, is classified by IARC as group 2B as possibly carcinogenic to humans. However, talc for general use not containing asbestos or asbestiform fibres is classified as group 3 as not classifiable to its carcinogenicity to humans. Talc containing asbestiform fibres is classified by IARC as group 1 for carcinogenic to humans. Talc alone failed to induce respiratory tumors, granulomas or mesothelial proliferation in a hamster study but produced tumours of the larynx, trachea and lungs when tested in association with benzo(a)pyrene. In a rat study of aerosol talc there was some evidence of carcinogenic activity of talc in male F344/N rats and clear evidence of carcinogenic activity in female F344/N rats. No evidence of carcinogenicity was evident in intraperitoneal or inhalation studies in hamsters. Male and female Wistar rats were given in their diet 0 or 50 mg/kg of commercial talc [characteristics unspecified] for the life of the animals (average survival was 702 and 649 days, respectively). There was no significant difference in the talc-fed animals compared with control animals (Gibel <i>et al.</i> , 1976). In humans and experimental animals, the effects of talc are dependent on the route of exposure, and the dose and properties of the talc. Talc pneumoconiosis was somewhat more prevalent and severe among miners exposed to talc containing asbestiform minerals and/or asbestos than among those exposed to talc without such contaminants. However, the role of quartz and asbestos in the observed pneumoconiosis could not be ruled out. Among drug users, intravenous injection of talc present as a filler in the drugs resulted in microembolization in a variety of organs and alterations in pulmonary function. In animal studies, talc has been shown to cause granulomas and mild inflammation when inhaled. Observations of the effects that occurred in the lungs of rats exposed by inhalation to talc suggested that the operative mechanisms may be similar to those identified for carbon black, and talc is known to cause the release of cytokines, chemokines and growth factors from pleural mesothelial cells. IARC: There is <i>inadequate evidence</i> in humans for the carcinogenicity of inhaled talc not containing asbestos or asbestiform fibres. There is <i>limited evidence</i> in experimental animals for the carcinogenicity of talc not containing asbestos or asbestiform fibres. Inhaled talc not containing asbestos or asbestiform fibres is <i>not classifiable as to its carcinogenicity (Group 3)</i> .
Mutagenicity/ Genotoxicity	Talc was not mutagenic in host-mediated assays in mice. It did not produce chromosomal aberrations or dominant lethal mutations in rats. The IARC (1987) review of talc included unpublished results from a 1974 study conducted by Litton Bionetics that showed no mutagenic activity for talc <i>in vitro</i> or <i>in vivo</i> . Talc did not induce mutations in <i>Salmonella typhimurium</i> strains TA1530 or HisG46, or in the yeast, <i>Saccharomyces cerevisiae</i> . No chromosomal aberrations were observed in human fibroblasts treated with talc <i>in vitro</i> . <i>In vivo</i> tests conducted in rats gave negative results for induction of chromosomal aberrations in bone marrow cells and dominant lethal mutations in germinal cells
Reproductive Toxicity Developmental Toxicity/Teratogenicity	No teratological effects were observed in hamsters, rats, mice, or rabbits after oral administration of 900-1600 mg/kg. No teratologic effects were observed in hamsters, rats, mice, or rabbits after oral administration of talc. The doses used were 1,600 mg/kg for rats and mice on days 6 through 15 of gestation; 1,200 mg/kg for hamsters on day 6 through 10 of gestation; and 900 mg/kg for rabbits on days 6 through 18 of gestation
Acute Toxicity	Acute inhalation exposure to talc causes symptoms such as cough, dyspnea, sneezing, vomiting, and cyanosis. Other inhalation exposure symptoms include diffuse pleural thickening and fibrous adhesions of pleural surfaces. Respiratory distress syndrome has been reported in children after massive accidental inhalation of talcum powder. Animal (rat, dog, rabbit) studies showed internal accumulation of talc after short- and long-term inhalation exposure as well as numerous lung afflictions such as fibrosis and inflammation.
Irritation	In monkey eyes, talc in the anterior chamber has induced persistent glaucoma. Talc can induce severe granulomatous reactions when introduced into wounds. It has induced granulomas in and about the human eye when as a dusting powder for surgeons' gloves.

Sensitisation	Talc particles are smaller than 1 um and these particles are respirable and produce an intense inflammatory response characterized by cough, rhinitis, dyspnea, and vomiting.	
Health Effects Summary	This chemical has been identified by NICNAS to be of low concern to human health, and it is listed by the US Food and Drug Administration (FDA) as a Generally Recognised as Safe (GRAS) substance.	
Key Study/Critical Effect for Screening Criteria	There are no adequate studies for which to derive am oral reference dose. Talc is poorly absorbed from the gastrointestinal tract, if at all, and the limited data available by the oral route indicate that talc is essentially non-toxic by the oral route of exposure	
Ecological Toxicity 2,3,4		
Aquatic Toxicity	No data were found. Talc is expected to have low toxicity to the environmental based on its ubiquity in the environment, its low bioavailability, and its widespread use in consumer products (Zazenski et al. 1995). This chemical poses no unreasonable risk to the environment based on Tier I assessment under the NICNAS IMAP assessment framework. It is an inorganic substance with low toxicity and/or low bioavailability. It is of low concern to the environment.	
Determination of PNEC aquatic	PNEC values for talc cannot be calculated.	
Current Regulatory Controls		
Listed as a Chemical of Concern on International Databases	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	Yes*
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dccew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
* Only for Talc-based body powder, when used perineally		
Australian Hazard Classification	No data available	
Australian Occupational Exposure Standards	TWA: 2.5 mg/m³	
International Occupational Exposure Standards	NIOSH: TWA 2 mg/m³	

Australian Food Standards	No data available
Australian Drinking Water Guidelines	No data available
Aquatic Toxicity Guidelines	No data available
PBT Assessment ⁴	
P/vP Criteria fulfilled?	Talc does not biodegrade in the environment. It is a naturally-occurring mineral and is persistent in the environment. However, for the purposes of this PBT assessment, it does not meet the criteria for persistence.
B/vB criteria fulfilled?	Talc is not expected to be bioavailable to aquatic organisms; thus, it does not meet the criteria for bioaccumulation
T criteria fulfilled?	Talc is not expected to be bioavailable to aquatic organisms; thus, it does not meet the criteria for toxicity.
Overall conclusion	It is not currently possible to categorise the environmental hazards of metals and other inorganic chemicals according to standard persistence, bioaccumulation and toxicity (PBT) hazard criteria. These criteria were developed for organic chemicals and do not take into account the unique properties of inorganic substances and their behaviour in the environment (UNECE 2007; US EPA 2007).

References

1. HSDB (n.d.). *Hazardous Substances Data Bank*. Retrieved 2015, from Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>
2. IARC (2010) Carbon Black, Titanium Oxide and Talc. Volume 93. International Agency for Research on Cancer Monographs on the Evaluation of Carcinogenic Risks to Humans. Available at <http://monographs.iarc.fr/ENG/Monographs/vol93/mono93.pdf>.
3. Pfizer (2006) Material Safety Data Sheet for Gemfibrozil Tablets, 90mg. Available at http://www.pfizer.com/files/products/material_safety_data/CI-719.pdf.
4. Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

Toxicity Summary - Crystalline silica

Chemical and Physical Properties ^{1,3}	
CAS number	14808-60-7
Molecular formula	SiO ₂
Molecular weight	60.09 g/mol
Solubility in water	Insoluble/negligible
Melting point	1610°C
Boiling point	2230°C
Vapour pressure	Not available
Henry's law constant	Not available
Explosive potential	Not explosive
Flammability potential	Not flammable
Colour/Form	Transparent crystals
Overview	Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO₂) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite. Particle size is a key determinate of silica toxicity, since toxicity is restricted to particles that are small enough to be deposited into the target regions of the respiratory tract. Uncalcined diatomaceous earth typically contains around 1% crystalline silica. When diatomaceous earth is subjected to pressure or is processed ("calcined") at temperatures above 1000°C some of the amorphous silica is converted to crystalline silica in the form of cristobalite. Calcined diatomaceous earth can contain anywhere from 1% to 75% cristobalite.
Environmental Fate ^{1,2}	
Soil/Water/Air	Crystalline Silica consists of diatomaceous earth, a naturally occurring material. Its primary component, silica, is found in common materials like quartz, sand and agate. The materials are ubiquitous and unlikely to react chemically with any other substance in the environment.
Human Health Toxicity Summary ^{1,2,3}	
Chronic Repeated Dose Toxicity	A number of animal studies have found that cristobalite is more toxic to the lung than quartz, and more tumorigenic (e.g., King et al. 1953; Wagner et al. 1980). However, several other authors concluded that this is not the case (Bolsaitis and Wallace 1996; Guthrie and Heaney 1995). OSHA (2013) has examined evidence on the comparative toxicity of the silica polymorphs (quartz, cristobalite, and tridymite) and found no difference in toxicity effects between cristobalite and quartz. Furthermore, no difference in toxicity between cristobalite and quartz has been observed in epidemiologic studies (NIOSH 2002). There is no information on the repeat dose oral, inhalation or dermal effect of calcined silica. However, since calcined diatomaceous earth contains varying amounts of crystalline silica in the form of cristobalite, and may also contain small amounts of quartz and tridymite, it is expected that any long-term health hazards associated with diatomaceous earth would mainly be due to the effects of crystalline silica. In humans, the most prevalent effect identified from long term exposure in occupational settings is silicosis, a diffused nodular pulmonary fibrosis (US EPA 1996).
Carcinogenicity	IARC (2012) concluded that there is sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica in the form of quartz or cristobalite from occupational sources. There is sufficient evidence in experimental animals for the carcinogenicity of quartz and cristobalite.

	The IARC has also concluded that inhaled crystalline silica in the form of cristobalite or quartz from occupational sources is carcinogenic to humans (Group 1) (IARC 2012).												
Mutagenicity/ Genotoxicity	Conflicting results have been reported in genotoxicity studies with crystalline quartz or cristobalite, and a direct genotoxic effect for crystalline silica has not been confirmed or ruled out. Studies on genotoxicity of calcined diatomaceous silica are not available.												
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No data available.												
Acute Toxicity	No data available.												
Irritation	No data available. Most acute toxicity studies for quartz or cristobalite were conducted using intratracheal instillation. Single intratracheal instillation of quartz caused inflammatory effects and formation of discrete silicotic nodules in rats, mice and hamsters (IARC 2012; WHO 2000). Other effects like oxidative stress, cellular proliferation and increases in water, protein, and phospholipid content of rat lungs, apoptosis (programmed cell death) and lung cancer were also noted. In general, exposure to high concentrations of dust may cause coughing and mild, temporary irritation (CCOHS 2001).												
Sensitisation	No data available. However, based on the structure and physico-chemical properties, the three forms of crystalline silica or the calcined diatomaceous silica are not expected to cause skin sensitisation.												
Health Effects Summary	The substances are not skin or eye irritants but acute inhalation of dust may cause discomfort and stress as well as signs of local irritation to nasal, bronchiolar and ocular mucous membranes. Based on the evaluation of the epidemiological data it is concluded that inhalation exposure to crystalline silica results in lung cancer. This conclusion is also supported by animal studies in which inhalation and intratracheal exposure to crystalline silica resulted in lung tumours. The most common types of lung tumour observed in rats were lung adenocarcinomas.												
Key Study/Critical Effect for Screening Criteria	Not applicable.												
Ecological Toxicity ^{1,2,3}													
Aquatic Toxicity	Aquatic toxicity studies performed at saturation concentrations of synthetic amorphous silica showed no acute toxicity to fish, Daphnia, or algae, though some physical effects were observed with loading rates of greater than or equal to 10 g/L (OECD 2004). Any harmful effects to aquatic ecosystems are therefore not ecotoxicological in nature. No chronic toxicity data were identified.												
Determination of PNEC aquatic	Not applicable.												
Current Regulatory Controls ³													
Listed as a Chemical of Concern on International Databases	<table><tr><th>International Database</th><th>Listed?</th></tr><tr><td>European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table</td><td>No</td></tr><tr><td>International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications</td><td>Yes</td></tr><tr><td>National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html</td><td>Yes</td></tr><tr><td>US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris</td><td>No</td></tr><tr><td>United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and</td><td>No</td></tr></table>	International Database	Listed?	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	Yes	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	Yes	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	International Database	Listed?											
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No											
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	Yes											
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	Yes											
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No											
United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No												

	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dccew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	Quartz and cristobalite are listed in the Hazardous Substances Information System (HSIS) (Safe Work Australia 2014a) as hazardous substances. Calcined silica is not listed in the HSIS.	
Australian Occupational Exposure Standards	Time Weighted Average (TWA) occupational exposure standard of 0.1 mg/m³ for quartz and cristobalite are recommended in Australia (Safework Australia 2013). A Short-Term Exposure Limit (STEL) is not recommended for any of the compounds.	
International Occupational Exposure Standards	TWA for quartz, cristobalite: Canada: 0.025 mg/m³ France: 0.05 mg/m³ Japan: 0.03 mg/m³ Sweden: 0.05 mg/m³ US (ACGIH): 0.025 mg/m³ US (NIOSH): 0.05 mg/m³ US (OSHA): 0.1 mg/m³ US: 0.3, 0.9, 1.5, 500 mg/m³ Temporary Emergency Exposure Limits (TEEL) (Diatomaceous silica, calcined)	
Australian Food Standards	No data found.	
Australian Drinking Water Guidelines	The Australian Drinking Water Guidelines state: 'To minimise an undesirable scale build up on surfaces, silica (SiO ₂) within drinking water should not exceed 80 mg/L' (National Health and Medical Research Council (NHMRC) 2001).	
Aquatic Toxicity Guidelines	No data found.	
PBT Assessment ³		
P/vP Criteria fulfilled?	No. Not applicable, inorganic substance, ubiquitous in environment.	
B/vB criteria fulfilled?	No. Not applicable, inorganic substance, ubiquitous in environment.	
T criteria fulfilled?	No. Long term data not available (acute data >0.1 mg/L).	
Overall conclusion	It is not currently possible to categorise the environmental hazards of metals and other inorganic chemicals according to standard persistence, bioaccumulation and toxicity (PBT) hazard criteria. These criteria were developed for organic chemicals and do not take into account the unique properties of inorganic substances and their behaviour in the environment (UNECE 2007; US EPA 2007). Further assessment of the environmental risks from the use of this chemical is not required as identified by DoEE	

References

1. HSDB. Hazardous Substances Data Bank. Retrieved 2015, from Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>
2. OECD-SIDS Initial Targeted Assessment Profile on Quartz and Cristobalite, SIAM 32, 19-21 April 2011.
3. Department of the Environment and Energy 2017, National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

Toxicity Summary - Mannanase

Chemical and Physical Properties ¹	
CAS number	37288-54-3
Molecular formula	No data available.
Molecular weight	UVCB
Solubility in water	125 g/L at 25°C
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	0.004 Pa at 25 °C
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	Non-flammable
Colour/Form	No data available.
Overview	Mannanase is a substance that is derived from natural products or materials, and which is not bioaccumulative or toxic. The natural decay and/or breakdown of this substance is unlikely to cause harm in the environment.
Environmental Fate ¹	
Soil/Water/Air	Mannanase is readily biodegradable, has a low octanol-water partition coefficient (<0) and is highly water soluble. From this it can be concluded that mannanase will not absorb to sediment or soil and that no bioaccumulation will occur in aquatic or terrestrial organisms.
Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	The repeated dose oral toxicity of mannanase has been tested by oral gavage in Han Wistar rats. Dosing of the animals at doses up to 100% of the mannanase (equivalent to 1277 mg enzyme concentrate dry matter/kg bw/day) for 13 weeks was well-tolerated and there was no significant finding of any toxicological relevance. The no-observed-adverse-effect level (NOAEL) in this study was considered to be 100% mannanase equivalent to 1277 mg enzyme concentrate dry matter/kg bw/day.
Carcinogenicity	Mannanase is not listed as a carcinogen.
Mutagenicity/ Genotoxicity	No mutagenic activity of mannanase could be detected in the Ames Assay. Mannanase did not induce chromosomal aberrations in the in vitro mammalian chromosome aberration test performed with human lymphocytes. These results are supported by read across from three in vitro gene mutation studies in L5178Y mouse lymphoma cells performed on three different amylases belonging to the same subclass of glycosidases as mannanase.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Mannanase does not affect fertility and is not a teratogen.
Acute Toxicity	The acute oral and acute inhalation toxicity of mannanase has been tested. Both studies were short-term toxicity tests conducted according to OECD guidelines and in compliance with GLP. No acute dermal toxicity test was conducted. The conclusion was that mannanase is non-toxic by acute oral or inhalation exposure. Based on weight of evidence, mannanase does not exert any acute dermal toxicity under foreseeable realistic exposures for either workers or consumers.
Irritation	Mannanase is neither a skin nor an eye irritant.
Sensitisation	Not expected to be a skin sensitiser.
Key Study/Critical Effect for Screening Criteria	Chronic toxicity is the critical effect for risk assessment. NOAEL= 1277 mg/kg bw/day.

Ecological Toxicity ¹		
Aquatic Toxicity	Mannanase, was not found to be acutely toxic to rainbow trout (<i>Oncorhynchus mykiss</i>) and <i>Daphnia magna</i>. at a nominal concentration of 105.8 mg enzyme concentrate dry matter/L equivalent to 55.5 mg active enzyme protein (aep)/L. The 'No observed effect concentration' was the highest concentration 105.8 mg enzyme concentrate dry matter/L. This chemical poses no unreasonable risk to the environment based on Tier I assessment under the NICNAS IMAP assessment framework. The substance that is derived from natural products or materials, and which is not bioaccumulative or toxic. The natural decay and/or breakdown of this substance is unlikely to cause harm in the environment.	
Determination of PNEC aquatic	A PNECaqua (marine water) = 5.55 µg/L can be calculated based on the lowest acute toxicity value (55.5 mg active enzyme protein (aep)/L) for rainbow trout and aquatic invertebrates (<i>Daphnia</i>) with the assessment factor of 10000.	
Current Regulatory Controls ²		
Listed as a Chemical of Concern on International Databases	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChecklist	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	Mannanase is classified as H334 (May cause allergy or asthma symptoms or breathing difficulties if inhaled) (HCIS, Safe Work Australia).	
Australian Occupational Exposure Standards	No data available	
International Occupational Exposure Standards	No data available	
Australian Food Standards	No data available	
Australian Drinking Water Guidelines	No data available	
Aquatic Toxicity Guidelines	No data available	
PBT Assessment ^{1,3}		

P/vP Criteria fulfilled?	No. Mannanase has been tested for ready biodegradation in the 'Ready Biodegradability, Modified Sturm Test' (OECD 301B), and was found to be readily biodegradable.
B/vB criteria fulfilled?	No. Mannanase has no considerable potential for bioaccumulation (log Kow -1.3).
T criteria fulfilled?	No. The NOECs from the acute aquatic toxicity data are >1 mg/L, hence does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT. Sorbitol poses no unreasonable risk to the environment based on Tier I assessment under the NICNAS IMAP assessment framework.

References

1. ECHA REACH, Mannanase, endo-1,4- β -, Retrieved 2021: <https://echa.europa.eu/>
2. Safe Work Australia, Hazardous Substances System, Starch, Retrieved 2021: <http://hcis.safeworkaustralia.gov.au/>
3. NICNAS (2020) Tier 1 Assessment for Mannanase. Retrieved 2021: <https://www.nicnas.gov.au>

Toxicity Summary - Fatty acids, tall-oil, ethoxylated and Tallow alkyl amines ethoxylated

Chemical and Physical Properties ¹	
CAS number	61791-00-2 61791-26-2
Molecular formula	C(18-50)H(34-98)O(3-8) (Fatty acids, tall-oil, ethoxylated)
Molecular weight	UVCB
Solubility in water	No data available.
Melting point	-85 °C at 101.3 kPa
Boiling point	No data available.
Vapour pressure	No data available.
Henry's law constant	No data available.
Explosive potential	Non-explosive (100%)
Flammability potential	Not classified
Colour/Form	Liquid
Overview	This substance is used by consumers, in articles, by professional workers (widespread uses), in formulation or re-packing, at industrial sites and in manufacturing.
Environmental Fate ¹	
Soil/Water/Air	One study investigating the adsorption/desorption behaviour of Fatty acids, tall-oil, ethoxylated (CAS 61791-00-2) is available. The study was performed according to GLP and OECD guideline 121 (BASF 2017). 6 different peaks were observed with log K _{oc} values ranging from < 1.8 to > 5.63. The two main components (> 85%) show log K _{oc} values > 4. Thus, adsorption of Fatty acids, tall-oil, ethoxylated to solid soil is expected. The test with the source substance was conducted according to OECD Guideline 301B, under GLP conditions (BASF 2005). Domestic, non-adapted activated sludge was exposed to the test substance for 28 days at 22°C, and biodegradation was measured by CO ₂ consumption. After 28 days, the test substance reached a biodegradation of 90 - 100 %. Based on the results for the read-across substance, Fatty acids, tall oil, ethoxylated (EO > 1 < 2.5) (CAS 61791-00-2) is considered to be readily biodegradable. The test substance consists of components with log K _{ow} values in the range of 5 to > 10 (KOWWIN v1.68) indicating a potential for bioaccumulation. But due to rapid environmental biodegradation, metabolism via enzymatic hydrolysis (monoesters and diesters) as well as sterical hindrance of crossing biological membranes (high molecular weight of diesters) a relevant uptake and bioaccumulation in aquatic organisms is not expected. This is supported by low BCF values of < 100 L/kg ww (BCFBAF v3.01, Arnot-Gobas, including biotransformation, upper trophic) calculated for different components of the UVCB (mono- and diester EO1 to EO5). Thus, taking all information into account, the test substance is not considered to be bioaccumulative.
Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	Under the conditions of this Combined Repeated Dose Toxicity Study with the Reproduction/Developmental Toxicity Screening Test, the oral administration by gavage of test substance to Wistar rats revealed no adverse signs of toxicity in male and female animals at a dose level of 1000 mg/kg bw/d. Thus, the no observed adverse effect level (NOAEL) for general systemic toxicity was 1000 mg/kg bw/d for male and female Wistar rats.
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	The test substance is not mutagenic in bacteria, as determined in an OECD 471 study.

	The test substance is not chromosome damaging, as determined in an OECD 487 study. The test substance is not mutagenic in mammalian cells, as determined in an OECD 476 study.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Under the conditions of this Combined Repeated Dose Toxicity Study with the Reproduction/Developmental Toxicity Screening Test, the oral administration by gavage of the test substance to Wistar rats revealed no adverse signs of toxicity in male and female animals at a dose level of 1000 mg/kg bw/d. Thus, the no observed adverse effect level (NOAEL) for general systemic toxicity was 1000 mg/kg bw/d for male and female Wistar rats. The NOAEL for reproductive performance and fertility was set to 1000 mg/kg bw/d for male and female Wistar rats.
Acute Toxicity	In an acute oral toxicity study performed similar to OECD guideline 401 (BASF 1971), three groups of rats consisting of 10 animals/sex/dose were treated by single gavage application with an aqueous solution of the test substance (10000, 8000, 6400 mg/kg bw). The animals were observed for mortality and for clinical symptoms of toxicity over a period of 7 days. At the end of the observation period, the surviving animals were sacrificed for the purpose of necropsy. No mortality occurred at the tested concentrations. At all doses mastication, irregular breathing, redness of the eyes and closed eyes were seen immediately after dosing. The next morning mastication and irregular breathing was observed. On the following days, no clinical signs were observed. Pathological examination revealed hydrometra in 3 animals exposed to 10000 mg/kg bw, 2 animals exposed to 8000 mg/kg bw, and 3 animals exposed to 6400 mg/kg bw. Based on the results obtained under the test conditions of this study, the acute oral LD50 was determined to be > 10000 mg/kg bw. To evaluate the potential acute inhalation toxicity of the test substance an Inhalation Risk Test conducted according to a BASF internal testing method (BASF 1971). The test demonstrates the toxicity of an atmosphere saturated with vapours of the volatile components of a test substance at the temperature chosen for vapour generation (20 °C). Rats were exposed sequentially to the vapours, generated by bubbling 200 l/h air through a substance column of about 5 cm above a fritted glass disc in a glass cylinder. The animals were exposed for 8 hour. The exposure concentration was estimated to be 0.28 mg/L based on evaporated substance. In addition to mortality, clinical signs were recorded and necropsy on surviving animals performed. No mortality occurred and no clinical sign were noted during exposure and observation period. In one animal exposed for 8 hours hydrometra was observed after necropsy. Since no mortality occurred at the concentrations tested an LC50 estimation cannot be made. In another Inhalation Risk Test of similar design, Rats (12 animals) were exposed sequentially to the vapours, generated by bubbling 200 l/h air through a substance column of about 5 cm above a fritted glass disc in a glass cylinder. This time vapours were generated at 20 °C as well as 50 °C. The exposure concentrations were 0.04 mg/L and 0.34 mg/L. Rats were exposed for 8 hour. As in the previous study, no mortality occurred after exposure up to 8 hours. Clinical signs observed in the animals exposed to the vapour generated at 20°C included mild escape attempts when exposure began and at the end of the exposure period slight eye irritation was observed. The next day, the animals were without symptoms. In the animals exposed to the vapour generated at 50 °C escape attempts were noted in the first 60 minutes of exposure. Exposure to the saturated atmosphere caused slight eye irritation. At the end of the exposure period, all clinical signs were resolved. Since no mortality occurred at the concentrations tested an LC50 estimation cannot be made. Based on the inhalation studies, no conclusion on LC50 can be drawn, because the tested concentrations are too low in relation to the classification criteria.
Irritation	The test substance was not irritant or corrosive to the skin in a GLP-compliant OECD 431 and 439 study. The test substance was not irritant to the eyes in a GLP-compliant OECD 492 study. Based on the available information, classification for skin and eye irritation is not warranted, in accordance with EU Classification, Labelling and Packaging of Substances and Mixtures (CLP) Regulation No. (EC) 1272/2008.

Sensitisation	The test substance did not show an indication of skin sensitising potential in an OECD 429 (LLNA) study. However, an earlier Buehler test (OECD 406) did indicate skin sensitising potential of the substance.	
Key Study/Critical Effect for Screening Criteria	Possible sensitiser. The NOAEL for general systemic toxicity was 1000 mg/kg bw/d.	
Ecological Toxicity ¹		
Aquatic Toxicity	Short-term toxicity tests with the target substance for all trophic levels (fish, daphnia, algae) are available. The test substance did not indicate to be harmful to freshwater fish (96h-LL50 > 100 mg/L), but showed to be toxic to aquatic invertebrates (48h-EL50 = 12.41 mg/L) and harmful to algae (72h-EL50 = 39.7 mg/L). Hence, aquatic invertebrates were most susceptible to the test substance and this effect value was used for the PNEC derivation. Long-term toxicity data with the source substance are only available for algae. The algal test revealed the substance to be of low toxicity to algae (72h-EL10 = 7.08 mg/L). In addition, data are available for toxicity to microorganisms. A test on respiration inhibition with activated sludge resulted in an 3h-EC10 of > 10000 mg/L indicating that detrimental effects in STPs are not to be expected.	
Determination of PNEC aquatic	A PNECaqua = 0.012 mg/L can be calculated based on the lowest acute toxicity value (EL50 = 12.41 mg/L) for aquatic invertebrates (Daphnia) with the assessment factor of 1000.	
Current Regulatory Controls		
Listed as a Chemical of Concern on International Databases	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	No data available.	
Australian Occupational Exposure Standards	No data available.	
International Occupational Exposure Standards	No data available.	
Australian Food Standards	No data available.	

Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment¹	
P/vP Criteria fulfilled?	No. Based on the results from the read-across substance, Fatty acids, tall oil, ethoxylated (EO > 1 < 2.5) (CAS 61791-00-2) is considered to be readily biodegradable.
B/vB criteria fulfilled?	No. The test substance consists of components with log Kow values in the range of 5 to > 10 (KOWWIN v1.68) indicating a potential for bioaccumulation. But due to rapid environmental biodegradation, metabolism via enzymatic hydrolysis (monoesters and diesters) as well as sterical hindrance of crossing biological membranes (high molecular weight of diesters) a relevant uptake and bioaccumulation in aquatic organisms is not expected. This is supported by low BCF values of < 100 L/kg ww (BCFBAF v3.01, Arnot-Gobas, including biotransformation, upper trophic) calculated for different components of the UVCB (mono- and diester EO1 to EO5). Thus, taking all information into account, the test substance is not considered to be B or vB.
T criteria fulfilled?	No. Available short-term and long-term toxicity tests with aquatic organisms resulted in effect values > 1 mg/L. Thus, this substance does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT

References

1. ECHA REACH, Fatty acids, tall-oil, ethoxylated, Retrieved 2021: <https://echa.europa.eu/>

Toxicity Summary - Distillates, Hydrotreated Light

Chemical and Physical Properties ^{1,2,3,4}	
CAS number	64742-47-8
Molecular formula	C48H94
Molecular weight	Not applicable - unknown or variable composition, complex reaction products or biological materials (UVCB)
Solubility in water	0.009 to 6.45 mg/L (at 25°C)
Melting point	-49 °C
Boiling point	146 to 299 °C
Vapour pressure	1 to 3.7 kPa at 37.8 °C
Henry's law constant	No data found.
Explosive potential	Above 66°C explosive vapour/air mixtures may be formed
Flammability potential	Combustible
Colour/Form	Liquid at room temperature
Overview	Distillates, hydrotreated light (also called deodorised kerosene) is a petroleum substance. The C₉-C₁₄ Aliphatic [< 2% Aromatic] Hydrocarbon Solvents Category is comprised of complex aliphatic hydrocarbon solvents that contain >98% aliphatic constituents with carbon numbers in the range of C₉-C₁₄ and less than 2% aromatic constituents. The chemical is used as a component of a drilling fluid formulation for coal seam gas extraction.
Environmental Fate ¹	
Soil/Water/Air	Members of the C ₉ -C ₁₄ Aliphatic [≤2% aromatics] Hydrocarbon Solvents Category have the potential to volatilize from surface waters, based on Henry's Law constants (HLC) representing volatility for category members that range from 4.76 x 10 ⁴ to 1.67 x 10 ⁶ Pa·m ³ /mole (at 25°C). In the air, category members have the potential to rapidly degrade through indirect photolytic processes mediated primarily by hydroxyl radicals (•OH) with calculated degradation half-lives ranging from 0.42 to 1.10 days or 10.8 to 26.4 hours based on a 12-hr day and an •OH concentration of 1.5 x 10 ⁶ •OH/cm ³ . These chemicals are unlikely to degrade by hydrolysis as they lack a functional group that is hydrolytically reactive.
Human Health Toxicity Summary ^{1,2,3}	
Chronic Repeated Dose Toxicity	In a 90-day study conducted in accordance with OECD TG 408, Sprague-Dawley rats were administered deodorized kerosene by gavage at doses of 0, 100, 500 or 1000 mg/kg bw/day (REACH 2013). Microscopic changes, such as incidence of α₂μ-globulin, were seen in male kidneys. These effects are not considered relevant to humans. No other treatment-related effects were observed. No Lowest Observed Adverse Effect Level (LOAEL) or No Observed Adverse Effect Level (NOAEL) could be established in this study. Repeated dermal exposures to members of the kerosene/jet fuel category showed minimal systemic effects (API 2010). Animal data on repeat dermal toxicity of kerosene (petroleum) are summarised from REACH (2013) and presented in Table A29.2. The LOAELs and NOAELs are indicated for each study. Prolonged skin exposure to kerosene (petroleum) in rats and rabbits were consistently associated with local irritation. In rabbits only, systemic effects included changes in bodyweight and organ weights. It is expected that deodorized kerosene would have similar effects in the animals. In a 13-week study, rats (strain not specified) were exposed to deodorized kerosene vapour at concentrations of 0, 0.02, 0.048 or 0.10 mg/L for six

	hours/day, five days/week. No treatment-related effects were reported (REACH 2013).
Carcinogenicity	A study for deodorized kerosene is available in the REACH Dossier (REACH 2013) but was not reported in enough detail to be able to determine the carcinogenicity of the substance. In a study conducted similarly to OECD TG 451, B6C3F1 mice were applied 0, 250 or 500 mg/kg bw/day kerosene (petroleum) in the interscapular region (type of wrapping not specified) for 103 weeks (REACH 2013). At the end of the study, less than 10% decrease in bodyweight gain was observed at the top dose in both sexes. Mortality in females was significantly higher at the two doses compared to controls. Increased incidence and severity of chronic dermatitis was seen in all treatment groups. At the top dose, increased incidence of the following non-neoplastic lesions was reported: amyloid in the liver, kidney, adrenal cortex (males only), spleen; granulocytic hyperplasia in the bone marrow; and hyperplasia of the axillary lymph nodes (females only). The only indication of neoplastic lesions was an increased incidence of malignant lymphomas observed in treated female animals but the values were within the range of historical controls. Under the conditions of the test, kerosene (petroleum) was not carcinogenic. The LOAEL for systemic effects is 250 mg/kg bw/day. The International Agency for Research on Cancer (IARC) concluded that there is inadequate evidence for the carcinogenicity of kerosene (petroleum) in experimental animals and humans, placing the chemical in Group 3 (Not classifiable as to its carcinogenicity to humans) (IARC 1989). Deodorized kerosene is not carcinogenic, based on reading across the information available for kerosene (petroleum).
Mutagenicity/ Genotoxicity	In vitro tests reported deodorized kerosene as negative both with and without metabolic activation in Ames tests conducted in accordance with OECD TG 471 (REACH 2013; OECD 2011) and in chromosomal aberration tests conducted in accordance with OECD TG 473 (OECD 2011, 2012). In an in vivo study, deodorized kerosene was negative in a dominant lethal assay, conducted in accordance with OECD TG 478, in male Swiss mice and Long Evans rats administered 10% deodorized kerosene intraperitoneally (REACH 2013). These studies demonstrate that deodorized kerosene is not genotoxic.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	C9-C14 aliphatic ($\leq 2\%$ aromatic) hydrocarbon solvents and C14-C20 aliphatic ($\leq 2\%$ aromatic) hydrocarbon solvents are not toxic to fertility (OECD 2011, 2012). Members of the kerosene/jet fuel category are not toxic to fertility (API 2010). Sprague-Dawley rats were administered undiluted kerosene (petroleum) by gavage at doses of 0, 750, 1500 or 3000 mg/kg bw/day in males treated for 70-90 days and 0, 325, 750 or 1500 mg/kg bw/day in females treated for 21 weeks. At 750 and 1500 mg/kg bw/day, increased absolute liver weight was observed in females but with no corresponding changes in clinical chemistry or histopathology. In females only, other effects included perianal dermatitis at 1500 mg/kg bw/day and stomach hyperplasia at 750 and 1500 mg/kg bw/day. These parameters were not measured in males. In males, the study indicated dose dependent decrease in male bodyweight that was linked to nephropathy specific to male rats. Data for this effect were not provided in the study description. There were no treatment related effects on fertility in both sexes (REACH 2013). The NOAEL for systemic effects in females only was 325 mg/kg bw/day. No NOAEL can be established for fertility effects. C9-C14 aliphatic ($\leq 2\%$ aromatic) hydrocarbon solvents and C14-C20 aliphatic ($\leq 2\%$ aromatic) hydrocarbon solvents are not developmental toxicants (OECD 2011, 2012). Members of the kerosene/jet fuel category are not developmental toxicants (API 2010). In a study conducted in accordance with OECD TG 414, Sprague-Dawley rats were administered kerosene (petroleum) by gavage on gestation days (GD) 6 to 15 at doses of 0, 500, 1000, 1500 or 2000 mg/kg bw/day (REACH 2013). Bodyweight gain was decreased at 1500 and 2000 mg/kg bw/day. Foetal weight was decreased at 1500 and 2000 mg/kg bw/day which may be attributed to decreased maternal bodyweight gain. No malformations were reported. The maternal NOAEL is 1000 mg/kg bw/day.

	In another study, Sprague-Dawley rats were exposed (whole body) to kerosene (petroleum) in air at concentrations of 0, 106 or 364 ppm on GD 6-15. There were no treatment-related effects observed in the dams and offspring (REACH 2013). Deodorized kerosene is not considered a developmental toxicant, based on reading across data available for kerosene (petroleum).								
Acute Toxicity	The chemicals have low acute toxicity based on results from animal tests following oral exposure. The median lethal dose (LD50) in rats is >2000 mg/kg bw (OECD, 2011; US EPA, 2011; OECD, 2012a; OECD, 2012b; OECD, 2012c). The chemicals have low acute toxicity based on results from animal tests following dermal exposure. The LD50 in rats and rabbits is >2000 mg/kg bw (OECD, 2011; US EPA, 2011; OECD, 2012a; OECD, 2012b; OECD, 2012c). The chemicals have low acute toxicity based on results from animal tests following inhalation exposure.								
Irritation	Semi-occlusive applications of commercial grade deodorized kerosene produced slight irritation in New Zealand White and SPF rabbits in dermal irritation studies conducted in accordance with OECD TG 404. The studies reported the range of erythema and oedema scores to be 0.3-0.9 and 0.2-1.0, respectively, based on Draize scoring at 24, 48 and 72 hours. Deodorized kerosene is slightly irritating to rabbit skin. Several studies conducted similarly to OECD TG 405 showed minimal effects to the eye with the reported range of conjunctival redness score to be 0-0.2 from instillation of undiluted deodorized kerosene in the eyes of New Zealand White and SPF rabbits (OECD 2011). Deodorized kerosene is slightly irritating to rabbit eye.								
Sensitisation	The C9-C14 aliphatic (≤2% aromatics) Category members do not cause skin sensitization.								
Health Effects Summary	Deodorised kerosene is an aspiration hazard since it has low viscosity and is composed of aliphatic and aromatic hydrocarbons up to 10%. Deodorised kerosene has low acute oral, dermal and inhalation toxicity, and is slightly irritating to the skin and eyes. The substance is not a skin sensitiser, based on reading across data available for kerosene (petroleum). No treatment-related effects were reported in repeated oral and inhalation exposures to deodorised kerosene. Prolonged dermal exposure to kerosene (petroleum) reported local irritation in rats and rabbits, and changes in bodyweight and organ weights in rabbits. It is expected that these effects would be similar for deodorised kerosene. Based on the absence of adverse effects observed in repeat dose toxicity studies, for the purposes of quantifying the health risk to the general worker and public, the highest dose tested in the study conducted in rats (1 000 mg/kg bw/day) is used in this risk assessment. The substance is not genotoxic. It is neither a carcinogen nor a reproductive toxicant, based on reading across data available for kerosene (petroleum).								
Key Study/Critical Effect for Screening Criteria	The most appropriate No-Observed-Adverse-Effect Level (NOAEL) for risk assessment is 1 000 mg/kg bw/day based on maternal toxicity (decreased bodyweight gain) at the Lowest- Observed-Adverse-Effect Level (LOAEL) of 1 500 mg/kg bw/day from a developmental toxicity study on kerosene (petroleum).								
Ecological Toxicity ²									
Aquatic Toxicity	Lowest acute endpoint for Daphnia = 0.018 mg/L (modelled)								
Determination of PNEC aquatic	Based on the lowest acute endpoint for Daphnia (0.018 mg/L), an assessment factor of 100 has been applied, resulting in a PNECaquatic of 1.80E-04 mg/L.								
Current Regulatory Controls ²									
Listed as a Chemical of Concern on International Databases	<table><tr><th>International Database</th><th>Listed?</th></tr><tr><td>European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table</td><td>No</td></tr><tr><td>International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications</td><td>No</td></tr><tr><td>National Toxicology Program (NTP) Report on Carcinogens (RoC)</td><td>No</td></tr></table>	International Database	Listed?	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No	National Toxicology Program (NTP) Report on Carcinogens (RoC)	No
	International Database	Listed?							
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No							
International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No								
National Toxicology Program (NTP) Report on Carcinogens (RoC)	No								

	https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIICChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	All of the chemicals are classified as hazardous, with the following risk phrase for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): Xn; R65 (acute toxicity) Mixtures containing the substance are classified as hazardous with the following risk phrase based on the concentration (Conc) of the substance in the mixtures: Conc ≥10%: Xn; R65 (May cause lung damage if swallowed)	
Australian Occupational Exposure Standards	No specific exposure standards are available.	
International Occupational Exposure Standards	No specific exposure standards are available for this chemical.	
Australian Food Standards	No data available.	
Australian Drinking Water Guidelines	No data available.	
Aquatic Toxicity Guidelines	Oils and greases (including petrochemicals) for freshwater production: <3006 µg/L (ANZECC 2000)	
PBT Assessment^{1,2}		
P/vP Criteria fulfilled?	No. This chemical is expected to be biodegradable. The ready biodegradability of SHELLSOL NF a solvent naphtha (petroleum), heavy aromatics (consists predominantly of C9 aromatics 25% m/m; C10 aromatics 65%, and indanes 10%) was studied in mineral nutrient medium inoculated with activated sludge (mixed liquor suspended solids 100-101 mg/L, pH 6.9) and incubated for 28 days at 20°C. SHELLSOL NF is readily biodegrade after 28 days but not within the 10 day window.	
B/vB criteria fulfilled?	Category members have a potential to bioaccumulate, based on calculated log BCF values for constituents that range from 2.78 to 4.06, and calculated BCF values of 598 to 11,430 L/kg wet-weight, based on the Arnot and Gobas model, that take into account biotransformation of the chemicals in fish tissue. This chemical also has a log Kow of 6.025.	
T criteria fulfilled?	Yes. The lowest acute endpoint is <1 mg/L.	
Overall conclusion	Not PBT	

References

1. OECD (2012) SIDS Initial Assessment Profile on C₉-C₁₄ Aliphatic [≤2% aromatic] Hydrocarbon Solvents Category. Available at: http://webnet.oecd.org/HPV/UI/SIDS_Details.aspx?id=476560b6-e2b7-4466-9c52-0b278c8b71a7
2. National Industrial Chemicals Notification and Assessment Scheme (NICNAS, 2017). National assessment of chemicals associated with coal seam gas extraction in Australia. Human health hazards of chemicals associated with coal seam gas extraction in Australia.
3. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier II Assessment for Kerosene, Retrieved 2019: <https://www.nicnas.gov.au>
4. ECHA REACH, Distillates (petroleum), hydrotreated light, Retrieved 2017: <https://echa.europa.eu/information-on-chemicals/registered-substances>
5. ICSC Distillates (petroleum), hydrotreated light, Retrieved 2017: <http://www.inchem.org>
6. ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality for protection for aquatic ecosystems

Toxicity Summary - Alcohols, C12-16, ethoxylated and Decanol

Chemical and Physical Properties ^{1,2,3,4}	
CAS number	68551-12-2, 26183-52-8
Molecular formula	Unspecified
Molecular weight	Unspecified
Solubility in water	0.1876 - 13.18 mg/L at 25 °C (C12-14 ethoxylated, 1-2.5 EO) (CAS 68131-39-5) 1.69 - 246.7 mg/L at 25 °C (C9-11, ethoxylated (EO < 2.5) (CAS 68439-46-3) 76 - 82 µg/L @ 25 °C and pH 6.5 (CAS 26183-52-8)
Melting point	7.2 °C at 101.3 kPa (CAS 68131-39-5) -20 °C at 101.3 kPa (CAS 68439-46-3) -27 °C @ 101 kPa (CAS 26183-52-8)
Boiling point	271.11 - 516.11 °C (CAS 68131-39-5) 260 °C (CAS 68439-46-3) 224 °C @ 101 kPa (CAS 26183-52-8)
Vapour pressure	< 1 Pa at 25 °C (CAS 68131-39-5) 0.004 - 117 Pa at 20 °C (CAS 68439-46-3) 1 hPa @ 20 °C (CAS 26183-52-8)
Henry's law constant	No data available.
Explosive potential	Non explosives
Flammability potential	Non flammable
Colour/Form	Organic liquid, colourless to light yellow
Overview	The AEs in this assessment are structurally related, where the hydrophilic ethylene oxide (EO) chain is attached via an ether linkage to the hydrophobic aliphatic alcohol chain (C =6). The alkyl chain can be linear, branched, saturated or unsaturated in the AE group. Ethoxylated shorter chain alcohols (C <6) do not show the same degree of surface activity compared with longer chains, and hence they are not included in this assessment. A generic structural formula of the AE is shown below: $\text{H}-(\text{CH}_2)_x-\text{y}-(\text{OCH}_2\text{CH}_2)_n-\text{OH}$ where n = average number of ethylene oxide (EO) units x-y = range of carbon units (C =6) A simpler notation of 'Cx-yEO_n' will be used to represent the corresponding AEs in this assessment. Generally, increasing the carbon chain length increases lipophilicity, whereas increasing alkoxylation increases hydrophilicity of the chemical. These trends are consistent across the linear, branched, saturated or unsaturated AEs of varying alkyl chain lengths and ethoxylation degrees (Lindner, 2010). It was demonstrated that branching of the AEs had a relatively minor impact on calculated partition coefficients (K_{ow}), and hence their biological properties (Lindner, 2010). Further, for unsaturated AEs, as the point of unsaturation is generally remote from the carbon where the EO chain is attached, they are expected to have similar physiochemical properties to saturated AEs. The AEs in this assessment have been shown to have similarities or trends in their toxicokinetic and toxicological profiles, although the alkyl chain length (whether linear, branched, saturated or unsaturated) and ethoxylation degree vary (see Health Hazard Information section). For this AE group, SARs were reported

	between the degree of ethoxylation and the acute toxicity (direct) and skin irritation (inverse). On the basis of the analogue and chain-length category approach (i.e. by considering similarities and trends in molecular structure, physiochemical properties (Kow), uses, and hazard profiles), the AEs in this assessment are qualified to be assessed as a group. Based on such trend analyses, the available datasets for AEs ranging from C6–C18 and EO3–EO12 were considered representative of the AE category for filling data gaps (HERA, 2009; Lindner, 2010). Available data for any AEs will be applicable to group members where data are incomplete or unavailable, such as for ethoxylates of coco, tallow, and C >20 alcohols. Overall, AEs are not expected to be systemically toxic, although some short chain ethylene glycol ethers, e.g. methyl and ethyl homologues are of concern for a range of adverse health effects. They include skin and eye irritation, liver and kidney damage, bone marrow and central nervous system (CNS) depression, testicular atrophy, developmental toxicity, and immunotoxicity. For higher propyl and butyl homologues, the toxicity involves haemolysis (anaemia) with secondary effects relating to haemosiderin accumulation in the spleen, liver and kidney, and compensatory haematopoiesis in the bone marrow. Systemic toxicity was shown to decrease with increasing alkyl chain lengths and/or alkoxylation degrees (ECETOC, 2005; US EPA, 2010). The chemicals ethylene glycol hexyl ether (with a longer alkyl chain length, CAS No. 112-25-4) and diethylene glycol butyl ether (with a higher ethoxylation degree, CAS No. 112-34-5) have no evidence of systemic effects including haemolysis (ECETOC, 2005; NICNASc). Commercially available AEs are mixtures of homologues of varying carbon chain lengths and it is possible that some of the chemicals with an average alkyl chain length C =6 may also contain shorter alkyl chains C <6. It is not practical to quantify the proportion of shorter C <6 chain lengths present in such chemicals, or these shorter chain lengths may not be present at all. The available data suggest a lack of systemic toxicity for the AE chemicals with potential short alkyl chain presence; therefore, the toxicity of the chemicals in this assessment is unlikely to be significantly affected by the presence of shorter chain alkyl groups.
Environmental Fate^{2,3}	
Soil/Water/Air	Alcohol ethoxylates are readily biodegradable under aerobic conditions and also anaerobically biodegradable (HERA, 2009). The main mechanism of primary biodegradation for the linear and essentially linear AE is the central cleavage of the molecule, leading to the formation of long chain alcohol and polyethylene glycol (HERA, 2009; Marcomini et al., 2000a; Marcomini et al., 2000b). Long chain alcohols themselves are readily biodegradable up to C18 (SIDS, 2006). Abiotic degradation in water, soil, sediment and air is not expected to occur because of the chemical structures of AE homologues. Neither hydrolysis under normal environmental conditions (pH range from 4 to 9) nor photolysis in the atmosphere, in water, or when absorbed to soil and sediment surfaces, is to be considered (HERA, 2009). Experimentally determined BCF-values given for pure homologues and summarized in the publication of Tolls et al. (2000) are used as read-across data for the endpoint bioaccumulation in water. It can be stated that bioaccumulation of alcohol ethoxylates is regarded to be negligible as the surfactants will be rapidly metabolised. For more detail see endpoint summary for bioaccumulation. Concerning transport and distribution of the alcohol ethoxylate mixtures a high adsorption of the substances is determined by using QSAR-models. Adsorption onto surfaces is an intrinsic property of alcohol ethoxylates and thus a high Koc-value is expected.
Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	Based on the available data, the chemicals in this group are not expected to cause serious damage to health (apart from local effects) from repeated oral and dermal exposure.

	In several 90-day feeding studies in rats (similar to OECD TG 408), the reported NOAELs were between 50 and 700 mg/kg bw/day for group members (covering the range of C9–C18 and EO5–EO10). Effects observed at higher concentrations included reduced mean body weights and increases in relative liver, kidney and heart weights (SCCS, 2007; HERA 2009; CIR, 2012). Similar effects were seen in longer-term 2-year feeding studies in rats. The NOAEL for the AEs CAS No. 66455-14-9 (C12–13EO6.5 group member) and CAS No. 68951-67-7 (C14–15EO7 not listed on the Inventory) were between 50 and 190 (females) mg/kg bw/day (HERA, 2009; CIR, 2012). Repeated oral or inhalation exposure to certain short chain ethylene glycol ethers (EGEs), such as 2-butoxyethanol (ethylene glycol butyl ether, EGBE, CAS No. 111-76-2) and its acetate (EGBEA, CAS No. 112-07-2), may cause haemolytic effects in rodents and effects on the liver, spleen and kidney. However, humans appear to be the least sensitive species for haemolytic effects (NICNAS, 1996; NICNAS; OECD, 2004; ECETOC, 2005). The AEs in this assessment are not expected to share these mechanisms of toxicity. Therefore, exposure to these AEs is not expected to cause haemolysis and associated organ toxicity in humans. In a well-reported OECD TG 411 (Subchronic 90-day Dermal Toxicity) study, Fischer rats were exposed to C9–11EO6 (CAS No. 68439-46-3) at 1, 10 or 25 % concentrations, 3 days/week. The application site was shaved and not covered. Dry, flaky skin and irritation (epidermal thickening with hyperkeratosis) were observed at >10 %. Relative kidney weights without histological lesions increased in both sexes at 25 %. The NOAEL was established at 10 %, equivalent to 80 mg/kg bw/day (HERA, 2009; CIR, 2012). In an 18-month study, C12–13EO6.5 was applied to the back of Swiss mice 3 days/week. There were no treatment-related systemic lesions at up to 270 mg/kg bw/day. No further study information was available (HERA, 2009).
Carcinogenicity	Based on the available data, chemicals in this group are not considered carcinogenic. Two AEs, CAS No. 66455-14-9 (C12–13EO6.5, group chemical) and CAS No. 68951-67-7 (C14–15EO7, not listed on the Inventory), were administered at up to 1 % in the diet to rats for 1–2 years. No treatment-related histopathological effect or increased tumour incidence were observed (HERA, 2009; CIR, 2012). There was no treatment-related lesions in mice, following 18-month dermal application of C12–13EO6.5 (HERA, 2009). The AEs are synthesised through processes which may result in 1,4-dioxane as an impurity. This impurity is classified as a Carcinogen—Category 2 (H351 Suspected of causing cancer). There are restrictions on the levels of this chemical in preparations available to consumers in Australia (SUSMP).
Mutagenicity/ Genotoxicity	Based on the data available, the chemicals in this group are not considered mutagenic or genotoxic. A broad spectrum of AEs (covering the range of C7–C22 and EO2–EO20) tested negative in multiple in vitro and in vivo tests (OECD and GLP compliant) for gene mutation and clastogenicity. In vitro, negative results were reported in bacterial reverse mutation tests in <i>Salmonella typhimurium</i> (TA98, TA100, TA102, TA104, TA1535, TA1537 and TA1538) and <i>Escherichia coli</i> (strains WP2 and WP2 uvrA pKM101), with or without metabolic activation. Negative results were also reported in chromosomal aberration tests (Chinese hamster lung V79, Chinese hamster ovary, and rat liver cells) and gene mutation tests (mouse lymphoma cells) (SCCP, 2007; HERA, 2009; CIR, 2012).

	In vivo, AEs (C12–C15 and EO3–EO9) did not induce chromosomal damage in Chinese hamster or Tunstall Wistar rat bone marrow cells after acute oral doses between 250 and 3400 mg/kg bw (SCCP, 2007; HERA, 2009).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on the data available, the chemicals of this group are not considered to cause reproductive or developmental toxicity. The oral NOAELs were determined at 250 mg/kg bw/day for reproductive toxicity, and >50 mg/kg bw/day for maternal and developmental toxicity. In a 2-generation study, the chemical C14–15EO7 was administered in the diet of Charles River CD rats (25/sex/group, at doses of 0, 25, 50 or 250 mg/kg bw/day). The NOAEL for reproductive toxicity was established as 250 mg/kg bw/day (or 0.5 % in diet), given no treatment related effects on fertility, gestation or viability index at this highest tested dose. The NOAEL for maternal and developmental toxicity was established as 50 mg/kg bw/day, based on reduced maternal and pup body weights and increased relative liver weights in both F1 (males and females) and F2 (males) generations at 250 mg/kg bw/day (HERA 2009; CIR, 2012). In a 2-generation study protocol using a different AE (C12EO6), the NOAEL for reproductive toxicity was set at the highest tested dose of 250 mg/kg bw/day. The NOAELs for parental (F0) and developmental toxicity were also 50 mg/kg bw/day, based on reduced body weight gains in F0 and F1 generations at 250 mg/kg bw/day (HERA, 2009; CIR 2012). In an oral developmental toxicity study, C12EO6 was administered in the diet of female rabbits at doses of 0, 50, 100 or 200 mg/kg bw/day from gestation days 2 to 16. Ataxia and a slight decrease in body weight were observed at =100 mg/kg bw/day. Nine rabbits in the control group and 31 in the treatment groups died during the study (details not available). There were no treatment related effects on corpora lutea, implantations, number of live foetuses and spontaneous abortions. No further information was available on live birth index, pup growth or developmental NOAEL. The NOAEL for maternal toxicity was reported at the lowest dose tested, i.e. 50 mg/kg bw/day (HERA, 2009; CIR, 2012). In a dermal 2-generation study, C9–11EO6 (CAS No. 68439-46-3) was applied to Fischer 344 rats (30/sex/group, at doses of 0, 10, 100 or 250 mg/kg bw/day, 3 times/week except mating periods). No effects were reported on mating, fertility or mean gestational length in both generations. No treatment-related effects on testicular weights or sperm counts were observed. There were no effects on F1 and F2 litter size, number of live pups or sex ratio. The NOAEL for reproductive and developmental toxicity was established as 250 mg/kg bw/day (HERA 2009; CIR, 2012). In 2 other dermal studies, the NOAEL values for developmental and teratogenicity of C12EO4 were reported at >240–300 mg/kg bw/day for rats and rabbits, respectively (HERA, 2009). Although certain short chain EGEs such as 2-ethoxyethanol (ethylene glycol ethyl ether, EGEE, CAS No. 110-80-5) are known reproductive toxicants, the ability of these glycol ethers to cause testicular atrophy decreases with increasing alkyl chain length, with effects not observed with chain lengths =C3 (OECD, 2004; ECETOC, 2005). In addition, no effects on reproductive organs were observed in several repeated dose toxicity studies (refer to the Repeated dose toxicity section above).
Acute Toxicity	Some of the AEs in this group are currently classified with hazard category 'Acute Toxicity – Category 4' and hazard statement 'H302 Harmful if swallowed' in the HCIS (refer to the Existing Work Health and Safety Controls section). Based on the available animal data and international reviews, the AEs in this group are expected to have low to moderate acute oral toxicity. The toxicity appears to correlate with the degree of ethoxylation (highest for EO5–EO14) and is unlikely to be greatly affected by the alkyl chain length (HERA, 2009; REACHa-h). Unless data for the specific chemical are available to indicate otherwise, moderate acute oral toxicity cannot be ruled out and hazard classification is recommended for the remaining chemicals in this group (refer to the Recommendation section).

	The oral median lethal dose (LD50) values in rats ranged from 600 mg/kg bw (C15–16EO10, C14–15EO11) to 10000 mg/kg bw (CxEO1–3, CxEO>15). The discrepancy in study results was attributable to variations in EO chain lengths and study designs. No relationship between the alkyl chain length and acute oral toxicity was observed (HERA, 2009). At necropsy, congestion of the lung, liver and kidney, haemorrhage of the gastric mucosa, and gastrointestinal irritation (e.g. stomach ulcerations) were observed, particularly after administration of a bolus dose or undiluted chemicals (HERA, 2009). Based on the available data, the AEs in this group are expected to have low acute dermal toxicity. No structural relationship was evident between the AEs and acute dermal toxicity. In rabbits, the dermal LD50s were between 2000 to 5000 mg/kg bw. In rats, the dermal LD50 values ranged from >800 mg/kg bw (C13–15EO10, C13–15EO11) to >5000 mg/kg bw. At necropsy, haemorrhage of subcutaneous tissues and hyperaemia of the small intestine were observed (SCCP, 2007; HERA, 2009). At high doses (>16000 mg/kg bw after a 24-hour dermal application), AEs caused severe skin irritation, ataxia and lung lesions in rabbits (HERA, 2009; CIR, 2012). Based on the available data, the AEs in this group are expected to have low acute inhalation toxicity. In a study compliant with OECD Test Guideline (TG) 403 (Acute Inhalation Toxicity), a single static 6-hour exposure to substantially saturated vapour (131.58 ppm) of C6EO2 (CAS No. 112-59-4) resulted in no mortality or other signs of toxicity in rats (REACHa). In a non-guideline study, a median lethal concentration (LC50) of greater than 0.22 mg/L was reported for C9–11EO5 following 4-hour inhalation as a mist in rats. Other studies reported LC50 values from 1.5 to 20.7 mg/L, indicating that acute toxic thresholds were reached when rats were exposed to undiluted AEs in the form of respirable mists or aerosols, or at concentrations exceeding the saturated vapour pressure in air. At necropsy, corneal opacity, congestion and mottling of the lung, liver and kidney and adrenals were observed (HERA, 2009).
Irritation	Inhalation of droplets and/or particles (aerodynamic diameters <10 µm) released from the aerosolised products of these surfactant chemicals may cause respiratory irritation and consequent damage to the lung through prolonged or repeated exposure (NICNASa). Some of the AEs in this group are currently classified with hazard category 'Skin Irritation – Category 2' and hazard statement 'H315 Causes skin irritation' in the HCIS (refer to the Existing Work Health and Safety Controls section). Based on the available data, this hazard classification is recommended for the remaining chemicals in the group (unless data for the specific chemical are available to indicate otherwise) (refer to the Recommendation section). Overall, the degree of irritation was reported to be dependent on the type of patch (open vs vs semi-occluded vs occluded), exposure time (4 hours to 4 weeks), single vs repeated applications, and the concentration used. The chemicals were moderately to severely irritating at 100 %, slightly to moderately irritating at 10 %, mildly irritating at 1 %, and non-irritating at 0.1–0.5 %. The severity of irritation appears to inversely correlate with the degree of ethoxylation (i.e. more severe irritation for lower ethoxylation EO1–EO3) and is unlikely to be greatly affected by the alkyl chain length (HERA, 2009). In a number of OECD TG 404 (Acute Dermal Irritation/Corrosion) compliant tests, AEs of varying chain lengths were applied undiluted to intact rabbit skin for 4 hours under fully occluded conditions. The chemicals ranged from slightly irritating (C11EO9, C12–14EO15, C13EO20), moderately irritating (C12–14EO10, C13EO6, C13EO5–6.5) to extremely irritating (C12–14EO6, C12–14EO3, C13EO3). The skin reactions from slightly irritating chemicals reversed by 6 days after exposure, and those from moderately to severely irritating chemicals

	persisted up to 14 days of the observation period. The data suggest a possible trend between irritation and degree of ethoxylation, i.e. AEs with lower EO units are likely more irritating than those with higher number of EO units (HERA, 2009). Some of the AEs in this group are currently classified with hazard category 'Eye Damage – Category 1' and hazard statement 'H318 Causes serious eye damage' in the HCIS (refer to the Existing Work Health and Safety Controls section). Based on the available data, this hazard classification is recommended for the remaining chemicals in the group (unless data are available for the specific chemical to indicate otherwise) (refer to the Recommendation section). In summary, undiluted AEs caused moderate to severe eye irritation in rabbits. The chemicals were also reported to be slightly to moderately irritating at 1–10 % and non-irritating at 0.1 %. The severity of irritation was considered concentration-dependent and appears not to correlate with ethoxylation or alkyl chain length of the AEs. Rinsing the eye immediately after application of some AEs with tap water for 20–30 seconds reduced the severity of the effects. In a number of OECD TG 405 and Good Laboratory Practice (GLP) compliant tests, the majority of undiluted AEs covering the range of C9–C19 and EO2.5–EO15 resulted in Draize eye irritation index (EII) scores of >25 to 50, and were considered moderately to severely irritating. Some chemicals caused irreversible damage to the eye, i.e. conjunctivitis and corneal opacity which persisted to the end of the observation period of 21 days. Vascularisation of the cornea was observed following exposure to undiluted AEs (C7–9EO6 and C14–15EO11; both not listed on the Inventory). Other AEs (C12–13EO2, C7–9EO12, and C14–15EO7) have reported EII scores between 0.5 and 15 (mildly irritating). Thus, there is no clear pattern between the eye irritant responses versus the alkyl or EO chain lengths. Other tests demonstrated that the irritancy of the chemicals (covering the range of C9–C18 and EO3–EO20) could be reduced by rinsing the eye immediately after instillation. Concentrations of 0.1 % were non-irritating and between 1–10 % were slightly to moderately irritating (HERA, 2009). Similar results were reported from Draize tests in albino and New Zealand White rabbits, which covered the range of C9–C15 and EO1–EO18. These chemicals (CAS No. 68439-46-3, 66455-14-9, 68131-39-5 (group members) and 68951-67-7 (not on the Inventory) were severely to extremely irritating when tested undiluted and without rinsing, slightly to moderately irritating at 10 %, and non-irritating to mildly irritating at 0.1–1 % (CIR, 2012).
Sensitisation	Based on available data, the AEs in this group are not considered skin sensitisers. Overall, AEs showed no evidence of skin sensitisation, based on 25 guinea pig maximisation tests (covering the range of C9 to C21 and EO2 to EO21), 13 non-adjuvant Buehler tests (covering the range of C9 to C15 and EO3 to EO13), and local lymph node assay (LLNA) (available for C6EO2, CAS No. 112-59-4). Most of the studies were scientifically well-conducted, and some were compliant with the OECD TG and GLP (HERA, 2009; REACHa; REACHb; REACHc; REACHE; REACHf; REACHg; REACHh).
Health Effects Summary	Undiluted AEs (covering the range of C11–C18 and EO3–EO20) were reported to cause mild skin irritation in a number of standard human occlusive patch tests (4–24 hours). In some cases, mild erythema was observed and cleared within 72 hours (HERA, 2009; CIR, 2012).
Key Study/Critical Effect for Screening Criteria	The critical human health effects of the AEs for risk characterisation are acute oral toxicity and skin and eye irritation. The irritant effects are similar to those caused by other surfactants. The severity of irritation appears to increase directly with the chemical concentration. Skin irritation, but not eye irritation, generally decreases with an increasing degrees of ethoxylation.
Ecological Toxicity^{2,3}	
Aquatic Toxicity	The 96 h LC50 value for Alcohols, C9-11, ethoxylated with Oncorhynchus mykiss was 5 - 7 mg/L based on nominal concentrations. In the long-term toxicity test to Lepomis macrochirus, the NOEC (30 days) was 0.11 – 0.33 mg/L.

	In the short-term toxicity test to <i>Daphnia magna</i>, the EC50 (48 h) was 2.5 mg/L. In the long-term toxicity test to <i>Daphnia magna</i>, the NOEC (21 days) was 0.77 – 1.75 mg/L. In the short-term toxicity test to <i>Pseudokirchneriella subcapitata</i> (green algae), the EC50 (96 h) was 1.4 mg/L. The EC50 (3 h) for microorganisms was 140 mg/L. In a study conducted with two different fish species (bluegill sunfish and fathead minnow) the effects of C14 -15 alcohol ethoxylates (7EO) were determined (Dorn et al., 1995, Shell). In two experiments fish were exposed for 10 d in a laboratory assay and for 30 d in an outdoor stream mesocosm. Effect parameters determined were survival and growth of juvenile bluegills and survival and reproduction of fathead minnows. In the laboratory experiment the NOEC for survival and swimming performance of bluegills and for survival of fathead minnows was 0.16 mg/L. In the stream mesocosm the NOEC for bluegill survival and growth was >0.33 mg/L and for fathead minnow survival 0.28 mg/L. There was an indication of decreased egg laying by fathead minnow in the streams at concentrations of 0.33 mg/L or greater. On the basis of the reported results a worst-case NOEC of 0.16 mg/L is assumed. One publication is available for an alcohol ethoxylate mixture with a chain length of C12 - C13 and approximately 6.5 ethoxy groups (Gillespie et al. 1999). The 21 days flow-through chronic experiment on daphnids is conducted according to the guidelines USEPA-TSCA (U.S. EPA, 1992) and ASTM (1988) and is well documented in the paper. Nevertheless the degree of ethoxylation of the tested mixture described in the paper (6.5 EO) is higher than the degree of ethoxylation described for CAS 68131-39-5 (2.5 EO). The NOEC of 0.77 mg/L for reproduction can be used for read-across.																				
Determination of PNEC aquatic	A PNECaquatic of 11 µg/L was calculated using the lowest chronic endpoint of NOEC of 0.11 mg/L for <i>Daphnia magna</i> . An assessment factor of 10 was used.																				
Current Regulatory Controls ¹																					
Listed as a Chemical of Concern on International Databases	<table><tr><th>International Database</th><th>Listed?</th></tr><tr><td>European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table</td><td>No</td></tr><tr><td>International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications</td><td>No</td></tr><tr><td>National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html</td><td>No</td></tr><tr><td>US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris</td><td>No</td></tr><tr><td>United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and</td><td>No</td></tr><tr><td>Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18</td><td>No</td></tr><tr><td>Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol</td><td>No</td></tr><tr><td>Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIICChemicals</td><td>No</td></tr><tr><td>Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx</td><td>No</td></tr></table>	International Database	Listed?	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No	Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol	No	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIICChemicals	No	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
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Australian Hazard Classification	Alcohols, C12-16, ethoxylated are classified as hazardous on the Hazardous Chemicals Information System (HCIS), with the hazard categories and hazard statements for human health (Safe Work Australia): Acute Toxicity – Category 4; H302 (Harmful if swallowed)																				

	Skin Irritation – Category 2; H315 (Causes skin irritation) Eye Damage – Category 1; H318 (Causes serious eye damage)
Australian Occupational Exposure Standards	No specific exposure standards are available.
International Occupational Exposure Standards	No specific exposure standards are available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	Trigger values for freshwater (95% species) (ANZECC 2000): Alcohol ethoxylated sulfate (AES) = 650 µg/L ⁻¹ Alcohol ethoxylated surfactants (AE) = 140 µg/L ⁻¹
PBT Assessment	
P/vP Criteria fulfilled?	No. These chemicals were found to be readily biodegradable. Thus, it does not meet the screening criteria for persistence.
B/vB criteria fulfilled?	No. Bioaccumulation in organisms is expected to be negligible, due to biotransformation and excretion of alcohol ethoxylates.
T criteria fulfilled?	No. The NOECs from the chronic aquatic toxicity data are >0.01 mg/L, hence does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier II Assessment for Ethoxylates of aliphatic alcohols (>C6), Retrieved 2020: <https://www.nicnas.gov.au>
2. ECHA REACH, Alcohols, C9-11 ethoxylated, < 2.5 EO, Retrieved 2020: <https://echa.europa.eu/information-on-chemicals/registered-substances>
3. ECHA REACH, Alcohols, C12-15 ethoxylated, Retrieved 2020: <https://echa.europa.eu/information-on-chemicals/registered-substances>
4. ECHA REACH, Decan-1-ol, ethoxylated, Retrieved 2020: <https://echa.europa.eu/information-on-chemicals/registered-substances>

Toxicity Summary - Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite

Chemical and Physical Properties ^{1,2}	
CAS number	68953-58-2
Molecular formula	Unspecified
Molecular weight	No data available
Solubility in water	Insoluble
Melting point	No data available
Boiling point	No data available
Vapour pressure	No data available
Henry's law constant	No data available
Explosive potential	Not inherently explosives
Flammability potential	Not oxidizers
Colour/Form	Free flowing solid powders
Overview	This chemical has been grouped under Organoclays Category and referred to as 2M(2Alk) bentonite (OECD SIDS). Although there may be some degradation when subjected to extreme heat beginning at about 180 °C up to approximately 600 °C, the organoclays do not melt or boil. Organoclays are free flowing solid powders that are essentially insoluble in water, in organic solvents and in lipids, and have no volatility under ambient conditions. Vapour pressure is not relevant because all members of the category are powders and are not volatile. This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate ²	
Soil/Water/Air	Organoclays are anticipated to be found primarily in soil or sediment, although it is possible that smaller particles will be suspended in water. Estimates of atmospheric photodegradation are also not relevant due to the nature of these compounds. Organoclays will not hydrolyse because they resist base or acid attack over a pH range of 3-11. Because of their physico-chemical nature the organoclays cannot be evaluated using EPIWIN for distribution among environmental compartments. In three separate OECD TG 306 biodegradation tests using B(2Alk)M bentonite, biodegradation ranged from 4.7 to 33.4% in 28 days, depending on the test. Based on these data as well as the structural and chemical properties of these compounds, it is assumed that other organoclay category members will also show limited biodegradation. It should be noted that biodegradation relates only to the organic component of the organoclays (i.e. the alkyl quaternary ammonium salts).
Human Health Toxicity Summary ²	
Chronic Repeated Dose Toxicity	The NOAEL for 2M(2Alk) bentonite in a 12-week rat dietary study was 25% (approx. 12,500-25,000 mg/kg-bw/day), the highest dose tested.
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	This substance was negative for gene mutations in bacterial reverse mutation assays (with and without metabolic activation).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	A one-generation reproduction study using B(2Alk)M hectorite at dose levels of 0, 50, 225, and 1,000 mg/kg bw/d has been conducted for the potential to cause developmental toxicity in rats. The compound was not found to be teratogenic, nor was there any reproductive toxicity at any dose level. Based on the lack of reproductive toxicity or developmental effects with B(2Alk)M hectorite, the sponsored organoclay materials are not expected to cause developmental toxicity or to demonstrate reproductive toxicity at doses up to 1,000 mg/kg bw/day.

Acute Toxicity	Acute toxicity studies show a low order of toxicity with inhalation 4-hr LC50s and oral (gavage) LD50s greater than 5.0 mg/L and 5,000 mg/kg bw, respectively. Common clinical signs associated with acute inhalation in several studies included transient weight loss and respiratory irregularity. Clinical signs observed in the oral studies included diarrhoea, rapid breathing, piloerection, swollen abdomen, ataxia and lethargy. Acute dermal toxicity studies were not located for the organoclays.																				
Irritation	This substance is not irritating to the skin. Eye irritation is generally minimal in humans (irritation due to the physical nature of the compounds were noted), although observations of moderate irritation have been reported in animals.																				
Sensitisation	Skin sensitization tests conducted on M(2Alk) bentonite indicate the organoclay materials are not sensitizers.																				
Health Effects Summary	This chemical has been identified by NICNAS to be of low concern to human health.																				
Key Study/Critical Effect for Screening Criteria	The NOAEL for 2M(2Alk) bentonite in a 12-week rat dietary study was 25% (approx. 12,500-25,000 mg/kg-bw/day), the highest dose tested.																				
Ecological Toxicity ²																					
Aquatic Toxicity	The nominal EC50 values for the water flea (Daphnia magna) was >100 mg/L (48 hrs) for 2M(2Alk) bentonite. Data on acute toxicity to the aquatic plant Skeletonema costatum shows 72-hr ErC50 (growth rate) was >1,000 mg/L (nominal) for 2M(2Alk) bentonite. The LC50s for 2M(2Alk) bentonite was >10,000, when assessed for toxicity to a sediment re-worker mud shrimp (Corophium volutator).																				
Determination of PNEC aquatic	PNECaquatic: On the basis of the acute toxicity endpoints for 2M(2Alk) bentonite >100 mg/L for Daphnia magna, an assessment factor of 1000 has been applied. The PNECaquatic is determined to be 0.1 mg/L.																				
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Australian Hazard Classification	No data available																				

Australian Occupational Exposure Standards	No data available
International Occupational Exposure Standards	No data available
Australian Food Standards	No data available
Australian Drinking Water Guidelines	No data available
Aquatic Toxicity Guidelines	No data available
PBT Assessment	
P/vP Criteria fulfilled?	Not applicable. Inorganic substance.
B/vB criteria fulfilled?	Not applicable. Inorganic substance.
T criteria fulfilled?	No. Based on measured acute toxicity endpoints of greater than 1 mg/L this substance does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT

References

1. NICNAS (2020) Human Health Tier 1 Assessment for Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite
2. OECD (2007) SIDS Initial Assessment Profile on Organoclays Category. Retrieved January 2020: https://hpvchemicals.oecd.org/UI/SIDS_Details.aspx?key=11cf11c3-224a-408b-94ad-430d1611bf08&idx=0

Toxicity Summary - Polyethylene glycol trimethylnonyl ether

Chemical and Physical Properties ^{1,2}	
CAS number	127087-87-0
Molecular formula	Not applicable. This substance is an unknown or variable-composition polymer. The general formula of nonylphenol ethoxylate (NPE) chemicals is $C_{15}H_{24}(C_2H_4O)_n$; where 'n' is the number of ethylene oxide (EO) units attached to the phenol ring, and can vary from 1–120.
Molecular weight	Not applicable. This substance is an unknown or variable-composition polymer as described above.
Solubility in water	1.104×10^{-3} g/L at 25 °C
Density	1.042 kg/L at 20°C
Melting point	Not applicable
Boiling point	188.6 °C at 97.77 kPa
Vapour pressure	4.86×10^{-13} kPa at 25 °C
Henry's law constant	No data available.
Explosive potential	Non-explosive
Flammability potential	Non-flammable
Colour/Form	Slightly hazy, colourless liquid
Overview	This chemical is a manufactured NPE. NPEs are primarily used as surfactants in a wide range of cosmetic, domestic and industrial products. This chemical is on the International Fragrance Association (IFRA) transparency list for use in fragrances (IFRA, 2022). It is also listed as an Organisation for Economic Co-operation and Development (OECD) High Production Volume (HPV) chemical, indicating that more than 1000 tonnes of the chemical is produced per year in at least one member country of the OECD. The chemical can be emitted into the environment in treated effluents and biosolids produced by sewage treatment plants.
Environmental Fate ³	
Soil/Water/Air	This chemical is slightly soluble in water and has low volatility. When released into the environment, long chain NPEs may remain in water due to their high water solubility and low volatility, whereas shorter chain NPEs have lower water solubility and can adsorb to solids such as sediments and sludge. NPEs are susceptible to substantial biodegradation in the environment. Under aerobic conditions, rapid biodegradation forms nonylphenol ethoxyacetates, and under anaerobic conditions, nonylphenols (NPs) and shorter-chain NPE degradants are formed. While some degradants are much more persistent relative to their parent chemicals, they are expected to be ultimately biodegradable in the environment. The chemical is not expected to undergo long-range transport based on biodegradability, low volatility, and adsorption to soil and sediment. Although soluble in water, NPEs have a relatively short primary half-life in water.
Chronic Repeated Dose Toxicity	Based on the available data from repeated dose oral toxicity studies undertaken in rats, mice and beagle dogs these chemicals are not considered to cause serious damage to health following repeated oral exposure. No data are available for NPEs from repeated dermal or inhalation exposure.
Carcinogenicity	Based on the available data from carcinogenicity studies in rats and mice exposed to NPEs orally and intravaginally, NPEs are not considered to be carcinogenic.
Mutagenicity/ Genotoxicity	Based on the available <i>in vitro</i> genotoxicity data, NPEs are not considered to be genotoxic, with negative results obtained for NPEs in several <i>in vitro</i> assays. No <i>in vivo</i> genotoxicity data are available for NPEs.
Reproductive Toxicity /	Studies are available only for NPE-9, NPE-10, NPE-30. No data are available for other NPEs. The chemical NPE-9 is a known spermicide and the studies available using NPE-9 have reported reproductive toxicity effects in rats from doses of 50 mg/kg bw/day, when administered intravaginally. However, oral studies in rats with NPE-9 showed reproductive

Developmental Toxicity/ Teratogenicity	and developmental effects only at a dose of ≥250 mg/kg bw/day. Based on the available data and considering the routes of exposure relevant for humans (excluding spermicide use), a conclusion on the reproductive and developmental toxicity of NPEs cannot be derived. However, NPs are classified for reproductive and developmental toxicity based on animal data.	
Acute Toxicity	The acute oral toxicity of NPEs and OPEs could range from low to moderate. The toxicity of NPEs and OPEs is considered to increase with decreasing EO units (or chain length) (Health Canada, 2002). Based on the available data (the median lethal dose (LD50) = 1300 or 1310 mg/kg bw in rats for some NPEs, and 691–1600 in rats for some OPEs.	
Irritation	This chemical can cause skin irritation and serious eye irritation. Moderate to severe skin and eye irritation has been reported in animal studies using rabbits and rats. Slight to mild skin irritation has been observed in humans.	
Sensitisation	Based on the available data, NPEs are generally not considered to have skin sensitisation potential, however, there is evidence of mild contact dermatitis in human patch tests with short-chain NPEs.	
Health Effects Summary	The critical health effects for risk characterisation are skin and eye irritation. NPEs could also cause systemic acute effects from oral exposure. However, these health effects are applicable mainly for short chain length NPEs and the effects could reduce with increasing chain lengths. Those with with ≥30 EO chains are reported to be generally non-toxic. While nonoxynol-9 is toxic to reproduction and this is expected to also apply to related NPEs, the effects appear to be specific to direct spermicidal use, which is not relevant to industrial uses of the chemicals. The NPEs biodegrade to NPs in the environment and some products containing NPEs can also contain residual amounts of NPs. Therefore, critical health effects of NPs could also be applicable for risk characterisation under those situations, particularly following secondary exposure from environmental sources.	
Key Study/Critical Effect for Screening Criteria	The lowest no observed effect level (NOEL) was determined as 50 mg/kg bw/day based on reproductive and developmental effects (increased pre-implantation losses, skeletal anomalies in the litters) observed at doses ≥250 mg/kg bw/day.	
Ecological Toxicity ^{2,3}		
Aquatic Toxicity	Read across from CAS 9016-45-9 (Polyoxyethylene Nonylphenol Ether) Acute: Fish: 96 h EC50 = 1.3 mg/L (<i>Lepomis macrochirus</i>) Invertebrates: 48 h LC50 = 1.821 mg/L (QSAR) Algae: 5 d EC50 = 37.4 mg/L (<i>Scenedesmus opoliensis</i>), Gallery worm: 48 h LC50 = 3.26 mg/L (<i>Capitella capitata</i>) Chronic: Fish: 21 d NOEC = 0.048 mg/L (<i>Oncorhynchus mykiss</i>) (read across from nonylphenol monoethoxylate) Invertebrates: 6 d NOEC = 1.0 mg/L (<i>Daphnia magna</i>) Algae: 96 h NOEC = 8.0 mg/L (<i>Pseudokirchneriella subcapitata</i>)	
Determination of PNEC aquatic	Fish are the most sensitive taxon to toxic effects of the chemicals in this group, based on the available information. The PNEC _{aqua} derived for the most toxic chemical in this group, nonylphenol monoethoxylate, is 0.48 µg/L based on the 21 d NOEC of 0.048 mg/L for <i>Oncorhynchus mykiss</i> . The laboratory chronic toxicity value for this fish species was divided by an assessment factor of 100 to account for both interspecies variation and the relative lack of chronic aquatic toxicity data available for chemicals in this group.	
Current Regulatory Controls ⁴		
Listed as a Chemical of Concern on International Databases	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	Yes
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No

	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol	No
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	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	This chemical is classified as hazardous in Safe Work Australia HCIS. - Hazard categories include: - Acute toxicity – Category 4 - Skin irritation – Category 2 - Eye irritation – Category 2A - Hazard statements include: - H302 (Harmful if swallowed) - H315 (Causes skin irritation) - H319 (Causes serious eye irritation)	
Australian Occupational Exposure Standards	No Australian occupational exposure standards are provided by Safe Work Australia HCIS for this chemical.	
International Occupational Exposure Standards	No exposure standards provided in NIOSH.	
Australian Food Standards	No Australian food standards were identified in FSANZ	
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified in the National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines (NHMRC, 2022).	
Aquatic Toxicity Guidelines	No Australian guidelines available.	
PBT Assessment ³		
P/vP Criteria fulfilled?	No. Based on results obtained from biodegradation studies, this chemical is categorised as Not Persistent.	
B/vB criteria fulfilled?	No. Based on the available measured bioconcentration data, this chemical is categorised as Not Bioaccumulative.	
T criteria fulfilled?	No. Based on available acute ecotoxicity values above 1 mg/L and chronic ecotoxicity values above 0.1 mg/L, this chemical is categorised as Not Toxic.	
Overall conclusion	Not a PBT substance.	

Notes: HCIS – Hazardous Chemical Information System; NIOSH – National Institute for Occupational Safety and Health; FSANZ – Food Standards Australia New Zealand; NHMRC (2022) – National Health and Medical research Council, Australian Drinking Water Guidelines 6, 2011 (Version 3.8, Updated September 2022)

References

1. AICIS (2019) Nonylphenol and octylphenol ethoxylates and related compounds: Human health Tier II assessment
2. ECHA, <https://echa.europa.eu/registration-dossier/-/registered-dossier/19064>
3. AICIS (2016) Nonylphenol ethoxylates and their sulfate and phosphate esters: Environment Tier II assessment
4. HCIS, Hazardous Chemical Information System, Safe Work Australia, Retrieved: <http://hcis.safeworkaustralia.gov.au/HazardousChemical>

Toxicity Summary - Sorbitol

Chemical and Physical Properties ¹	
CAS number	50-70-4
Molecular formula	C ₆ H ₁₄ O ₆
Molecular weight	182.17
Solubility in water	2750000 mg/L (at 30 °C)
Melting point	88 to 102 °C
Boiling point	295 °C at 3.5 mm Hg
Vapour pressure	9.9 x 10 ⁻⁹ mm Hg at 25 °C
Henry's law constant	7.3 x 10 ⁻¹³ atm-cu m/mol at 25 °C
Explosive potential	Finely dispersed particles form explosive mixtures in air.
Flammability potential	Non-flammable
Colour/Form	White crystalline powder
Overview	Sorbitol is a sugar alcohol found in fruits and plants with diuretic, laxative and cathartic property. Unabsorbed sorbitol retains water in the large intestine through osmotic pressure thereby stimulating peristalsis of the intestine and exerting its diuretic, laxative and cathartic effect. In addition, sorbitol has one-third fewer calories and 60% the sweetening activity of sucrose and is used as a sugar replacement in diabetes. This chemical has been identified by NICNAS to be of low concern to human health based on a Tier I assessment under the NICNAS IMAP assessment framework and thus required no further assessment.
Environmental Fate ¹	
Soil/Water/Air	D-Sorbitol's production and use as a non-nutritive sweetener and as a starting material in the synthesis of sorbose and vitamin C may result in its release to the environment through various waste streams. D-Sorbitol occurs naturally in apples, plums, pears, cherries, dates, peaches, apricots and other fruits. If released to air, an estimated vapor pressure of 4.9X10⁻⁹ mm Hg at 25 °C indicates D-sorbitol will exist in the particulate phase. Particulate-phase D-sorbitol will be removed from the atmosphere by wet and dry deposition. If released to soil, D-sorbitol is expected to have very high mobility based upon an estimated K_{oc} of 2. Volatilization from moist soil surfaces is not expected to be an important fate process based upon an estimated Henry's Law constant of 7.3X10⁻¹³ atm-cu m/mole. D-Sorbitol is a simple sugar alcohol and should be readily biodegraded in the environment. If released into water, D-sorbitol is not expected to adsorb to suspended solids and sediment in the water column based upon the estimated K_{oc}. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's estimated Henry's Law constant.
Human Health Toxicity Summary ^{1,4}	
Chronic Repeated Dose Toxicity	Rats fed a diet enriched in sorbitol presented a readily detectable decrease of liver hexokinase. At the same time the glycogen content of liver increased. In a 13 week feeding study conducted in rats, upon exposure to polyglycitol syrup (polyglycitol syrup belongs to the hydrogenated starch hydrolysate syrups composed of maltitol, sorbitol and higher molecular weight polyols) in the diet, the following effects were observed: a decrease in the average testis to body weight ratio of male rats, which upon microscopic examination of both testes (including epididymides) did not reveal any treatment-related effect; an increase in the empty caecum to body weight ratio in both sexes; an increase in urinary excretion of calcium in the absence of elevated serum calcium in both sexes (observed in the 4700 and 9700 mg/kg bw/day male groups and in the 2400 and 5000 mg/kg bw/day female groups); and an increase in blood glucose concentration in male animals only (observed in the 4700 and 9700 mg/kg bw/day groups). NOAELs of approximately 15,400 mg/kg bw/day in males and 7600 mg/kg bw/day in females,

	the highest doses levels tested, were identified for this study. The Panel considered these effects as non–adverse, being commonly observed also with other authorised indigestible polysaccharides																				
Carcinogenicity	No data available.																				
Mutagenicity/ Genotoxicity	No data available.																				
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No abnormalities of the adrenal medulla were seen grossly in any generation or microscopically in the high-dose and control F3a rats. It is concluded that sorbitol administered in the diet to three successive generations of rats at levels up to 10% had no adverse effect on growth or reproductive performance in either sex.																				
Acute Toxicity	Acute oral toxicity (LD50): 15900 mg/kg (rat)																				
Irritation	May cause respiratory tract irritation. May cause skin irritation. May cause eye irritation.																				
Sensitisation	No data available.																				
Key Study/Critical Effect for Screening Criteria	The most appropriate NOAEL for risk assessment purposes, determined from the 13-week dietary study in rats is 7600 mg/kg bw/day.																				
Ecological Toxicity ¹																					
Aquatic Toxicity	No data available.																				
Determination of PNEC aquatic	No data available.																				
Current Regulatory Controls																					
Listed as a Chemical of Concern on International Databases	<table><tr><th>International Database</th><th>Listed?</th></tr><tr><td>European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table</td><td>NO</td></tr><tr><td>International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications</td><td>NO</td></tr><tr><td>National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html</td><td>NO</td></tr><tr><td>US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris</td><td>NO</td></tr><tr><td>United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and</td><td>NO</td></tr><tr><td>Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18</td><td>NO</td></tr><tr><td>Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol</td><td>NO</td></tr><tr><td>Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals</td><td>NO</td></tr><tr><td>Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx</td><td>NO</td></tr></table>	International Database	Listed?	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	NO	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	NO	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	NO	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	NO	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	NO	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	NO	Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol	NO	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	NO	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	NO
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	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	NO																			
	Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol	NO																			
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	NO																			
Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	NO																				
Australian Hazard Classification	No data available.																				
Australian Occupational Exposure Standards	No data available.																				

International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment¹	
P/vP Criteria fulfilled?	No. Utilizing the Japanese MITI test, 81% of the Theoretical BOD was reached in 2 weeks indicating that biodegradation is an important environmental fate process in soil.
B/vB criteria fulfilled?	No. Sorbitol has no considerable potential for bioaccumulation (log Kow -2.2).
T criteria fulfilled?	No data available.
Overall conclusion	Not PBT. Sorbitol poses no unreasonable risk to the environment based on Tier I assessment under the NICNAS IMAP assessment framework.

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Toxicity Summary - Propylene glycol

Chemical and Physical Properties ^{3,5,6,7}	
CAS number	57-55-6
Molecular formula	CH ₃ CHOHCH ₂ OH
Molecular weight	76.09 g/mol
Solubility in water	Soluble at 25°C
Density	1.032-1.036 g/cm ³
Melting point	< -60°C
Boiling point	187.4-189°C
Vapour pressure	0.11 hPa at 20°C
Henry's law constant	1.3X10 ⁻⁸ atm-cu m/mol at 25 °C
Explosive potential	Above 99 °C explosive vapor/air mixtures may be formed.
Flammability potential	No data
Colour/Form	Clear, colourless and hygroscopic liquid
Overview	Propylene glycol is a colorless, odorless liquid which is generally recognized as safe (GRAS) by the Food and Drug Administration (FDA) for use as a direct food additive. It is also approved by the U.S. FDA for use as certain indirect food additives. Propylene glycol is used as a constituent in a large variety of cosmetics, and is approved and used as a vehicle for topical pharmaceutical preparations. It has a wide range of other practical applications, e.g., used as deicers, coolants, antifreeze, heat transfer and hydraulic fluids, plasticizers and other products. Propylene glycol has low toxicity, is not acutely toxic, and does not irritate the skin. A Tier 1 Human Health and Environmental Assessment has been undertaken for this chemical by AICIS which concluded that it poses no unreasonable risk to human health and the environment, and thus required no further assessment.
Environmental Fate ^{3,5}	
Soil/Water/Air	Propylene glycol is a liquid at room temperature, it has a low vapor pressure, and is miscible with water. Releases to the environment are expected to partition primarily to water and soil where they will be readily degraded. It is not expected to bioaccumulate, based upon a calculated BCF of 1.
Human Health Toxicity Summary ^{1,3,4,5,6}	
Chronic Repeated Dose Toxicity	Chronic feeding studies in rats (Gaunt et al., 1972) demonstrated only minimal changes following administration of up to 5% w/w in the diet, equivalent to a NOAEL of 1700 mg/kg bw/day in males and 2100 mg/kg/day in females. Dogs tolerated dietary administration of 8% w/w in diet over 2 years (NOAEL equivalent to 2000 mg/kg bw/day), although mild hematological changes were apparent in animals fed 20% w/w propylene glycol, equivalent to a LOAEL of 5000 mg/kg bw/day (Weil et al., 1971).
Carcinogenicity	Propylene glycol is not listed as a carcinogen by IARC. The carcinogenic potential of propylene glycol has been investigated in two long term feeding studies (see section 4.1.3 for details of study design). No increase in tumors was recorded in rats receiving the equivalent of 1700 (males) or 2100 (females) mg/kg bw/d over two years (Gaunt et al., 1972). Tumor incidences were also unchanged in male and female Beagle dogs ingesting 20% propylene glycol in diet (equivalent to 5000 mg/kg bw/day), again over two years (Weil et al., 1971).

	Skin painting studies with propylene glycol have shown no increase in dermal tumors in female mice after chronic treatment with 2, 10 or 21 mg/day over a lifetime (Stenbeck and Shubik, 1974). In a non-standard investigation, Wallenius and Lekholm (1973) used propylene glycol as vehicle (dose not specified) in an ear painting study in rats. No tumors were apparent by visual or microscopic examination after 10-14 months treatment.
Mutagenicity/Genotoxicity	Propylene glycol is not a genetic toxicant as demonstrated by in vivo (micronucleus, dominant lethal, chromosome aberration) and in vitro (bacterial and mammalian cells and cultures) studies.
Reproductive Toxicity / Developmental Toxicity/ Teratogenicity	Propylene glycol is not a reproductive or developmental toxicant. The impact of propylene glycol on reproductive performance in male and female mice has been assessed using a continuous breeding protocol (Morrissey et al., 1989; Lamb et al., 1997). Propylene glycol was administered in drinking water (1-5%), with received doses of approx. 1800, 4800 or 10100 mg/kg bw/d for up to 98 days. There was no treatment-related effect on growth or viability in the F1 and F2 generations, or on reproductive performance in the F0 or F1 generations. Effects on fetal development have been investigated in pregnant rats, mice, hamsters and rabbits (Food and Drug Research Laboratories, 1973). Appropriate positive control substances were included in these studies (aspirin for rats, mice and hamsters, 6-aminonicotinamide for rabbits). Orally administered propylene glycol (gavage) was well tolerated with no adverse effect on pregnancy parameters or maternal or fetal survival at any treatment level. There was no evidence of teratogenicity at any dose level.
Acute Toxicity	Propylene glycol is not acutely harmful after ingestion or skin contact. Representative data indicate oral LD50 values of 24900 mg/kg bw in the mouse, 22000 mg/kg bw in the rat, 18000 mg/kg bw in the rabbit, 19700 mg/kg bw in guinea pig and 20000 mg/kg bw in the dog. The acute dermal toxicity of propylene glycol in rabbits was 20800 mg/kg bw (20.8 grams; NPIRI, 1974).
Irritation	Propylene glycol is not irritating to skin or eye.
Sensitisation	Propylene glycol does not cause sensitization by skin contact.
Health Effects Summary	Propylene glycol does not present an acute, chronic, reproductive, or developmental hazard. Acute toxicity is very low, with LD50 values exceeding 19000 mg/kg after ingestion or skin contact. It is not a skin or eye irritant, and does not cause sensitization. The weight of the evidence indicates that it is not genotoxic in vitro or in vivo. Adequate long-term feeding studies are available which indicate that it does not represent a cancer hazard.
Key Study/Critical Effect for Screening Criteria	A Tier 1 Human Health Assessment has been undertaken for this chemical by AICIS which concluded that it poses no unreasonable risk to human health, and thus required no further assessment.
Ecological Toxicity ^{2,,3,5}	
Aquatic Toxicity	Acute toxicity to Fish: LC50 range from 43500 mg/L to 51600 mg/L Acute Toxicity to Aquatic Invertebrates: LC50 range from 18340 mg/L to 43500 mg/L Toxicity to Aquatic Plants: Algae 14-day growth rate (OECD TG 201) NOEC = 15000 mg/L Chronic Toxicity to Aquatic Invertebrates (Daphnia): NOEC = 13020 mg/L
Determination of PNEC aquatic	A Tier 1 Environmental Assessment has been undertaken for this chemical by AICIS which concluded that it poses no unreasonable risk to the environment, and thus required no further assessment.
Current Regulatory Controls	
Listed as a Chemical of	

Concern on International Databases	International Database	Listed ?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No	
Australian Hazard Classification	This chemical is not listed as a Hazardous Chemical in Safe Work Australia HCIS.	
Australian Occupational Exposure Standards	Time Weighted Average (TWA) exposure standards recommended by Safe Work Australia HCIS for this chemical are: • 474 mg/m³ (150 ppm) for vapour and particulates; and • 10 mg/m³ for particulates only	
International Occupational Exposure Standards	No exposure standards provided in NIOSH.	
Australian Food Standards	No Australian food standards were identified in FSANZ	
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified in the National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines (NHMRC, 2022).	
Aquatic Toxicity Guidelines	No Australian guidelines available.	
PBT Assessment ⁷		
P/vP Criteria fulfilled?	Manometric respirometry tests (OECD 301F) and other OECD 301 studies showed that this substance is ready biodegradable. Therefore, this substance can be regarded as not persistent.	
B/vB criteria fulfilled?	No experimental data are available for bioaccumulation of this substance. The calculated BCF value is 1.4 l/kg (Lyman, 1982). On the basis of the calculated BCF value and the log10 Pow -1.07 further testing in the scope of the PBT assessment is not deemed necessary.	
T criteria fulfilled?	Experimental data on acute toxicity to aquatic organisms are available for this substance. All short-term toxicity EC/LC50 values are much higher than the screening criterion of 0.1 mg/l and the chronic NOEC values are much higher than the screening criterion of 0.01 mg/l. This substance is not classified as being a CMR substance and there is no evidence	

	that this substance is chronically toxic towards mammals. It can therefore be expected that this substance is not toxic towards aquatic organisms.
Overall conclusion	Not a PBT substance

Notes: AICIS – Australian Industrial Chemicals Introduction Scheme; HCIS – Hazardous Chemical Information System; NIOSH – National Institute for Occupational Safety and Health; FSANZ – Food Standards Australia New Zealand; NHMRC (2022) – National Health and Medical research Council, Australian Drinking Water Guidelines 6, 2011 (Version 3.8, Updated September 2022)

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Toxicity Summary - Ethanol

Chemical and Physical Properties ^{1,2,3}	
CAS number	64-17-5
Molecular formula	C ₂ H ₆ O
Molecular weight	46.07
Solubility in water	1 x 10 ³ g/L at 25 °C
Melting point	114.14 °C
Boiling point	78.3 °C
Vapour pressure	57.3 hPa at 20°C
Henry's law constant	0.000252
Explosive potential	Non explosive
Flammability potential	Highly flammable (100%)
Colour/Form	Clear, colourless liquid with a characteristic pleasant odour and burning taste.
Overview	Ethanol, also known as grain alcohol, is a clear, colourless liquid. It has an alcohol odour a burning taste. Ethanol mixes easily with water. Ethanol is present in emissions from plants, fires, volcanoes, animal wastes, insects and natural fermentation of sugars. Ethanol is an important commercial chemical used in alcoholic beverages, which may contain up to 50% ethanol. It is also used as a solvent in cleaners and as a fuel additive. Ethanol is used in the production of other chemicals, pharmaceuticals, perfumes, and cosmetics. It is also used as a fungicide and to regulate plant growth. It is an ingredient in many consumer products, such as cleaners, sprays, inks, mouthwash, perfume and aftershave, and human and veterinary medicines. Ethanol is a food additive.
Environmental Fate ³	
Soil/Water/Air	Ethanol is stable to hydrolysis but is readily biodegradable (74% after 5 days) and is not likely to bioaccumulate (calculated logBCF=0.5). Ethanol is not persistent in the environment. Fugacity-based modelling shows that ethanol released into the environment will become distributed mainly into air and water. Relative distributions between compartments based on an emission pattern of 1000:100:10 were 57 % in air, 34 % in water, and 9 % in soil. These predictions are supported by the limited data available on prevailing concentrations, which shows that ethanol has been detected in outdoor air and in river water. The total tropospheric half-life of ethanol is estimated to be 10-36 hours, with degradation due to hydroxyl, NO _x and SO _x radical-mediated photooxidation. As a volatile organic compound in the atmosphere, ethanol is a potential contributor to tropospheric ozone formation under certain conditions, however its photochemical ozone creation potential is considered to be moderate to low (40-45 relative to ethylene as 100).
Human Health Toxicity Summary ^{1,2}	
Chronic Repeated Dose Toxicity	Many repeated dose studies of chemical have been conducted in many species, predominantly with the aim of assessing adverse effects associated with the consumption of alcoholic beverages. Consequently, these are mostly conducted through oral exposure and with doses well in excess of those that might be encountered in occupational exposure or consumer products (OECD, 2005), or unintentional public exposures from environmental contamination. Considering the lowest observed adverse effect level (LOAEL) available from a 90-day rat study (3600 mg/kg bw/day), and based on the treatment-related effects reported in various repeated dose toxicity studies, the chemical is not considered to cause serious damage to health from repeated oral exposure, except from exposure to high doses.

	In a well-conducted repeated dose toxicity study, the chemical was administered (in a liquid diet) to Sprague Dawley (SD) rats at a 1, 2, 3, 4, 5, and 10 % concentration for 90 days. Water consumption in the 10 % group was reduced relative to controls. There were no adverse clinical signs or mortality during the study. Serum liver enzymes were unaffected by treatment and kidney findings were reported to be minimal. A LOAEL was established at 3 % (approximately 3600 mg/kg bw/day), based on dose-related hepatic yellowing, centrilobular steatosis, increased frequency and severity of Mallory bodies (hyaline), and acidophilic degeneration and necrosis. The no observed adverse effect level (NOAEL) was 2 % (approximately 2400 mg/kg bw/day) (OECD, 2005; REACH). In another repeated dose toxicity study conducted in accordance with national test guidelines of USA (EPA OPPTS 870.3100), the chemical was administered in drinking water to Fischer 344 (F344) rats and B6C3F1 mice at a single dose of 5 % concentration for 90 days. Even though male rats showed minor changes in thymus weights, and some slight but inconsistent changes in haematology and clinical chemistry, these effects were not considered adverse. Based on water consumption data, this single dose study established a 5 % nominal NOAEL for male rats (approximately 3250 mg/kg bw/day). Although minor changes in clinical chemistry were also seen in female rats, some female rats (4/10) also exhibited liver nodules (diaphragmatic nodules) and small increases in liver weights. As no NOAEL could be established for female rats, a LOAEL of 4400 mg/kg bw/day was established. For male mice, a LOAEL at 9700 mg/kg bw/day was established, based on increased organ weights (liver, heart, kidney and lung) and decreased sperm counts in the cauda epididymis. Although female mice showed small changes in the length of dioestrus and pro-oestrus, the overall cycle length was unchanged. As biological significance of these changes was unclear, a NOAEL for female mice was established at 5 % (9400 mg/kg bw/day) (OECD, 2005; REACH). As properly conducted studies in animals are not available, there are no valid data on the effects of repeated inhalation exposure to the chemical. However, limited information is presented below to indicate that the chemical is likely to be of low toxicity following repeated inhalation exposure. In a repeated dose toxicity study, SD male rats (10/dose) were exposed to the chemical through inhalation (whole body exposure) continuously at 20 mg/L for three, six, nine, and 26 days. Although initial exposure to the chemical produced a number of transient effects (lethargy, ataxia and intoxication, mild hepatic vacuolisation and changes to clinical chemistry parameters), animals adapted and appeared normal at the end of the study. Induction of metabolic tolerance to the chemical was also indicated as it was noted that the levels of the chemical in the blood of animals exposed for 26 days were much lower than those exposed for shorter periods (REACH). In another repeated dose toxicity study, the chemical was administered through inhalation at 0 or 6300 ppm (1 ppm = 1.92 mg/m³) to SD rats (10/sex/dose) for six hours/day, five days/week, for four weeks (total of 20 days exposure). Additional groups of animals (five/sex/dose) were also included in the study to determine reversibility of effects for a further four weeks following cessation of treatment. There were no treatment-related clinical signs of toxicity and there were also no gross pathological or histological changes reported of the major organs. Body weights, liver enzyme levels, haematology, and clinical chemistry parameters were otherwise normal (REACH).
Carcinogenicity	The International Agency for Research on Cancer (IARC) has concluded that there is sufficient evidence in humans and experimental animals to establish carcinogenicity of alcohol consumption and ethanol, respectively. It was also concluded that there is sufficient evidence in experimental animals to establish carcinogenicity of acetaldehyde (major metabolite of ethanol). Consequently, IARC has classified that 'alcohol consumption is carcinogenic to humans (Group 1)' and that 'ethanol in alcoholic beverages is carcinogenic to humans (Group 1)'. This conclusion was supported by an analysis of the expanded human dataset that carcinogenic effects appeared independent of the type of alcoholic beverage (IARC, 2010; IARC, 2012).

	As the use of the chemical in alcoholic beverages is not considered in this report, the above assessment of carcinogenicity of alcohol beverages may not be relevant to occupational exposure to the chemical or from using the chemical in consumer products (OECD, 2005). Furthermore, studies in animals conducted mostly through oral exposure at very high doses, exceeding the 'maximum tolerated dose', may be of little relevance when assessing risks associated with occupational exposure or using consumer products containing the chemical (OECD, 2005). Thus, classification is not considered appropriate.
Mutagenicity/ Genotoxicity	Overall, the data indicate that the chemical has no mutagenic or genotoxic potential (OECD, 2005; REACH). The results from numerous bacterial mutation assays of the chemical have generally been negative. A very weak positive effect of the chemical was found in an Escherichia coli DNA repair test but not in Ames tests with Salmonella typhimurium conducted by the same authors. In separate studies, there have been positive results reported in Ames tests, but only at concentrations of the chemical significantly greater than those specified in test guidelines. The chemical is therefore not considered mutagenic in bacteria.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	The chemical does not show specific reproductive or developmental toxicity. Any reproductive and developmental effects were only observed secondary to maternal toxicity. As results of inhalation studies showed no developmental toxicity from chemical exposures even at maternally toxic doses, it can be concluded that deliberate oral consumption of alcoholic beverages is required for any reproductive or developmental toxicity (OECD, 2005).
Acute Toxicity	The chemical has low acute toxicity by oral exposure in animal tests. The median lethal dose (LD50) in rats is >2000 mg/kg bw. Observed sub-lethal effects included central nervous system depression, e.g. inebriation, disturbances of gait, dose-related decreases in responses to painful stimuli, respiratory depression, and coma. Deaths were reported due to cardiorespiratory failure (OECD, 2005; HSDB; REACH). Few studies are available on the dermal toxicity of the chemical. A poorly documented rabbit study reported death in one of four animals following a dose of 20000 mg/kg bw. Although limited data are available, the apparent low dermal toxicity from this study is regarded as consistent with low uptake of ethanol through intact skin. The median lethal dose (LD50) in rats is greater than 2000 mg/kg bw. Observed sub-lethal effects were not reported for the study (OECD, 2005; REACH). The chemical has low acute toxicity by inhalation exposure in animal tests. The lowest reported median lethal concentration (LC50) is 124.7 mg/L/four hours in rats. Observed sub-lethal effects included attempts to escape, reddish-watery eyes, nasal secretions, closing of eyelids, snout wiping, intermittent respiration, loss of pain reflex, abdominal position, and apathy (OECD, 2005; REACH).
Irritation	The chemical is not regarded as irritating to skin. In a skin irritation study conducted in accordance with OECD Test Guideline (TG) 404, the chemical was applied to six New Zealand White rabbits for four hours using exposure chambers. The mean score for erythema was one at 24 hours and remained zero at all other time points (48, 72 hours); the mean score for oedema remained zero at all time points (24, 48, 72 hours). The chemical was concluded not to be irritating to the skin of rabbits. Another skin irritation study in rabbits, where the chemical was applied under occlusion for 24 hours, also showed only very slight skin irritation (OECD, 2005; REACH). The chemical produced irritant effects in several eye irritation studies in rabbits. In an eye irritation study conducted in accordance with US Federal guideline (Fed. Reg. Vol. 38, No. 187, 1973), the chemical (0.1 mL) was applied on the conjunctival sac of one eye of each of three New Zealand White rabbits. Irritation responses were observed at 24, 48 and 72 hours and eight days following application. Mean Draize scores following grading at 24, 48 and 72 hours for three rabbits were 1 for corneal opacity, 0.22 for iritis, 2.45 for conjunctivitis, and 1.89 for chemosis. Mean Draize scores following grading at day eight were 0.67 for corneal opacity, 1.67 for conjunctivitis, and 1.33 for chemosis. While iris lesions were fully reversible by day eight, other eye lesions were not fully reversible at

	this time. Given the observation period did not extend to 21 days, it is difficult to conclude any findings on the reversibility of the irritation. The average response of 2/3 animals was sufficiently severe in terms of conjunctival effects (>2.5) and chemosis (³2) observed, that classification as an eye irritant is warranted (REACH). In another eye irritation study (OECD TG 405), the chemical (0.1 mL) was applied to the eyes of three rabbits (strain not specified) and observed up to 14 days. Mean Draize scores at 24, 48 and 72 hours were 2.11 for conjunctivitis, 1.33 for chemosis, 0.44 for iritis, and 1.11 for corneal opacity. Although all symptoms subsided by day 14, conjunctivitis was still present at day seven. As positive responses for corneal opacity (mean score >1 for 2/3 animals) and conjunctival redness (mean score >2 for 2/3 animals) were noted in the study, the chemical is considered to be an eye irritant (category 2A) (OECD, 2005; REACH). In an eye irritation study (OECD TG 405), the chemical (0.1 mL) was applied into the lower conjunctival sac of one eye of six New Zealand White rabbits and observed up to 72 hours. Reported average Draize scores at 24, 48 and 72 hours were 2.39 for redness of the conjunctivae, 1.2 for chemosis, 0.28 for iritis, and 1.2 for corneal opacity. As conjunctival redness persisted for 24 hours with a mean score of >2 and corneal opacity was noted with a mean score >1, the chemical is considered to be an eye irritant (category 2A) (OECD, 2005; REACH). In an eye irritation study conducted in accordance with US Federal guideline (Fed. Reg. 28 (119), 5582, 1963), the chemical (0.1 mL) was applied on the lower lid of one eye of six New Zealand White rabbits. The eyes were examined at 24, 48, and 72 hours and at day seven following administration of the chemical. Mean Draize scores following grading at 24, 48 and 72 hours were 1.72 for conjunctivitis, 1.78 for chemosis, 0.83 for iritis, and 1.28 for corneal opacity. While iris lesions were fully reversible at day seven, other eye lesions were not. Mean Draize scores following grading at day seven were 0.83 for conjunctivitis, 0.83 for chemosis, and 1.17 for corneal opacity. As corneal opacity was noted with a mean score >1, the chemical is considered an eye irritant (category 2A). In addition, whilst mean scores for conjunctival redness and chemosis were <2, scores ³2 were noted in four out of six animals (OECD, 2005; REACH).
Sensitisation	The available data indicate that the chemical does not induce skin sensitisation in animals. The chemical, at 75 % concentration, was used as a solvent in a Magnusson and Kligman guinea pig maximisation test of a polyalkylene glycol. Skin reactions were not observed at challenge with the polyalkylene glycol in 75 % ethanol in either the test or negative control animals (OECD, 2005). In a mouse ear swelling test, no increase in ear thickness was observed following a challenge application of the chemical at 95 % (OECD, 2005; REACH). In a mouse local lymph node assay (LLNA) (OECD TG429) the chemical, or diethyl phthalate, were used as vehicles to examine the skin sensitisation potential of four test fragrance materials. The concentration of the chemical in this study varied from 0–100 %. The level of induced T-lymphocyte proliferation was low for the chemical compared with that for fragrance materials known to be mild to moderate skin sensitisers, and comparable with the other negative control vehicle (diethyl phthalate). On the basis of a lack of sensitising potential up to a concentration of 100 %, the test concluded that the chemical is an appropriate vehicle for use in a local lymph node assay (REACH).
Health Effects Summary	Ethanol has low acute toxicity by all exposure routes. It is not irritating to skin and is irritating to eyes. It is not a skin sensitiser. Many repeat dose studies have been conducted, predominantly with the aim of assessing effects associated with the consumption of alcoholic beverages. Overall, ethanol has low repeat dose oral toxicity.
Key Study/Critical Effect for Screening Criteria	The critical study for oral repeat dose effects is a 90-day drinking water study which established a NOAEL of 2400 mg/kg bw/day. The LOAEL was 3600 mg/kg bw/day based on hepatic effects.
Ecological Toxicity ^{2,3}	

Aquatic Toxicity	The aquatic toxicity data in fish, invertebrates, and algae indicate a low order of acute toxicity with LC50/EC50 values greater than 1000 mg/L. The most sensitive species were algae <i>Chlorella vulgaris</i> with a 96hr EC50 of 1000 mg/L and the invertebrate <i>Artemia Salina</i> with a 24hr LC50 of 1833 mg/L. Valid chronic toxicity data are available for two trophic levels. NICNAS (2017) reported a measured chronic endpoint of 7800 mg/L for <i>Daphnia</i> .		
Determination of PNEC aquatic	A PNECaqua = 780 mg/L can be calculated based on the chronic toxicity value (NOEC = 7800 mg/L) for aquatic invertebrates (<i>Daphnia</i>) with the assessment factor of 10.		
Current Regulatory Controls ^{1,4}			
Listed as a Chemical of Concern on International Databases	International Database		Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table		No
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications		Yes*
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html		No
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris		No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and		No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18		No
	Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol		No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals		No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx		No
* For Ethanol in alcoholic beverages			
Australian Hazard Classification	The chemical is not classified for health hazards on the Hazardous Substances Information System (HSIS) (Safe Work Australia).		
Australian Occupational Exposure Standards	The chemical has an exposure standard of 1880 mg/m ³ (1000 ppm) time weighted average (TWA).		
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica): An exposure limit (TWA) of 960–1920 mg/m ³ (500-1000 ppm) in countries such as Canada, Denmark, Germany, Sweden, South Africa, Switzerland, United Kingdom, and the United States of America. An exposure limit (STEL) of 1900–1920 mg/m ³ (1000 ppm) in countries such as Canada, Sweden, and Switzerland.		
Australian Food Standards	Ethanol has the following listings in the Australia New Zealand Food Standards Code (Food Standards Australia and New Zealand 2013): · as a permitted food additive subject to GMP (ethanol) (Standard 1.3.1 Food additives) · as a generally permitted processing aid (ethyl alcohol) (Standard 1.3.3 Processing aids)		

	· as a permitted component of wine (alcohol) (Standard 2.7.3 Fruit wine and vegetable wine) · as subject to a composition limit in brewed soft drinks (no more than 1.15% alcohol/volume) (Standard 2.6.2 Non-alcoholic beverages and brewed soft drinks) · As subject to a composition limit in: – wine and sparkling wine (no less than 45mL ethanol/L and not to contain added ethanol) – fortified wine (no less than 150 mL ethanol/L and no more than 220 mL ethanol/L) – brandy (must contain no less than 250 mL/L of the spirit distilled at a strength of no more than 830 mL ethanol/L at 20°C (Standard 4.5.1 Wine production requirements).
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified for this chemical in the Australian Drinking Water Guidelines (NHMRC 2011).
Aquatic Toxicity Guidelines	1400 µg/L (95% protection level) (ANZECC & ARMICANZ, 2000)
PBT Assessment ²	
P/vP Criteria fulfilled?	No. Ethanol is readily biodegradable (74% after 5 days).
B/vB criteria fulfilled?	No. Ethanol is not likely to bioaccumulate (calculated logBCF=0.5).
T criteria fulfilled?	No. Chronic aquatic toxicity (NOEC) >1mg/l, thus ethanol does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier II Assessment for Ethanol: Retrieved 2019: <https://www.nicnas.gov.au>
2. National Industrial Chemicals Notification and Assessment Scheme (NICNAS, 2017). National assessment of chemicals associated with coal seam gas extraction in Australia. Human health hazards of chemicals associated with coal seam gas extraction in Australia.
3. ECHA REACH, Ethanol, Retrieved 2019: <https://echa.europa.eu/>
4. OECD (2005) SIDS Initial Assessment Profile for Ethanol
5. ANZECC & ARMICANZ (2000), Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Toxicity Summary - Methanol

Chemical and Physical Properties ^{1,3,4}	
CAS number	67-56-1
Molecular formula	CH ₄ O
Molecular weight	32.04
Solubility in water	1,000 g/L at 20 °C
Density	0.791 kg/L
Melting point	-98 °C
Boiling point	65 °C
Vapour pressure	16.927 kPa at 25 °C
Henry's law constant	0.461 Pa m ³ /mol
Explosive potential	Vapour/air mixtures are explosive
Flammability potential	Highly flammable
Colour/Form	Clear colourless liquid
Overview	Methanol occurs naturally in humans, animals and plants. The general population is exposed to methanol mainly through consumption of food and beverages and through use of consumer products such as paints, sealers and adhesives that contain methanol as a solvent. This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the NICNAS IMAP assessment framework.
Environmental Fate ^{1,3}	
Soil/Water/Air	Air is the main target compartment, based on a fugacity model calculation (Mackay Level III) with about 73 % of environmental methanol distributing to air and 16 % to water. Methanol is degraded in the atmosphere by photochemical, hydroxyl-radical dependent reactions. The estimated elimination half-life is calculated to be about 17-18 days with a rate constant of 0.93 x 10⁻² cm³/molecule-sec. Methanol is completely miscible in water and has a low octanol/water partition coefficient. These properties are indicative of high mobility in soil.
Human Health Toxicity Summary ^{1,2,3}	
Chronic Repeated Dose Toxicity	Considering the no observed adverse effect level (NOAEL) available from a 90-day rat study (500 mg/kg bw/day), the chemical is not considered to cause serious damage to health by repeated oral exposure. In a 20-day inhalation study in monkeys, 3.9 mg/L (3000 mL/m³) was identified as the LOAEL (continuous exposure) where neurotoxic lesions appeared to progress in monkeys (according to NEDO 1987). This exposure concentration correlated with methanol blood levels 80 mg/L and formate levels 30 mg/L. There was no evidence of adverse effects in rats exposed to methanol up to 6.6 mg/L, six hours/day for 28 days, except local nasal irritation and increased relative spleen weights, which were observed only at the middle dose and not considered treatment-related (Andrews et al. 1987). A NOAEL could not be established in this study. In the chronic exposure studies in rats and mice, slight treatment-related decreases in body and organ weights were reported at the highest dose. These are however not considered as 'adverse' effects. In monkeys, slight degeneration of the inside nucleus of the thalamus was observed at 0.13 and 1.3 mg/L after seven months or more (NEDO 1987). One monkey at 0.13 mg/L and two at 1.3 mg/L showed slight but clear changes in peroneal nerves indicating damage to peripheral nerves. Some signs of fibrosis at 1.3 mg/L, which were considered

	borderline. There were mild but significant effects on heart and kidney at 0.13 and 1.3 mg/L. Histologically, a significant increase of Sudan positive granules was noted in the 1.3 mg group without pathological manifestations (e.g. fibrosis). Although the authors considered the lowest dose (0.013 mg/L) as the LOAEL, it was observed that effects at this dose were very mild and reversible and therefore not considered to be adverse effects. Based on these observations, a NOAEL of 0.013 mg/L was established in this study.
Carcinogenicity	The chemical is not likely to be a carcinogen. In a chronic inhalation study, Fisher rats and B6C3F1 mice were exposed to 0.013, 0.13, and 1.3 mg/L methanol for 24 and 18 months, respectively (NEDO 1987). No differences in survival were noted in the treatment groups compared with the control group. There was no evidence of an increase in liver tumours in rats or in the spontaneous liver tumour rate in mice. In the rats, some tumours such as papillary lung adenomas (males only), adrenal phaeochromocytomas (females only) and metastatic (transition) tumours appeared at a somewhat higher incidence in high-dose group rats after week 79 and 104 without clear dose-response relationship. However these tumour incidences were not statistically significantly different from those in the control group. In the mice, there were no appreciable differences from the control in either numbers of animals with tumours or in degree of malignancy observed. Proliferative effects on the astroglia cells were observed in monkeys continuously exposed to 0.013, 0.13 and 1.3 mg/L methanol by the inhalation route (NEDO 1987). These effects however were of a transient nature and disappeared after a six-month recovery period. There were no signs of histological degeneration.
Mutagenicity/ Genotoxicity	Methanol has been examined in numerous in vitro and in vivo test systems, including bacterial, mammalian and fungal test systems. Most in vitro studies did not demonstrate mutagenic activity. A small number of studies gave ambiguous results. All other studies produced negative results consistently. The majority of in vivo assays were negative for mutagenicity and clastogenicity (OECD 2004). Methanol was therefore concluded to be not mutagenic.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No impairment of fertility or reproductive performance was reported in male and female rats exposed to the chemical, except at very high doses. Male mice had morphological anomalies in spermatozoa after repeated oral dosing at 1000 mg/kg bw/day (blood level > 500 to 1000 mg/L in mice) (OECD 2004). Rodent studies indicate that methanol has developmental toxicity effects. The rodent data on developmental toxicity are relevant for humans despite the known differences in methanol metabolism between the two species. However, rodents are considered adequate models for humans only at levels where formate does not accumulate (NTP 2003). Blood methanol levels associated with serious developmental effects in rodents were in the range associated with formate accumulation (1000 to 2000 mg methanol per litre of blood), which is likely to result in metabolic acidosis, and visual and clinical effects in humans (NTP 2003; OECD 2004). The limited data available in humans do not show an association between reproductive and developmental toxicity and methanol (NTP 2003). Following a review of the developmental toxicity studies, the NTP concluded that there is evidence to suggest that females with low folate levels may be more susceptible to the adverse developmental effects of methanol, but more information was necessary to clarify this issue (NTP 2003). Based on the data available, the chemical is not considered to have reproductive or developmental toxicity in humans.
Acute Toxicity	In rats, mice, rabbits and dogs, the LD50 values after single oral administration range from about 5600 to 14 400 mg/kg bw (EHC 1997). Adverse effects noted in these animals were ataxia, narcosis and coma after high methanol doses. The animals did not exhibit acidosis and ophthalmologic changes typically seen in humans at high lethal and sub-lethal doses. In rhesus monkeys, no deaths were reported at doses of 1000 to 2000 mg/kg bw, while animals receiving 3000 to 8000 mg/kg bw died within two days (OECD 2004). Treated animals showed acidosis, and some exhibited semi-coma and ophthalmologic changes. Human data, however, indicate acute oral toxicity at comparatively lower doses of 300 to 1000 mg/kg bw (EHC 1997). The reported median lethal doses (LD50) for experimental animals are 7300 mg/kg bw (mouse), 5628 mg/kg bw (rat), 14 200 mg/kg bw (rabbit) and 7000 mg/kg bw (monkey). The lowest lethal dose (LDLo) for humans ranges from 143 to 428 mg/kg bw (ChemIDplus 2012).

	There are limited available dermal toxicity studies in animals. In one dermal exposure study all the rats survived after application of 35 000 mg/kg bw methanol to the skin under occlusive conditions, while deaths were reported at 45 000 mg/kg bw (Eulner and Gedicke 1955). In rabbits, a dermal LD50 of 17 000 mg/kg bw was reported although no details of the study were provided (Carnegie-Mellon 1981). Limited data in monkeys indicate that the chemical is toxic via the dermal route (McCord 1931). Humans have been found to be more susceptible to methanol as compared to monkeys. Therefore, acute dermal toxicity with methanol is expected in humans (OECD 2004). The lowest reported dermal LD50 is 17 000 mg/kg bw, which was recorded in rabbits. Median lethal concentrations (LC50) of 87.5 and 128.2 mg/L were reported in rats following six and four hour inhalation exposures to methanol, respectively (BASF 1980a, 1980b). Clinical signs of toxicity were secretions from eyes and nose, laboured breathing, staggering, apathy and narcosis. A similar LC50 value (79 mg/L) was reported for mice following 2.25 hours exposure (Von Burg 1994). In cats, LC50 values after six-hour exposures ranged from 26 to 48 mg/L. A shorter duration of 4.5 hours led to an LC50 of 85.4 mg/L (Von Burg 1994). Studies in Rhesus monkeys indicated lethal concentrations (percent mortality not reported) at 13 mg/L after 18 hour exposure and 52 mg/L after one to four hour exposure (OECD 2004).
Irritation	The chemical is not a skin irritant. The chemical is a slight eye irritant in rabbits. High concentration of methanol vapours may cause irritation of the respiratory tract. In a short-term exposure study (details not available), exposure of rats to an atmosphere saturated with methanol vapours produced severe irritation of mucous membranes and milky corneal opacity (BASF 1975). All animals died after eight hours (BASF 1975).
Sensitisation	The chemical is not a skin sensitiser.
Health Effects Summary	Methanol has low acute oral, dermal and inhalation toxicity in experimental animals but moderate to high acute oral and dermal toxicity in humans. A Lowest Lethal Dose (LDLo) of 143 - 428 mg/kg bw (humans) has been reported. It is not a skin or eye irritant but is expected to be a moderate respiratory irritant, based on its effect on the mucous membrane in rats exposed to methanol vapours and on the effects observed in repeat dose inhalation studies. Tests with guinea pigs indicated that methanol is not a skin sensitiser. The critical effects to human health are acute toxicity from inhalation, skin contact and swallowing, and possible irreversible effects from acute oral exposure. No deaths were reported in Rhesus monkeys dosed at 2 000 mg/kg bw, but treated animals showed acidosis, and some exhibited semi-coma and ophthalmic changes. Human data, however, indicate acute oral toxicity and ophthalmic changes at comparatively lower doses of 300 - 1 000 mg/kg bw. Information on repeated dose toxicity by the dermal route is not available. Methanol was not genotoxic or carcinogenic. Reproductive and developmental toxicity studies did not show any significant effects of relevance to humans.
Key Study/Critical Effect for Screening Criteria	A No-Observed-Adverse-Effect-Concentration (NOAEC) of 0.013 mg/L (13 mg/m³) is used for this risk assessment. This NOAEC is derived from a chronic inhalation study in monkeys, in which degenerative effects in the brain and slight damage to the optic and peripheral nerves were noted at 0.13 mg/L and above. Changes in peroneal nerves were also noted in higher dosed animals, indicating damage to peripheral nerves. An oral No Observed Adverse Effect Level (NOAEL) of 500 mg/kg bw/day was also established in rats in a 90-day oral study based on increased liver enzymes (enzymes not specified) and decreased absolute brain weights at the highest dose. This value is not used in this risk assessment because acute oral data indicate that humans are more sensitive to methanol toxicity than rodents.
Ecological Toxicity ^{2,3}	
Aquatic Toxicity	In several 96-hour studies in fish in which methanol concentrations were measured during the tests, LC50s ranged from 15,400 to 29,400 mg/L. In the chronic toxicity study to invertebrates, the NOEC was 32,000 mg/L.
Determination of PNEC aquatic	This chemical has been identified by NICNAS to be of low concern to the environment based on Tier I assessment under the NICNAS IMAP assessment framework. No further assessment is required.

Current Regulatory Controls ^{1,2,4}		
Listed as a Chemical of Concern on International Databases	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIICChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	The chemical is classified as hazardous with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): T; R23/24/25 (acute toxicity) T; R39/23/24/25 (irreversible effects from acute exposure) Mixtures containing the chemical are classified as hazardous based on the concentration (Conc) of the chemical in the mixtures. The risk phrases for this chemical are: Conc ≥20%: T; R23/24/25; (Toxic: Toxic by inhalation, in contact with skin and if swallowed); R39/23/24/25; (Toxic: danger of very serious irreversible effects through inhalation, in contact with skin and if swallowed) 10% ≤Conc <20%: T; R20/21/22; (Toxic: Harmful by inhalation, in contact with skin and if swallowed); R39/23/24/25; (Toxic: danger of very serious irreversible effects through inhalation, in contact with skin and if swallowed) 3% ≤Conc <10%: Xn; R20/21/22; (Harmful: Harmful by inhalation, in contact with skin and if swallowed); R68/20/21/22; (Harmful: possible risk of irreversible effects through inhalation, in contact with skin and if swallowed).	
Australian Occupational Exposure Standards	The chemical has an exposure standard of 262 mg/m³ (200 ppm) Time Weighted Average (TWA) and 328 mg/m³ (250 ppm) Short-Term Exposure Limits (STEL) (Safe Work Australia).	
International Occupational Exposure Standards	The following were identified (Galleria Chemica): 250-270 mg/m³ (200 ppm) TWA in USA, Canada, Denmark, United Kingdom, Germany, France, Estonia, Greece, Hungary, South Africa, Spain, Singapore, Taiwan, Sweden, Malta, Malaysia, Latvia, Japan, Indonesia, India, Iceland, Egypt, Ireland, Mexico, Philippines and Switzerland;	

	250-350 mg/m³ (250-328 ppm) STEL in USA, Canada, United Kingdom, Greece, South Africa, Singapore, Sweden, India, Egypt and Mexico; 50 mg/m³ TWA in Bulgaria; 100 mg/m³ TWA and 300 mg/m³ STEL in Poland; 133 mg/m³ TWA in Netherlands; 25 mg/m³ TWA and 50 mg/m³ STEL in China; 1300 mg/m³ (1000 ppm) STEL in France; and 1040 mg/m³ STEL in Hungary and Switzerland.
Australian Food Standards	No Australian food standards were identified (FSANZ 2013)
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified for methanol in the Australian Drinking Water Guidelines (National Health and Medical Research Council (NHMRC) 2011).
Aquatic Toxicity Guidelines	No data available.
PBT Assessment⁴	
P/vP Criteria fulfilled?	No. Methanol is expected to be readily biodegradable.
B/vB criteria fulfilled?	No. The Log Kow for methanol is -0.77. Thus, methanol does not meet the screening criteria for bioaccumulation.
T criteria fulfilled?	No. The EC50s from the acute aquatic toxicity data on methanol are >1 mg/L, hence does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT

References

1. NICNAS (2017) Human Health Tier II Assessment for Methanol
2. National Industrial Chemicals Notification and Assessment Scheme (NICNAS, 2017). National assessment of chemicals associated with coal seam gas extraction in Australia. Human health hazards of chemicals associated with coal seam gas extraction in Australia.
3. OECD (2008) SIDS Initial Assessment Profile on Methanol
4. ECHA REACH, Methanol, Retrieved 2017: <https://echa.europa.eu/information-on-chemicals/registered-substances>

Toxicity Summary - Propan-2-ol (Isopopropanol)

Chemical and Physical Properties ^{1,3,4,5,6}	
CAS number	67-63-0
Molecular formula	C ₃ H ₈ O
Molecular weight	60.10 g/mol
Solubility in water	100 vol% at 20 °C (miscible)
Melting point	-88.5 °C
Boiling point	82.5 °C
Vapour pressure	45.4 mm Hg at 25°C
Henrys law constant	7.52 x 10 ⁻⁶ atm m ³ /mole
Explosive potential	Is classified as explosive. The vapours may form an explosive mixture with air.
Flammability potential	Flammable liquid and vapour.
Colour/Form	Colourless liquid with a pleasant odour.
Overview	Isopropanol (IPA) is a high production volume chemical which has wide use as an industrial solvent and as a component in numerous industrial and consumer products. It has a potential for widespread exposure to both workers and consumers. Based upon physical and chemical properties, isopropanol is not expected to persist in the environment. Aerobic biodegradation of isopropanol occurs rapidly. IPA is not expected to persist in soil due to low soil adsorption and rapid evaporation to air. In the air, isopropanol is subject to rapid oxidation by hydroxyl radical attack. IPA has a low order of toxicity to aquatic organisms and plants, and bioconcentration in aquatic organisms is not expected to occur.
Environmental Fate ^{1,4,5,6}	
Soil/Water/Air	Based on calculated results from a Level I fugacity model, isopropanol is expected to partition primarily to the aquatic compartment (77.7%) with the remainder to the air (22.3%) (OECD, 1977a,b). Aerobic biodegradation of isopropanol has been shown to occur rapidly under nonacclimated conditions, based on a result of 49% biodegradation from a 5-day BOD test (Bridie <i>et al.</i> , 1979). Additional biodegradation data developed using standardized test methods show that isopropanol is readily biodegradable in both freshwater and saltwater media (72 to 78% biodegradation in 20 days) (Price <i>et al.</i> , 1974). Bioconcentration of isopropanol in aquatic organisms is not expected to occur based on a measured log n-octanol/water partition coefficient (log Kow) of 0.05, a calculated bioconcentration factor of 1 for a freshwater fish, and the unlikelihood of constant, long-term exposures (OECD 1977a,b).
Human Health Toxicity Summary ^{1,2,3,4,5,6}	
Chronic Repeated Dose Toxicity	Considering the lowest observed adverse effect levels (LOAELs) available from a 12-week rat study (1390 mg/kg bw/day), and based on the treatment-related effects reported in various repeated dose toxicity studies, the chemical is not considered to cause serious damage to health from repeated oral exposure. Male Wistar rats were administered the chemical at concentrations of 0, 1, 2, 3, or 5 % (0, 870, 1390, 1700, or 2500 mg/kg bw/day) in drinking water for 12 weeks. The top dose was reduced to 4 % due to unpalatability after two weeks. Significantly decreased bodyweights were seen at the two highest doses and dose-related increases in relative liver and kidney weights were also significant at 1390 mg/kg bw/day and above. Relative adrenal weights were also significantly increased at the two highest doses; increased testis weight was noted only at the top dose. A dose-dependent increase of hyaline casts and hyaline droplet formation in the proximal tubules of the kidneys was also noted. The no observed adverse effect level (NOAEL) was determined to be 870 mg/kg bw/day, based on

	liver and kidney effects observed at the LOAEL of 1390 mg/kg bw/day (OECD, 2002; EFSA, 2005). In another repeated dose study, rats (strain not specified) were administered the chemical in drinking water at doses of 600 or 2300 mg/kg bw/day for males and 1000 or 3900 mg/kg bw/day for females for 27 weeks. Male rats showed decreased bodyweight gain during the first 13 weeks and increased bodyweight gain for the remainder of the treatment. Female rats showed decreased bodyweight gain throughout the dosing period. No other effects were reported. The NOAELs were 2300 and 1000 mg/kg bw/day for males and females, respectively. The LOAEL in females was 3900 mg/kg bw/day but could not be established in males (OECD, 2002). Several repeated dose inhalation studies were available in rats and mice. Considering the no observed adverse effect concentrations (NOAECs) available from these studies (500 ppm), and based on the treatment-related effects reported, the chemical is not considered to cause serious damage to health from repeated inhalation exposure. The kidney appears to be the target organ with kidney lesions and changes in urine chemistry indicative of impaired kidney function observed at doses ≥ 2500 ppm in animals exposed to the chemical for 78 weeks (effects not observed in 13-week studies). Transient signs of narcosis were observed for both mice and rats at doses ≥ 1500 ppm (OECD, 2002; REACH; US EPA, 1986). The investigation by Burleigh-Flayer et al. (1997), showed chronic kidney effects in rodents and is the only study that conducted lifetime rodent exposure to isopropanol. The kidney effects seen in this study were not reported in the 13-week studies by Burleigh-Flayer et al. (1994) which possibly indicates that longer term exposure is necessary for the development of the lesions. The increased hyaline droplets in the kidney observed in the study of Burleigh-Flayer et al. (1994) are a male rat-specific nephropathy and is not considered to be relevant to humans. The LOAEC and NOAEC established from the critical study were 2500 and 500 ppm, respectively, which are equivalent to 1275 and 255 mg/kg bw/day, respectively. Although limited information is available, it has been reported that oral intake of low doses of the chemical (2.6 or 6.4 mg/kg bw/day) by groups of eight men for six weeks had no effect on their blood cells, serum or urine and also produced no clinical symptoms (HSDB).
Carcinogenicity	Based on available data, the chemical is not considered to be carcinogenic (OECD, 2002; WHO, 1990a; EFSA, 2005; REACH). The International Agency for Research on Cancer (IARC) has concluded that there is inadequate evidence for the carcinogenicity of isopropanol in laboratory animals and humans, placing the chemical in Group 3 (Not classifiable as to its carcinogenicity to humans) (IARC, 1999). Although there are no carcinogenicity studies available for the chemical by oral exposure, studies are available for inhalation exposure in rats and mice. In a carcinogenicity study (OECD TG 451), F344 rats were exposed (whole-body) through inhalation to vapours of the chemical at concentrations of 0, 500, 2500, and 5000 ppm for six hours a day, five days a week for two years. The only neoplastic lesion found was stated to be increased frequency of interstitial (Leydig) cell adenoma of the testis (77.3, 86.7 and 94.7 % at low, mid and top dose groups, respectively). The authors did not consider the tumours to be treatment related as testicular adenomas are a common finding in aged male rats and that incidence of this spontaneous tumour reported for the control group (64.9 %) of this study was lower than the historical incidence (88 %) of control F344 rats of numerous two-year National Toxicology Program (NTP) carcinogenicity studies. In a similar carcinogenicity study, CD-1 mice were also exposed (whole-body) through inhalation to vapours of the chemical at concentrations of 0, 500, 2500, and 5000 ppm for six hours a day, five days a week for 18 months. No

	increased frequency of neoplastic changes was reported in any of the treated groups (OECD, 2002; EFSA, 2005; REACH).
Mutagenicity/ Genotoxicity	The chemical does not show specific reproductive or developmental toxicity. Any reproductive and developmental effects were only observed secondary to maternal toxicity.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	The chemical does not show specific reproductive or developmental toxicity. Any reproductive and developmental effects were only observed secondary to maternal toxicity. Several one or two-generation reproductive toxicity studies (rats) and developmental studies (rats and rabbits) were available. Other than a statistically significant reduction in the male mating index observed in a recent two generation study (high dose, 1000 mg//kg bw/day second generation males), there were no other effects on reproductive indices, including fertility and gestational indices and histopathology of the reproductive organs. The NOAELs for reproductive toxicity were reported as ≥ 500 mg/kg bw/day. A benchmark dose (BMD) assessment was conducted for the study's developmental and reproductive findings (Shipp et al., 1996). For the offspring developmental effects, BMD dosages (BMDL5) of 449 and 418 mg/kg/day were estimated for the F1 and F2 generations, respectively. Based upon the decrease in male mating index observations in the P2 males, a BMDL10 of 407 mg/kg/day was estimated for reproductive effects (OECD, 2002; EFSA, 2005; REACH). Developmental effects, including a reduction in postnatal survival and decreased foetal bodyweights, occurred only at maternally toxic doses. No accompanying malformations were observed. In a developmental toxicity study (US EPA TSCA Guidelines), pregnant Sprague Dawley (SD) rats were administered the chemical by gavage at 0, 400, 800 or 1200 mg /kg bw/day on gestational days 6–15. In the same study, pregnant New Zealand white rabbits were dosed orally with the chemical at 0, 120, 240 or 480 mg/kg bw/day during gestational days 6–18. There was no evidence of developmental toxicity in rats and rabbits at any tested dose. There was mortality of two dams (8%) at 1200 mg/kg and one dam (4%) at 800 mg/kg. Reduced maternal gestational weight gain associated with significantly reduced gravid uterine weights was noted in the higher dose group. The NOAEL for maternal toxicity in rats was reported to be 400 mg/kg bw/day. The NOAEL for developmental toxicity in rats was established as 400 mg /kg bw/day, based on significantly reduced foetal litter body weights at the 800 and 1200 mg/kg dose levels. The NOAEL for maternal toxicity in rabbits was determined to be 240 mg/kg bw/day, based on decreased maternal bodyweight and profound clinical signs (peripheral vasodilatation, cyanosis, lethargy, laboured respiration) of toxicity seen at the top dose. There was no evidence of any developmental toxicity and the NOAEL for developmental toxicity was established as the highest dose: 480 mg/kg bw/day. There was no evidence of any teratogenicity in either studies in rats and rabbits (US EPA, 1995; OECD, 2002; EFSA, 2005; HSDB; REACH).
Acute Toxicity	The chemical was of low acute toxicity in animal tests following oral exposure. The median lethal dose (LD50) in rats is greater than 2000 mg/kg bw. Observed effects included irritation and respiratory arrest while under narcosis (OECD, 2002; WHO, 1990a; HSDB). The chemical was of low acute toxicity in an animal test following dermal exposure. The median lethal dose (LD50) in rats is greater than 2000/kg mg/kg bw. Observed effects were not reported (OECD, 2002; WHO, 1990a; HSDB). The chemical was of low acute toxicity in animal tests following inhalation exposure with reported median lethal concentrations (LC50) >20 mg/L in rats (OECD, 2002; HSDB). Observed effects included severe irritation of the mucous membranes and central nervous system depression as indicated by ataxia, prostration and narcosis.

	The chemical is currently classified with the risk phrase 'Vapours may cause drowsiness and dizziness (R67)' in Australia (Safe Work Australia—HSIS). In an acute inhalation toxicity study (OECD TG 403), Fischer 344 (F344) rats were exposed (whole-body exposure) to the chemical at 500, 1500, 5000, and 10000 ppm for six hours (instead of the standard four hours). Transient concentration-related narcosis and/or central nervous system sedation was noted in the study and the motor activity was decreased at 1500 ppm (males only), 5000 ppm (both sexes). Severe central nervous system depression was seen in the 10000 ppm group. After one and six hours exposure at 10000 ppm, prostration, severe ataxia, decreased arousal, slowed or laboured respiration, decreased neuromuscular tone, hypothermia, and loss of reflex function was observed (OECD, 2002; REACH). Acute intoxication incidents in humans with the chemical have been reported (WHO, 1990b; OECD, 2002; HSDB). Ingestion and inhalation are the common routes of poisoning in humans. Acute intoxication of the chemical has a rapid onset (30–60 minutes) following ingestion, and reported symptoms included drowsiness, poor coordination, abdominal pain, cramps, nausea, vomiting and diarrhea, with unconsciousness and death following massive exposure. Inhaling high concentrations of the chemical can cause nausea, headache, light headedness, drowsiness, ataxia and deep narcosis (WHO, 1990b; OECD, 2002; HSDB).
Irritation	Isopropanol applied to the intact or abraded skin of rabbits and guinea pigs produced negligible irritation (Nixon <i>et al.</i>, 1975). Liquid isopropanol is moderately irritating to the eyes of rabbits (Griffith <i>et al.</i>, 1980; WHO, 1990). Isopropanol produced little irritation when tested on the skin of six human subjects (Bevan, 2012). The chemical is classified as hazardous with the risk phrase 'Irritating to eyes' (Xi; R36) in HSIS (Safe Work Australia). The available data support this classification (OECD, 2002; WHO, 1990a; REACH).
Sensitisation	There have been reports of isolated cases of dermal irritation and/or skin sensitization (Bevan, 2012). Except for three case reports, the positive reactions were observed on patch testing patients with contact dermatitis due to ethanol. These patients also had a positive reaction to ethanol. The chemical does not contain a structural alert for skin sensitisation (OECD Toolbox).
Health Effects Summary	The critical health effects for risk characterisation include the potential for eye irritation and intoxication symptoms following inhalation of high vapour concentrations.
Key Study/Critical Effect for Screening Criteria	The most appropriate NOAEC for risk assessment, determined from the 104-week study by Burleigh-Flayer <i>et al.</i> (1997), is 255 mg/kg bw/day based on kidney effects at the LOAEC of 1275 mg/kg bw/day. Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability) Oral Reference Dose = 255/100 = 2.55 mg/kg/day Drinking water = 10 mg/L
Ecological Toxicity ^{2,4,5}	
Aquatic Toxicity	The 96-hour LC50 in <i>Pimephales promelas</i> is 9,640 mg/L (Veith <i>et al.</i>, 1983). The 24- hour EC50 in <i>Daphnia magna</i> is >10,000 mg/L (Brinkmann and Kuehn, 1977). Chronic aquatic toxicity has also been shown to be of low concern, based on 16- and 21-day NOEC values of 141 and 30 mg/L, respectively, for the freshwater invertebrate <i>Daphnia magna</i> (Hermens <i>et al.</i>, 1985; OECD, 1977a,b). Toxicity of isopropanol to plants is expected to be low, based on a 7-day toxicity threshold value of 1,800 mg/L for freshwater algae (Brinkmann and Kuehn, 1980).
Determination of PNEC aquatic	PNECaquatic: Experimental results are available for three trophic levels. Acute E(L)C50 values are available for fish (9,640 mg/L) and invertebrates (>10,000 mg/L). Results from chronic studies are available for invertebrates (16- and 21-day NOECs for <i>Daphnia</i> are 141 and 30 mg/L, respectively). On the basis that the data consists of a chronic study on one trophic level, an assessment factor of 100 has been applied to the lowest reported NOEC of 30 mg/L for <i>Daphnia</i>. The PNECaquatic is 0.3 mg/L.
Current Regulatory Controls ⁷	

Listed as a Chemical of Concern on International Databases	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dcccew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No	
Australian Hazard Classification	The chemical is classified as hazardous, with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): Xi; R36 (Irritation) R67 (Vapours may cause drowsiness and dizziness)	
Australian Occupational Exposure Standards	The chemical has an exposure standard of 983 mg/m ³ (400 ppm) time weighted average (TWA) and 1230 mg/m ³ (500 ppm) short-term exposure limit (STEL).	
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica): An exposure limit (TWA) of 245–999 mg/m ³ (100–400 ppm) in countries such as Canada, Denmark, Iceland, Germany, Norway, Sweden, Spain, Switzerland, UK, and USA. An exposure limit (STEL) of 600–1250 mg/m ³ (250–500 ppm) in countries such as Canada, France, Spain, Sweden, Switzerland, UK, and USA.	
Australian Food Standards	Isopropanol is listed in Standard 1.3.1 of the Australia New Zealand Food Standards Code and has a permitted use as a food additive at a maximum permitted level of 1000 mg/kg (Food Standards Australia New Zealand 2013).	
Australian Drinking Water Guidelines	No data available	
Aquatic Toxicity Guidelines	No data available	
PBT Assessment ^{4,5}		
P/vP Criteria fulfilled?	Isopropanol is readily biodegradable and thus it does not meet the screening criteria for persistence.	
B/vB criteria fulfilled?	Based on a measured log Kow of 0.05 and a calculated BCF of 1, isopropanol does not meet the screening criteria for bioaccumulation.	
T criteria fulfilled?	The chronic toxicity data on isopropanol show NOECs of >0.01 mg/L. Thus, isopropanol does not meet the screening criteria for toxicity.	
Overall conclusion	Not a PBT substance (based on screening data).	

References

1. HSDB (n.d.). *Hazardous Substances Data Bank*. Retrieved 2017, from Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>
2. ECHA REACH database: <http://apps.echa.europa.eu/registered/registered-sub.aspx>
3. IPCS Inchem, Isopropyl Alcohol, CAS#67-63-3
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5. OECD (1997b) Screening Information Dataset (SIDS) Initial Assessment Report for 2- Propanol (CAS No. 67-63-0), UNEP Publications.
6. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier II Assessment for 2-Propanol CAS Number: 67-63-0, Retrieved 2018: <https://www.nicnas.gov.au>
7. Safe Work Australia 2011. Workplace Exposure Standards for Airborne Contaminants.
8. Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

Toxicity Summary - Cinnamaldehyde

Chemical and Physical Properties ^{1,2,3,4}	
CAS number	104-55-2
Molecular formula	C ₉ H ₈ O
Molecular weight	132.16
Solubility in water	2.11 g/L at 22 °C
Melting point	-18 °C
Boiling point	250°C
Vapour pressure	3.85 Pa at 25 °C
Henrys law constant	0.162 Pa.m ³ .mol ⁻¹ at 25 °C
Explosive potential	Non-explosive
Flammability potential	Non-flammable
Colour/Form	Yellowish oily liquid with strong odour of cinnamon
Overview	Cinnamaldehyde is a plant natural product that is present in some essential oils extracted from plants. For large scale applications such as in the flavouring and fragrance industries, this chemical is synthesised.
Environmental Fate ^{1,3}	
Soil/Water/Air	Cinnamaldehyde is expected to remain in soil, or partition to water and sediment, when released as a result of industrial uses. It is not expected to be persistent in the environment and is expected to undergo rapid and ultimate biodegradation in water. Cinnamaldehyde is not expected to bioaccumulate in aquatic organisms. No evidence has been identified to indicate that Cinnamaldehyde biomagnify through the aquatic food chain. The atmospheric oxidation half-life of cinnamaldehyde was estimated using the level III multimedia model. It was estimated that the substance is not persistent in air medium as the half-life period of cinnamaldehyde in air is only 0.31 days. This indicates that cinnamaldehyde is rapidly phototransformed in air. The Hydrolysis rate constant of Cinnamaldehyde is estimated to be 3.36 x 10 ⁻¹⁷ cm ³ /molecule-sec. at half-life of 3.411 days indicating that the substance is slowly hydrolysable.
Human Health Toxicity Summary ^{2,4}	
Chronic Repeated Dose Toxicity	Cinnamaldehyde is 'generally regarded as safe' for use as a flavour ingredient by the US Food and Drug Administration (US FDA, 2015), reflecting the low level of concern regarding its potential for long-term toxicity via the oral route. Considering the no observed adverse effect levels (NOAELs) of 68–200 mg/kg bw/day, based on 17-week to 2-year rat studies (read across), and no toxicologically significant treatment-related effects reported in various studies, repeated oral exposure to the chemical is not considered to cause serious damage to health. Based on the limited data available, the chemical is not considered to cause serious damage to health by repeated dermal exposure.
Carcinogenicity	Based on the limited data available for cinnamaldehyde and trans-cinnamaldehyde (CAS No. 14371-10-9), the chemical is not expected to have carcinogenic potential. In a two-year carcinogenicity study, groups of F344/N rats and B6C3F1 mice (50 animals/sex/dose) were fed microencapsulated trans-cinnamaldehyde (CAS No. 14371-10-9) by daily gavage at doses of 0, 1000, 2100 or 4100 ppm (equivalent to 0, 50, 100 or 200 mg/kg bw/day). Increased incidences of preputial and prostate gland adenomas and mononuclear cell leukaemia were considered to be within the historical range in controls, or likely to represent biological variations unrelated to exposure to the chemical. No other treatment-related neoplasms or non-neoplastic lesions were reported in either species (Adams et al., 2004; NTP, 2004; REACH; US HPVIS, 2009).
Mutagenicity/ Genotoxicity	The chemical cinnamaldehyde contains an a,b-unsaturated aldehyde group, a common structural alert for genotoxicity due to the ability of the chemical to form DNA adducts. However, based on the available data, the chemical is not

	considered to be genotoxic. The chemical cinnamaldehyde and the isomer trans-cinnamaldehyde (CAS No. 14371-10-9) were negative for point mutations in almost all strains of <i>Salmonella typhimurium</i> in the Ames test. A positive result was found only with TA100 strain, and in only two out of eleven tests. Evidence of genotoxic activity was also observed in isolated mammalian cells. However, these results were weakly positive and observed at cytotoxic concentrations. A sex-linked recessive lethal test in <i>Drosophila melanogaster</i> demonstrated that systemically-available chemical (administered via injection) could enter germ cells and induce mutations; however, oral dosing did not produce the same effect. Importantly, the reported activity in in vitro and insect studies did not translate into significant genotoxic activity in mammalian systems in vivo.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	The chemical is not expected to have the potential for reproductive or developmental toxicity. Any developmental effects were only observed secondary to maternal toxicity. In a two-generation study in rats (strains not reported), cinnamaldehyde (absolute dose 2 mg—route not specified) was dosed every two days for 223 and 210 days and did not have any effects on body weight gain, reproductive ability, development or viability of offspring (NTP, 2004). Cinnamaldehyde in olive oil was administered to female SD rats via oral gavage at doses of 0, 5, 25 or 250 mg/kg bw/day on gestation days (GD) 7–17. Treatment-related, increased incidence of defective cranial ossification in all dose groups was observed. Renal abnormalities including dilated pelvis and reduced papilla and dilated ureters were observed at low and mid doses, but not at high dose. Offspring at ≥ 25 mg/kg bw/day had significantly increased instances of reduced ossification of the tympanic bulla. An increase in the incidence of abnormal sternebrae was also reported in the 25 mg/kg bw/day group. However, these effects were not found to be dose-related and may be attributed to a decrease in maternal weight gain that was noted in the mid- and high-dose groups. A LOAEL of 5 mg/kg bw/day for developmental toxicity was reported based on the reduced cranial ossification and kidney variations. A LOAEL of 25 mg/kg bw/day was reported for maternal toxicity based on the reduced weight gain observed in the dams (Adams et al., 2004; NTP, 2004; US HPVIS, 2009; HSDB; REACH). No signs of toxicity were reported in the dams or in the offspring of CD-1 mice after exposure to 1200 mg/kg bw/day during GD 6–13 (cinnamaldehyde) or GD 7–14 (trans-cinnamaldehyde) (NTP, 2004; US HPVIS, 2009; REACH).
Acute Toxicity	Cinnamaldehyde has low acute oral toxicity based on animal studies. The median lethal dose (LD₅₀) in rats is >2000 mg/kg bw. Cinnamaldehyde has moderate acute dermal toxicity based on animal studies, warranting hazard classification. The dermal LD₅₀ in rabbits was in the range of 620–1260 mg/kg bw (Bickers et al., 2005; Cocchiara et al., 2005; FFHBVC, 2005; and US HPVIS, 2009). Albino rabbits (2 animals/dose) were administered a single dose of cinnamaldehyde (0, 0.25, 0.50, 1.0, 2.0 or 4.0 mL/kg bw—equivalent to 0, 263, 525, 1050, 2100 or 4200 mg/kg bw) by application to intact and abraded skin. All animals in the 1.0 mL/kg and higher dose groups died after treatment. The LD₅₀ was reported to be 620 mg/kg bw (Cocchiara et al., 2005; FFHPVC, 2005; US HPVIS, 2009; REACH).
Irritation	Respiratory irritation was assessed in CF-1 female mice by recording their respiratory rate following exposure to nebulised cinnamaldehyde for 1 minute, either through nose-only breathing or via a tracheal cannula. Marked respiratory depression with nose-only inhalation was observed. The ED₂₅ (dose providing a 25 % reduction in respiratory rate) was calculated to be 241 μg/L. No significant effects were observed when inhalation was through the tracheal cannula (Cocchiara et al., 2005). Cinnamaldehyde produced severe irritation in rabbits when applied undiluted, mild irritation in mice and guinea pigs at concentrations of 3–5 %, and was non-irritating to rabbits at 1 % (Bickers et al., 2005). The US EPA considers cinnamaldehyde a strong skin irritant in guinea pigs (no study details provided) (US HPVIS, 2009). Several international agencies have concluded that cinnamaldehyde is an eye irritant (US HPVIS, 2009; REACH), and a number of notifications to the Classification and Labelling Inventory by industry in the European Union have indicated the chemical as irritating to the eyes (ECHA C&L).
Sensitisation	The chemical was considered to be a moderate to strong skin sensitiser based on the positive results in several local lymph node assays (LLNA). The EC₃ value (concentration required to provoke a 3-fold increase in lymph node cell

	proliferative activity compared with controls) was reported to be as low as 0.2 % (SCCS, 2012).														
Health Effects Summary	Cinnamaldehyde is a well-recognised and frequently reported consumer contact allergen (SCCNFP, 1999; RIVM, 2009; SCCS, 2012; IFRA, 2013). It is one of eight components of the diagnostic test, the fragrance mix, used by dermatologists to determine if a patient has allergies to common chemicals used in fragrances. It is an established contact allergen in humans according to the Scientific Committee on Consumer Safety (2012), and accounts for 5–36 % of the reactions to the fragrance mix (SCCNFP, 1999). A number of human repeat insult patch tests (HRIPTs) have been undertaken to determine the skin sensitisation potential of cinnamaldehyde in healthy volunteers, as well as groups of subjects suspected of skin allergies to fragrances (SCCNFP, 1999; NTP, 2004; Cocchiara et al., 2005). Although fewer cases of sensitisation were found when the concentration of the chemical was less than 1 %, positive allergic responses have been reported in cases where the administered concentration of cinnamaldehyde was as low as 0.2 % (Cocchiara et al., 2005). Skin irritation effects were generally predominant at concentrations above 3 % cinnamaldehyde, and often impeded the interpretation of results from the patch testing (SCCNFP, 1999; NTP, 2004). Many cases of skin sensitisation have occurred following occupational and consumer exposure to the chemical. Workers in spice manufacturing plants, hairdressing salons and bakeries have reported cases of contact dermatitis that were traced back to cinnamaldehyde. In addition, exposure of consumers to toothpaste, cosmetics and perfumes containing the chemical as a fragrance ingredient have resulted in a number of case studies identifying cinnamaldehyde as an agent responsible for the allergic reactions (see SCCNFP, 1999; NTP, 2004; Cocchiara et al., 2005 for review).														
Key Study/Critical Effect for Screening Criteria	The critical health effect for risk characterisation is skin sensitisation. Other observed health effects include systemic acute effects (acute toxicity from dermal exposure) and local effects (eye/skin/respiratory irritation).														
Ecological Toxicity ¹															
Aquatic Toxicity	The following data are measured acute toxicity values for cinnamaldehyde: Danio rerio (Zebrafish) EC Directive 92/69/EEC C.1 Acute Toxicity for Fish: 96 h LC50 = 3.1 mg/L; Daphnia magna (Water flea) OECD TG 202: 48 h EC50 = 3.86 mg/L; Pseudokirchneriella subcapitata (Green algae) OECD TG 201: 72 h EC50 = 4.07 mg/L. In the chronic toxicity study, the 72 h NOEC value of 2.0 mg/L was reported for Pseudokirchneriella subcapitata (Green algae) OECD TG 201.														
Determination of PNEC aquatic	A PNECaqua = 0.2 mg/L can be calculated based on the chronic toxicity value (72 h NOEC = 2 mg/L) for green algae with the assessment factor of 10.														
Current Regulatory Controls⁴															
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	https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	
	Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	The chemical is not listed in the Hazardous Substances Information System (HSIS) (Safe Work Australia).	
Australian Occupational Exposure Standards	No specific exposure standards are available for the chemical.	
International Occupational Exposure Standards	The US Temporary Emergency Exposure Limits (TEELs) for cinnamaldehyde are 14, 150 and 670 mg/m ³ (Galleria Chemica).	
Australian Food Standards	No data available.	
Australian Drinking Water Guidelines	No data available.	
Aquatic Toxicity Guidelines	No data available.	
PBT Assessment		
P/vP Criteria fulfilled?	Not Persistent. Based on the results of the ready biodegradability studies, cinnamaldehyde is categorised as Not Persistent.	
B/vB criteria fulfilled?	Not Bioaccumulative. Based on low log K values and/or expected natural metabolism and regulation of internal concentrations, the chemical is categorised as Not Bioaccumulative	
T criteria fulfilled?	Not Toxic. Based on measured acute toxicity endpoints of greater than 1 mg/L cinnamaldehyde is categorised as Not Toxic.	
Overall conclusion	Not PBT	

References

1. NICNAS (2017a) Environment Tier II Assessment for Cinnamic Aldehydes
2. NICNAS (2017b) Human Health Tier II assessment for 2-Propenal, 3-phenyl-
3. HSDB (n.d.). *Hazardous Substances Data Bank*. Retrieved 2015, from Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>
4. ECHA REACH, Cinnamaldehyde, Retrieved 2017: <https://echa.europa.eu/information-on-chemicals/registered-substances>

Toxicity Summary - Glutaraldehyde

Chemical and Physical Properties ^{1,2,3}	
CAS number	111-30-8
Molecular formula	C ₅ H ₈ O ₂
Molecular weight	100.11
Solubility in water	Soluble in all proportions in water and ethanol; soluble in benzene and ether.
Melting point	-14°C
Boiling point	188°C
Vapour pressure	2.03 x 10 ⁻³ kPa at 25 °C (50% solution)
Henry's law constant	0.011 Pa m ³ /mol @ 25 °C
Explosive potential	Non explosive
Flammability potential	Non flammable
Colour/Form	Colourless oily liquid. In the vapour state, glutaraldehyde has a pungent odour, with an odour threshold of 0.04 ppm.
Overview	Glutaraldehyde is manufactured in Germany by BASF and in the USA by Union Carbide Corporation. It is usually sold commercially as a 45% or 50% aqueous solution. Glutaraldehyde has a wide variety of uses throughout the world with its use spread over a number of different industries. It is used primarily as a biocide but it also has wide use as a fixative, and some use as a therapeutic agent. The principal health effects of glutaraldehyde are irritation of the skin, eye and respiratory tract, skin sensitisation and occupational asthma. Exposure data indicated that, in some situations, particularly the health care industry (disinfection), x-ray film processing and the animal health industry (spray use), health concerns may arise where available control measures such as ventilation have not been implemented to minimise exposure. Due to low and intermittent exposure, the public health risk from the industrial use of glutaraldehyde is minimal. For the use of glutaraldehyde in cosmetics, a safety margin of >400 for extensive use indicated low concern.
Environmental Fate ¹	
Soil/Water/Air	Glutaraldehyde is a hydrophilic substance that will be mainly associated with the aquatic compartment, with minor amounts partitioning to the atmosphere, following release to the environment. Hydrolysis is slow, but glutaraldehyde, like other aldehydes, undergoes aerial oxidation in solution. It biodegrades rapidly in aerobic and anaerobic aquatic environments at sublethal concentrations (below 10 mg/L) and will not bioaccumulate. Tropospheric degradation is also rapid.
Human Health Toxicity Summary ^{1,2,3}	
Chronic Repeated Dose Toxicity	A two-year chronic study was conducted in male and female Fischer 344 rats (NICNAS 1994). Groups of 100 male and 100 female rats were administered 0, 50, 250, or 1000 ppm w/v glutaraldehyde in drinking water (4, 17 and 64 mg/kg bw/day for the males and 6, 25 and 86 mg/kg/day for the females). The mortality rate over the treatment period was 25 to 30% for males and 19 to 23% for females with no dose-related increase. The major cause of death in all rats (control and dose groups) was large granular cell lymphatic leukaemia (LGLL). Small dose-related decreases in absolute body weight and body weight gain occurred at 250 and 1000 ppm in males and at 1000 ppm in females. Dose-related decrease in urine volumes and associated increase in osmolality were observed in higher dose animals. At necropsy at 52, 78 and 104 weeks, the only statistically significant changes in organ weights were for the kidney. Relative kidney weights were increased for males and females at 52 and 78 weeks. A significant dose-related increase in kidney weight relative to final body weight occurred for males and females in the 250 and 1000 ppm groups, including an increase in absolute kidney weight for the female rats. Changes in final body

	weights and the weights of other organs were minor and / or sporadic and were unlikely to be related to glutaraldehyde exposure. The total leucocyte count was significantly increased at week 104 in males at 250 and 1000 ppm, and in females at 250 ppm only. The variation in counts was large, possibly due to the large monocyte count at 250 and 1000 ppm. Changes in clinical chemistry parameters included decreases in the activities of some enzymes at 250 and 1000 ppm and occasional decreases in total protein, globulin and phosphorous; these were probably due to reduced food consumption and body weight. Gross pathology showed evidence of gastric inflammation, particularly in rats sacrificed at the end of the study, with irritation observed as ulceration, a multifocal colour change and thickening of the mucosa (dose groups not specified). Histologic examination of the tissues revealed squamous epithelial hyperplasia and keratinised cysts and oedema. Based on the observations, a NOAEL of 4 mg/kg bw/day for males and 6 mg/kg bw/day for females was established in this study. For the purpose of human health risk assessment, the lowest NOAEL (4 mg/kg bw/day) established in the two-year chronic study in rats will be used.
Carcinogenicity	In a two-year chronic/carcinogenicity study by Van Miller et al. (2002), groups of 100 male and 100 female Fischer 344 rats were treated with 0, 50, 250, or 1000 ppm w/v glutaraldehyde in drinking water. The mean glutaraldehyde consumption for each of the three groups was 4, 17 and 64 mg/kg bw/day for the males and 6, 25 and 86 mg/kg bw/day for the females. The mortality rate during the study period was 25 to 30% for males and 19 to 23% for females and was not dose-related. Gross pathology showed evidence of gastric inflammation. The main finding of the study was an increased incidence of large granular lymphocytic leukaemia (LGLL) in the spleen and liver of male and female rats in all groups, including the control group. Treated females showed a significantly increased incidence of LGLL and analysis for dose-response trend for the severity of LLGL revealed an increased severity in females at the higher dosages (53% in spleen and 54% in liver versus respectively 20% and 23% in untreated females) while no such observation were made for the males. No other significant oncogenic effects were observed during the study. Occurrence of LGLL was seen in all groups including controls; the incidence of LGLL in the 1000 ppm group was high compared to controls but no clear dose-response relationship was evident, and LGLL mainly affected treated females whereas the incidence in treated males was within the control range (REACH 2013). Historical control data for untreated Fischer 344 rats in NTP studies also indicates that the ranges for this tumour are 10 to 72% in males and 6 to 31% in females (REACH 2013). The control data in the Van Miller et al. study fitted in with the historical control data reported from NTP studies. The variability in control data for LGLL and the wide variation reported in the literature makes a definitive conclusion difficult. Base on this study, glutaraldehyde was considered not to be carcinogenic.
Mutagenicity/ Genotoxicity	Glutaraldehyde has been extensively tested for genetic activity in vitro and in vivo, however there is disagreement in the literature regarding glutaraldehyde's genetic activity (Zeiger et al. 2005). While all in vivo genotoxicity tests with glutaraldehyde gave negative results, mixed results were reported for in vitro mutagenicity tests. Early in vitro tests were negative (Watts 1984), but some recent bacterial assays and tests in mammalian cells indicated that glutaraldehyde could be mutagenic in vitro. A series of reverse mutation assays was carried out with various Salmonella typhimurium strains, with and without metabolic activation (REACH 2013). All assays with TA 100, 1535, 1537 and 98 were negative. Some assays with TA 102 and 104 gave positive results. Tests with Escherichia coli also yielded both positive as well as negative results. Glutaraldehyde induced sister chromatid exchanges in CHO cells with and without S9 metabolic activation in one laboratory, but was negative without S9 and only weakly positive with S9 in the second laboratory (NICNAS 1994). The difference in the results was attributed to slight differences between the data evaluation systems used in the two laboratories. Glutaraldehyde was not mutagenic in any of the in vivo assays such as peripheral blood micronucleus test, rat bone marrow chromosomal aberration assay and the Drosophila melanogaster sex-linked recessive lethal test (NICNAS 1994; REACH

	2013). Chromosome aberrations in bone marrow cells were reported in only one out of eight studies using rats and mice, micronuclei were not induced in bone marrow cells of mice, and dominant lethal mutations were not induced in mice. Glutaraldehyde did not induce cell transformation in Syrian hamster embryo cells in vitro (Zeiger et al. 2005). In vivo, inhalation of glutaraldehyde induced cell proliferation in nasal tissue in rats and mice, but did not induce DNA damage at these sites. Based on these observations, it is concluded that glutaraldehyde is not a genotoxin.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Studies on the incidence of miscarriage in pregnant women have shown no difference between those exposed to glutaraldehyde and those not exposed to the chemical. Studies in female rats and mice have resulted in embryotoxicity/foetotoxicity for glutaraldehyde, but only at doses which are maternally toxic. A number of studies have found no evidence of teratogenicity.
Acute Toxicity	Several acute oral toxicity studies with glutaraldehyde have been reported in rats and other species. In one reliable study, administration of 0.2, 0.3, 0.5, 1.0, 1.7 mL/kg bw glutaraldehyde (corresponding to 226, 339, 565, 1130 and 1921 mg/kg bw, respectively) to male/female Wistar rats by gavage gave a median lethal dose (LD50) of 226 mg/kg bw (REACH 2013). Necropsy of animals that died during the observation period revealed congestion of the lungs and the abdominal viscera. In another study in Sprague-Dawley rats, the oral LD50 was 316 mg/kg bw for males and 285 mg/kg bw for females, when 10 mL of 2.15, 3.16, 4.64, 14.7% glutaraldehyde (corresponding to 215, 316, 464 and 1470 mg/kg bw) was administered by oral gavage (REACH 2013). In a separate study using different strengths of glutaraldehyde, Ballantyne (1986) showed that the oral LD50 for glutaraldehyde in rats varied with the concentration of the glutaraldehyde used. By using different concentrations of glutaraldehyde solutions (1% to 50%) and varying the administration volume to maintain a constant dose, oral LD50 in the range 66 to 733 mg/kg bw were obtained. These studies indicate that glutaraldehyde has high acute oral toxicity. Of the 18 acute dermal toxicity studies reported in REACH (2013) dossiers, results from 14 studies indicated LD50 higher than 2000 mg/kg bw. In four other studies, LD50 ranged between 250 and 1432 mg/kg bw. These studies however did not follow international guidelines and have low reliability. Based on these studies, glutaraldehyde is considered to have low acute dermal toxicity. In a well-defined study, 10 male and 10 female Sprague-Dawley rats per dose group were exposed to glutaraldehyde as liquid aerosol at 0.22, 0.31 and 0.63 mg/L for 4 hours (REACH 2013). Exposure was followed by an observation period of 14 days. During the exposure period slight nasal discharge, snout wiping, flank respiration and irregular to intermittent respiration were reported in rats. During the post-exposure period, bloody nasal discharge, red crusts surrounding the nose, whooping or gasping respiration with rasping sounds and a tremulous gait were observed. These symptoms disappeared in the surviving animals within 5 to 9 days post-exposure. Mortalities were noted in all treated groups. The determination of the LC50 values was based on the Probit Analysis. An LC50 of 0.48 mg/L was calculated for both male and female rats. In another acute inhalation study conducted in a similar manner to the above study, Sprague-Dawley rats, 10 rats per sex per dose group, were exposed to 0.1, 0.18, 0.28, 0.39 and 0.44 mg/L glutaraldehyde as liquid aerosol for 4 hours (REACH 2013). During and after exposure, mortality and clinical signs of toxicity were recorded at regular time intervals. The LC50 in this study was established as 0.28 mg/L for females and 0.39 mg/L for males. Based on the above studies, glutaraldehyde is considered to have high acute inhalation toxicity.
Irritation	Glutaraldehyde is corrosive to the skin and eyes of rabbits at high concentrations, with signs of skin irritation evident at 2%, and eye irritation at 0.2%. Exposure to glutaraldehyde vapours in acute inhalational studies resulted in nasal irritation and respiratory difficulties. Joint irritation was seen in rabbits after intra-articular administration.
Sensitisation	The skin sensitisation effect of glutaraldehyde was demonstrated in tests with guinea pigs.
Health Effects Summary	Glutaraldehyde has high acute oral and inhalation toxicity and low to moderate acute dermal toxicity. Based on human and animal data, it is corrosive, the vapours are irritating to the respiratory tract, and it has skin and respiratory sensitisation potential. Glutaraldehyde has high repeat dose oral and inhalation toxicity, with an oral No-Observed-Adverse-Effect Level (NOAEL) of 4 mg/kg

	bw/day based on changes in liver and kidney weights and clinical chemistry parameters. Glutaraldehyde is not genotoxic or carcinogenic. It did not have any adverse effects on the reproductive system of adult rats or on the development of foetuses. The critical adverse health effects of glutaraldehyde are corrosivity, skin and respiratory tract sensitisation and acute and repeat dose oral and inhalation toxicity.																
Key Study/Critical Effect for Screening Criteria	From the hazard characterisation, the critical (most sensitive) adverse health effects for repeated exposures to the chemical are changes in clinical chemistry parameters and relative organ (liver and kidney) weights. Glutaraldehyde has high repeat dose oral toxicity with an oral NOAEL of 4 mg/kg bw/day. This NOAEL is used in this human health risk assessment.																
Ecological Toxicity^{1,2,3,4}																	
Aquatic Toxicity	96 h acute Bluegill sunfish LC50 = 11.2 mg/L 48 h acute Oyster larvae LC50 = 2.1 mg/L 96 h acute Green crabs LC50 = 465 mg/L 96 h acute Grass shrimp LC50 = 41 mg/L 48 acute Daphnia magna LC50 = 0.35 mg/L 48 acute Daphnia magna LC50 = 16.3 mg/L 21 d reproduction Daphnia magna LOEC = 4.3 mg/L, NOEC = 2.1 mg/L 96 h algal growth inhibition Selenastrum capricornutum ILM = 3.9 mg/L (median inhibitory limit) 96 h algal growth inhibition Scenedesmus subspicatus EC50 = 1.0 mg/L Bacterial inhibition Sewage microbes IC50 = 25-34 mg/L In summary, the test results indicate that glutaraldehyde is slightly to moderately toxic to aquatic fauna and moderately to highly toxic to algae. In some instances, glutaraldehyde appeared to be rapidly lost from test waters in the laboratory. Such behaviour in aquatic toxicity tests generally means that their results will underestimate the inherent toxicity of a substance. However, the toxicity that will prevail under environmental conditions is likely to be lower than that recorded in the laboratory in view of the rapid degradation that would be expected to occur in natural surface waters.																
Determination of PNEC aquatic	As a wide selection of species is available, applying a safety factor of 10 to the NOEC (2.1 mg/L) derived from Daphnia seems most appropriate, giving a PNEC of $2100/10 = 0.21$ mg/L.																
Current Regulatory Controls^{1,2,4}																	
Listed as a Chemical of Concern on International Databases	<table> <tr> <th>International Database</th><th>Listed?</th></tr> <tr> <td>European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table</td><td>Yes</td></tr> <tr> <td>International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications</td><td>No</td></tr> <tr> <td>National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html</td><td>No</td></tr> <tr> <td>US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris</td><td>No</td></tr> <tr> <td>United States Endocrine Disruptor Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and</td><td>No</td></tr> <tr> <td>Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18</td><td>No</td></tr> <tr> <td>Montreal Protocol</td><td>No</td></tr> </table>	International Database	Listed?	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	Yes	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No	United States Endocrine Disruptor Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No	Montreal Protocol	No
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Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No																
Montreal Protocol	No																

	https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol	
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	Glutaraldehyde is classified as hazardous in the Hazardous Substances Information System (HSIS) with the following risk phrase (Safe Work Australia 2013): · T (Toxic); R23/25 (Toxic by inhalation and if swallowed) · C (Corrosive ; R34 (causes burns) · R42/43 (May cause sensitisation by inhalation and skin contact). Mixtures containing the chemical are classified as hazardous with the following risk phrases based on the concentration (Conc) of the chemical in the mixtures. The risk phrases for this chemical are: · Conc ≥50%: T; R23/25; R34; R42/43 (Toxic; toxic by inhalation and if swallowed; causes burns; may cause sensitisation by inhalation and skin contact) · ≥25% Conc <50%: T; R23; R22; R34; R42/43 (Toxic; toxic by inhalation, harmful if swallowed, causes burns; may cause sensitisation by inhalation and skin contact) · ≥10% Conc <25%: C; R20/22; R34; 42/43 (Corrosive; harmful by inhalation and if swallowed; causes burns; may cause sensitisation by inhalation and skin contact) · ≥2% Conc <10%: Xn; R20/22; R37/38; R41; R42/43 (Harmful; harmful by inhalation and if swallowed; irritating to respiratory system and skin; risk of serious eye damage; may cause sensitisation by inhalation and skin contact) · ≥1% Conc <2%: Xn; R36/37/38 R42/43 (Harmful; Irritating to eyes, respiratory system and skin; may cause sensitisation by inhalation and skin contact) · ≥0.5% Conc <1%: Xi; R36/37/38; R43 (Irritating; irritating to eyes, respiratory system and skin; may cause sensitisation by skin contact)	
Australian Occupational Exposure Standards	The chemical has an exposure standard of 0.41 mg/m ³ , 0.1 ppm; Time Weighted Average (TWA).	
International Occupational Exposure Standards	The following exposure standards are identified in Galleria Chemica (2013): · Occupational Exposure limit (TWA) of 0.2 mg/m³ [Canada, China, Denmark, Japan, Korea, UK] · 0.4 mg/m³ TWA [Sweden] · 0.8 mg/m³ TWA [US (NIOSH), Greece]	
Australian Food Standards	No Australian food standards relating to the chemical have been identified (Food Standards Australia New Zealand 2013).	
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified for this chemical in the Australian Drinking Water Guidelines. (National Health and Medical Research Council (NHMRC) 2011).	
Aquatic Toxicity Guidelines	No data available.	
PBT Assessment		
P/vP Criteria fulfilled?	No. Readily biodegradable and as such not persistent in the environment.	
B/vB criteria fulfilled?	No. As the Log Pow is -0.01 (Log Pow < 4.5), it is not expected to be bioaccumulative.	
T criteria fulfilled?	No. Chronic toxicity data >1 mg/L in invertebrates, thus glutaraldehyde does not meet the screening criteria for toxicity.	
Overall conclusion	Not PBT	

References

1. NICNAS (1994) Priority Existing Chemical 3, Glutaraldehyde: Retrieved 2019: <https://www.nicnas.gov.au>

2. National Industrial Chemicals Notification and Assessment Scheme (NICNAS, 2017). National assessment of chemicals associated with coal seam gas extraction in Australia. Human health hazards of chemicals associated with coal seam gas extraction in Australia.
3. OECD (1995) SIDS Initial Assessment Profile on Glutaraldehyde
4. ECHA REACH, Glutaral, Retrieved 2019: <https://echa.europa.eu/>
5. Hazardous Chemical Information System (HCIS), Safe Work Australia. Retrieved 2019: <http://hcis.safeworkaustralia.gov.au/>
6. National Occupational Health and Safety Commission, Approved Criteria for Classifying Hazardous Substances [NOHSC:0006(1993)], AGPS, Canberra, 1993.

Toxicity Summary - Phenoxyethanol

Chemical and Physical Properties ^{1,2,3,4}	
CAS number	122-99-6
Molecular formula	C ₈ H ₁₀ O ₂
Molecular weight	138.17
Solubility in water	28.9 g/L
Melting point	14°C
Boiling point	245.6°C at 1013 hPa
Vapour pressure	0.013 hPa at 20°C
Henry's law constant	1.55 E-8 atm-m ³ /mole at 25°C
Explosive potential	Non-explosive
Flammability potential	Non-flammable
Colour/Form	Colourless liquid with faint aromatic odour
Overview	The substance is a glycol ether used as a perfume fixative, insect repellent, antiseptic, solvent, preservative, and also as an anaesthetic in fish aquaculture. Phenoxyethanol is an ether alcohol with aromatic properties. It is both naturally found and manufactured synthetically. Demonstrating antimicrobial ability, phenoxyethanol acts as an effective preservative in pharmaceuticals, cosmetics and lubricants. Phenoxyethanol is the most commonly used globally approved preservative in personal care formulations. It is very easy to use in various types of formulations and is chemically stable. It has also been used in vaccines and shown to inactivate bacteria, and several types of yeast.
Environmental Fate ²	
Soil/Water/Air	Phenoxyethanol is a high boiling liquid (boiling point 245.2°C) with a very low vapor pressure (0.000134 hPa at 20°C). The photodegradation half-life is 3.9 hrs. Like other glycol ethers, phenoxyethanol possesses no functional groups in its molecular structure that are readily subject to hydrolysis in the presence of water. Level III fugacity modelling assuming equal distribution to the various compartments indicates mass balances of 0.685% to air, 46.3% to water, 53.0% to soil and 0.0867% to sediment compartments. Although the material preferentially partitions to water and soil when released into the aqueous environment, it is readily biodegradable, and based on the log partition coefficient of 1.16, has a very low potential to bioaccumulate.
Human Health Toxicity Summary ^{1,2,3}	
Chronic Repeated Dose Toxicity	Considering the no-observed-adverse-effect level (NOAEL) values and treatment-related effects reported in various repeat dose toxicity studies, the chemical is not considered to cause serious damage to health from repeated oral exposure. In a 90-day oral gavage study in rats conducted according to OECD Test Guideline (TG) 408, a NOAEL of 700 mg/kg bw/day (nominal top dose tested in males) was reported. No significant toxicological effects were observed. Functional observation battery, motor activity data and the reflex testing did not provide indications of treatment related neurotoxic effects. Haemolysis was observed at all doses (100 mg/kg bw/day) in a 10 day study in rabbits. Increased erythrocyte fragility was found in collected blood. Considering the NOAEL values and treatment-related effects reported in various repeat dose toxicity studies, the chemical is not considered to cause serious damage to health from repeated dermal exposure. In a 13 week dermal study in rabbits no significant toxicological effects including haemolytic changes were observed. The NOAEL was reported to be 500 mg/kg bw/day (top dose tested). In a 14-day repeat dose inhalation toxicity study (OECD TG 412) in male and female Sprague Dawley rats, the no observed adverse effect concentration (NOAEC) for the chemical was reported to be 48.2 mg/m³ based on

	histopathological findings in the respiratory tract. Morphological changes indicating irritation potential of the test compound were found in nasal cavity, larynx and lung of animals treated with mid (246 mg/m ³) and high (1000 mg/m ³) doses.	
Carcinogenicity	No carcinogenicity data are available.	
Mutagenicity/ Genotoxicity	The negative results for the chemical from several in vitro and in vivo genotoxicity studies supports a conclusion that the chemical is not genotoxic	
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	There is no evidence of reproductive toxicity and developmental effects were only observed secondary to maternal toxicity, so the chemical does not show specific developmental toxicity.	
Acute Toxicity	The chemical is classified as hazardous with the risk phrase 'Harmful if swallowed' (Xn; R22) in HSIS (Safe Work Australia). A large amount of acute toxicity data of varying reliability was available. Several studies considered reliable reported median lethal dose (LD50) values in the range of 1300-2000 mg/kg bw, supporting this classification. Reported signs of toxicity include lethargy, increasing weakness, changes in motor activity and laboured respiration. The chemical was of low acute toxicity in animal tests following dermal exposure. The median lethal dose (LD50) in rats is greater than 2000 mg/kg bw. Observed sub-lethal effects included haemorrhagic lungs. The chemical was of low acute toxicity in animal tests following inhalation exposure with no mortalities or clinical signs of toxicity observed with the median lethal concentration (LC50) > 1000 ppm).	
Irritation	The chemical is reported to slightly irritate skin in animal studies, particularly following repeated exposure. The effects were not sufficient to warrant a hazard classification. The chemical is classified as hazardous with the risk phrase 'Irritating to eyes' (Xi; R36) in HSIS (Safe Work Australia). The chemical is reported to be non-irritating to human skin up to concentrations of 10 % in several patch tests studies. Mild reactions were observed in five out of 12 people following application of the undiluted chemical to skin.	
Sensitisation	The negative results seen for the chemical from several skin sensitisation guinea pig studies support a conclusion that the chemical is not a skin sensitizer	
Key Study/Critical Effect for Screening Criteria	The critical health effects for risk characterisation include systemic acute effects (acute toxicity by the oral route of exposure) and local effects (eye irritation). Sensitisation may occur in susceptible individuals. The most appropriate NOAEL for risk assessment purposes, determined from the 90-day gavage study in rats is 700 mg/kg bw/day.	
Ecological Toxicity ^{1,2,3}		
Aquatic Toxicity	Adequate acute toxicity tests in fish and aquatic invertebrates show that this chemical is of low toxicity to these species (LC/EC50 values are 344 and 488 mg/l, respectively). The 16-hr LC50 value for bacteria (sewer microorganisms) is 1,650 mg/l. Since the highest concentration used in the algal toxicity test (500 mg/l) did not have an effect on cell biomass, the EC50 value in algae is greater than this value. There are no data on chronic toxicity of this chemical to aquatic organisms or toxicity of this chemical to terrestrial plants.	
Determination of PNEC aquatic	PNEC_{aquatic}: Experimental results are available for three trophic levels. Acute E(L)C₅₀ values are available for fish (344 mg/L), Daphnia (488 mg/L). A LC50 value of 1650 mg/L was obtained for bacteria from which no dependable EC50 can be derived. There were no chronic studies conducted on fish or Daphnia. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 344 mg/L for fish. The PNEC_{aquatic} was calculated to be 0.344 mg/L.	
Current Regulatory Controls ¹		
Listed as a Chemical of Concern on	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV	No

International Databases	https://echa.europa.eu/candidate-list-table	
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No
	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dccew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	The chemical is classified as hazardous, with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): Xn; R22 (acute toxicity) Xi; R36 (irritation)	
Australian Occupational Exposure Standards	No specific exposure standards are available.	
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica): An exposure limit (TWA, STEL, PEL or STV) of 100–230 mg/m ³ (20-40 ppm) in different countries such as Germany, Canada (Ontario), Poland and Switzerland.	
Australian Food Standards	No data available.	
Australian Drinking Water Guidelines	No data available.	
Aquatic Toxicity Guidelines	No data available.	
PBT Assessment		
P/vP Criteria fulfilled?	No. The substance is readily biodegradable.	
B/vB criteria fulfilled?	No. Based on the log partition coefficient of 1.16, phenoxyethanol has a very low potential to bioaccumulate.	
T criteria fulfilled?	No. Long term data not available (acute data >0.1 mg/L); potentially not toxic.	
Overall conclusion	Not PBT.	

References

- NICNAS (2017) Human Health Tier II Assessment for Ethanol, 2-phenoxy-
- OECD (2005) SIDS Initial Assessment Profile on Ethylene glycol phenyl ether
- ECHA REACH, 2-phenoxyethanol, Retrieved 2021: <https://echa.europa.eu/>
- National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 31236, 2-Phenoxyethanol. Retrieved September 22, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/2-Phenoxyethanol>.

Toxicity Summary - 1,6-Hexanediol

Chemical and Physical Properties ^{1,2,3}	
CAS number	629-11-8
Molecular formula	C ₆ H ₁₄ O ₂
Molecular weight	118.17
Solubility in water	miscible at 20°C
Melting point	40-42 °C
Boiling point	243 °C (at 101.3 kPa)
Vapour pressure	< 0.01 hPa at 20°C
Henrys law constant	2.2X10 ⁻¹⁰ atm-cu m/mole at 25 deg C (estimation)
Explosive potential	Non-explosive
Flammability potential	Not easily ignitable / combustible
Colour/Form	Crystals
Overview	All the produced Hexane-1,6-diol is used as an intermediate in chemical industry for the synthesis of polyesters and polyesterol-type polyurethanes, which are used for paints, lacquers and varnishes. This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate ¹	
Soil/Water/Air	Based on the physico-chemical properties, the preferred environmental compartment of 1,6-Hexanediol is the hydrosphere (Mackay I: 99%). 1,6-Hexanediol is biologically readily degradable. According to the model SIMPLETREAT, a removal rate of 91% is predicted in wastewater treatment plants. In water solution, hydrolysis or photolysis are not likely to occur. The calculated half-life due to photochemical-oxidative degradation in the atmosphere by OH-radicals is about 1.2 days.
Human Health Toxicity Summary ^{1,2,3}	
Chronic Repeated Dose Toxicity	In valid OECD studies, tested up to the highest recommended dose of 1,000 mg/kg b.w. hexanediol revealed no effects of toxicological relevance beside a borderline effect on body weight either in males (OECD 421) or in females (OECD 407). NOAEL = 400 mg/kg b.w.
Carcinogenicity	No studies were identified.
Mutagenicity/ Genotoxicity	Hexanediol was not mutagenic in the Ames test (OECD 471) when Salmonella typhimurium strains (TA 98, TA 100, TA 1535 and TA 1537) were exposed up to 5,000 µg/plate with and without metabolic activation. In vitro point mutation was also studied in mammalian cells (Chinese hamster V79 HPRT locus, OECD 476) with no indication of a mutagenic response either in the presence or absence of metabolic activation. This holds also for chromosome aberration according to OECD 473 performed with the same cell line with and without S9 mix. In the absence of positive mutagenicity data in vitro no in vivo mutagenicity studies have been performed. These data indicate that Hexanediol has no mutagenic potential in the above described in vitro assays. No in vivo mutagenicity studies have been performed.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Male and female Wistar rats received 0, 100, 400 and 1,000 mg/kg body weight Hexanediol by gavage for 4 (males) to 6 (females) weeks in compliance with OECD test method 421 to screen the effect of hexanediol on reproduction and developmental toxicity. The premating exposure period was at least 14 days and the study was terminated 4 days postpartum of the F1 generation pups. Marginal retarded body weight development in males at 1,000 mg/kg b.w. was the only effects noted in this study. This dose level represents the highest concentration required for this type of study. There were no signs indicating impairment of reproductive function of F0 rats and no signs of developmental toxicity in their

	offspring. The NOAEL for parental toxicity is 400 mg/kg b.w. (males) and 1,000 mg/kg b.w. (females). The NOAEL for reproductive function and development toxicity is 1,000 mg/kg b.w.	
Acute Toxicity	The acute oral toxicity was tested in rats with comparable LD50 values of 3,000 mg/kg b.w. or 3,730 mg/kg b.w. Hexanediol was not lethal to 3 rabbits given 3,000 mg/kg b.w. by gavage. Two cats dosed once with 300 mg/kg b.w. by gavage survived, while 2 out of 4 animals receiving 1,000 mg/kg b.w. died. No mortality was observed when six rats were exposed to an atmosphere that had been saturated at 100 degrees centigrade with the vapor of the substance. This holds also for eight rats exposed at room temperature for 8 hours to the volatile part of the compound. No mortality occurred when 5 rabbits/sex received 2,500 mg/kg b.w. for eight hours dermally under occlusive conditions. Another author reported an LD50 > 10,000 mg/kg after dermal application of rabbits. Comparable LD50 values (about 2,300 and 1,738 mg/kg b.w.) were noted for mice after intraperitoneal application. The data indicate that Hexanediol is not acute toxic.	
Irritation	An 80% aqueous preparation of hexanediol was not irritating to rabbit skin after up to 20h occlusive exposure. In another study the irritation index according to Smyth-Carpenter reached 2 out of 10 points, which is considered to be not irritant. Eye irritation was tested in rabbits according to the method of Draize. Initial findings were slight chemosis and slight corneal opacity. The findings were completely reversible within 8 days after application. In another eye irritation study according to the method of Smyth-Carpenter the compound reached grade 3 on a 10 point scale indicating an irritant effect based on this grading scheme. Hexanediol is considered as not irritant to the skin and only slightly irritant to the eyes.	
Sensitisation	In a Guinea pig maximization test according to the method of Magnusson and Kligman (OECD 406) Hexanediol was not sensitizing. The intradermal induction was performed with 5%, while the dermal induction (48 hours occlusive exposure) was performed with a concentration of 50%. The challenge concentration was 25% (24 hours occlusive exposure). Water was used as vehicle in this study. There was no indication that Hexanediol is a skin sensitizer.	
Health Effects Summary	This chemical has been identified by NICNAS to be of low concern to human health. This chemical is not acutely toxic. It is considered as non-irritating to the skin and only slightly irritating to the eyes. No skin sensitising potential was revealed. No indication of toxic effects on reproductive function or developmental toxicity were observed. Neither mutagenic nor clastogenic potential could be detected in in vitro tests with this chemical. No in vivo mutagenicity testing has been performed.	
Key Study/Critical Effect for Screening Criteria	28 day repeated dose testing in rats revealed slight effect upon body weight in males or females at 1000 mg/kg bw/day. The oral NOAEL was determined as 400 mg/kg bw/day.	
Ecological Toxicity ³		
Aquatic Toxicity	The following aquatic effects concentrations are available: Leuciscus idus: 460-1,000 mg/L (LC50, 96h) for test substance: Hexane-1,6-diol crude 65%, Leuciscus idus: 4,600-10,000 mg/L (LC50, 96h) for test substance: Hexane-1,6-diol flakes, Daphnia magna >500 mg/L (EC50, 24h & 48h), Scenedesmus subspicatus: 2,200 mg/L (EC50, 72h). The different results in the fish acute toxicity test are probably caused by impurities in the technical product.	
Determination of PNEC aquatic	Data from short-term tests with three trophic levels are available. An assessment factor of 1000 is applied to the lowest effect value of 500 mg/l derived from tests with Leuciscus idus and Daphnia magna. A PNECaqua of 500 µg/L was derived.	
Current Regulatory Controls ⁴		
Listed as a Chemical of Concern on International Databases	International Database	Listed?
	European REACH regulation Substances of very high concern (SVHCs) according to Annex XV https://echa.europa.eu/candidate-list-table	No
	International Agency for Research on Cancer (IARC) as a Group 1, 2A or 2B carcinogen https://monographs.iarc.who.int/list-of-classifications	No
	National Toxicology Program (NTP) Report on Carcinogens (RoC) https://ntp.niehs.nih.gov/whatwestudy/assessments/cancer/roc/index.html	No

	US EPA Integrated Risk Information System (IRIS) as carcinogenic to humans, or likely / probable / possibly carcinogenic to humans EU list chemicals with endocrine disruption listed in Category 1 or Category 2 https://www.epa.gov/iris	No
	United States Endocrine Disrupter Screening Program https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-tier-1-screening-determinations-and	No
	Agency for Toxic Substances and Disease Registry (ATSDR) as a neurotoxin https://wwwn.cdc.gov/TSP/index.aspx?sysid=18	No
	Montreal Protocol https://www.dcceew.gov.au/environment/protection/ozone/montreal-protocol	No
	Rotterdam Convention http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals	No
	Stockholm Convention http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx	No
Australian Hazard Classification	No data available.	
Australian Occupational Exposure Standards	No specific exposure standards were available.	
International Occupational Exposure Standards	No data available.	
Australian Food Standards	No data available.	
Australian Drinking Water Guidelines	No data available.	
Aquatic Toxicity Guidelines	No data available.	
PBT Assessment		
P/vP Criteria fulfilled?	No. Based on test guideline OECD 301C, 1,6-Hexanediol is readily biodegradable.	
B/vB criteria fulfilled?	No. The substance has no considerable potential for bioaccumulation.	
T criteria fulfilled?	No. The acute EC(L)50 are >0.1 mg/L in fish, invertebrates and algae for 1, 6-Hexanediol. Therefore, it does not meet the screening criteria for toxicity.	
Overall conclusion	Not PBT	

References

1. NICNAS (2020) Human Health Tier 1 Assessment for 1,6-Hexanediol
2. ECHA REACH, 1,6-Hexanediol, Retrieved January 2020: <https://echa.europa.eu/>
3. OECD (1997) SIDS Initial Assessment Profile on Hexamethylene glycol, Retrieved January 2020: <https://hpvchemicals.oecd.org/ui/handler.axd?id=a521f813-adb4-4d98-8a24-df93e783240b>

Appendix D

Exposure and Risk Calculations

Toxicity and Dermal Absorption Parameters - HVFR_A

C = calculated from chronic value, Ch = chronic value adopted

CAS#	Chemical	<u>Oral/Dermal Exposures</u>										
		Non-Threshold Slope Factor	Threshold Chronic TDI		Dermal Permeability	Reference	Drinking Water Guideline		NOAEL or LOAEL	UF	Reference	
		(mg/kg/day) ⁻¹	(mg/kg/day)		(cm/hr)		(mg/L)		(mg/kg bw/d)			
		COPC in Hydraulic Fracturing Fluid Injected into Well										
111-30-8	Glutaraldehyde		0.04	D	3.25E-04	EPI	0.2	D	4	100	NICNAS (2017)	
64742-47-8	Hydrotreated light petroleum distillate		10	D	1.96	EPI	39	D	1000	100	NICNAS (2017)	
127087-87-0	Polyethylene glycol trimethylnonyl ether		0.05	D	3.99E-03	EPI	0.2	D	50	1000	NICNAS (2019)	

D = Derived (refer to individual Toxicity Profiles); EPI - USEPA Estimation Programs Interface (EPI) Suite
NICNAS (2017) - Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme
NICNAS (2019) Human Health Tier II Assessment for Nonylphenol and octylphenol ethoxylates and related compounds

Ingestion of Chemicals via Incidental Contact with Flowback Water (20% Mass Return) - HVFR_A

Adult Trespassers

General Data/ Equations					Exposure Calculations (RME) Flowback Water (20% return)				
Exposure Parameters					Units				
Exposure Frequency (EF)					days/year				
Exposure Duration (ED)					years				
Body Weight (BW)					kg				
Averaging Time - NonThreshold (ATc)					days				
Averaging Time - Threshold (ATn)					days				
Ingestion Rate (IRw)					L/day or L/hr				
Bioavailability (B)					-				
Intake Factor = $\frac{IRw \cdot ET \cdot B \cdot EF \cdot ED}{BW \cdot AT}$					L/kg/day				
Daily Intake from Water = Concentration in Water x Intake Factor									
NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor									
Hazard Quotients = (Daily Intake for Threshold Effects/ADI)									
Chemical	Toxicity Data				Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI- Background)		NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)		(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.00E+01		1.0E+01	294.17	2.2E-05	5.2E-04	--	5.17E-05
Glutaraldehyde		4.00E-02		4.0E-02	46.41	3.5E-06	8.1E-05	--	2.04E-03
Polyethylene glycol trimethylnonyl ether		5.00E-02		5.0E-02	0.91	6.9E-08	1.6E-06	--	3.20E-05
Total Risk (mixture)								--	2.12E-03

Dermal Exposure to Chemicals via Incidental Contact with Flowback Water (20% mass return) - HVFR_A

Adult Trespassers

General Data/ Equations				Units	Flowback Water (20% return)						
Exposure Parameters											
Exposure Frequency (EF)			days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site						
Exposure Duration (ED)			years	3	Maximum duration of a flow back pond on-site						
Body Weight (BW)			kg	78	Average male and female adults as per enHealth 2012						
Averaging Time - NonThreshold (ATc)			days	25550	USEPA 2009						
Averaging Time - Threshold (ATn)			days	1095	USEPA 2009						
Surface Area (SAw)			cm ²	20000	Whole adult body surface area as per enHealth 2012						
Exposure Time (ET)			hr/day	1	Assume adult gets completely wet for 1 hour each time						
Conversion Factor (CF)			L/cm ³	1.E-03	Conversion of units						
Intake Factor = $\frac{SAw*ET*CF*EF*ED}{BW*AT}$				L-hr/(cm ³ -kg-day)	3.0E-05	NonThreshold					
					7.0E-04	Threshold					
<i>Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor</i>											
<i>NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor</i>											
<i>Hazard Quotients = (Daily Intake for Threshold Effects/ADI)</i>											
Chemical	Toxicity Data		Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk		
	Non-Threshold Slope Factor	Chronic Threshold TDI					NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient	
	(mg/kg-day) ⁻¹	(mg/kg/day)					(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)	
Hydrotreated light petroleum distillate		10		1.0E+01	1.96E+00	294.17	1.7E-02	4.1E-01	--	4.05E-02	
Glutaraldehyde		0		4.0E-02	3.25E-04	46.41	4.5E-07	1.1E-05	--	2.65E-04	
Polyethylene glycol trimethylnonyl ether		0		5.0E-02	3.99E-03	0.91	1.1E-07	2.6E-06	--	5.10E-05	
							Total Risk (mixture)			4.08E-02	

Ingestion of Chemicals via Incidental Contact with Flowback Water (20% mass return) - HVFR_A

Older Children Trespassers (5-15 yrs)

General Data/ Equations					Exposure Calculations (RME) Flowback Water (20% return)				
Exposure Parameters					Units				
Exposure Frequency (EF)					days/year				
Exposure Duration (ED)					years				
Body Weight (BW)					kg				
Averaging Time - NonThreshold (ATc)					days				
Averaging Time - Threshold (ATn)					days				
Ingestion Rate (IRw)					L/day or L/hr				
Bioavailability (B)					-				
Intake Factor = $\frac{IRw \cdot EF \cdot B \cdot ED}{BW \cdot AT}$					L/kg/day				
Daily Intake from Water = Concentration in Water x Intake Factor									
NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor									
Hazard Quotients = (Daily Intake for Threshold Effects/ADI)									
Chemical	Toxicity Data				Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI- Background)		NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)		(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	294.17	4.4E-05	1.0E-03	--	1.03E-04
Glutaraldehyde		4.0E-02		4.0E-02	46.41	7.0E-06	1.6E-04	--	4.07E-03
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	0.91	1.4E-07	3.2E-06	--	6.40E-05
Total Risk (mixture)									4.24E-03

Dermal Exposure to Chemicals via Incidental Contact with Flowback Water (20% mass return) - HVFR_A

Older Children Trespassers (5-15 yrs)

General Data/ Equations		Exposure Calculations (RME) Flowback Water (20% return)	
Exposure Parameters			
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site
Body Weight (BW)	kg	39	Mean body weight (from 4-7, 8-11 and 12-15 year old data) as per enHealth 2012
Averaging Time - NonThreshold (ATc)	days	25550	Averaging of exposure over 70yr lifetime as per USEPA 1989 and CSMS 1996
Averaging Time - Threshold (ATn)	days	1095	Averaging of exposure over exposure duration as per USEPA 1989 and CSMS 1996
Surface Area (SAw)	cm ²	15900	Wholebody surface area (child 11-15 yrs) as per enhealth 2012
Exposure Time (ET)	hr/day	1	Assume child gets completely wet for 1 hour each time
Conversion Factor (CF)	L/cm ³	1.E-03	Conversion of units
Intake Factor = $\frac{SAw \cdot ET \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$		4.8E-05	NonThreshold
		1.1E-03	Threshold

Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor

NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor

Hazard Quotients = (Daily Intake for Threshold Effects/ADI)

Chemical	Toxicity Data		Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI					NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)					(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	2.0E+0	294.17	2.8E-02	6.4E-01	--	6.44E-02
Glutaraldehyde		4.0E-02		4.0E-02	3.3E-4	46.41	7.2E-07	1.7E-05	--	4.21E-04
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	4.0E-3	0.91	1.7E-07	4.1E-06	--	8.12E-05
Total Risk (mixture)										6.49E-02

Ingestion of Chemicals via Incidental Contact with Flowback Water (60% Mass Return) - HVFR_A

Adult Trespassers

Adult Trespassers		Exposure Calculations (RME)						
General Data/ Equations		Flowback Water (60% return)						
Exposure Parameters								
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site					
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site					
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012					
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 2009					
Averaging Time - Threshold (ATn)	days	1095	USEPA 2009					
Ingestion Rate (IRw)	L/day or L/hr	0.05	Assume incidental ingestion of 50 mL					
Bioavailability (B)	-	100%	Assume 100% bioavailability via ingestion of chemicals in water.					
Intake Factor = $\frac{IRw \cdot ET \cdot B \cdot EF \cdot ED}{BW \cdot AT}$	L/kg/day	7.5E-08 1.8E-06	NonThreshold Threshold					
Daily Intake from Water = Concentration in Water x Intake Factor NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor Hazard Quotients = (Daily Intake for Threshold Effects/ADI)								
Chemical	Toxicity Data		Concentration	Daily Intake		Calculated Risk		
	Non-Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)	in Water	NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.00E+01		882.50	6.6E-05	1.5E-03	--	1.55E-04
Glutaraldehyde		4.00E-02		139.22	1.0E-05	2.4E-04	--	6.11E-03
Polyethylene glycol trimethylnonyl ether		5.00E-02		2.73	2.1E-07	4.8E-06	--	9.59E-05
Total Risk (mixture)								6.36E-03

Dermal Exposure to Chemicals via Incidental Contact with Flowback Water (60% mass return) - HVFR_A

Adult Trespassers

Adult Trespassers				Exposure Calculations (RME) Flowback Water (60% return)						
General Data/ Equations				Units						
Exposure Parameters										
Exposure Frequency (EF)			days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site					
Exposure Duration (ED)			years	3	Maximum duration of a flow back pond on-site					
Body Weight (BW)			kg	78	Average male and female adults as per enHealth 2012					
Averaging Time - NonThreshold (ATc)			days	25550	USEPA 2009					
Averaging Time - Threshold (ATn)			days	1095	USEPA 2009					
Surface Area (SAw)			cm ²	20000	Whole adult body surface area as per enHealth 2012					
Exposure Time (ET)			hr/day	1	Assume adult gets completely wet for 1 hour each time					
Conversion Factor (CF)			L/cm ³	1.E-03	Conversion of units					
Intake Factor = $\frac{SAw \cdot ET \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$				L-hr/(cm ³ -kg-day)	3.0E-05	NonThreshold				
					7.0E-04	Threshold				
<i>Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor</i> <i>NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor</i> <i>Hazard Quotients = (Daily Intake for Threshold Effects/ADI)</i>										
Chemical	Toxicity Data			Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)				NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)					(mg/kg/day)	(cm/hr)	(mg/L)	(mg/kg/day)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	2.0E+0	882.50	5.2E-02	1.2E+00	--	1.22E-01
Glutaraldehyde		4.0E-02		4.0E-02	3.3E-4	139.22	1.4E-06	3.2E-05	--	7.95E-04
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	4.0E-3	2.73	3.3E-07	7.7E-06	--	1.53E-04
Total Risk (mixture)										1.22E-01

Ingestion of Chemicals via Incidental Contact with Flowback Water (60% mass return) - HVFR_A

Older Children Trespassers (5-15 yrs)

General Data/ Equations					Exposure Calculations (RME) Flowback Water (60% return)				
Exposure Parameters					Units				
Exposure Frequency (EF)					days/year				
Exposure Duration (ED)					years				
Body Weight (BW)					kg				
Averaging Time - NonThreshold (ATc)					days				
Averaging Time - Threshold (ATn)					days				
Ingestion Rate (IRw)					L/day or L/hr				
Bioavailability (B)					-				
Intake Factor = $\frac{IRw \cdot EF \cdot B \cdot ED}{BW \cdot AT}$					L/kg/day				
Daily Intake from Water = Concentration in Water x Intake Factor									
NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor									
Hazard Quotients = (Daily Intake for Threshold Effects/ADI)									
Chemical	Toxicity Data				Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI- Background)		NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)		(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	882.50	1.3E-04	3.1E-03	--	0.000310
Glutaraldehyde		4.0E-02		4.0E-02	139.22	2.1E-05	4.9E-04	--	0.012225
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	2.73	4.1E-07	9.6E-06	--	0.000192
Total Risk (mixture)									1.27E-02

Dermal Exposure to Chemicals via Incidental Contact with Flowback Water (60% mass return) - HVFR_A

Older Children Trespassers (5-15 yrs)

Older Children Trespassers (5-15 yrs)				Exposure Calculations (RME) Flowback Water (60% return)						
General Data/ Equations		Units								
Exposure Parameters										
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site							
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site							
Body Weight (BW)	kg	39	Mean body weight (from 4-7, 8-11 and 12-15 year old data) as per enHealth 2012							
Averaging Time - NonThreshold (ATc)	days	25550	Averaging of exposure over 70yr lifetime as per USEPA 1989 and CSMS 1996							
Averaging Time - Threshold (ATn)	days	1095	Averaging of exposure over exposure duration as per USEPA 1989 and CSMS 1996							
Surface Area (SAw)	cm ²	15900	Wholebody surface area (child 11-15 yrs) as per enhealth 2012							
Exposure Time (ET)	hr/day	1	Assume child gets completely wet for 1 hour each time							
Conversion Factor (CF)	L/cm ³	1.E-03	Conversion of units							
Intake Factor = $\frac{SAw*ET*CF*EF*ED}{BW*AT}$		L-hr/(cm-kg-day)	4.8E-05 1.1E-03	NonThreshold Threshold						
<i>Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor</i> <i>NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor</i> <i>Hazard Quotients = (Daily Intake for Threshold Effects/ADI)</i>										
Chemical	Toxicity Data		Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI					NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)					(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	2.0E+0	882.4955692	8.3E-02	1.9E+00	--	1.93E-01
Glutaraldehyde		4.0E-02		4.0E-02	3.3E-4	139.2165665	2.2E-06	5.1E-05	--	1.26E-03
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	4.0E-3	2.731563343	5.2E-07	1.2E-05	--	2.43E-04
Total Risk (mixture)										1.95E-01

Summary of Risk to Trespassers - 20 and 60% Mass Return (Theoretical) Data - HVFR_A

Exposure fo Target Chemicals

Receptor/Exposure Pathway	Calculated Non-Threshold Risk 20% Mass Return	Calculated HI 20% Mass Return	Calculated Non-Threshold Risk 60% Mass Return	Calculated HI 60% Mass Return
Adult Trespassers				
Ingestion of Chemicals via Incidental Contact with Flowback Water	--	0.002	--	0.006
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	--	0.04	--	0.1
Total Risk	--	0.04	--	0.1
Child Trespassers				
Ingestion of Chemicals via Incidental Contact with Flowback Water	--	0.004	--	0.01
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	--	0.06	--	0.2
Total Risk	--	0.07	--	0.2

Aquatic Toxicity Endpoints - Risk Calculations - HVFR_A

General Equations

PNEC Aquatic mg/L = $\frac{E(L)C50 \text{ or NOEC}}{\text{Assessment Factor}}$

HQ = $\frac{EPC}{PNEC \text{ Aquatic}}$

Where PNEC Aquatic = Predicted No Effects Concentration (Aquatic Receptors)
 E(L)C50 = Median effective concentration
 NOEC = No Observed Effect Concentration
 HQ = Hazard Quotient
 EPC = Exposure Point Concentration
 Total HI = Hazard Index (Sum of HQ)

CAS#	Chemical	Endpoint	E(L)C50 or NOEC	Assessment Factor	PNEC Aquatic	EPC		Calculated HI	
			mg/L		mg/L	20% Mass Return mg/L	60% Mass return mg/L	20% Mass Return mg/L	60% Mass Return mg/L
111-30-8	Glutaraldehyde	48 h acute Daphnia	2.1	10	2.10E-01	4.64E+01	1.39E+02	2.21E+02	6.63E+02
7647-01-0	Hydrochloric Acid	Chronic Daphnia	62	10	6.20E+00	2.38E+02	7.13E+02	3.83E+01	1.15E+02
64742-47-8	Hydrotreated light petroleum distillate	Acute Daphnia	0.018	100	1.80E-04	2.94E+02	8.82E+02	1.63E+06	4.90E+06
68551-12-2	Ethoxylated C12-C16 Alcohol	Chronic daphnia	0.11	10	1.10E-02	2.56E-01	7.68E-01	2.33E+01	6.98E+01
104-55-2	Cinnamaldehyde	72 hr Algae	2	10	2.00E-01	9.95E-02	2.99E-01	4.98E-01	1.49E+00
26183-52-8	Ethoxylated Decanol	Chronic daphnia	0.11	10	1.10E-02	9.47E-02	2.84E-01	8.61E+00	2.58E+01
61791-26-2	Ethoxylated Tallow Alkyl Amine*	Acute daphnia	12.41	1000	1.24E-02	4.48E-02	1.35E-01	3.61E+00	1.08E+01
127087-87-0	Polyethylene glycol trimethylnonyl ether	Chronic fish	0.048	100	4.80E-04	9.11E-01	2.73E+00	1.90E+03	5.69E+03
22042-96-2	Hepta sodium phosphonate	Chronic fish	25.6	100	2.56E-01	2.55E+01	7.66E+01	9.98E+01	2.99E+02
6381-77-7	Sodium erythorbate	Acute Algae	1020	100	1.02E+01	3.25E+00	9.75E+00	3.19E-01	9.56E-01
67-63-0	Propan-2-ol	Chronic Daphnia	5000	10	5.00E+02	3.27E-01	9.82E-01	6.55E-04	1.96E-03
Total HI								1.64E+06	4.91E+06

Toxicity and Dermal Absorption Parameters - HVFR_B

C = calculated from chronic value, Ch = chronic value adopted

CAS#	Chemical	<u>Oral/Dermal Exposures</u>									
		Non-Threshold Slope Factor	Threshold Chronic TDI	Dermal Permeability	Drinking Water Guideline	NOAEL or LOAEL	UF	Reference			
		(mg/kg/day) ⁻¹	(mg/kg/day)	(cm/hr)	(mg/L)	(mg/kg bw/d)					
		COPC in Hydraulic Fracturing Fluid Injected into Well									
111-30-8	Glutaraldehyde			0.04	D	3.25E-04	0.156	D	4	100	NICNAS (2017)
64742-47-8	Hydrotreated light petroleum distillate			10	D	1.96	39	D	1000	100	NICNAS (2017)
127087-87-0	Polyethylene glycol trimethylnonyl ether			0.05	D	3.99E-03	0.2	D	50	1000	NICNAS (2019)
7173-51-5	Didecyl dimethyl ammonium chloride			0.1	D	1.81E-02	0.39	D	10	100	USEPA (2017)

D = Derived (refer to individual Toxicity Profiles); EPI - USEPA Estimation Programs Interface (EPI) Suite
NICNAS (2017) - Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme
NICNAS (2019) Human Health Tier II Assessment for Nonylphenol and octylphenol ethoxylates and related compounds
USEPA (2017) Didecyl Dimethyl Ammonium Chloride (DDAC) Final Work Plan, March 2017

Ingestion of Chemicals via Incidental Contact with Flowback Water (20% Mass Return) - HVFR_B

Adult Trespassers

Adult Trespassers					Exposure Calculations (RME) Flowback Water (20% return)				
General Data/ Equations				Units					
Exposure Parameters									
Exposure Frequency (EF)				days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site			
Exposure Duration (ED)				years	3	Maximum duration of a flow back pond on-site (3 yrs)			
Body Weight (BW)				kg	78	Average male and female adults as per enHealth 2012			
Averaging Time - NonThreshold (ATc)				days	25550	USEPA 2009			
Averaging Time - Threshold (ATn)				days	1095	USEPA 2009			
Ingestion Rate (IRw)				L/day or L/hr	0.05	Assume incidental ingestion of 50 mL			
Bioavailability (B)				-	100%	Assume 100% bioavailability via ingestion of chemicals in water.			
Intake Factor = $\frac{IRw \cdot ET \cdot B \cdot EF \cdot ED}{BW \cdot AT}$				L/kg/day	7.5E-08 1.8E-06	NonThreshold Threshold			
<i>Daily Intake from Water = Concentration in Water x Intake Factor</i> <i>NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor</i> <i>Hazard Quotients = (Daily Intake for Threshold Effects/ADI)</i>									
Chemical	Toxicity Data				Concentration	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	in Water	NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.00E+01		1.0E+01	326.29	2.5E-05	5.7E-04	--	5.73E-05
Glutaraldehyde		4.00E-02		4.0E-02	51.47	3.9E-06	9.0E-05	--	2.26E-03
Polyethylene glycol trimethylnonyl ether		5.00E-02		5.0E-02	1.01	7.6E-08	1.8E-06	--	3.55E-05
Didecyldimethyl ammonium chloride		1.00E-01		1.0E-01	0.73	5.5E-08	1.3E-06	--	1.29E-05
Total Risk (mixture)								--	2.37E-03

Dermal Exposure to Chemicals via Incidental Contact with Flowback Water (20% mass return) - HVFR_B

Adult Trespassers

Adult Trespassers				Exposure Calculations (RME)						
General Data/ Equations		Units		Flowback Water (20% return)						
Exposure Parameters										
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site							
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site (3 yrs)							
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012							
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 2009							
Averaging Time - Threshold (ATn)	days	1095	USEPA 2009							
Surface Area (SAw)	cm²	20000	Whole adult body surface area as per enHealth 2012							
Exposure Time (ET)	hr/day	1	Assume adult gets completely wet for 1 hour each time							
Conversion Factor (CF)	L/cm³	1.E-03	Conversion of units							
Intake Factor = $\frac{SAw \cdot ET \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$		L-hr/(cm-kg-day)	3.0E-05	NonThreshold						
			7.0E-04	Threshold						
<i>Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor</i>										
<i>NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor</i>										
<i>Hazard Quotients = (Daily Intake for Threshold Effects/ADI)</i>										
Chemical	Toxicity Data	Chronic	Background	Chronic TDI	Dermal	Concentration	Daily Intake		Calculated Risk	
	Non-Threshold	Threshold TDI	Intake (%	Allowable for	Permeability	in Water	NonThreshold	Threshold	NonThreshold	Chronic Hazard
	Slope Factor		Chronic TDI)	Assessment (TDI-Background)					Risk	Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(cm/hr)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.00E+01		1.0E+01	1.96E+00	326.29	1.9E-02	4.5E-01	--	4.49E-02
Glutaraldehyde		4.00E-02		4.0E-02	3.25E-04	51.47	5.0E-07	1.2E-05	--	2.94E-04
Polyethylene glycol trimethylnonyl ether		5.00E-02		5.0E-02	3.99E-03	1.01	1.2E-07	2.8E-06	--	5.66E-05
Didecyldimethyl ammonium chloride		1.00E-01		1.0E-01	1.81E-02	0.73	4.0E-07	9.3E-06	--	9.31E-05
Total Risk (mixture)										4.54E-02

Ingestion of Chemicals via Incidental Contact with Flowback Water (20% mass return) - HVFR_B

Older Children Trespassers (5-15 yrs)

General Data/ Equations					Exposure Calculations (RME) Flowback Water (20% return)				
Exposure Parameters					Units				
Exposure Frequency (EF)					days/year				
Exposure Duration (ED)					years				
Body Weight (BW)					kg				
Averaging Time - NonThreshold (ATc)					days				
Averaging Time - Threshold (ATn)					days				
Ingestion Rate (IRw)					L/day or L/hr				
Bioavailability (B)					-				
Intake Factor = $\frac{IRw \cdot ET \cdot B \cdot EF \cdot ED}{BW \cdot AT}$					L/kg/day				
Daily Intake from Water = Concentration in Water x Intake Factor									
NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor									
Hazard Quotients = (Daily Intake for Threshold Effects/ADI)									
Chemical	Toxicity Data				Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI- Background)		NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)		(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	326.29	4.9E-05	1.1E-03	--	1.15E-04
Glutaraldehyde		4.0E-02		4.0E-02	51.47	7.7E-06	1.8E-04	--	4.52E-03
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	1.01	1.5E-07	3.5E-06	--	7.09E-05
Didecylidimethyl ammonium chloride		1.0E-01		1.0E-01	0.73	1.1E-07	2.6E-06	--	2.57E-05
Total Risk (mixture)									4.73E-03

Dermal Exposure to Chemicals via Incidental Contact with Flowback Water (20% mass return) - HVFR_B

Older Children Trespassers (5-15 yrs)

General Data/ Equations		Exposure Calculations (RME) Flowback Water (20% return)	
Exposure Parameters		Units	
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site (3 yrs)
Body Weight (BW)	kg	39	Mean body weight (from 4-7, 8-11 and 12-15 year old data) as per enHealth 2012
Averaging Time - NonThreshold (ATc)	days	25550	Averaging of exposure over 70yr lifetime as per USEPA 1989 and CSMS 1996
Averaging Time - Threshold (ATn)	days	1095	Averaging of exposure over exposure duration as per USEPA 1989 and CSMS 1996
Surface Area (SAw)	cm ²	15900	Wholebody surface area (child 11-15 yrs) as per enhealth 2012
Exposure Time (ET)	hr/day	1	Assume child gets completely wet for 1 hour each time
Conversion Factor (CF)	L/cm ³	1.E-03	Conversion of units
Intake Factor = $\frac{SAw \cdot ET \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$		L-hr/(cm ² -kg-day)	
		4.8E-05	NonThreshold
		1.1E-03	Threshold

Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor

NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor

Hazard Quotients = (Daily Intake for Threshold Effects/ADI)

Chemical	Toxicity Data		Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI					NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)					(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	2.0E+0	326.29	3.1E-02	7.1E-01	--	7.14E-02
Glutaraldehyde		4.0E-02		4.0E-02	3.3E-4	51.47	8.0E-07	1.9E-05	--	4.67E-04
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	4.0E-3	1.01	1.9E-07	4.5E-06	--	9.00E-05
Didecyldimethyl ammonium chloride		1.0E-01		1.0E-01	1.8E-2	0.73	6.3E-07	1.5E-05	--	1.48E-04
Total Risk (mixture)										7.21E-02

Ingestion of Chemicals via Incidental Contact with Flowback Water (60% Mass Return) - HVFR_B

Adult Trespassers

Adult Trespassers					Exposure Calculations (RME) Flowback Water (60% return)				
General Data/ Equations				Units					
Exposure Parameters									
Exposure Frequency (EF)				days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site			
Exposure Duration (ED)				years	3	Maximum duration of a flow back pond on-site (3 yrs)			
Body Weight (BW)				kg	78	Average male and female adults as per enHealth 2012			
Averaging Time - NonThreshold (ATc)				days	25550	USEPA 2009			
Averaging Time - Threshold (ATn)				days	1095	USEPA 2009			
Ingestion Rate (IRw)				L/day or L/hr	0.05	Assume incidental ingestion of 50 mL			
Bioavailability (B)				-	100%	Assume 100% bioavailability via ingestion of chemicals in water.			
Intake Factor = $\frac{IRw \cdot ET \cdot B \cdot EF \cdot ED}{BW \cdot AT}$				L/kg/day	7.5E-08 1.8E-06	NonThreshold Threshold			
<i>Daily Intake from Water = Concentration in Water x Intake Factor</i> <i>NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor</i> <i>Hazard Quotients = (Daily Intake for Threshold Effects/ADI)</i>									
Chemical	Toxicity Data				Concentration	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	in Water	NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.00E+01		1.0E+01	978.87	7.4E-05	1.7E-03	--	1.72E-04
Glutaraldehyde		4.00E-02		4.0E-02	154.42	1.2E-05	2.7E-04	--	6.78E-03
Polyethylene glycol trimethylnonyl ether		5.00E-02		5.0E-02	3.03	2.3E-07	5.3E-06	--	1.06E-04
Didecylidimethyl ammonium chloride		1.00E-01		1.0E-01	2.20	1.7E-07	3.9E-06	--	3.86E-05
Total Risk (mixture)									7.10E-03

Dermal Exposure to Chemicals via Incidental Contact with Flowback Water (60% mass return) - HVFR_B

Adult Trespassers

General Data/ Equations		Exposure Calculations (RME) Flowback Water (60% return)	
Exposure Parameters		Units	
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site (3 yrs)
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 2009
Averaging Time - Threshold (ATn)	days	1095	USEPA 2009
Surface Area (SAw)	cm ²	20000	Whole adult body surface area as per enHealth 2012
Exposure Time (ET)	hr/day	1	Assume adult gets completely wet for 1 hour each time
Conversion Factor (CF)	L/cm ³	1.E-03	Conversion of units
Intake Factor = $\frac{SAw \cdot ET \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$		L-hr/(cm ³ -kg-day)	3.0E-05 7.0E-04
			NonThreshold Threshold

Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor

NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor

Hazard Quotients = (Daily Intake for Threshold Effects/ADI)

Chemical	Toxicity Data		Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI					NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)					(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	2.0E+0	978.87	5.8E-02	1.3E+00	--	1.35E-01
Glutaraldehyde		4.0E-02		4.0E-02	3.3E-4	154.42	1.5E-06	3.5E-05	--	8.81E-04
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	4.0E-3	3.03	3.6E-07	8.5E-06	--	1.70E-04
Didecylidimethyl ammonium chloride		1.0E-01		1.0E-01	1.8E-2	2.20	1.2E-06	2.8E-05	--	2.79E-04
Total Risk (mixture)										1.36E-01

Ingestion of Chemicals via Incidental Contact with Flowback Water (60% mass return) - HVFR_B

Older Children Trespassers (5-15 yrs)

Older Children Trespassers (5-15 yrs)					Exposure Calculations (RME) Flowback Water (60% return)				
General Data/ Equations					Units				
Exposure Parameters									
Exposure Frequency (EF)					days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site		
Exposure Duration (ED)					years	3	Maximum duration of a flow back pond on-site (3 yrs)		
Body Weight (BW)					kg	39	Mean body weight (from 4-7, 8-11 and 12-15 year old data) as per enHealth 2012		
Averaging Time - NonThreshold (ATc)					days	25550	USEPA 2009		
Averaging Time - Threshold (ATn)					days	1095	USEPA 2009		
Ingestion Rate (IRw)					L/day or L/hr	0.05	Assume incidental ingestion of 50 mL		
Bioavailability (B)					-	100%	Assume 100% bioavailability via ingestion of chemicals in water.		
Intake Factor = $\frac{IRw \cdot ET \cdot B \cdot EF \cdot ED}{BW \cdot AT}$					L/kg/day	1.5E-07 3.5E-06	NonThreshold Threshold		
<i>Daily Intake from Water = Concentration in Water x Intake Factor</i> <i>NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor</i> <i>Hazard Quotients = (Daily Intake for Threshold Effects/ADI)</i>									
Chemical	Toxicity Data				Concentration in Water	Daily Intake		Calculated Risk	
	Non- Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI- Background)		NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	978.87	1.5E-04	3.4E-03	--	0.000344
Glutaraldehyde		4.0E-02		4.0E-02	154.42	2.3E-05	5.4E-04	--	0.013560
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	3.03	4.6E-07	1.1E-05	--	0.000213
Didecylidimethyl ammonium chloride		1.0E-01		1.0E-01	2.20	3.3E-07	7.7E-06	--	0.000077
Total Risk (mixture)									1.42E-02

Dermal Exposure to Chemicals via Incidental Contact with Flowback Water (60% mass return) - HVFR_B

Older Children Trespassers (5-15 yrs)

General Data/ Equations		Exposure Calculations (RME) Flowback Water (60% return)	
Exposure Parameters			
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site (3 yrs)
Body Weight (BW)	kg	39	Mean body weight (from 4-7, 8-11 and 12-15 year old data) as per enHealth 2012
Averaging Time - NonThreshold (ATc)	days	25550	Averaging of exposure over 70yr lifetime as per USEPA 1989 and CSMS 1996
Averaging Time - Threshold (ATn)	days	1095	Averaging of exposure over exposure duration as per USEPA 1989 and CSMS 1996
Surface Area (SAw)	cm ²	15900	Wholebody surface area (child 11-15 yrs) as per enhealth 2012
Exposure Time (ET)	hr/day	1	Assume child gets completely wet for 1 hour each time
Conversion Factor (CF)	L/cm ³	1.E-03	Conversion of units
Intake Factor = $\frac{SAw \cdot ET \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$		4.8E-05	NonThreshold
		1.1E-03	Threshold

Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor

NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor

Hazard Quotients = (Daily Intake for Threshold Effects/ADI)

Chemical	Toxicity Data		Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI					NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)					(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	2.0E+0	978.8705995	9.2E-02	2.1E+00	--	2.14E-01
Glutaraldehyde		4.0E-02		4.0E-02	3.3E-4	154.4200432	2.4E-06	5.6E-05	--	1.40E-03
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	4.0E-3	3.029870223	5.8E-07	1.4E-05	--	2.70E-04
Didecylidimethyl ammonium chloride		1.0E-01		1.0E-01	1.8E-2	2.195750347	1.9E-06	4.4E-05	--	4.44E-04
Total Risk (mixture)										2.16E-01

Summary of Risk to Trespassers - 20 and 60% Mass Return (Theoretical) Data - HVFR_B

Exposure fo Target Chemicals

Receptor/Exposure Pathway	Calculated Non-Threshold Risk 20% Mass Return	Calculated HI 20% Mass Return	Calculated Non-Threshold Risk 60% Mass Return	Calculated HI 60% Mass Return
Adult Trespassers				
Ingestion of Chemicals via Incidental Contact with Flowback Water	--	0.002	--	0.007
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	--	0.05	--	0.1
Total Risk	--	0.05	--	0.1
Child Trespassers				
Ingestion of Chemicals via Incidental Contact with Flowback Water	--	0.005	--	0.01
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	--	0.07	--	0.2
Total Risk	--	0.08	--	0.2

Aquatic Toxicity Endpoints - Risk Calculations - HVFR_B

General Equations

PNEC Aquatic mg/L = $\frac{E(L)C50 \text{ or NOEC}}{\text{Assessment Factor}}$

HQ = $\frac{EPC}{PNEC \text{ Aquatic}}$

Where PNEC Aquatic = Predicted No Effects Concentration (Aquatic Receptors)
 E(L)C50 = Median effective concentration
 NOEC = No Observed Effect Concentration
 HQ = Hazard Quotient
 EPC = Exposure Point Concentration
 Total HI = Hazard Index (Sum of HQ)

CAS#	Chemical	Endpoint	E(L)C50 or NOEC mg/L	Assessment Factor	PNEC Aquatic mg/L	EPC		Calculated HI	
						20% Mass Return mg/L	60% Mass return mg/L	20% Mass Return mg/L	60% Mass Return mg/L
64742-47-8	Hydrotreated light petroleum distillate	Acute Daphnia	0.018	100	1.80E-04	3.26E+02	9.79E+02	1.81E+06	5.44E+06
7647-01-0	Hydrochloric Acid	Chronic Daphnia	62	10	6.20E+00	2.64E+02	7.91E+02	4.25E+01	1.28E+02
111-30-8	Glutaraldehyde	48 h acute Daphnia	2.1	10	2.10E-01	5.15E+01	1.54E+02	2.45E+02	7.35E+02
6381-77-7	Sodium erythorbate	Acute Algae	1020	100	1.02E+01	3.60E+00	1.08E+01	3.53E-01	1.06E+00
22042-96-2	Hepta sodium phosphonate	Chronic fish	25.6	100	2.56E-01	2.83E+01	8.50E+01	1.11E+02	3.32E+02
127087-87-0	Polyethylene glycol trimethylnonyl ether	Chronic fish	0.048	100	4.80E-04	1.01E+00	3.03E+00	2.10E+03	6.31E+03
7173-51-5	Didecyldimethyl ammonium chloride	96 h EC50 Algae	0.014	5	2.80E-03	7.32E-01	2.20E+00	2.61E+02	7.84E+02
64-17-5	Ethanol	Chronic Daphnia	7800	10	7.80E+02	8.27E-02	2.48E-01	1.06E-04	3.18E-04
						Total HI		1.82E+06	5.45E+06

Toxicity and Dermal Absorption Parameters - HVFR_Hybrid

C = calculated from chronic value, Ch = chronic value adopted

CAS#	Chemical	<u>Oral/Dermal Exposures</u>										
		Non-Threshold Slope Factor	Threshold Chronic TDI	Dermal Permeability	Reference	Drinking Water Guideline	NOAEL or LOAEL	UF	Reference			
		(mg/kg/day) ⁻¹	(mg/kg/day)	(cm/hr)		(mg/L)	(mg/kg bw/d)					
COPC in Hydraulic Fracturing Fluid Injected into Well												
7727-54-0	Diammonium peroxidisulphate					1.00E-03	EPI	0.082	D	2.1	100	NICNAS (2017)
111-30-8	Glutaraldehyde		0.02	D	3.25E-04	EPI	0.2	D	4	100	100	NICNAS (2017)
10043-35-3	Boric acid		0.055	D	1.00E-03	EPI	3.5	A (boron)	55	1000	1000	NICNAS (2017)
9016-45-9	Polyoxyethylene nonylphenol ether		0.05	D	5.00E-03	EPI	0.2	D	50	1000	1000	NICNAS (2019)
64742-47-8	Hydrotreated light petroleum distillate		10	D	1.96	EPI	39	D	1000	100	100	NICNAS (2017)
127087-87-0	Polyethylene glycol trimethylnonyl ether		0.05	D	3.99E-03	EPI	0.2	D	50	1000	1000	NICNAS (2019)

D = Derived (refer to individual Toxicity Profiles); EPI - USEPA Estimation Programs Interface (EPI) Suite; A = ADWG

NICNAS (2017) - Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

NICNAS (2019) Human Health Tier II Assessment for Nonylphenol and octylphenol ethoxylates and related compounds

Ingestion of Chemicals via Incidental Contact with Flowback Water (20% Mass Return) - HVFR Hybrid

Adult Trespassers

General Data/ Equations		Exposure Calculations (RME) Flowback Water (20% return)	
Exposure Parameters		Units	
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 2009
Averaging Time - Threshold (ATn)	days	1095	USEPA 2009
Ingestion Rate (IRw)	L/day or L/hr	0.05	Assume incidental ingestion of 50 mL
Bioavailability (B)	-	100%	Assume 100% bioavailability via ingestion of chemicals in water.
Intake Factor = $\frac{IRw \cdot ET \cdot B \cdot EF \cdot ED}{BW \cdot AT}$		L/kg/day	7.5E-08 NonThreshold 1.8E-06 Threshold

Daily Intake from Water = Concentration in Water x Intake Factor
NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake for Threshold Effects/ADI)

Chemical	Toxicity Data				Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI- Background)		NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.00E+01		1.0E+01	380.04	2.9E-05	6.7E-04	--	6.67E-05
Glutaraldehyde		4.00E-02		4.0E-02	47.44	3.6E-06	8.3E-05	--	2.08E-03
Polyethylene glycol trimethylnonyl ether		5.00E-02		5.0E-02	0.39	3.0E-08	6.9E-07	--	1.39E-05
Polyoxyethylene nonylphenol ether		5.00E-02		5.0E-02	83.65	6.3E-06	1.5E-04	--	2.94E-03
Diammonium peroxidisulphate		2.10E-02		2.1E-02	26.75	2.0E-06	4.7E-05	--	2.24E-03
Boric acid		5.50E-02		5.5E-02	91.98	6.9E-06	1.6E-04	--	2.94E-03
Total Risk (mixture)								--	1.03E-02

Dermal Exposure to Chemicals via Incidental Contact with Flowback Water (20% mass return) - HVFR Hybrid

Adult Trespassers

General Data/ Equations		Exposure Calculations (RME) Flowback Water (20% return)	
Exposure Parameters		Units	
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 2009
Averaging Time - Threshold (ATn)	days	1095	USEPA 2009
Surface Area (SAw)	cm ²	20000	Whole adult body surface area as per enHealth 2012
Exposure Time (ET)	hr/day	1	Assume adult gets completely wet for 1 hour each time
Conversion Factor (CF)	L/cm ³	1.E-03	Conversion of units
Intake Factor = $\frac{SAw \cdot ET \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$		L-hr/(cm-kg-day)	3.0E-05 7.0E-04 NonThreshold Threshold

Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor

NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor

Hazard Quotients = (Daily Intake for Threshold Effects/ADI)

Chemical	Toxicity Data		Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI					NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)					(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.00E+01		1.0E+01	1.96E+00	380.04	2.2E-02	5.2E-01	--	5.23E-02
Glutaraldehyde		4.00E-02		4.0E-02	3.25E-04	47.44	4.6E-07	1.1E-05	--	2.71E-04
Polyethylene glycol trimethylnonyl ether		5.00E-02		5.0E-02	3.99E-03	0.39	4.7E-08	1.1E-06	--	2.21E-05
Polyoxyethylene nonylphenol ether		5.00E-02		5.0E-02	5.00E-03	83.65	1.3E-05	2.9E-04	--	5.88E-03
Diammonium peroxidisulphate		2.10E-02		2.1E-02	1.00E-03	26.75	8.1E-07	1.9E-05	--	8.95E-04
Boric acid		5.50E-02		5.5E-02	1.00E-03	91.98	2.8E-06	6.5E-05	--	1.17E-03
Total Risk (mixture)										6.06E-02

Ingestion of Chemicals via Incidental Contact with Flowback Water (20% mass return) - HVFR Hybrid

Older Children Trespassers (5-15 yrs)

General Data/ Equations					Exposure Calculations (RME) Flowback Water (20% return)				
Exposure Parameters					Units				
Exposure Frequency (EF)					days/year				
Exposure Duration (ED)					years				
Body Weight (BW)					kg				
Averaging Time - NonThreshold (ATc)					days				
Averaging Time - Threshold (ATn)					days				
Ingestion Rate (IRw)					L/day or L/hr				
Bioavailability (B)					-				
Intake Factor = $\frac{IRw \cdot EF \cdot B \cdot ED}{BW \cdot AT}$					L/kg/day				
Daily Intake from Water = Concentration in Water x Intake Factor									
NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor									
Hazard Quotients = (Daily Intake for Threshold Effects/ADI)									
Chemical	Toxicity Data				Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI- Background)		NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)		(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	380.04	5.7E-05	1.3E-03	--	1.33E-04
Glutaraldehyde		4.0E-02		4.0E-02	47.44	7.1E-06	1.7E-04	--	4.17E-03
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	0.39	5.9E-08	1.4E-06	--	2.77E-05
Polyoxyethylene nonylphenol ether		5.0E-02		5.0E-02	83.65	1.3E-05	2.9E-04	--	5.88E-03
Diammonium peroxidisulphate		2.1E-02		2.1E-02	26.75	4.0E-06	9.4E-05	--	4.48E-03
Boric acid		5.5E-02		5.5E-02	91.98	1.4E-05	3.2E-04	--	5.87E-03
Total Risk (mixture)									2.06E-02

Dermal Exposure to Chemicals via Incidental Contact with Flowback Water (20% mass return) - HVFR Hybrid

Older Children Trespassers (5-15 yrs)

General Data/ Equations		Exposure Calculations (RME) Flowback Water (20% return)	
Exposure Parameters			
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site
Body Weight (BW)	kg	39	Mean body weight (from 4-7, 8-11 and 12-15 year old data) as per enHealth 2012
Averaging Time - NonThreshold (ATc)	days	25550	Averaging of exposure over 70yr lifetime as per USEPA 1989 and CSMS 1996
Averaging Time - Threshold (ATn)	days	1095	Averaging of exposure over exposure duration as per USEPA 1989 and CSMS 1996
Surface Area (SAw)	cm ²	15900	Wholebody surface area (child 11-15 yrs) as per enhealth 2012
Exposure Time (ET)	hr/day	1	Assume child gets completely wet for 1 hour each time
Conversion Factor (CF)	L/cm ³	1.E-03	Conversion of units
Intake Factor = $\frac{SAw \cdot ET \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$		4.8E-05	NonThreshold
		1.1E-03	Threshold

Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor

NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor

Hazard Quotients = (Daily Intake for Threshold Effects/ADI)

Chemical	Toxicity Data		Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI					NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)					(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	2.0E+0	380.04	3.6E-02	8.3E-01	--	8.32E-02
Glutaraldehyde		4.0E-02		4.0E-02	3.3E-4	47.44	7.4E-07	1.7E-05	--	4.31E-04
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	4.0E-3	0.39	7.5E-08	1.8E-06	--	3.52E-05
Polyoxyethylene nonylphenol ether		5.0E-02		5.0E-02	5.0E-3	83.65	2.0E-05	4.7E-04	--	9.34E-03
Diammonium peroxodisulphate		2.1E-02		2.1E-02	1.0E-3	26.75	1.3E-06	3.0E-05	--	1.42E-03
Boric acid		5.5E-02		5.5E-02	1.0E-3	91.98	4.4E-06	1.0E-04	--	1.87E-03
Total Risk (mixture)										9.63E-02

Ingestion of Chemicals via Incidental Contact with Flowback Water (60% Mass Return) - HVFR Hybrid

Adult Trespassers

Adult Trespassers		Exposure Calculations (RME) Flowback Water (60% return)							
General Data/ Equations		Units							
Exposure Parameters									
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site						
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site						
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012						
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 2009						
Averaging Time - Threshold (ATn)	days	1095	USEPA 2009						
Ingestion Rate (IRw)	L/day or L/hr	0.05	Assume incidental ingestion of 50 mL						
Bioavailability (B)	-	100%	Assume 100% bioavailability via ingestion of chemicals in water.						
Intake Factor = $\frac{IRw*ET*B*EF*ED}{BW*AT}$	L/kg/day	7.5E-08 1.8E-06	NonThreshold Threshold						
Daily Intake from Water = Concentration in Water x Intake Factor NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor Hazard Quotients = (Daily Intake for Threshold Effects/ADI)									
Chemical	Toxicity Data		Concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	in Water	NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.00E+01		1.0E+01	1140.13	8.6E-05	2.0E-03	--	2.00E-04
Glutaraldehyde		4.00E-02		4.0E-02	142.31	1.1E-05	2.5E-04	--	6.25E-03
Polyethylene glycol trimethylnonyl ether		5.00E-02		5.0E-02	1.18	8.9E-08	2.1E-06	--	4.16E-05
Polyoxyethylene nonylphenol ether		5.00E-02		5.0E-02	250.94	1.9E-05	4.4E-04	--	8.81E-03
Diammonium peroxidisulphate		2.10E-02		2.1E-02	80.26	6.0E-06	1.4E-04	--	6.71E-03
Boric acid		5.50E-02		5.5E-02	275.94	2.1E-05	4.8E-04	--	8.81E-03
Total Risk (mixture)									3.08E-02

Dermal Exposure to Chemicals via Incidental Contact with Flowback Water (60% mass return) - HVFR Hybrid

Adult Trespassers

General Data/ Equations		Exposure Calculations (RME) Flowback Water (60% return)	
Exposure Parameters		Units	
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 2009
Averaging Time - Threshold (ATn)	days	1095	USEPA 2009
Surface Area (SAw)	cm ²	20000	Whole adult body surface area as per enHealth 2012
Exposure Time (ET)	hr/day	1	Assume adult gets completely wet for 1 hour each time
Conversion Factor (CF)	L/cm ³	1.E-03	Conversion of units
Intake Factor = $\frac{SAw \cdot ET \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$		L-hr/(cm ² -kg-day)	3.0E-05 NonThreshold 7.0E-04 Threshold

Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor

NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor

Hazard Quotients = (Daily Intake for Threshold Effects/ADI)

Chemical	Toxicity Data		Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI					NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)					(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	2.0E+0	1140.13	6.7E-02	1.6E+00	--	1.57E-01
Glutaraldehyde		4.0E-02		4.0E-02	3.3E-4	142.31	1.4E-06	3.2E-05	--	8.12E-04
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	4.0E-3	1.18	1.4E-07	3.3E-06	--	6.64E-05
Polyoxyethylene nonylphenol ether		5.0E-02		5.0E-02	5.0E-3	250.94	3.8E-05	8.8E-04	--	1.76E-02
Diammonium peroxidisulphate		2.1E-02		2.1E-02	1.0E-3	80.26	2.4E-06	5.6E-05	--	2.69E-03
Boric acid		5.5E-02		5.5E-02	1.0E-3	275.94	8.3E-06	1.9E-04	--	3.52E-03
Total Risk (mixture)										1.82E-01

Ingestion of Chemicals via Incidental Contact with Flowback Water (60% mass return) - HVFR Hybrid

Older Children Trespassers (5-15 yrs)

General Data/ Equations					Exposure Calculations (RME) Flowback Water (60% return)				
Exposure Parameters					Units				
Exposure Frequency (EF)					days/year				
Exposure Duration (ED)					years				
Body Weight (BW)					kg				
Averaging Time - NonThreshold (ATc)					days				
Averaging Time - Threshold (ATn)					days				
Ingestion Rate (IRw)					L/day or L/hr				
Bioavailability (B)					-				
Intake Factor = $\frac{IRw \cdot EF \cdot B \cdot ED}{BW \cdot AT}$					L/kg/day				
Daily Intake from Water = Concentration in Water x Intake Factor									
NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor									
Hazard Quotients = (Daily Intake for Threshold Effects/ADI)									
Chemical	Toxicity Data				Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI	Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI- Background)		NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)		(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	1140.13	1.7E-04	4.0E-03	--	0.000400
Glutaraldehyde		4.0E-02		4.0E-02	142.31	2.1E-05	5.0E-04	--	0.012497
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	1.18	1.8E-07	4.2E-06	--	0.000083
Polyoxyethylene nonylphenol ether		5.0E-02		5.0E-02	250.94	3.8E-05	8.8E-04	--	0.017628
Diammonium peroxidisulphate		2.1E-02		2.1E-02	80.26	1.2E-05	2.8E-04	--	0.013425
Boric acid		5.5E-02		5.5E-02	275.94	4.2E-05	9.7E-04	--	0.017623
Total Risk (mixture)									6.17E-02

Dermal Exposure to Chemicals via Incidental Contact with Flowback Water (60% mass return) - HVFR Hybrid

Older Children Trespassers (5-15 yrs)

General Data/ Equations		Exposure Calculations (RME) Flowback Water (60% return)	
Exposure Parameters			
Exposure Frequency (EF)	days/year	1	Assume direct contact with flowback water occurs over 1 day within the time period that the flow back pond is on-site
Exposure Duration (ED)	years	3	Maximum duration of a flow back pond on-site
Body Weight (BW)	kg	39	Mean body weight (from 4-7, 8-11 and 12-15 year old data) as per enHealth 2012
Averaging Time - NonThreshold (ATc)	days	25550	Averaging of exposure over 70yr lifetime as per USEPA 1989 and CSMS 1996
Averaging Time - Threshold (ATn)	days	1095	Averaging of exposure over exposure duration as per USEPA 1989 and CSMS 1996
Surface Area (SAw)	cm ²	15900	Wholebody surface area (child 11-15 yrs) as per enhealth 2012
Exposure Time (ET)	hr/day	1	Assume child gets completely wet for 1 hour each time
Conversion Factor (CF)	L/cm ³	1.E-03	Conversion of units
Intake Factor = $\frac{SAw \cdot ET \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$		4.8E-05	NonThreshold
		1.1E-03	Threshold

Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor

NonThreshold Risk = Daily Intake for NonThreshold Effects x Slope Factor

Hazard Quotients = (Daily Intake for Threshold Effects/ADI)

Chemical	Toxicity Data		Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Chronic Threshold TDI					NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)					(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	2.0E+0	1140.126659	1.1E-01	2.5E+00	--	2.50E-01
Glutaraldehyde		4.0E-02		4.0E-02	3.3E-4	142.3136205	2.2E-06	5.2E-05	--	1.29E-03
Polyethylene glycol trimethylnonyl ether		5.0E-02		5.0E-02	4.0E-3	1.184146486	2.3E-07	5.3E-06	--	1.06E-04
Polyoxyethylene nonylphenol ether		5.0E-02		5.0E-02	5.0E-3	250.9409852	6.0E-05	1.4E-03	--	2.80E-02
Diammonium peroxodisulphate		2.1E-02		2.1E-02	1.0E-3	80.2648751	3.8E-06	9.0E-05	--	4.27E-03
Boric acid		5.5E-02		5.5E-02	1.0E-3	275.9433412	1.3E-05	3.1E-04	--	5.60E-03
Total Risk (mixture)										2.89E-01

Summary of Risk to Trespassers - 20 and 60% Mass Return (Theoretical) Data - HVFR Hybrid

Exposure fo Target Chemicals

Receptor/Exposure Pathway	Calculated Non-Threshold Risk 20% Mass Return	Calculated HI 20% Mass Return	Calculated Non-Threshold Risk 60% Mass Return	Calculated HI 60% Mass Return
Adult Trespassers				
Ingestion of Chemicals via Incidental Contact with Flowback Water	--	0.01	--	0.03
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	--	0.06	--	0.2
Total Risk	--	0.07	--	0.2
Child Trespassers				
Ingestion of Chemicals via Incidental Contact with Flowback Water	--	0.02	--	0.06
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	--	0.10	--	0.3
Total Risk	--	0.1	--	0.4

Aquatic Toxicity Endpoints - Risk Calculations - HVFR Hybrid

General Equations

PNEC Aquatic mg/L = $\frac{E(L)C50 \text{ or NOEC}}{\text{Assessment Factor}}$

HQ = $\frac{EPC}{\text{PNEC Aquatic}}$

Where PNEC Aquatic = Predicted No Effects Concentration (Aquatic Receptors)
 E(L)C50 = Median effective concentration
 NOEC = No Observed Effect Concentration
 HQ = Hazard Quotient
 EPC = Exposure Point Concentration
 Total HI = Hazard Index (Sum of HQ)

CAS#	Chemical	Endpoint	E(L)C50 or NOEC	Assessment Factor	PNEC Aquatic	EPC		Calculated HI	
			mg/L			20% Mass Return mg/L	60% Mass return mg/L	20% Mass Return mg/L	60% Mass Return mg/L
64742-47-8	Hydrotreated light petroleum distillate	Acute Daphnia	0.018	100	0.000	3.80E+02	1.14E+03	2.11E+06	6.33E+06
7647-01-0	Hydrochloric Acid	Chronic Daphnia	62	10	6.200	2.64E+02	7.91E+02	4.25E+01	1.28E+02
111-30-8	Glutaraldehyde	48 h acute Daphnia	2.1	10	0.210	4.74E+01	1.42E+02	2.26E+02	6.78E+02
67-63-0	Propan-2-ol	Chronic Daphnia	5000	10	500.000	3.63E-01	1.09E+00	7.26E-04	2.18E-03
68551-12-2	Ethoxylated C12-C16 Alcohol	Chronic daphnia	0.11	10	0.011	2.84E-01	8.52E-01	2.58E+01	7.74E+01
104-55-2	Cinnamaldehyde	72 hr Algae	2	10	0.200	1.10E-01	3.31E-01	5.52E-01	1.66E+00
26183-52-8	Ethoxylated Decanol	Chronic daphnia	0.11	10	0.011	1.05E-01	3.15E-01	9.55E+00	2.86E+01
6381-77-7	Sodium erythorbate	Acute Algae	1020	100	10.200	3.60E+00	1.08E+01	3.53E-01	1.06E+00
61791-26-2	Ethoxylated Tallow Alkyl Amine*	Acute daphnia	12.41	1000	0.012	4.97E-02	1.49E-01	4.01E+00	1.20E+01
22042-96-2	Hepta sodium phosphonate	Chronic fish	25.6	100	0.256	2.61E+01	7.83E+01	1.02E+02	3.06E+02
127087-87-0	Polyethylene glycol trimethylnonyl ether	Chronic fish	0.048	100	0.000	3.95E-01	1.18E+00	8.22E+02	2.47E+03
9000-30-0	Guar gum	Acute fish	218	1000	0.218	1.87E+02	5.62E+02	8.59E+02	2.58E+03
9016-45-9	Polyoxyethylene nonylphenol ether	Chronic fish	0.048	100	0.00048	8.36E+01	2.51E+02	1.74E+05	5.23E+05
68953-58-2	Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	Acute daphnia	100	1000	0.100	1.26E+02	3.79E+02	1.26E+03	3.79E+03
7727-54-0	Diammonium peroxidisulphate	Acute Daphnia	92	100	0.920	2.68E+01	8.03E+01	2.91E+01	8.72E+01
10043-35-3	Boric acid	Chronic fish	2.1	100	0.021	9.20E+01	2.76E+02	4.38E+03	1.31E+04
122-99-6	Phenoxy ethanol	Fish	344	1000	0.344	5.11E-03	1.53E-02	1.48E-02	4.45E-02
2634-33-5	1,2-Benzisothiazonlin-3(2H)	Algae	0.283	100	0.0028	5.66E-03	1.70E-02	2.00E+00	6.00E+00
Total HI								2.29E+06	6.88E+06

Appendix E

PAH and BTEX
analytical results

Additive Type	Supplier	Manufacturer	Typical Conc.	UOM	Manufacturer Product Name	Main Component	Purpose Of Chemical	CAS Number(s)	Examples of chemical use in normal environment	BTEX/PAH Testing				Application(s)	Comments	
										Benzene	Toluene	Ethylbenzene	Tot. Xylene			Tot. PAH
										Government Regulatory Requirements						
										1 µg/L	180 µg/L	80 µg/L	75 µg/L	0.02 µg/L		
Primary fluid system																
Friction Reducer	Contractor	Supplier	4	Gal/Mgal	CF550KCB	Polyacrylamide	Thickener, proppant transport, reduce leak off in formation	9003-05-8 (30-60%)	CAS 9003-05-8 is used for sewage, waste treatment, paper treatment and to make dyes, adhesives.	<1	<2	<2	<2	<0.012	Stimulation Fluids	
Biocide	Contractor	Supplier	0.5	Gal/Mgal	CFBE5	Gluteraldehyde	Biocide	111-30-8 (20-50%) 67-56-1 (1-5%)	CAS 111-30-8 use to disinfect medical and dental equipment. CAS 67-56-1 is used for manufacturing I ncluding plastics, paints, car parts and construction materials.	<1	<2	<2	<2	<0.005	Stimulation Fluids	
Scale Inhibitor	Contractor	Supplier	0.5	Gal/Mgal	CF1055C	Phosphonic acid	Scale Inhibitor	22042-96-2 (10-30%)	Industrial water treatments and detergents	<1	<2	<2	<2	<0.005	Stimulation Fluids	
Acid and inhibition package																
Hydrochloric Acid	Contractor	Norkem	15	%	HCl	HCl	Reduces near wellbore tortuosity issues	7647-01-0 (32%), 7732-18-5 (remainder)	CAS 7647-01-0 is used as cleaning product in pools, and in various manufacturing products. CAS 7732-18-5 is water.	<1	<2	<2	<2		Stimulation Fluids	
Iron Control	Contractor	Supplier	35	LB/Mgal	CA370FE	Sodium salt of organic acid (70-100%) No CAS No.	Prevents precipitation of metal oxides	Sodium salt of organic acid (70-100%) No CAS No.	Does not contain components that require registration	<1	<2	<2	<2	<0.09	Stimulation Fluids	As per conversation with Supplier/Contractor on the 18th Nov. This product will be tested again. Unlikely to have any PAH as normally food grade application
Corrosion Inhibitor	Contractor	Champion X	2	Gal/Mgal	CAI500LT	Isopropanol	Corrosion Inhibitor	67-63-0 (30-60%), 68551-12-2 (10-30%), 26183-52-8 (5-10%), 104-55-2 (5-10%), 61791-26-2 (1-5%), 67-56-1 (0.1-1%)	CAS 67-63-0 is mixed with water for use as a rubbing alcohol antiseptic. CAS 68551-12-2 is used in wetting, detergent, and emulsifying applications, CAS 26183-52-8 is used as a wetting and detergent, and emulsifying applications, CAS 104-55-2 is used in flavor and fragrance formulation of daily chemical products and agriculture, CAS 61791-26-2 is used in food, leather dressings, soaps, candles, and lubricant, CAS 67-56-1 is used in for manufacturing I ncluding plastics, paints, car parts and construction materials.	<1	<2	<2	<2	<0.012	Stimulation Fluids	Updated based on email 26/03/2023
Surface Flushing system																
Flush Solution (surface use)	Contractor	Supplier	N/A		CF53179F		Flush Solution (not part of any fluid formulation)	64742-46-7 (70-100%)		<1	<2	<2	<2	<0.9	Surface use - clean lines	
Soda Ash (surface use)	Contractor	Norkem	N/A	Gal/Mgal			Soda Ash (not part of any fluid formulation)	497-19-8 (>99.5%)							Surface use - buffer	
Contingency fluid system																
Liquid Guar	Contractor	Supplier	25	lb/Mgal	CF10GGC		Guar	64742-47-8	Guar	<1	<2	<2	<2	<9.4	Stimulation Fluids	
Citric Acid	Contractor	Supplier		Gal/Mgal	CF210PH		Lowers pH	77-92-9 (30-60%)	Lowers pH	<1	<2	<2	<2	<0.005	Stimulation Fluids	
Sodium Hydroxide (high pH) if required	Contractor	Supplier		Gal/Mgal	CF260PH		Increases pH	1310-73-2 (30-60%)	Increases pH	<1	<2	<2	<2	<0.09	Stimulation Fluids	
Surfactant	Contractor	Supplier	1	Gal/Mgal	CF150FBS		Flowback Surfactant	107-21-1 (15-20%)	Flowback Surfactant	<2	<5	<2	<2	<0.012	Stimulation Fluids	
SCALE INHIBITOR	Contractor	Supplier	0.5	Gal/Mgal	CF1055C		Scale Inhibitor	22042-96-2 (10-30%)	Scale Inhibitor	<1	<2	<2	<2	<0.005	Stimulation Fluids	
Instant Crosslinker	Contractor	Supplier	1	Gal/Mgal	CF450IXL		Instant Crosslinker	10043-35-3 (10-30%), 1310-58-3 (10-30%), 584-08-7 (10-30%)	Instant Crosslinker	<1	<2	<2	<2	<0.006	Stimulation Fluids	
Delayed Crosslinker	Contractor	Supplier	3.2	Gal/Mgal	CF380DXL		Delayed Crosslinker	527-07-1 (30-50%), 10043-35-3 (10-25%), 1310-58-3 (10-25%)	Delayed Crosslinker	<1	<2	<2	<2	<0.005	Stimulation Fluids	
Shale Inhibition (for primary or contingency systems)																
Clay Inhibitor	Contractor	Supplier	2	Gal/Mgal	CF750CL		Clay Inhibitor	67-48-1 (>60%)	Clay Inhibitor	<1	<2	<2	<2	<0.09	Stimulation Fluids	
Breakers																
Enzyme Breaker	Contractor	Supplier	0.02	Gal/Mgal	CF8300E		Enzyme Breaker	No CAS numbers	Enzyme Breaker	<1	<2	<2	<2	<0.006	Stimulation Fluids	
Oxidising Breaker	Contractor	Supplier	0.5	Gal/Mgal	CF8500		Oxidising Breaker	7727-54-0 (60-100%)	Oxidising Breaker	<1	<2	<2	<2	<0.09	Stimulation Fluids	
Encapsulated Oxidising Breaker	Contractor	Supplier	4	lb/Mgal	CF8550EA		Encapsulated Oxidising Breaker	7727-54-0 (60-100%)	Encapsulated Oxidising Breaker						Stimulation Fluids	
CTU Fluid System																
Pipe to Pipe Lubricant (Coil Tubing application)	Contractor	Supplier		Gallons	CC100PS		Pipe to Pipe Lubricant (Coil Tubing application)	172343-37-2 (50-60%), 111-76-2 (2-8%)	Pipe to Pipe Lubricant (Coil Tubing application)	<1	<2	<2	<1	<0.012	Stimulation Fluids	ALS sample needed dilution for analysis
Corrosion Inhibitor (Coil Tubing application/Not pumped downhole)	Contractor	Champion X	NA	gallons	EC9281A		Corrosion Inhibitor (Coil Tubing application/Not pumped downhole)	64742-46-7 (60-100%), 64742-52-5 (10-30%), 68153-72-0 (1-5%), 8009-03-08 (1-5%)	Corrosion Inhibitor (Coil Tubing application/Not pumped downhole)						Stimulation Fluids	Used for storage. It is not used in a downhole environment.

Column to be provided to external relations